Powertech
Transformers

Assessing the features of the Quality Management System at Powertech Transformers

by

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Executive Summary

Quality Management Systems (QMS) are developed for many companies to forecast and manage the quality of products. It is the responsibility of a company to manage its QMS and its suppliers. The development of the International Organization of Standardization (ISO) and the South African Bureau of Standards (SABS) has made it compulsory for companies that are accredited to comply with the standards. Over the time companies tend to deviate from these standards which causes problems such as customer dissatisfaction, short life expectancy of the product and poor product reliability. Many companies have experienced large costs and losses due to non-conformance to the standards; therefore it is necessary to constantly test the level of compliance with the standards and to meet the customer's requirements adequately. This is important for companies to remain competitive and allow them to compete globally in their respective industries. The use of analysis techniques allows for diagnosing problems in systems so as to focus the efforts of the company to eliminate them.

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List of Abbreviations

PTT-Powertech Transformers

- QMS-Quality Management System
- ISO- The International Organization of Standardization
- SABS- The South African Bureau of Standards
- COPQ-Cost of Poor Quality
- CoQ-Cost of Quality
- RCA-Root Cause Analysis
- KPI-Key Performance Indicators
- CRT-Current Reality Tree

1. Introduction and Background

In general terms, Powertech Transformers formerly known as ABB Powertech transformers is a company focused on the supply, distribution and storage of electricity across South Africa. Power and distribution transformers are manufactured in three factories situated in Pretoria west, Booysens and Cape Town. This project is based on the factory that is situated in Pretoria west. The factory in Pretoria west is one of the largest within Sub-Saharan Africa. The facility is capable of manufacturing one of the largest transformers (up to 795MVA, 500kV) and distribution transformers (up to 10MVA to 20MVA). One of their major clients that they supply their product to is ESKOM and Municipalities as shown in the customer segmentation below. According to the company profile, PTT is an SABS ISO 9001 listed company. Furthermore the company has ISO 14001 accreditation for its environmental awareness and ISO 18001 accreditation for health and safety.

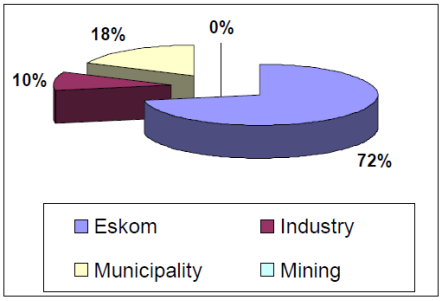


Figure 1: Powertech Customers

In April 2008, ABB Powertech transformers changed its name to Powertech Transformers. After the name change, Powertech Transformers seeks to test the effectiveness of certain procedures and systems in the factory. The QMS is one of systems that is being assessed and tested for effectiveness by continual improvement, internal audits and patrol inspections.

There are three main sizes of the power transformers. The standard and complex small power transformers (SPT) range from 20MVA to 63MVA and up to 172KV. There are different transformers in the SPT range including the double bound or the Auto-connected, Standard or high impedance transformer and the low sound pressure level transformers. The standard and complex medium power transformers (MPT) range up to 200MVA and 275KV. The standard and complex large power transformer (LPT) has a three phase power rating reaching higher than 200MVA and the voltage ratings higher than 275kV. The range of transformers for the MPT and LPT are similar to the SPT.

1.1 Problem definition

The Powertech Transformers (PTT) quality management system has been identified as a possible project due to the possible inefficiency of the system. The company plans to test the QMS to ensure that it is aligned to ISO and SABS standards. The Quality Manual is in the process of being updated and revised and several changes will be made.

The company manages their documents using a program called Microsoft SharePoint. According to the Wikipedia dictionary (2011), Microsoft SharePoint is a web application platform that has been established by Microsoft. It is an application that is designed to centralise and replace multiple web applications. It supports many different combinations of business website requirements. It is usually associated with content and document management for many companies. It provides functions like intranet portals, file management, social networking tools and many others. The system is very effective and it is also used by PTT to manage the quality management system.

PTT must identify possible areas in the QMS that could be improved to make the system more efficient. There are a large number of non-conformances stored on SharePoint but the data must be evaluated for possible trends for the trends to be analysed and ultimately to improve the efficiency of the QMS. The Costs of Poor Quality are to be analysed as these costs increase yearly. The current state of the system is to be analysed if improvements are to be made to the QMS.

2. Project Aim and deliverables

The main aim of the project is to assist PTT in the development of an effective QMS for the winding and the active part departments. The aim will be achieved by assessing the various features of the QMS using the tools that will be explored in the literature review. The objectives are stated below:

- **Objective 1**: This analysis aims to find the possible root causes using the best suitable method for PTT. The root cause trends will be analysed using root cause analysis (RCA) tools and methods.
- **Objective 2**: The COPQ will be analysed and recommendations will be made on a possible method of managing the costs.
- **Objective 3**: The analysis of root cause data will be used to deduct the trends and recommendations will be made.
- **Objective 4**: The project aims to also define Key Performance Indicators (KPIs) for PTT.

- **Objective 5**: Analysis of the Quality Auditing procedure and testing its effectiveness.

After the evaluation of the various aspects using different approaches for the assessment, a recommendation will be made to identify possible problems or trends that may be revealed. In this report the data that will be collected from the PTT Quality Management System. At the end of the project the deliverables will be as follows:

- **Deliverable 1**: The results from the analysis of trends in the Cost of Poor Quality (COPQ) and a method that was selected to be used when analysing the Cost of Quality (CoQ).
- **Deliverable 2**: The results from the analysis of trends and behaviour of the Root causes obtained from Sharepoint.
- **Deliverable 3**: The results of the analysis of a Quality Audit using researched methods.
- **Deliverable 4**: The KPIs defined for the QMS.
- **Deliverable 5**: The results from the RCA and recommendations of the methods to be used for RCA.

2.1 The stakeholders

In this project the stakeholders are the student for responsibility of conducting the proper research and analysis. The mentor at the Department of Industrial is also a major stakeholder along with the project sponsor from Powertech Transformers (PTT). PTT is a stakeholder as the results from this project may highlight important trends and information that was not realised prior to the project. If the project reveals important information then the Quality Department stands to gain momentum to implement some of the recommendations or further investigate the problems.

3. Project Scope

The scope of the project is based in two main departments, manufacturing of the windings and the active parts departments. There are four stations in the windings department which are the manufacturing station, the assembly station, the drying station and the packaging station. There are two main stations for the active parts department.

1. The student will be required to observe the manufacturing process along with the supervisors and the quality auditing technician; this will allow the student to identify the non-conforming products during the Quality Audit.

