Design of a Manufacturing Procedure to Improve the production rate of InvestorData CC

by

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An Efficient Manufacturing System

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Executive Summary

This document contains the project titled: *An Efficient Manufacturing System.* InvestorData CC was started in 1999. The company is very technologically sound and strives to maintain its competitive edge within the industry at all times. A new opportunity had been seen, this opportunity related to a new and innovative 'on-off' switch that is used to operate day/night lights.

Engaging in this project provided the opportunity to combine theory and creative problem solving techniques to:

- Investigate the conceptualization of the current production system
- Search for alternative production procedures and techniques
- Develop and analyze the chosen production techniques through time studies.
- Validate the time standards using quality control charts

The manufacturing process was producing manufactured units on small scale. The owner Mr. Jenkins wished to expand the venture and required a new manufacturing system to be developed in the most optimal way to ensure that the market demand and volume could be met and thus increase the throughput of product and increase the total amount of products manufactured.

Table of Contents:

Section 3: Data Collection

List of Graphs, Figures and Tables:

List of Appendices:

Section 1: Problem Background:

1.1 Introduction and Background:

InvestorData CC is a company based in Fish Hoek, Cape Town. The company was started in 1999, and is/was primarily focused on selling stock exchange data, received from the JSE stock exchange, to customers. The owner Mr. Jenkins had always had a love for electronics, it was for this reason that he had decided to create a new venture and was starting to explore the electronic industry. InvestorData had found a new opportunity within the market which entailed a new kind of imbedded processing unit that is used as an "on-off" switch or a "day-night" switch.
InvestorData had entered this new and innovative product into the market place, but only on small scale, producing a mere 400-600 products/units per month, hence the manufacturing process was of small scale. The requirements' of the client was that the bridge from small scale to larger scale production be established. Competitive advantage had to be maintained. This would ensure that InvestorData CC would be able to manufacture more products for the market and not get overtaken by the bigger competitors. In order to do this a leaner and more efficient manufacturing process needed to be created. Time measurements were to be performed, jigs and aiding equipment needed to be designed to ensure that the manufacturing process was highly productive and quality control techniques were to be applied to certify time standards for the processes. With these efficient processes and system designs, InvestorData would be able to meet the market demand whilst remaining competitive within the industry and provide InvestorData with the ability to produce greater measurable quantities of units manufactured.

1.2 Problem Statement:

InvestorData CC required that their current manufacturing system be standardised and improved. The client wished to have an efficient manufacturing system. It was required that the number of products that were being manufactured, be improved and greatly increased.

1.3 Project Aim:

The aim and main goal of the project was to design an efficient manufacturing process using Industrial Engineering techniques and provide a lean, efficient and highly productive manufacturing system for InvestorData CC. A new step by step procedure was to be established, a manufacturing procedure that became the standard way of constructing the products. The company wanted to provide its new product to the market and needed to increase the production of the product to cater for the mass market. The client wished to increase the productivity from 400-600 manufactured units per month to an estimated +/-2500 manufactured products/units per month. In addition the company required a strategy for employment and wanted to pay employees on a “work completed” level, whereby an employee got paid per successful product completed, hence another aim for the project was to formulate an idea whereby products could be checked and workers who built the products rewarded accordingly. This related to quality control and specific detail was to be paid to the daily procurement to ensure that the designed manufacturing procedure was flawless and was also used as a validation technique for the determined time standards.

1.4 Project Scope:

Primarily the project focused on the manufacturing system and how to design the system in order to make it as reliable, accurate, efficient, fast and as optimal as possible. This provided InvestorData with the ability to have a faster throughput of product and maintain its competitive edge in the market. The project further focused on time studies to improve the productivity of the organisation. The designed manufacturing process was tested and evaluated. Time measurements studies were then performed. With the time measurements, quality control techniques were utilised to test the systems stability and aid in establishing the manufacturing process standard times. To ensure the quality of the products, an incentive scheme/idea for the workers had to be developed to ensure that the products were made as efficiently and accurately as possible. This scheme/idea also prompted workers to work diligently, and this in turn created a reliable throughput of manufactured components.

Section 2: Literature Study:

2.1 Work Measurement:

Management is in constant search of more effective ways to improve employee productivity. One time proven method is work measurement. Work measurement is determining the time required to perform a physical task and is used in many industries to eliminate inefficiencies, reduce operational costs and increase productivity. Work measurement programs enable management to establish fair standards for a day's work for a specific job or operation. These standards in turn, can be used to measure performance by a department or an individual employee. The objective of any work measurement program is to find the most efficient way to complete a given task.

Current work methods are not always the most effective way of performing a job or task. Work measurement may reveal that entirely new operational procedures are required to maximize the productivity of the company. Work measurement can lead directly to more cost effective operations. Specific benefits of work measurement include:

- Improved work flow
- Higher quality products
- Objective standards for measuring the cost of producing a definable unit of work
- Upgrade schedules and work assignments
- More efficient allocation of materials and human resources
- A basis for evaluating the effects of possible changes in the organizational structure
- Enhanced planning and capabilities, including more reliable budgets and forecasts (*Marvin E. Mundel,Work Measurement for Lean Manufacturing,6th Edition)*

A portion of time saved through work measurement comes from the simplification of procedures and the elimination of unnecessary steps in a job or task. Substantial savings also come from the development of more appropriate performance standards, which can ensure that employees work consistently and continuously, without the pressure of unrealistic demands or expectations.

Work measurement techniques are usually grouped into two categories:

1. Time Studies

Motion and time study literature is a very extensive field of study and for the project research would be based on the works of Marvin E. Mundel, Benjamin W. Niebel and P.E Randall. There were also a number of Engineering Journals and publishing's that had been used and dually referenced. All authors have vast experience and knowledge in motion and time study for lean manufacturing systems.

- ***Objective of methods, motion and time studies:***

The main objective is to increase productivity and lower production costs. Making the production system lean, efficient and ensuring that the production is as optimal as possible, by taking into consideration the relevant times it takes to manufacture the products. Steps that apply to achieving the objective are as follows:

1. Minimize the time required to perform tasks.
2. Conserve resources and minimize costs by specifying the most appropriate direct and indirect materials for the production of goods.
3. Produce with a concern for the availability of power.
4. Produce an increasingly reliable and high-quality product.
5. Maximize the safety, health and well being of all employees.
6. Produce with an increasing concern to protect our environment.
7. Follow humane program of management that result in job interest and satisfaction for each employee.(*Benjamin W. Niebel," Methods, Standards and Work Design", 11th edition)*

Time studies measure worker productivity in terms of output per period of time (eg. units per hour). Typically current company output is then compared with output standards established for the same or similar task elsewhere, or in the case of the project, compared from current manufactured product units (400-600 units) to the required units (2500 units) needed. There are three types of tools used for conducting time studies, namely: Historical records, Productivity reports and Work Sampling.
(*Which Work Measurement Tool? C.Bruce Gowan, Manufacturing Engineering, March 1999)*

- ***Historical records:***

Due to the fact that this project was based on a new venture, there only existed minimal historical data pertaining to productivity standards. Hence this method would not be applicable to the project, but the technique primarily focuses on the retrieval of past records and establishing standards from the historical or past trends.

- ***Productivity reports:***

With this technique, a period of production time (called the base period) is designated a work measurement period. Work conducted in this period is closely monitored and measured to determine a rate of production. Compiling these reports only moderately interrupts operation and little training is required to measure the outputs.

- ***Work Sampling:***

Work Sampling is a reliable method of measuring set-up time, direct work, transportation time and idle time associated with company operations. With this technique, activities of randomly selected workstations are observed and recorded at regular intervals. This technique would be primarily used throughout the duration of the project to ensure that production standard times were as efficient as possible and also to monitor that the production time standard was consistent to time standards established.