2. The winding stations that will be investigated are for the small, medium and large transformers since the processes are similar for all the transformers.
3. A quality audit will be performed for the four departments and recommendations will be made from the audit findings.
4. The costs of poor quality will be analysed for trends and recommendations will be made to manage the costs.
5. A number of selected cases will be analysed using Root cause analysis (RCA) techniques. The techniques will be compared and the best fitting techniques will be selected.
6. The RCA techniques will be used to analyse variation in human performances for the PTT employees.
7. The recommendations that will be made will only diagnose problems and not solve actual problems in the QMS.

4. Literature Review

4.1 Conformance and non-conformance

The general definition of a non-conformance is that it is an item, process or event that does not match the requirements that have been defined for it. A non-conformance usually has costs with which impacts the overall system negatively. The term “non-conformance” is derived from the root word “conformance”; conformance is defined in the Total Quality management (TQM) magazine (Stevenson: 1996) as carrying out an action according to a set of specified standards. The main purpose of a conformance is to find a balance between empowerment and control. The conformance cycle is used to describe all the elements that are involved in conformance.

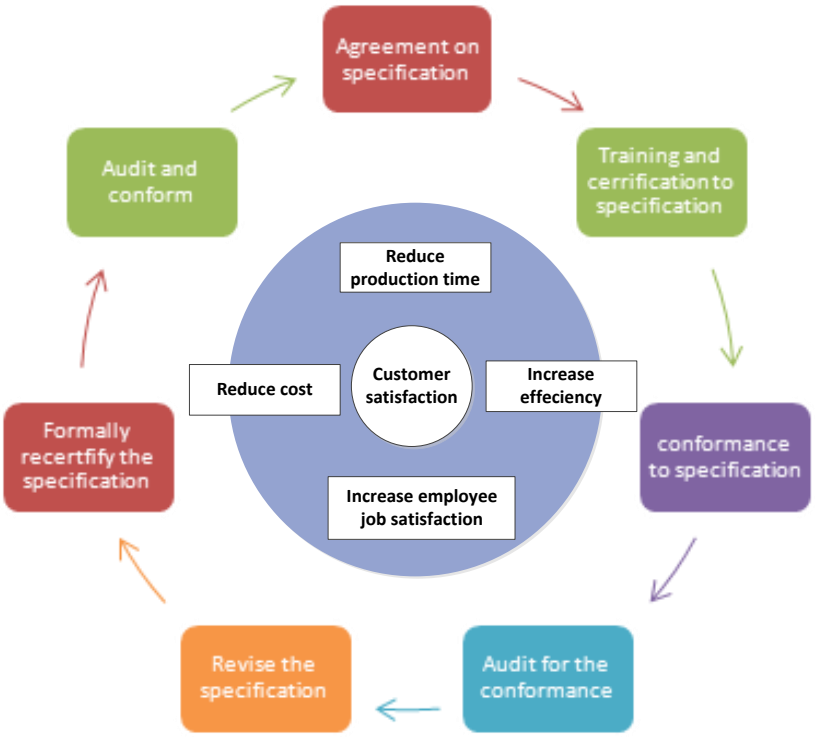


Figure 2: The conformance cycle (Stevenson: 1996)

The main focus of the conformance cycle is customer satisfaction. To attain customer satisfaction with the product or service there must be a focus on issues like reducing the overall production time, increasing the efficiency of production and reducing the cost of production. The conformance cycle is fundamentally focused on specifications. The specification is implemented and the conformance to the specification is analysed using various methods like auditing. The specification may also be analysed and revised after audits.

Non-conformances in an organisation need to be addressed to ensure that the final product is not affected. The ISO standards (ISO 9001:2008) state that an organisation should define procedures to address non-conforming products before they are delivered to the customer. According to the standards, action should be taken to eliminate nonconformities even after the product has been delivered to the customer.

4.2 Continual Improvement

The ISO standards (ISO 9001:2008) state that organizations must frequently improve the effectiveness of their quality management systems through the use of quality policies, audit results and many other methods. This is an important aspect that would make the company more competitive. The model for continuous improvement is illustrated in the ISO 9001:2008(E) standards.

The model illustrated below is the core of Quality Management Systems (QMS) that are implemented in many companies including PTT.

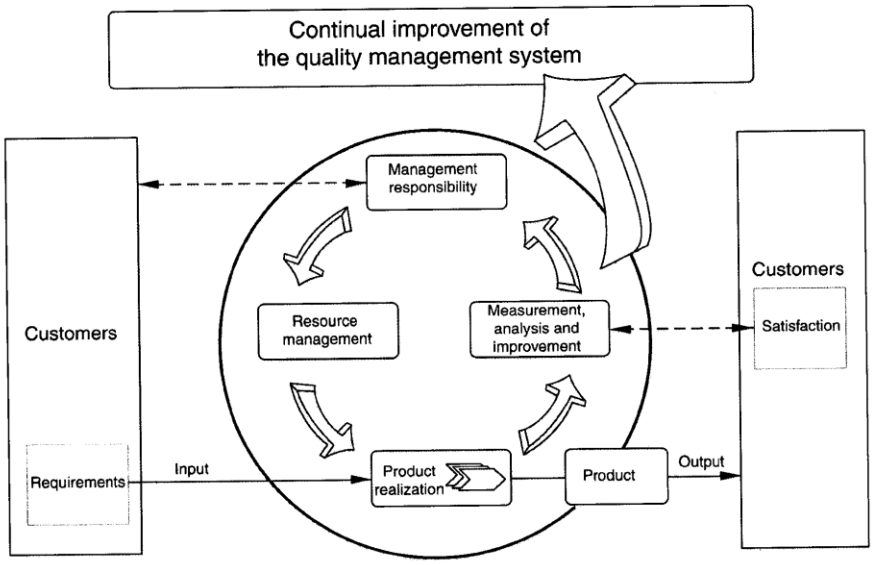


Figure 3: Continuous Improvement cycle (ISO 9001:2008)

The project is however focused on the process of dealing with products that do not conform to the quality standards that have been defined. Solving of non-conformances usually requires that preventive and corrective measures be specified for that situation to avoid future re-occurrences and costs. The need for improvement of quality via QMS is an essential part of continuous improvement.

4.3 Corrective action

According to (Russel & Regel, 2000), a corrective action is the action taken to remove the cause of non-conformities that have been detected in order to ensure that they do not re-occur. It is important to note that corrective action is a part of continuous improvement but it is not the entire QMS because a QMS has more components and aspects to it. This implies that an effective corrective action initiative does not mean continuous improvement. Complimentary to this definition, corrective action is defined

in the ISO standards (ISO 9001:2008) as the action that is taken by an organization to eliminate the cause of a non-conformance to eradicate the risk of its reoccurrence. The standards emphasize that an organization should have documented procedures on how to deal with non-conformances particularly:

- The re-evaluation of non-conformances
- Define requirements on finding the cause on non-conformities
- The evaluation of action to ensure that the non-conformity will not reoccur
- Ensuring that the action is implemented
- Gathering the results of the corrective action taken
- Evaluating the usefulness of the corrective action taken

Remedial action, on the other hand, is defined as an action taken to lessen the effect of the symptoms of non-conformities or undesirable situation (Russel & Regel, 2000). The purpose of a remedial action is to contain the effects of the non-conformity. It forms part of a corrective action process. The reasons for taking remedial actions may be:

- That there is no data to confirm that the problem is serious
- That there limited time for performing full corrective actions on all nonconformities

The corrective, preventive and remedial actions operate in the QMS and the relationship between them is shown in the figure below.

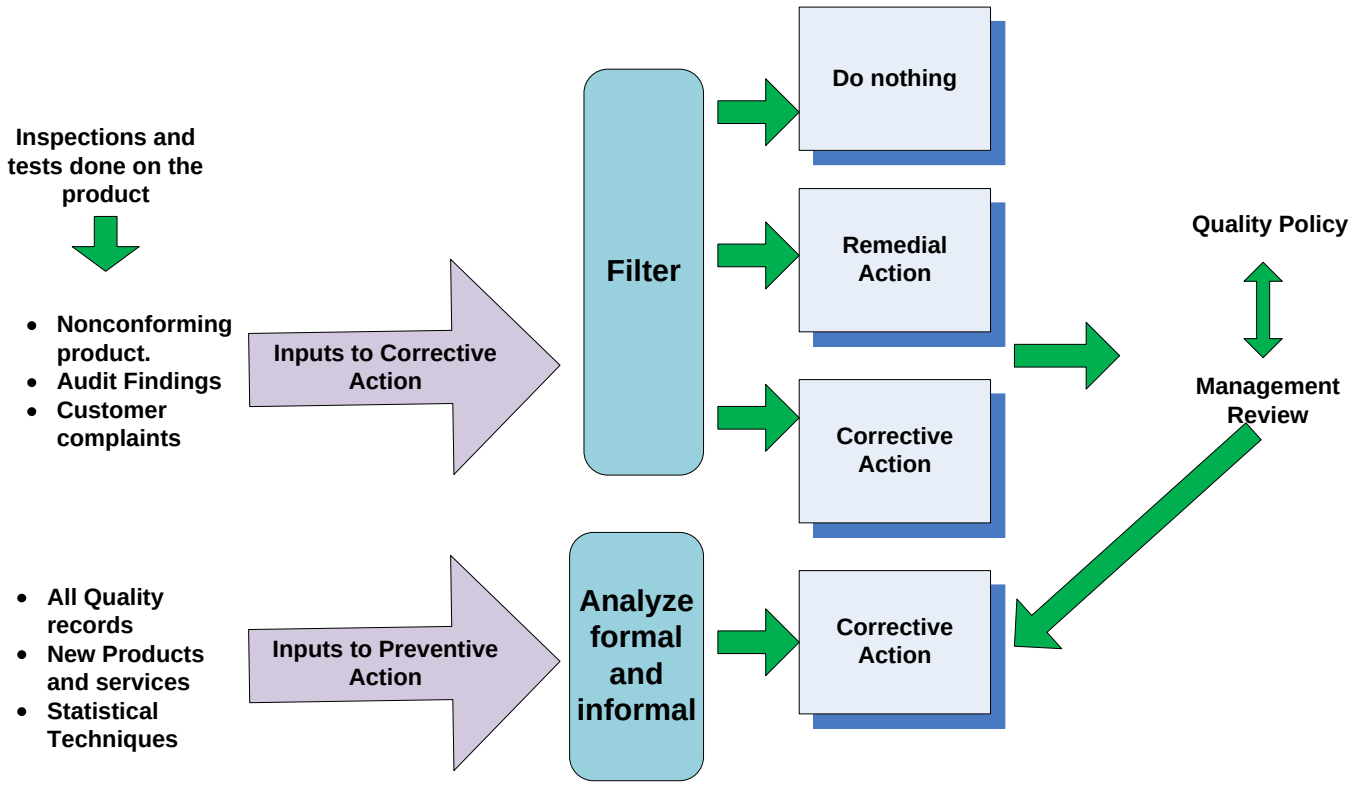


Figure 4: Corrective and preventive action process inputs and outputs (Russel & Regel, 2000)

The process begins with the results from testing and inspecting products then the non-conformance of a product will be detected from the results. The non-conformance will then be screened and filtered to see whether it is a minor issue that can easily be resolved or a more complex issue. Once this has been analysed, the action chosen can either be to do nothing, to perform a remedial action because the issue is minor or to take corrective action because the issue is serious.

Dennis (Arter, 1947) adds that the general program for executing a corrective action consists of three core components. The first component is to identify the problem using the tools that are available in the organisation. The second component is to fix the problem and then to find the underlying cause of the problem and to correct it.

4.4 Preventive action

Preventive action is defined by J.P Russel (Russel & Regel, 2000) as an action taken to eliminate a potential cause of a nonconformity in order to prevent its occurrence. Wikipedia (Corrective and preventive action) states that the purpose of a preventive action is to prevent potential failures from

occurring. J.P Russel also relates to Figure 4 and states that inputs to the preventive action program are as follows:

- Collect data- this data can be in the form of quality records relating to nonconforming data, audit findings and customer complaints
- Analyse the performance data-the data will be analysed by using different techniques. The techniques for analysis of the data may include statistical techniques, Pareto charts, cause and effects diagrams and scatter plots
- Reveal trends and patterns-once the tools have been used then the trends may be observed. These trends may mean potential improvement areas therefore plans will be made to eliminate the potential occurrence of the failure.

Preventive action programs may be seen as proactive methods when compared to the reactive nature of the corrective actions. The ISO standards (ISO 9001:2008) require that there be documented procedures defined to address preventive actions:

- To determine the potential causes
- To test the need of the preventive action to eliminate occurrences of nonconformities
- To actually implement the action that is required to eliminate the nonconformity
- To keep the records of the results when the preventive action was executed
- To test the effectiveness of the preventive action

4.5 Quality Audits

There are many different meanings to the term “audit”. A few sources were examined establish an apt meaning for the word. Firstly, the Oxford Dictionary states:

> “An audit is an examination of organizations accounts”

The second definition obtained from the investor’s word website (Webfinance Inc)states that the definition of an audit is:

> “An examination and verification of a company’s financial and accounting records and supporting documents”

The definition of an audit seems to be generally focused on the examination of financial records but this definition is incomplete since auditing is not only based on financial systems, it has more aspects to it. When one adds the specific context into which one wishes to base the term “audit”, a different definition is obtained.