2. The Engineered Approach

The engineered approach involving time-motion studies is a more precise method of determining levels of worker output for a given period of time. The approach goes beyond a simple time study. Where a time study only measures the time it takes to perform a task, motion-time study takes the motions required to perform the task into consideration. Each movement is then analyzed in terms of time, efficiency and necessity. Wasted motions are then identified and eliminated.

Three work measurement techniques used in engineered time motions are: Stop Watch readings, Predetermined Motion Time Systems (PMTS) and Maynard Operation Sequence Technique (MOST).

- ***Stop Watch readings:***

Most commonly used engineering approach to work measurement. Work motions are timed using a stop watch and then compiled detailed records of the times it takes an employee, on average, to perform each phase of a single task or operation. Stop watch readings help set standards for highly routine repetitive work. Accuracy can be improved when determining time standards by taking multiple stop watch readings and calculating an average.

- ***Predetermined Motion Time Systems (PMTS):***

This technique would not be used within the project and referred to time standards that were formulated by efficiency experts in laboratories. Thus due to the extensiveness of the standards and procedures used to determine the predetermined time standards, the technique would be irrelevant to apply to this project.

- ***Maynard Operation Sequence Technique (MOST):***

This technique although very advantageous did not fall within the scope of the project. Primarily the technique was convenient when applying time studies to non-routine jobs or tasks. The technique also had the ability to adjust time standards quickly when methods change. This was a nice attribute to the technique but would not be applicable to the project due to the fact that the client wished to maintain one manufacturing procedure.

"The best approach to implementing a work measurement program is to develop good communication with all personnel. The program should be explained in sufficient detail so that all employees understand the expected benefits for them as well as for the company" *(P.E Randall, Motion and Time Study for Lean Systems,6th Edition)*

Flow charts can be very useful in any of the work measurement methods. By having a visual representation of the company activities, management is better able to deal with complicated schedules requiring precise resource allocation.

Basic steps for constructing a flow chart are:

1) List activities covered
2) Select the subject
3) Choose beginning and end points
4) Define each step
5) Summarize
6) Follow up by announcing the results
7) Reward individuals that show productive improvement

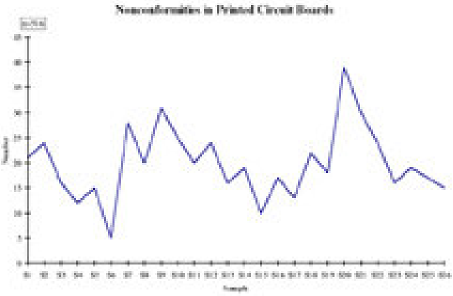
(C.Bruce Gowan, Manufacturing Engineering, March 1999)

2.2 Variable and Attribute Control:

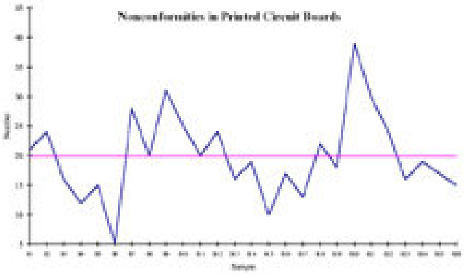
- ***Statistical Process Control (SPC) Chart's:***

Many companies employ SPC throughout various operations in their facility. Individuals who manage the SPC programs may be familiar with the formulas required to calculate control chart limits, but they are not always aware of the basic requirements or "rules" for control charts that must be followed in order to obtain valid results. There are many prerequisites or considerations for all control charts. These general requirements are specific as to whether you have variable or attribute data, whether or not the subgroup sizes are constant or changing, and how much sensitivity for variation detection is desired. A facility using SPC that is unaware of these requirements can be making mistakes, or errors in judgment, without knowing they have violated the general rules and in return may be actually harming the process rather than improving it. The analysis of control chart requirements and rules can be somewhat extensive. (*Quality Management, Third Edition, Howard S. Gitlow, Alan J. Oppenheim, Rosa Oppenheim, David M. Levine, McGraw-Hill International Edition.)*

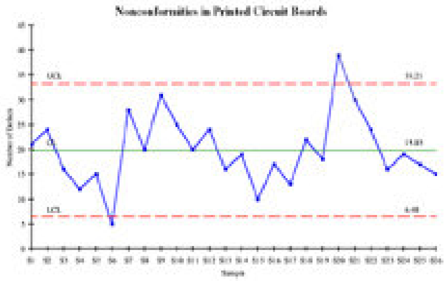
Figure 1: The Evolution of Control Charts



Line Graphs



Run Charts



Control Charts

1. The earliest version of the *control chart* is the **line graph** showing defects or delay.
2. The next version, a **run chart**, included a line showing the average of all values
3. The next version, added upper and lower control limits calculated as +/-3σ from the average. Since it was difficult to measure every item produced, sampling was used to reduce the cost of measurement. This reduction, however, led to many different formulas to handle the various sample sizes.
4. The latest versions include 1- and 2- σ lines to facilitate stability analysis, and highlighting to automatically pinpoint potential problems.

- ***Basic Statistics:***

The Mean: measure of central tendency
The Range: difference between largest/smallest observations in a set of data
Standard Deviation: measures the amount of data dispersion around mean

Mean

$$\overline{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

Standard Deviation

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} \left(x_i - \overline{X}\right)^2}{n-1}}$$

- UCL(R) = D_4R
- LCL(R) = D_3R
- UCL($\overline{X}$) = $\overline{\overline{X}} + A_2 \overline{R}$
- LCL($\overline{X}$) = $\overline{\overline{X}} - A_2 \overline{R}$
- UCL(S) = $B_4 \overline{S}$
- LCL(S) = $B_3 \overline{S}$
- $\sigma = \frac{\overline{S}}{C_4}$
- UCL($\overline{X}$) = $\overline{\overline{X}} + A_3 \overline{S}$
- UCL($\overline{X}$) = $\overline{\overline{X}} - A_3 \overline{S}$

(*Quality Management, Third Edition, Howard S. Gitlow, Alan J. Oppenheim, Rosa Oppenheim, David M. Levine, McGraw-Hill International Edition.)*

2.2.1 Variable Control Charts:

Variables control charts for subgroup data are powerful and simple visual tools for determining whether a process may be in or out of control.

- An in-control process exhibits only random variation.
- An out-of-control process exhibits non-random variation due to the presence of special-causes.

Control charts can help you determine whether the process average (center) and process variability (spread) are operating at normal levels. Control charts help you focus problem-solving efforts by distinguishing between common and special-cause variation.

A variables control chart for subgroup data will consist of the following:

- Plotted points, each of which represents a rational subgroup of data sampled from the process, such as a subgroup mean or average.
- A center line, which represents the expected value of the characteristic for all subgroups.
- Upper and lower control limits (UCL and LCL), which are set at the distance of 3σ above and below the center line. These control limits provide a visual display, or "zone", for the expected amount of variation. Control limits predict how the process should behave. The control limits are based on probability and the actual behavior of the process, not the desired behavior. Control chart limits are different from specification limits. A process can be in control and still not be capable of meeting the specification limit requirements.

A graphical example of a basic control chart is shown at the below with a center line (green) and upper/lower control limits (red).