The term quality audit has been defined using Wikipedia (Quality Audit, 2011)as:

> "The process of examination of a quality system carried out by an auditor or an audit team"

The common ground for all the different kinds of audits is that they are all examination processes for testing an aspect of a system. According to Dennis Arter (Arter, 1947), there are three main types of audits based on their applications in the quality, finance and environmental areas. The quality audit is further broken down into four kinds of audits as illustrated in the image that follows. There are process-, product-, and system audits as well as vendor surveys.

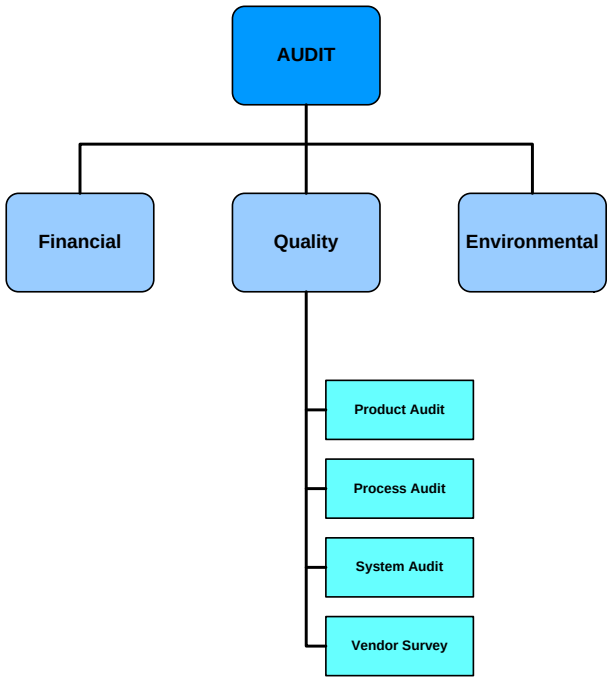


Figure 5: Characteristics of all the Audits (Arter, 1947)

A product audit re-examines the quality of the finished product in detail before the product is delivered to the customer. A process audit is a less extensive audit performed on a smaller scale; it measures a selected area of the work effort. A system audit examines most or a part of the management control components for non-conformance. Finally, a vendor survey reviews the vendor's management of their products.

The common characteristics of the above mentioned audits are as follows:

1. They examine a selected portion or area of a larger system.

2. The methods of the audits are to examine a portion and then make deductions for the entire process
3. The audits are performed by a third person who is not directly involved in the area to be audited.

Findings and observations identify the unsatisfactory elements and conditions that are found during the audit. It illustrates a noncompliance and is detected as a weakness in the system.

The basic auditing process as defined by J.P Russel (Russel & Regel, 2000) consists of six main elements that need procedures to be defined, these are:

- Methods
    - Procedures for planning the audits.
    - Procedures for selecting the auditors.
    - Procedures for executing the audit.
- Measures
    - Formats for the audit reports.
- People
    - Methods of training the auditors.
- Equipment
    - Used for communication and compiling audit reports.
- Materials
    - Standard company documents and procedures.
- Environment
    - Good working conditions.

An important aspect to note about quality audits is that the manner in which they are conducted is important to the success of the audit. The audit is also defined by ISO standards (ISO 9001:2008) as an important component of a QMS. ISO states, in section 8.2.2 that an internal audit must be conducted in an organization at planned times as a part of monitoring the system. The audits must conform to the requirements of ISO and the requirements set by the organization.

4.5.1 The procedure of the quality Audit

The structure of an audit mainly consists of seven phases that each have subcomponents. It is important to follow these steps to ensure that the correct results will be obtained from the audit and that the audit is effective. The audit phases are shown in the image below.

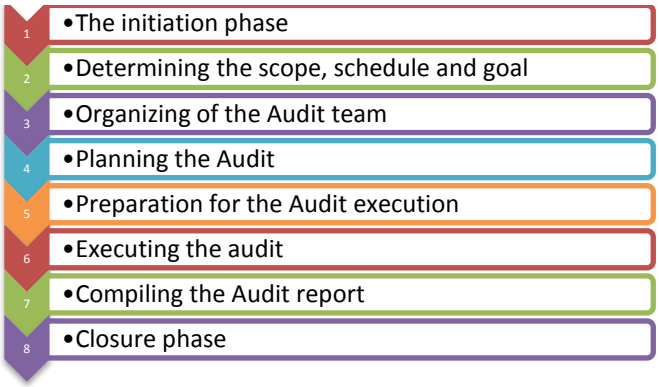


Figure 6: The phases of a quality audit (I.A Bechmerhagen, 2004)

The first few phases consist of setting the date, preparing the audit team, checklists, notifying the department to be audited, planning for the audit. The execution phase is composed of gathering the data and the analysis of the information. The reporting phase is the translating and communicating the findings to the rest of the staff and management, and publication of the formal audit report. The closure phase follows up on the actions planned, tracking, and further evaluation. The team addresses the problems by corrective actions and by eliminating the root cause by preventive action.

An important phase in the audit is during the preparation for the audit. There are many key elements to that phase and it is important that it is done thoroughly. Dennis (Arter, 1947) emphasizes that the formal notification should contain the following elements:

1. The departments that will be audited.
2. The date of the audit (especially when there is no preliminary schedule).
3. Reason for the audit procedure.
4. The sections or the activities that will be audited.
5. The standards that will judge the performance.
6. The person (team) who will be leading the audit.
7. How the audit has been scoped.

The next vital part of the audit is the execution of the audit where the physical data is collected from the factory. This part is the inspection of the process, documentation or procedure. The physical examination requires criteria that will be assessed according to the performance standards (ISO 9001:2008) stated in the audit notification. Any faults found after testing are called audit findings. The findings are recorded and will be discussed with the respective department to resolve them.

4.5.2 The Audit report

The Audit report is a method of communicating the results and the findings of an audit to management and other members. The characteristics of a good audit are suggested by Dennis Arter (Arter, 1947):

1. The audit results must be verifiable, meaning that the evidence to support the findings must be easily traceable.
2. The report will contain judgements which express either approval or disapproval.
3. There should be a summary section in the report. This section should assess the overall performance of the system from the findings.
4. The findings must be in the report and they must have supporting evidence in the report. Some similar findings should be consolidated into one generic finding.
5. The report must be clear and unambiguous.

4.5.3 Analysis of the Quality Audit Findings

After the compilation of the audit report it is necessary that the report be discussed with the managers and other participants to ensure that they understand the findings. The next step is the closure phase where the audit team and the managers set up a meeting to discuss the corrective and preventive actions for the findings. There are many tools to analyse the findings. One of the tools is named a reason matrix and will be explored further. This matrix is a tool of analysing audit findings to see which are the most important and need to be addressed. The purpose of a reason matrix tool is to connect the audit findings to the defined company objectives. It is one method of analysing the cause and effect of a finding.