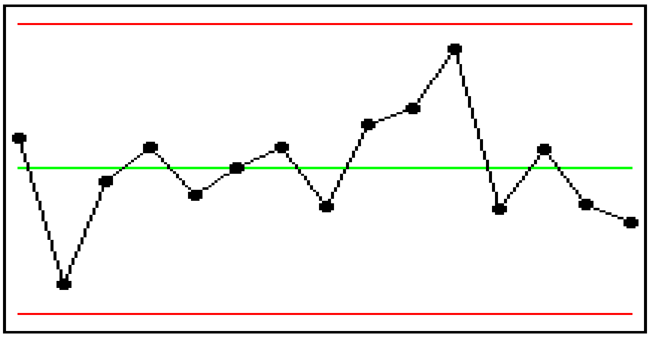


Figure 2: Basic control chart

Control charts evaluate the patterns of variation for stability through the use of tests for special causes. If you detect special cause variation, you should seek out the factors that contribute to this variation so that you can implement corrective actions.

- ***$\overline{X}$/S Chart vs. $\overline{X}$/R Chart:***

Both $\overline{X}$/*S* charts and $\overline{X}$/*R* charts measure subgroup variability. The S chart uses the "standard deviation" to represent the spread in the data and the R chart uses the "range". Both charts lead to a similar estimate of the process standard deviation and similar control limits for the charts. The calculation of the range uses only two data points - the largest and smallest values - while the calculation of the standard deviation uses all the data from the sub-group. R charts are not as sensitive to small amounts of variation as the S chart. You must decide what is most important for your specific requirements when deciding between an S chart and an R chart.

- ***$\overline{X}$ Chart (Averages):***

The $\overline{X}$ chart is where the sub-group averages or mean values are plotted. Probability shows us that the averages of our processes tend to stay constant unless special-cause is present. A process can be behaving normally for the averages and at the same time be considered out-of-control for the R and S charts. The reverse is also true, R and S charts can remain in-control while the averages become out-of-control

- ***S Chart (Standard Deviations):***

Use the S chart when the subgroup sizes are nine or greater. S charts use all the data collected to calculate the subgroup and process standard deviations. S charts provide a more accurate indication of the process variation and result in a chart that is very sensitive to small changes in the process average. You should consider using S charts for processes with a high rate of production, when data collection is quick and inexpensive, or when increased sensitivity to variation is desired. S charts can detect smaller amounts of variation when compared to R charts. The only negative aspect in managing an S chart is the need to perform the more difficult calculations for the standard deviation which typically are accomplished by using a computer.

- ***R Chart (Ranges):***

Use the R chart when your subgroup sizes are eight or less. R charts are efficient for small subgroup sizes and are easier to manage due to basic shop math calculations that need to be performed. R charts can be highly influenced by a single data value from the sub-group.

- ***I Charts (Individuals):***

When collecting samples to learn about a process, it is sometimes easier to combine the samples into subgroups, if it makes sense to group the samples together. When grouping is not appropriate, then a subgroup size of one (1) provides a method for evaluating the process. Samples that cannot logically be grouped together are good candidates for individuals (I) and moving range (MR) charts.

Examples of conditions that make using subgroups unfeasible or undesirable could be similar to the following:

- When each sample is unique with respect to a specific period of time.
- When each sample represents one distinct batch or group.
- When there are extremely long time intervals between each sample or production cycle time is extended.
- When sampling or testing is destructive or may be cost prohibitive due to expense.

- When the output is continuous and homogenous or When the measurements (results) are not necessarily related in time to each other.

2.2.2 Attributes Control Charts (P and NP charts):

Attributes control charts represent a rational sample of data sampled from the process and are either counts (n) of the number of defectives or defects per sample, or proportions of the defectives or defects per sample (%).

- An in-control process exhibits only random variation any will remain within the control chart limits.

An attributes control chart for subgroup data will consist of the following:

- Plotted points, each of which represents a rational subgroup of data sampled from the process, such as a subgroup mean or average.
- Center line, which is the average number (NP Chart) or average proportion (P Chart) of defectives or defects.
- Control limits, which are set at a distance of 3σ on either side of the center line and provide a visual display for the expected number or proportion of defectives or defects. These control limits provide a visual display, or "zone", for the expected amount of variation. Control limits predict how the process should behave. The control limits are based on probability and the actual behavior of the process, not the desired behavior. Control chart limits are different from specification limits. A process can be in control and still not be capable of meeting the specification limit requirements.

- ***P Chart vs. NP Chart:***

An attribute defect is a product or service in which a nonconformity renders the product or service unusable. Examples of this type of defect include broken articles, late deliveries, unanswered calls, scratched paint, and flat tires. Attributes can have only one of two outcomes, pass/fail, good/bad, go/no-go, etc.

- ***P Chart (Proportion Defective..%):***

Use P charts to study the proportion of defectives in each sample and determine whether or not the process is in control. Use P charts when your sub-group sample sizes vary.

- ***NP Chart (Number Defective..n):***

Use NP charts to examine the number of defectives in each sample and determine whether or not the process is in control. You should not use an NP chart when your sub-group sample sizes vary because the control limits and center line change when sample size changes. This variation in sub-group sample sizes and changing limits would make the NP chart difficult to manage and interpret. (*Quality Management, Third Edition, Howard S. Gitlow, Alan J. Oppenheim, Rosa Oppenheim, David M. Levine, McGraw-Hill International Edition.)*

2.3 Conclusion to Literature Study:

Work measurement programs are an important tool for improving employee productivity. Properly established performance standards, which is the end result of a well planned and effective work measurement program, can improve worker output and morale while significantly increasing a company's productivity and their profits. Only when clear cut performance standards are set and strictly enforced will a company benefit from work measurement programs.

Variables data consist of numerical measurements and contain more information than attribute data. Variable data control charts do not mask valuable information and are therefore more powerful than attribute charts. While attribute control charts help identify special process variation, as the process improves and the number of defects becomes smaller, the subgroup size required to detect these events becomes prohibitively large. This fact renders attribute charts on the road to never ending improvement.

Frequently regular revision of control limits is undesirable and inappropriate. Control limits should be revised only for one of three reasons:

- A change in the process
- When trial control limits have been used and are to be replaced with regular control limits
- When points out of control have been eliminated from the data set.

Proper organization of the data to be control charted is critical if a control chart is to be helpful in process improvement.

Section 3: Data Collection :

3.1 Overview:

The manufacturing process was comprised of two sub-sections, one being the preparation of components and the other being the construction of the product/units.

3.2 Preparation and Manufacturing:

Before time studies could be conducted it was important to determine well defined, simple and efficient procedures' to (i) prepare and (ii) manufacture the units/products. The logic behind developing the manufacturing procedure was governed by the fact that it was wiser to start manufacturing from the smallest components and gradually proceed with the manufacturing process, through the gradual increase in size of components, until completed with the procedure. The reason for starting with the smallest components was to ensure that when manufacturing the products, the components could be held securely in place whilst being manufactured. This eliminated the wasted time spent on having to replace the smaller components when maneuvering the incomplete work piece. By determining a standard procedure to be followed and implementing the procedure, a controlled and standardised working environment was created, which was then measured and evaluated. The following two diagrams indicate the designed manufacturing and preparation processes and procedures that were implemented and were being followed. These diagrams set out a standard manufacturing procedure that each worker was required to follow when either preparing kits or when manufacturing products.

3.2.1 The Designed Standard Manufacturing Procedure:

Manufacturing Procedure

- **STEP 1**: Install IC
- **STEP 2:** Install 4k7 Resistors
- **STEP 3**: Install 33k Resistor
- **STEP 4**: Install 12k Resistor
- **STEP 5**: Install 330k Resistor
- **STEP 6**: Install 47k Resistor
- **STEP 7**: Install Transistor
- **STEP 8**: Install 2 Diodes
- **STEP 9**: Install 4 Diodes
- **STEP 10**: Install Zener Diode
- **STEP 11**: Install 2 Small Capacitors
- **STEP 12**: Install Relay
- **STEP 13**: Install Large Capacitor
- **STEP 14**: Install Main Wires
- **STEP 15**: Test unit for Robustness
- **STEP 16**: Install LDR Wires
- **STEP 17:** Test Unit
- **STEP 18:** Potting
- **STEP 19**: Mark Unit
- **STEP 20:** Final Testing
- **STEP 21:** Package Unit

Figure 3.2.1: Manufacturing Standard Procedure

The manufacturing procedure was further broken down into the following conclusive and fully explained steps. Time measurement was conducted on each of these steps for all three workers. The procedure is broken up as follows:

Step 1 - Install IC

- Orientate IC upside down
- Insert 4 pins closest to PCB center and then assist to insert into remaining 4 holes near PCB edge
- Lay PCB pins up
- Solder 2 on all pins
- Remove any solder balls. If no solder bridge, place into box else place into repair box which are done at end of units.

Step 2 - Install 2 x 4k7 Resistors

- Insert 2 x 4k7 resistors.
- Lay board upside down and solder one leg of each resistor to min heat damage
- Solder other leg and trim
- Remove any solder balls. If no solder bridge, place into box else place into repair box which are done at end of units.

Step 3 - Install 33k Resistor

- Insert 33k resistor into PCB
- Lay board upside down and solder one leg of each resistor to min heat damage
- Solder other leg and trim
- Remove any solder balls. If no solder bridge, place into box else place into repair box which are done at end of units.

Step 4 - Install 12k Resistor

- Insert 12k Resistor
- Lay board upside down and solder one leg of each resistor to min heat damage
- Solder other leg and trim
- Remove any solder balls. If no solder bridge, place into box else place into repair box which are done at end of units.

Step 5 - Install 330k Resistor

- Insert 330k Resistor
- Lay board upside down and solder one leg of each resistor to min heat damage
- Solder other leg and trim
- Remove any solder balls. If no solder bridge, place into box else place into repair box which are done at end of units.

Step 6 - Install 47k Resistor

- Insert 47k Resistor
- Lay board upside down and solder one leg of each resistor to min heat damage
- Solder other leg and trim
- Remove any solder balls. If no solder bridge, place into box else place into repair box which are done at end of units.

Step 7 - Install Transistor

- Insert Transistor
- Lay board upside down and solder bottom-right triangle leg
- Solder top triangle leg
- Trim all three legs
- Solder remaining leg
- Remove any solder balls. If no solder bridge, place into box else place into repair box which are done at end of units.

Step 8 - Install 2 Diodes

- Insert 2 x 1n4007 Diode
- Lay board upside down and solder one leg of each diode to min heat damage
- Solder other leg and trim
- Remove any solder balls. If no solder bridge, place into box else place into repair box which are done at end of units.

Step 9 - Install 4 Diodes

- Insert 4 x 1n4007 Diodes
- Use screwdriver and cutter to seat diodes
- Lay board upside down and solder two furthest legs of four diodes to min heat damage
- Solder two furthest legs of four diodes to min heat damage.
- Now trim all eight wires
- Solder remaining two legs of four diodes to min heat damage. Check no solder bridges
- Remove any solder balls. If no solder bridge, place into box else place into repair box which are done at end of units.

Step 10 - Install Zener Diode

- Insert Zener Diode
- Lay board upside down and solder one leg of each diode to min heat damage
- Solder other leg and trim
- Remove any solder balls. If no solder bridge, place into box else place into repair box which are done at end of units.

Step 11- Install 2 Small Capacitors

- Insert 2 x Small Capacitors
- Lay board upside down and solder one leg of each cap to min heat damage
- Solder other leg and trim
- Remove any solder balls. If no solder bridge, place into box else place into repair box which are done at end of units.

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Step 12 - Install Relay

- Insert Relay
- Lay board upside down and solder top-left leg
- Solder bottom-left and top-right leg, to minimise heat damage.
- Solder middle-left and right-most leg, to minimise heat damage. Check for solder bridges.
- Remove any solder balls. If no solder bridge, place into box else place into repair box which are done at end of units.

Step 13 - Install Large Capacitor

- Insert Large Capacitor
- Lay board upside down and solder one leg of each cap to min heat damage
- Solder other leg and trim
- Remove any solder balls. If no solder bridge, place into box else place into repair box which are done at end of units.

Step 14 - Install Main Wires

- Insert black wire at corner and solder to board
- Insert brown wire next from corner and solder to board
- Insert pink wire next to relay and solder to board
- Insert orange wire in remaining hole and solder to board
- Remove any solder balls. If no solder bridge, place into box else place into repair box which are done at end of units.

Step 15 - Test Unit for Robustness

- Connect unit to test jig
- Switch on and ensure all lights come on and stay on

Step 16 - Install LDR Wires

- Insert bell wire and solder to board
- Remove any solder balls. If no solder bridge, place into box else place into repair box which are done at end of units.

Step 17 - Test Unit

- Connect to test jig, sensor clipped to top of tin so sensor at bottom of tin in the dark.
- Switch on and ensure all lights come on cycle 3 times

Step 18 – Potting

- Place shrink wrap square into potting mould
- Prepare epoxy and place 5ml into mould
- Insert PCB into mold, ensuring wires not in another mould
- Pour epoxy into mold
- Once cured, gently remove from mold

Step 19 - Mark Unit

- Using engraver, write year and month of manufacture
- Apply warranty sticker

Step 20 - Final Test Unit

- Connect to test jig, sensor clipped to top of tin so sensor at bottom of tin in the dark
- Switch on and ensure all lights come on and cycle 3 times

Step 21 - Package Unit
• Print instructions
• Insert instructions and unit into small plastic bag
• Heat seal plastic bag