The method considers the reasons for raising a finding and the possible effect of the nonconformity on the company. The matrix plots the reasons raising findings against the effect that it may cause and then the severity of the finding is assessed. The possible reasons for an auditor to report a problem may be in one of the following categories:

Reason 1-Not defined or documented

This reason addresses the findings that do not meet the requirements of quality management standards

Reason 2-Not implemented

This reason says that the system is designed very well but it has not been implemented properly in all the sections of the company that were inspected.

Reason 3-Does not meet objectives

This reason means that the system meets all the requirements but the results from the performance of the system are not in line with the objectives that were defined.

There are interests of the manager from a quality audit. These interests are referred to the “pains” and they may be classified in to three comprehensive categories:

Pain 1: Cost

Managers need to know that if they address a problem, that costs may be reduces. These costs may be direct product costs or decreased production costs from a more efficient system.

Pain 2: Opportunity

It is important to know that, by focusing on the findings”, there may be a new opportunities created in the forms of new products and markets or increasing the capacity to produce more products.

Pain 3: Risk

If it will be possible to reduce the risk of loss by addressing a finding, managers will find an interest in it. The loss can be in the form of monetary loss or the loss of customers.

Table 1: Format of a Reason-Pain Matrix

No.	Finding	Reason			Pain			Comments
		R1	R2	R3	P1	P2	P3	

4.6 Cost of Poor Quality

The definition of the cost of quality may be summarised as the cost of the planning, designing, implementing and maintaining of a QMS. The cost of quality is defined as the cost of conformance which is the cost of operating the QMS and the costs of non-conformance which are the costs of poor quality (Andrea Schiffauerova, 2006).

Wikipedia (Cost of Poor Quality, 2011)defines the cost of poor quality (COPQ) as the cost that would be eliminated if a system, process or product was faultless.

There are various methods of analysing the COPQ. These methods are (Andrea Schiffauerova, 2006):

1. The P-A-F model.
2. The Crosby model.
3. The Process cost model.

These methods are further discussed below.

The P-A-F model (F. Merle Bland, 1998) allocates costs to three different groups as follows:

Prevention cost is the cost associated to all that actions that are taken to prevent nonconformities in the product, process and system. These are the costs according to the author (Taylor, 2011):

1. Costs of planning and implementing a QMS.
2. Costs of training people to regulate the QMS.
3. Process or product costs.

Appraisal cost is the cost of testing and assessing the effectiveness of the quality system (Taylor, 2011) such as:

1. The cost to inspect the product or process.
2. The cost to gather data.

3. The cost to test equipment.

Failure cost is the cost linked to a non-conformance. There are two types of failure costs namely the internal failure cost and the external failure cost.

1. The cost due to scrapping and wasting of material.
2. The cost of reworking.
3. The cost of downtime in the production line.

Crosby's model

This model considers the cost of quality similar to the P-A-F model but Crosby defines the "conformance to requirements" and emphasizes the idea of zero defects. He defines the COPQ in terms of conformance and non-conformance and also reasons that the costs of poor quality outweigh the costs of preventing poor quality as illustrated in the figure that follows:

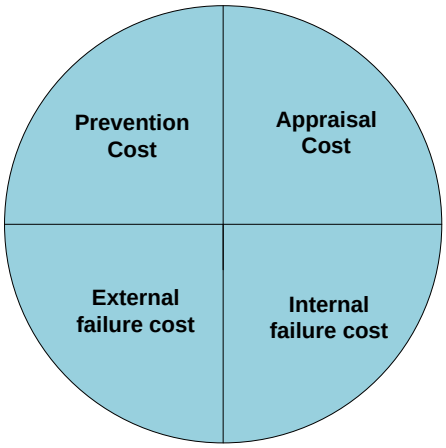


Figure 7: The COPQ categories (Beercroft, Dennis Inc)

Process cost model (F. Merle Bland, 1998) allocates costs to either conformance or non-conformance

Cost of conformance is the minimum cost of a process. Cost of conformance includes the prevention and appraisal costs as defined in the P-A-F model.

Cost of non-conformance is the cost of an efficient QMS and it composed of external and internal failure cost from the P-A-F model

In conclusion the costs of poor quality can be divided into the following broad categories (Harrington, 1999):

Direct cost of poor quality

1. Controllable cost of poor quality:
    a. Prevention cost,
    b. Appraisal cost,
    c. and non-value added cost.
2. Resulting cost of poor quality:
    a. Internal cost of failure
    b. and external cost of failure
3. The cost of failed equipment

Indirect cost of poor quality

1. Customer-incurred cost.
2. The cost of customer dissatisfaction.
3. The cost of losing reputation.
4. The cost of the opportunity lost.

The traditional methods of analysing the COPQ according to the TQM magazine article (Andrea Schiffauerova, 2006) is based on the prevention, appraisal and failure costs. The P-A-F model is the most frequently used model in most companies. The P-A-F model is an excellent model for viewing costs of poor quality but there are also alternatives as mentioned before namely the process model cost and the Activity Based Costing (ABC). It is important for companies to assess their situation and see which model bests suits the needs of the company. The process model and ABC model focuses on the process and they allow the company to observe the trends of the Cost of Quality.

The main idea behind analysing the costs of poor quality is to analyse the trends and then find methods to reduce the costs. Once the trends are analysed it will be clear to see which costs contribute the most to the poor quality. The analysis of the COPQ along with root cause analysis can largely reduce the nonconformities that occur in a company.

4.7 Root Cause Analysis

Root cause analysis (RCA) is defined by James Rooney (reference) as

“a process designed for use in investigating and categorizing the root causes of events”.

The second definition of RCA is from an article on quality and productivity (Mahto & Kumar, 2008) which states that

"*..It is the process of defining causes of problems using a structured approach with techniques designed to provide a focus for identifying and resolving problems*"

Root cause analysis (RCA) is a tool used for identifying the underlying cause of an event. The RCA tracks the cause and effect trail from the failure to the root cause .There are several factors that justify the use of RCA.

1. The number of repairs that were performed during a stated period.
2. The percentage of the productivity that was delayed due to non-conformances.
3. The number of products that were rejected by the customer.

The main categories of root causes are stated below:

1. Equipment.
2. Procedure.
3. Personnel error.
4. Design problem.
5. Training deficiency.
6. Management problems.

There are seven steps for conducting a root cause analysis. It is essential to note the importance of collecting the relevant data that will be used for the RCA.

1. Find and describe the actual root cause.
2. Describe the physical event of the root cause.
3. Organize the details of the root cause.
4. Assemble a team that will work together in finding the root cause.
5. Consider all possible root causes.
6. Verify the logical root causes and eliminate illogical root causes.
7. Separate the human-error causes from physical causes.

James Rooney (Heuvel, 2004), however, summarises the RCA process in the four main phases.

1. The data collection phase where all the data is collected from the different sources and studies that are conducted in the facility.
2. The causal charting phase gives a framework for the investigators to organise the data that has been collected.
3. The phase when the root cause is identified using the tools that will be discussed later in the report.
4. The recommendation phase includes the presentation of the RCA results and recommends the actions to be taken in eliminating the root cause.

The tools that are used for RCA are divided into the basic tools and the advanced tools.

Table 2: Tools and methods of RCA

Basic Tools	Advanced tools
Ishikawa(cause and effect diagram)	Logical tree
Pareto chart	Affinity diagrams
Histograms and frequency plots	Statistical Process Control
Change Analysis	GAP analysis
Process Flow charts	Process failure mode effects analysis (PFMEA)
Barrier Analysis	Process capability analysis

Each tool is briefly explained in this report in terms of use and the logic behind the model. To effectively use the tools and methods stated in Table 2, the criteria for comparison must be defined

The Ishikawa diagram is also known as a cause-and-effect diagram (Latino R. J., 2007). It is designed to help stimulate creative thinking and it is framework for planning the data that will be collected. It visually displays the causes that are being studied and may also reveal potential causes. The most popular categories for the Ishikawa diagram are the 4Ms, 4Ps and 4Ss. The 4Ms stand for material, methods, machines and manpower. The 4Ps stand for people, policies, procedures and places. Lastly, the 4Ss stand for systems, suppliers, skills and surroundings. A representation of the Ishikawa diagram is shown below.

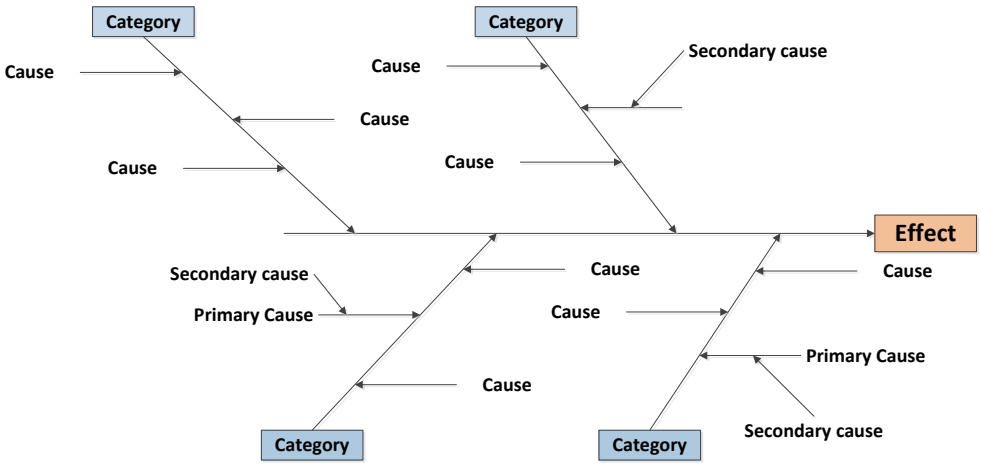


Figure 8: The Ishikawa diagram (Latino R. J., 2007)

The process flow charts represent the steps of a process on a graph. It helps the users to see the entire process from start to finish. It also shows the inputs and the outputs of a process. It is used to locate problems in a process and shows the relationships between the steps of a process (Northrop Grumman Corporation, 2006). There are three main types of process charts (1)the high level overview,(2) the operational level chart that links the inputs to the outputs ,and (3) the design level chart that shows the operator methods and materials.

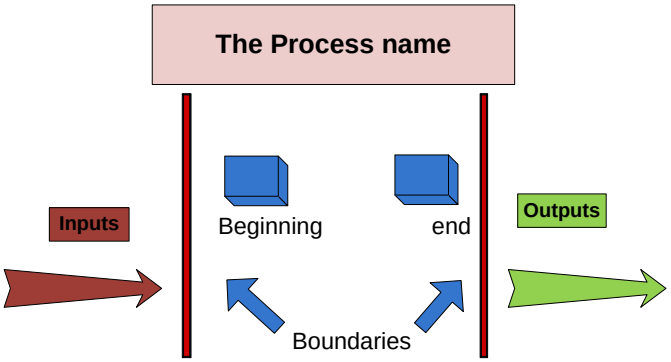


Figure 9: The process flow diagram template (Northrop Grumman Corporation, 2006)

Histograms and frequency plots display large quantities of complex information. They are similar since both give a summary of data from a process and represent the data graphically. They are normally used to see the capability of a process to meet the needs of the customer. They are used to show the information in an easy to read format other than tables. The frequency plot shows the relative frequency that an event occurs as well as the distribution of the data. The histogram uses the information from the frequency table for its construction.

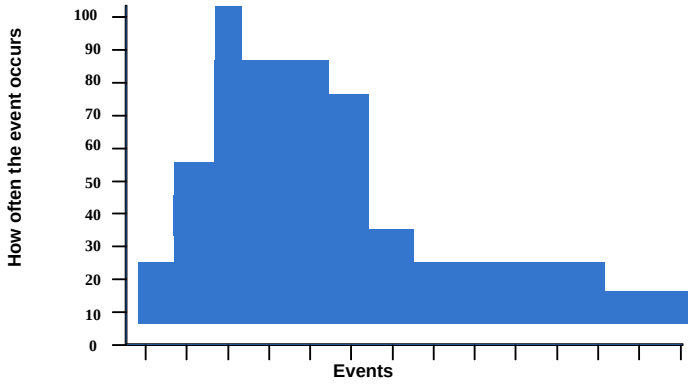


Figure 10: Frequency diagram (Northrop Grumman Corporation, 2006)

The Pareto Chart can be used to find the underlying causes of an event. Firstly, it is used to show the highest number of occurrences. The information is plotted on the Pareto chart so that it can be viewed graphically. Secondly, they are often used to improve chaotic processes since they draw attention to the major issues. For RCA, Pareto charts help to focus the efforts of the team. The basic construction of a Pareto chart is shown below.