Table 3.2.1.1: Manufacturing Standard Procedure breakdown table

3.2.2 The Designed Standard Preparation Procedure:

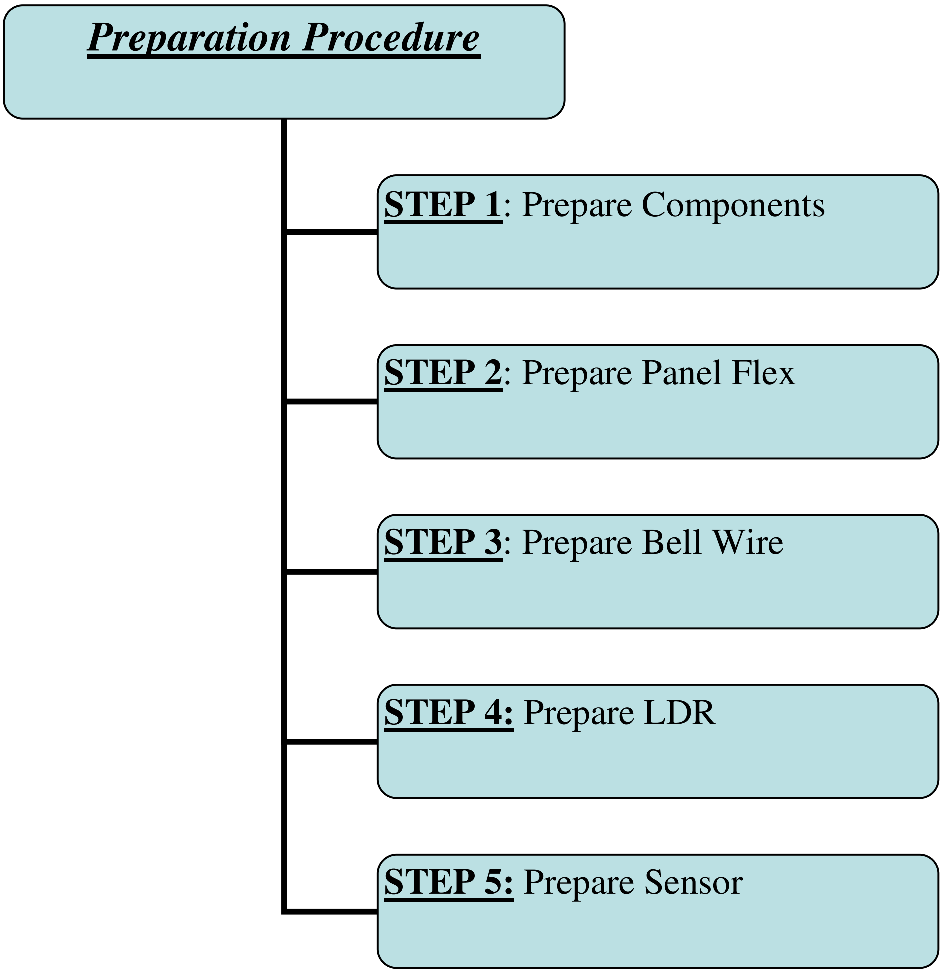


Figure 3.2.2: Preparation Standard Procedure

The preparation procedure was also further broken down into the following conclusive and fully explained steps. Time measurement was conducted on each of these steps for all three workers. The procedure is broken up as follows:

Step 1: Prepare Components
• Trim string of parts into about 15cm-20cm lengths
• Using right-angle metal plate, bend each 15cm-20cm length by 180 degrees.
• Using scissors, trim each bent section so part drops into 2L ice-cream holder for each part type/value
• Write part ID on each of four sides and lid and under lid to ensure know what part is in box.
Step 2: Prepare Panel Flex
• Trim rolls panel flex into 20cm lengths
• Expose 4-5mm off an end
• Solder each exposed wire by dipping in flux and then into solder pot
Step 3: Prepare Bell Wire
• Trim bell wire into about 20cm lengths
• Split pair on one side by 6 mm and other side by 12mm and expose 3mm off each wire end
• Solder each exposed wire by dipping in flux and then into solder pot
Step 4: Prepare LDR
• Trim LDR lead so that about 3-4mm remains
Step 5: Prepare Sensor
• Attach bell wire to sensor and ferrules
• Attach LDR (Light Dependent Resistor)
• Secure into boot
• Silicone together

Table 3.2.2.1: Preparation Standard Procedure breakdown table

3.3 Development of Standard Procedures:

Although looking at the process as a whole, one would like to recommend that the manufacturing procedures be split into designated and assignable workstations. The three workers could then be rotated around the workstations. This would ensure that the work does not get tedious/relentless/boring and stimulates the workers who then acquire working knowledge within the system. After talking to the client, and making the before mentioned statement to him, it was decided not to split the workers into designated workstations. The reasoning for this was that the client did not want to rely too heavily on the workers, by this it was meant that the three workers would have to be reliant on each other in order to meet their quota of manufactured products for the day. For instance if one worker was to be ill or absent from work then the manufacturing process would be drastically delayed. The second reason which the client specified was that he would prefer that the workers remain solely responsible for their own manufactured units and this would then ensure that the individual workmanship and quality of the manufactured product would be maintained. This would also help in setting an incentive scheme for the workers as would primarily be based on their own personal performance and competency.

3.4 Time Measurements:

The established working hours an employee is required to work is 9 hour days, from Monday to Friday, with a 30 minute lunch and two 15 minute tea breaks. Further more, their working hours also include a 6 hour shift on Saturdays, but these days were primarily focused on preparing the kits which consisted of enough components to manufacture 5 units/products.

The time measurement studies were done by using a stopwatch. The previously mentioned preparation and manufacturing standard procedures were timed. These logical breakdowns (refer to Figure 3.2.1 and Figure 3.2.2) defined the basic overview of the requirements needed to perform the specified tasks. On further evaluation, the two processes were broken down in more depth so that the step by step procedures could be time studied (refer to Table 3.2.1.1 and Table 3.2.2.1). The time studies were done daily. Three time measurements were taken at random intervals, per day per worker.

This provided 9 time measurements per day, per kit (or 5 units). The 9 time measurements were then averaged per worker and entered into the appropriate recording excel in its relevant cell and column which represented the day. This raw data is reflected in Appendix C.
The data was collected for 20 days, and preparation time studies were done for three Saturdays as the raw data in Appendix D indicates.

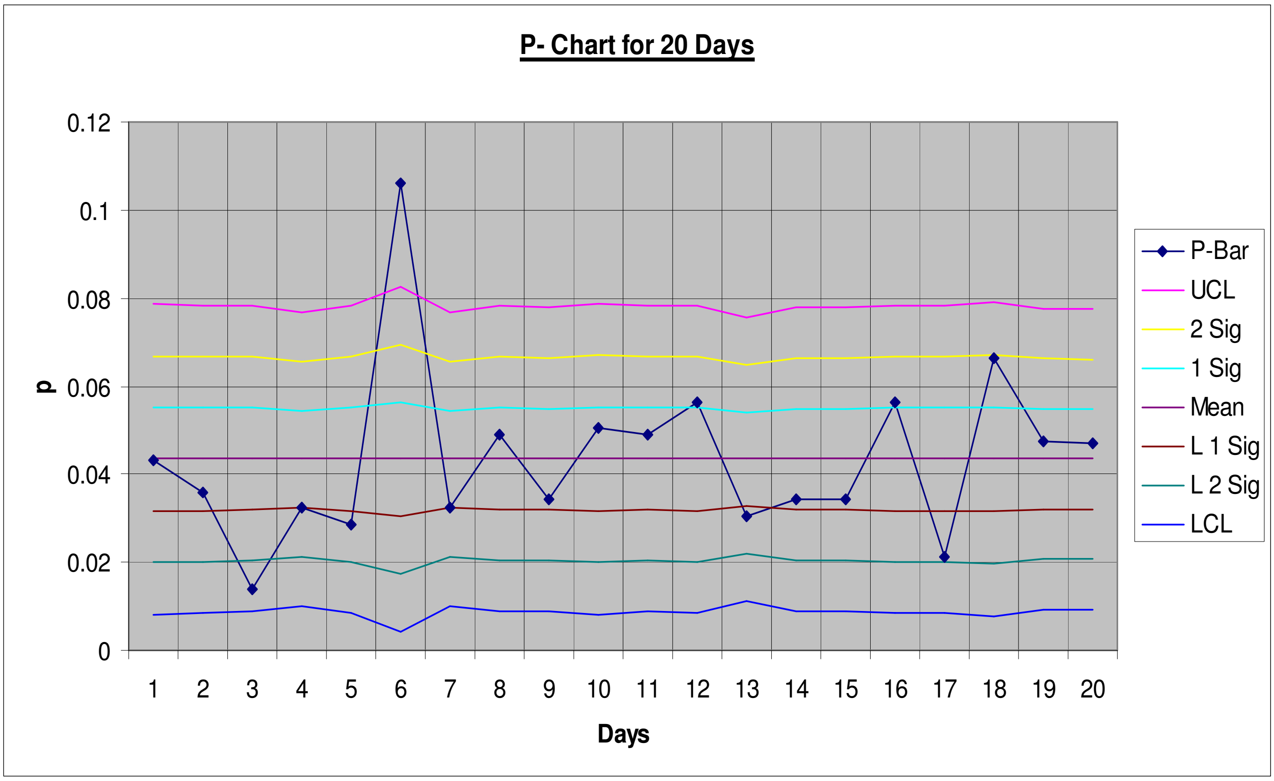
3.5 Work Completed:

After performing the time measurements studies, it was easy to calculate the amount of products that were manufactured per day. This data is reflected in Appendix E. The data recorded depicts the amounts of completed units, the amount of re-worked units and the amount of wastage that was present for the particular day. This data was counted by hand at the end of each working day for the 20 day time measurement cycle.