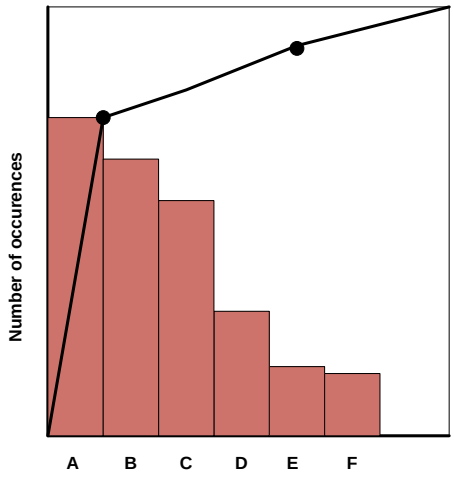


Figure 11: Pareto Chart (Gitlow, Oppenheim, Oppenheim, & Levine, 2005)

Affinity diagrams are techniques that are used to capture all the views, ideas and responses to particular problems including behavioural aspects. Affinity diagrams group the data into comparable categories so that they can be analysed (Northrop Grumman Corporation, 2006). They are also considered as one of the less structured forms of RCA.

Process failure mode effects analysis (PFMEA) is a tool that helps in identifying occurrences and detections of failure. It provides a guide in the creation of corrective plans and the mitigation of the

risks. The goal is to eliminate the failure mode and reduce the risk of its occurrence. The process identifies the failure mode before it occurs, then determines the severity of the failure mode and then identifies possible controls (Northrop Grumman Corporation, 2006)

Process capability analysis is a tool that determines whether a process is unstable, and then determines the causes of the instability. The tool also recommends actions to be taken to remove the cause of instability. It mainly compares the output of the process (known as the voice of the process) to the input of the process (known as the voice of the customer). The aim is to align the inputs to the outputs of a process (Gitlow, Oppenheim, Oppenheim, & Levine, 2005)

Change Analysis: It is a six step process that describes a problem or an effect. The same situation without the problem is also analyses then the differences between the situations are compared. The causes for the differences in the two situations are identified from this analysis. This method does not provide a specific root cause but can generally identify all the causes.

Barrier Analysis: It is an incident analysis that detects all the barriers that are in place to protect an object from harm. It investigates whether the barriers failed, held or were compromised. The conclusion drawn from the barrier analysis identifies the reason for the barrier failure as the root cause.

There is a difference between a tool and a method. The tool is defined in the Oxford dictionary (Catherine Soanes, 2006)as the equipment used to carry out a function. A method is the technique of doing an action i.e. the manner in which tools are used. There are methods and tools used for RCA. There are several methods that will be briefly explained in this report (L.Gano, 2007).

Method 1: Fault tree is used to trace an event to its root cause by identifying the sequence of the failure and then aligns them to the cause. The results from this chart are used in the construction of a tree diagram which is discussed below. The events and the conditions are analysed on the causal chart and placed onto a timeline.

Method 2: Tree diagrams are very common methods of analysing root causes. The common forms of this method are the Ishikawa diagram, the human performance evaluation systems and other methods. The main problem is placed at the top of the tree and the categories of causes are placed as branches of the trees. The categories are further broken down into sub–categories. At the end of the analysis the team is asked to review the causes that are most likely.

Method 3: Five-Whys method aims to uncover the root causes by asking “why” five times. Through every cycle of asking why, the answer reveals a new layer of contributing factors and the end result is identification of the root cause. This method is usually used in conjunction with the Ishikawa diagram to provide more effective results. This method is also ideal for defects that have more than one root-cause associated to it.

Method 5: Current reality trees (CRT) are similar to the 5-Whys analysis during construction and are based on the theory of constraints (TOC). The reality tree evaluates the problem or the effects and the causes of the problem are investigated by answering the question “why?” The answers are plotted onto the reality chart and the solutions are added to each root cause. The chart clearly shows the relationships between the causes and all the causes must have supporting evidence added.

Failure can be classified into 4 main categories namely problems, opportunities, sporadic and chronic. The problems category looks at failure as a disturbance to the system and failure in the opportunity classification is the ability to perform better. The sporadic failure is dramatic and requires a great deal of attention but only occurs occasionally. A chronic failure is the type of failure that is accepted as part of routine and forms part of the status quo. The failure type that is mostly overlooked in companies is the chronic failure.

4.7.1 Human performance variation

To encourage day-to-day continuous improvement, it is important to adopt methods to manage root causes. Human-error is a common cause of non-conformances but it is seldom easy to find the pattern to this root cause. Human behaviour is subject to many external factors and the trend of human-error is called the error-change phenomena. This phenomenon is shown in the Figure 12. Human error is not a valid root cause due to the other underlying factors that can be investigated to find the reason for the variation. Most errors committed by the employees have causes like tools, machines and the work environment.

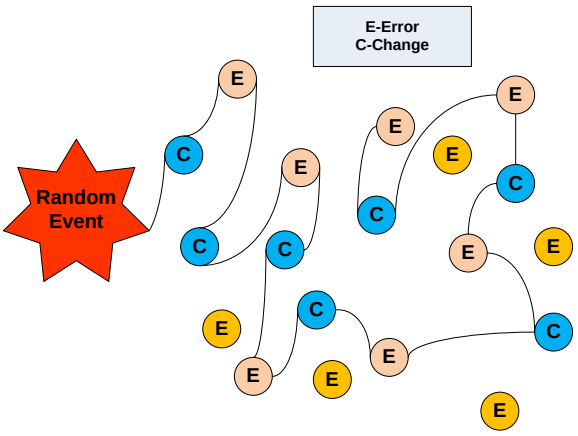


Figure 12: The error-change phenomenon (Latino & Latino, 2002)

The error-change phenomena theory states that the trend of human error can be seen as a chain that consists of a cause and an effect. The elements are interlinked and breaking one link in the chain can break the entire chain and eliminate the root cause.

There is variation among people and it is important to manage and reduce this variation. The sources that contribute largely to the variation of human performance must be thoroughly investigated and eliminated. Performance management refers to the actions taken to reduce uncontrolled variation by eliminating the root causes and preventing reoccurrence. Performance improvement refers to the strategies that are developed for short or long terms, to remove uncontrolled variation. The common techniques that are used to find root causes cannot easily identify the root causes of human variation. Pareto charts, Line and bar graphs are effective when it comes to root cause analysis for human performance variation.

4.7.2 A3 brainstorming methods

A3 is defined traditionally by the oxford dictionary (Catherine Soanes, 2006) as a “standard size of paper with the dimensions of 420x297mm”. The definition that is applicable to this project is the definition from the six sigma conference (Anthony Manos, Ptofero Inc, 2009) that states that it is a “standardized approach for team based problem solving”. A3 brainstorming uses the A3 size paper to structure a solution to a problem. It presents the solution in one page from start to finish so it makes it easy for the reader to trace the solution.

Most companies, like PTT, use the A3 structure as a tool of solving problems mainly due to non-conformances in the company. According to Anthony Manos (Anthony Manos, Ptofero Inc, 2009), the

method encourages “collaborative and in-depth problem solving” and it addresses many aspects of the company including the strategic, system and process as illustrated in the image below.