Section 4: Data Analysis :

4.1 Attribute Control Charts:

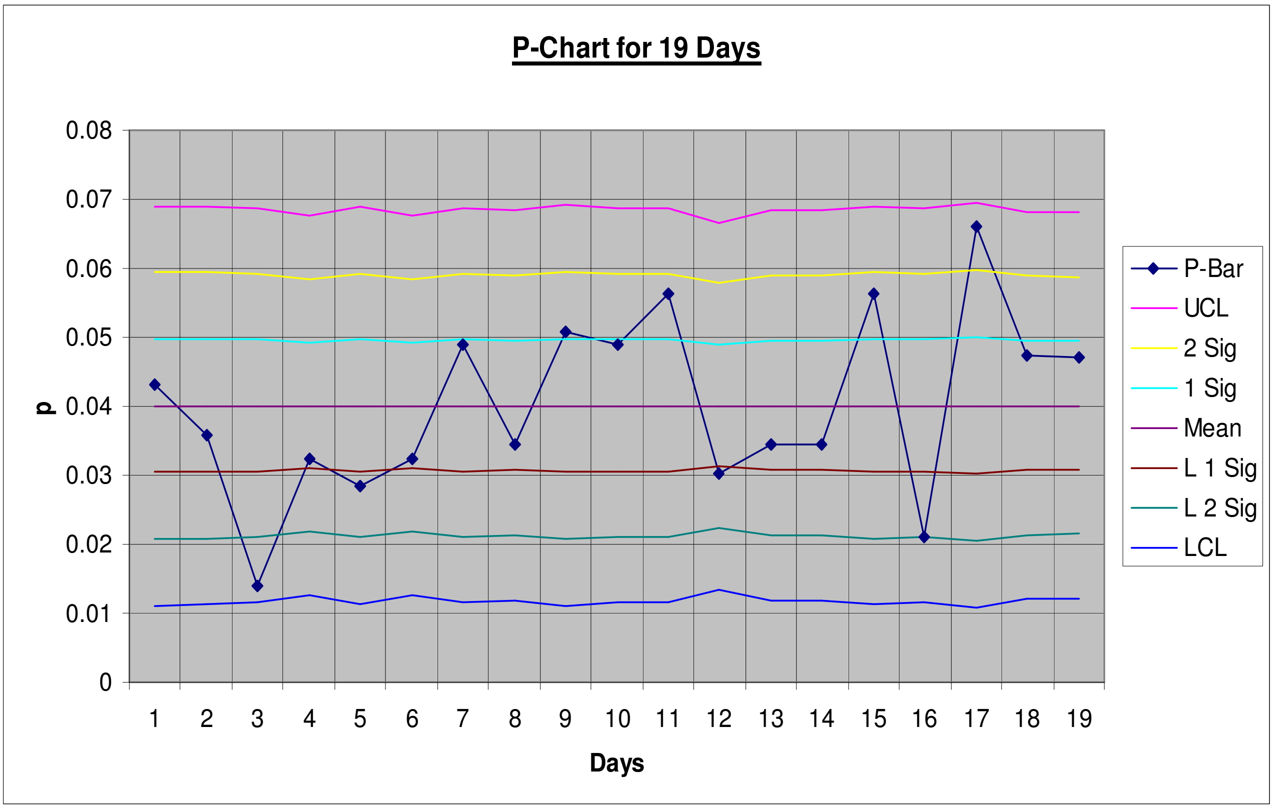
Evaluating the work completed was to be the first step in determining if the amount of manufactured units were stable and in statistical control according to the new implementation of the manufacturing procedure/process. The data that was used is referenced in Appendix E (on cd). The reader should note that on one particular day (Day 6), worker 3 accidentally knocked the soldering pot over and this delayed procurement drastically. This is seen within the first P-Chart for 20 Days. A P-Chart was used, because this attribute control chart was the most relevant chart for the data that had been obtained. Below is a graph which shows the occurrence of day 6 and how the process was out of control.



Graph 4.1.1: P-Chart for 20 Days showing discrepancy

The problem on Day 6 which rendered the process out of statistical control (above the UCL), had been eliminated by providing a new holding fixture which was attached to the workers desk. With this fact in mind the data for Day 6 was appropriately discarded and another P-Chart drawn. The new P-Chart for 19 Days was drawn and this chart indicated that statistical control was indeed reached (reference to Appendix F (on cd)).

The data obtained on the amounts of manufactured products was well between the Upper Control and Lower Control Limits. This meant that the manufacturing process was in statistical control and the manufacturing procedure was stable as shown in the graph below.



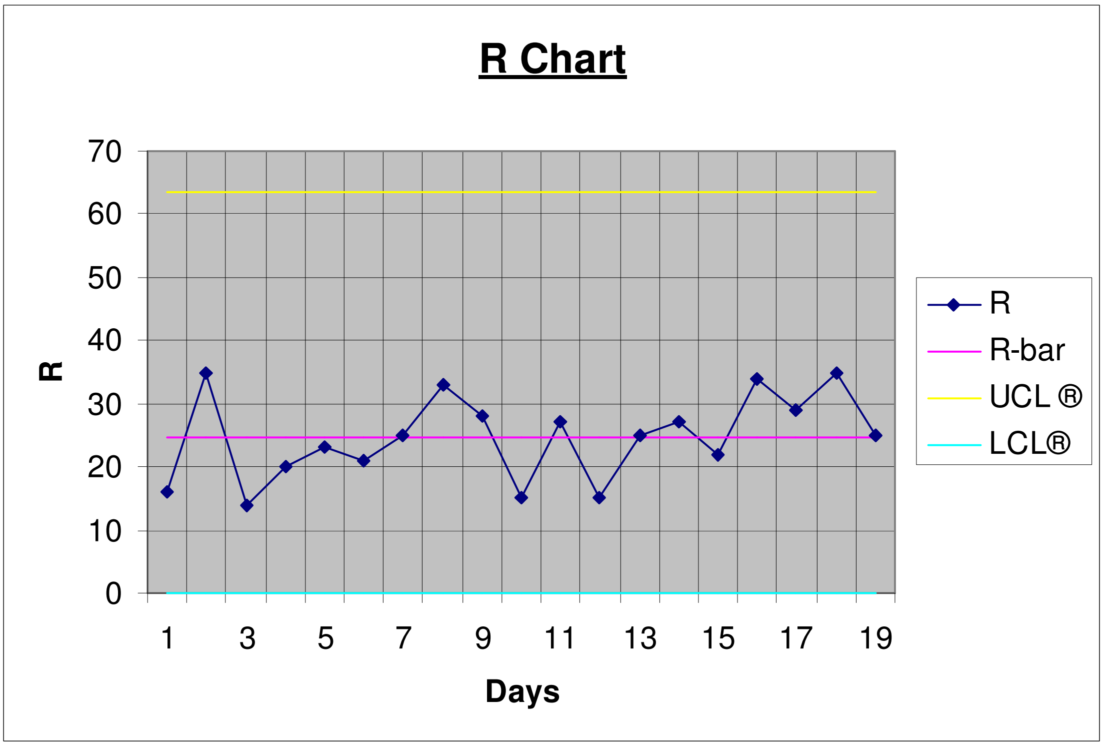
Graph 4.1.2: P-Chart for 19 Days showing no discrepancy

From these results it was possible to evaluate the time measurements that were recorded and consequently determine if the time measurements were in statistical control. In essence what it would mean (if the manufacturing process time measurements were in fact stable), was that the time standards could be set around the mean values. These results would be able to validate the time measurement standards. Once this was proven the evaluated time standards were set as the standard times for the manufacturing process.

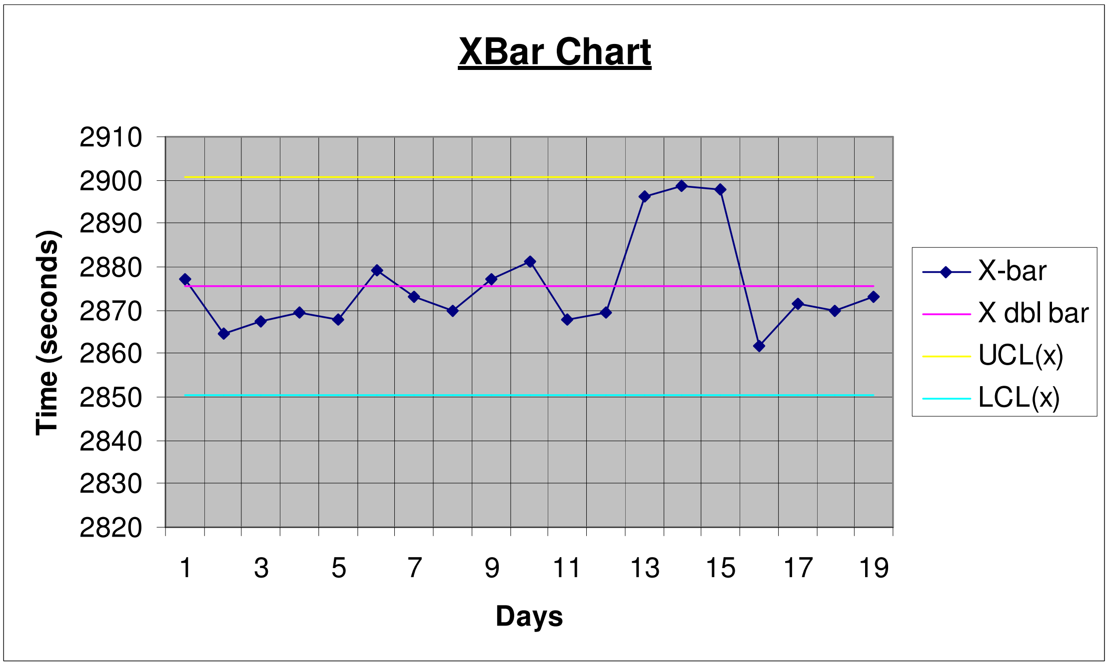
4.2 Variable Control Charts:

After evaluating the time studies, and noting that the sample size is only 3 (the three workers), it was decided that an X-Bar and R chart be determined using the collected data.

The data I am talking about is with reference to Appendix C (on cd). Here the average of the averages is taken, the recorded times for each worker on average per day for the total completion of 1 kit or 5 products is being used. These averages are known to be the X-Bar Values. Performing this type of quality control technique was to ensure that the time measurements that were recorded from each worker were in fact in statistical control. By statistical control it is meant that the data represented is within the defined parameters, these being the Upper Control Limit (UCL) and the Lower Control Limit (LCL). By tracking the ranges and the variances, it could be shown that the system was stable and hence derive that the associated process was in statistical control and justifiably that the standard times could be set around the mean. The following graphs represent the R and X-Bar value sets respectively. Although the X-Bar chart does seem to show a bit of a discrepancy form day 13 to day 15, the process remains within the specified limits namely the Upper Control Limit (UCL) and the Lower Control Limit (LCL). This validated the time measurements and thus the standard times for the manufacturing procedure were determined.



Graph 4.2.1: R-Chart showing ranges



Graph 4.2.2: XBar-Chart showing statistical control

These results are shown in Appendix G (on cd). With regards to days 13-15, as shown above, one can see that the workers were not performing well. They had slowed down their working pace. This fact results in the higher characteristics of the line graph depicted in the X-Bar chart. On further investigation it was found that the workers seemed to work slower towards the 15th of every month due to the fact that they were being paid every 15 days/fortnight or 2 weeks ("half-monthly"). A recommendation, which was suggested, was to pay the workers once a month, based on their performance to ensure that the workers would maintain their performance. Although the workers did show their human tendency to slow down towards payday, they still manufactured the components within the set out parameters and in reasonable time. This was also seen in the total amount of unit produced for the relevant days. The times remained within the control limits, which meant that the process was stable and in control. This then provided the justification that was needed to set the appropriate time standards.

Section 5: Results:

5.1 Results from time measurements:

With the data being in statistical control, it was then confirmed that the standard times associated with the manufacturing procedure were indeed the standard times that were to be used. Subsequently it can be said that the average time or standard time for a worker to complete one kit or manufacture 5 units/products is centered around the normal of 2875.456 seconds. This meant that it took approximately 47.9242 minutes to manufacture the 1 kit or 5 units, which meant that it would take approximately 9.585 minutes to manufacture 1 product/unit. With these time standards it was calculated that on average a worker was to finish 10 kits, or 50 products a day. This meant that if three workers were to manufacturer products on a day, the days' total amount of products would be 150 manufactured units. Assuming that there were 20 manufacturing days in a month, this meant that a total of 3000 manufactured products/units could be expected. This result was exceptional, and entailed a 600% increase in production.

Section 6: Formulating an Incentive Strategy:

6.1 A preliminary solution:

As a final task, the client required a strategy to evaluate the workers performance and develop a conceptual idea that would help him in determining whether the workers were manufacturing the products according to the standard time measurements previously determined. As a least expensive idea, it was suggested that once the products were completed, and had been tested, they get placed back into the kit plastic bag and a labeled coloured sticker placed on the bag. The coloured sticker would represent the specific worker, and a total number of completed products would be written on the sticker. This would enforce traceability and provide the incentive strategy needed. Although this concept would only be a temporary solution, it was the easiest to implement immediately. A more reliable solution to the problem would be to implement bar code scanning identification and provide scanning devices. This option would provide a more conclusive way to perform traceability as the bar code would be referenced to the circuit board identification number and serial numbers which were both unique to the manufactured product. This solution would need a database system and would be costly to implement, however would be the best solution for the future.

Section 7: Conclusion and References:

7.1 Conclusion:

Having established the standard times and processes to be followed the productivity of the company has tremendously increased. The six times increase in manufactured products/units is a direct result of applying the time study techniques previously discussed. These techniques are important for organisations and help set time standards and procedures that can be very reliable. With these time standards and procedures an organization has the ability to investigate into its processes, find discrepancies and eliminate them. It allows organisations to look for improvements within their processes and helps establish a norm within the organisation for the associated process. By clearly defining a systematic procedure that had to be followed for the manufacturing and preparation of the product, order within the processes was established. This aided in a more reliable and efficient way of recording the time measurement studies for a standardised process. Using the quality control techniques ensures that the measurements that you have recorded are within statistical control and ensures that the process is stable. This validation of results enables you to set the time standards with confidence, knowing that processes are in control.

"Clearly identify those problems that are caused by the workers and those that are caused by the system. Make continued efforts to identify problems in the system and find ways to solve them." Marvin E. Mundel

7.2 References:

All references within this document have been indicated by quotation marks and are indexed in Italics, which also appear where statements were referenced. The following sources have been used:

1. *W. Edwards Deming and Richard D. Elliott joined IIE in 1997 and currently work as industrial engineers for Boeing Commercial Airplane Co. in the Puget Sound region of Washington. Elliott is an industrial and manufacturing engineering graduate of Oregon State University.*
2. *Which Work Measurement Tool? C.Bruce Gowan, Manufacturing Engineering, March 1999*
3. *Motion and Time Study-Improving Productivity by Marvin E, Mechanical Engineering, October 1996*
4. *Work Measurement Practices, Vincent G. Reuter, California Management Review 1991*
5. *Work Measurement, Michael, Edward A, Small business report, March 1989.*
6. *Applying the techniques of motion and time study, plant layout and TQM to the real situation, Faculty of California State University Dominguez Hills, by Sanyaluck Paosila, 2002.*
7. *Marvin E. Mundel,Work Measurement for Lean Manufacturing*
8. *Benjamin W. Niebel, Methods Standards and Work Design, 11th edition.*
9. *P.E Randall, Motion and Time Study for Lean Systems.*

Appendices:

Appendix A

A1: 33k Resistors

A2: Small Capacitors

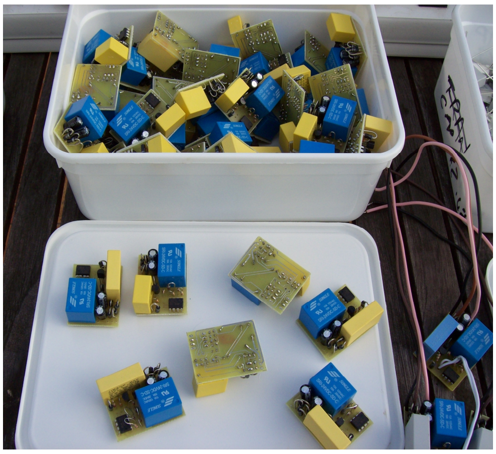
A3: Large Capacitors

A4: All Components and Testing Jig

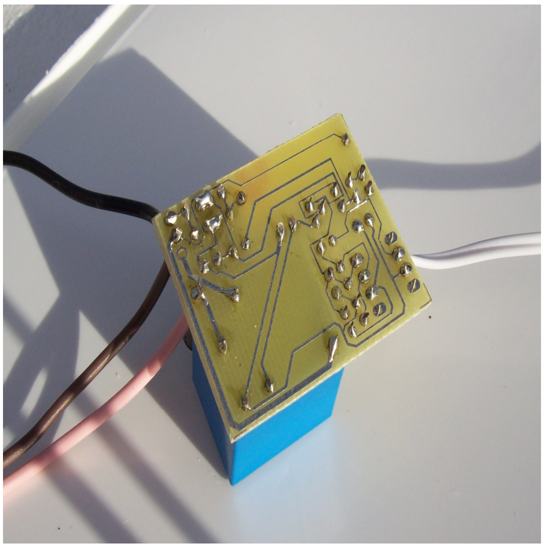
A5: PCB Circuit Boards

A6: Relay Switches

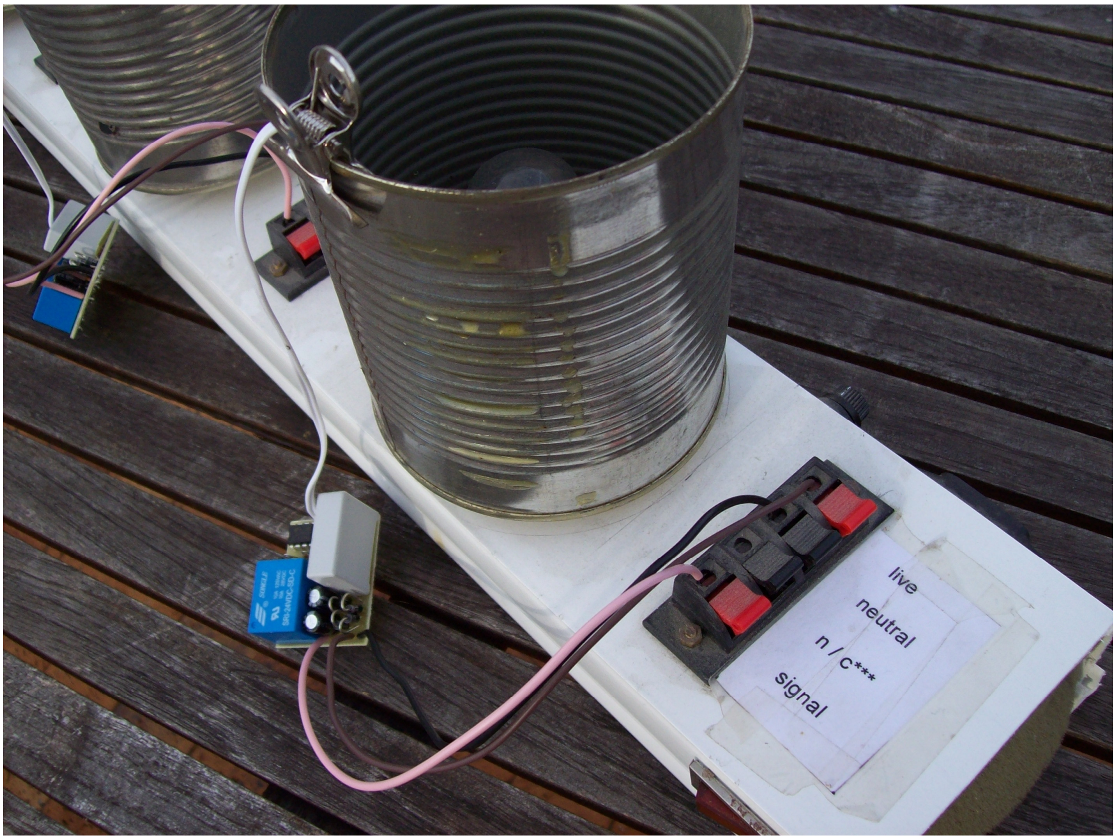
A7: Sensor Being Tested In the Testing Jig



A8: Final Product



A9: Soldering on Back



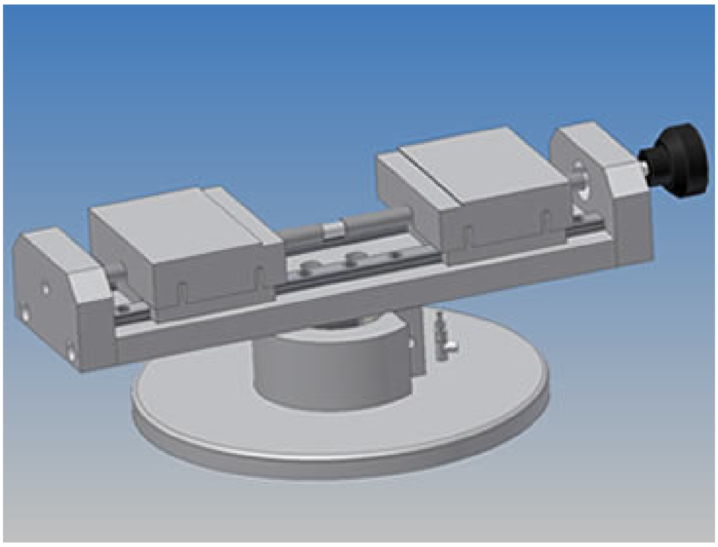
A10: Testing Jig Used To Test The Manufactured Units

Appendix B

B1: Soldering Iron

B2: Soldering Pot

B3: Flux



B4: Conceptualized Jig Design for Manufacturing Process