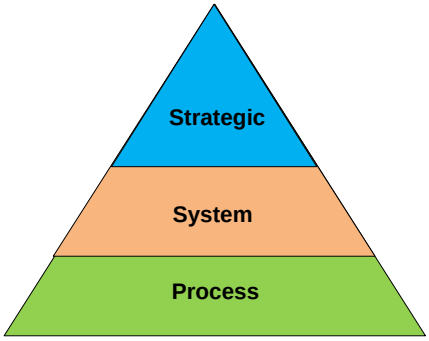


Figure 13: the scope of the A3 process

The strategic components include business planning. The system components are the other kinds of planning such as the design team planning and mapping of the value stream. The process is composed is of solving problems and the work that is standard in the business. Within these components there are forms that are related to them. The strategic forms include the Swot analysis forms, tree diagrams and the competitor analysis. The system forms include the value stream map which consists of the comparison between the future ideal state and the current state. The process analysis forms include the standard combination work sheet and the problem solving from. The tools of the A3 are identical to the root-cause-analysis tools therefore they will be analysis in-depth in the root cause analysis sections of this report. :

- Pareto diagrams
- Gantt charts
- Flow charts
- Tree diagrams
- Histograms
- Ishikawa diagram
- And Control charts

4.7.2.1 Procedure for A3 brainstorming

The A3 method is for addressing a specific problem in a business. The structure of the A3 brainstorming process is based on the A3 report where the solution is laid out. A3 is a standard procedure that is

described in the figure below. The span of the A3 project could either be short, medium or long term. The process can be summarised (AaronscreationsCompany, 2008-2011) in the diagram below.

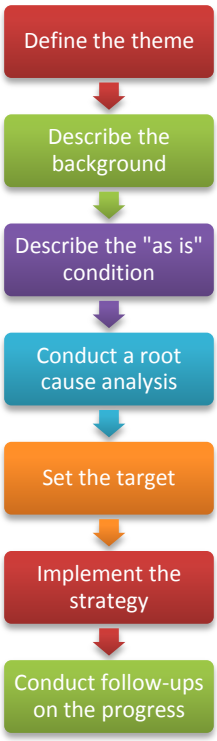


Figure 14: The steps of A3 process (AaronscreationsCompany, 2008-2011)

The A3 process begins with the definition of the theme or the topic that will be discussed during the barnstorming sessions to follow. The theme is usually based on a recurring nonconformity from the company. Once the theme is established then the background of the issue is described in detail. The next phase requires the analysis of the “as is” condition to be analysed. Analysing the current state of does not mean defining the solution already. To illustrate the current situation graphs and data can be used. The root cause analysis tools will then be used to investigate the root causes of nonconformity. These tools have been mentioned in the previous section. The ideal or target condition is set and plans are made to achieve the target. Once the solution has been laid out then it is implemented and then a follow-up must be done to see the effectiveness of the solution. The effectiveness can be tested using metrics and cost benefit results.

5. Analysis of the current environment

5.1 The IO System

The current system that is used to manage and control all the documents of PTT is SharePoint. This software, as previously mentioned, is an effective system but there are still non-conformances that occur at the plant. The non-conformances are called Improvement opportunities (IO). All of the non-conformances are required, by the company quality policy, to be investigated internally by appointed employees. The figure below illustrates the flow of the investigation process of an IO.

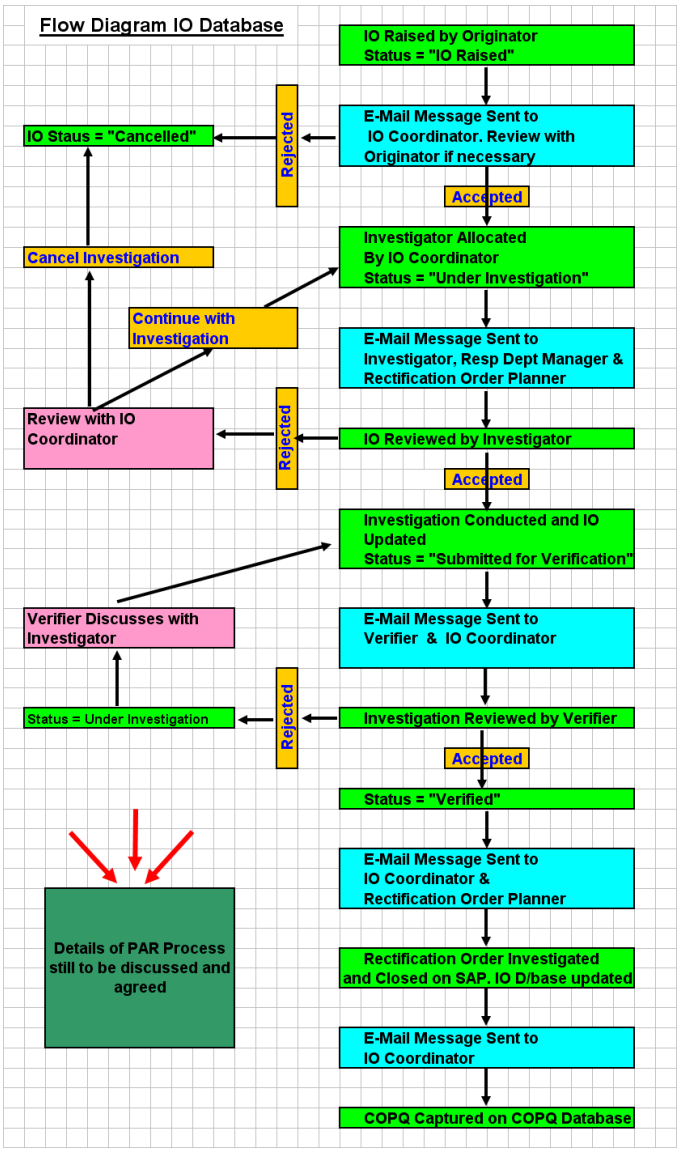


Figure 15: SharePoint process flow

The process is traceable and maintained on SharePoint. A section of the manufacturing process of a transformer has been attached to Appendix A. The process begins with an IO raised on SharePoint by an originator. The coordinator is notified via email and the IO is reviewed. An investigator will then be assigned to the IO and the IO will be reviewed. Once the review has been completed, the IO will be investigated. The Investigation process consists of the investigator communicating with the originator and visiting the site where the non-conformance has been reported. The investigator will then discuss the corrective actions that will be taken as a remedy then the preventive action will be finalised. The costs of the non-conformance will be analysed during the investigation of IOs.

5.2 Cost of Poor Quality

As of February 2006 the COPQ method was redefined and the current cost system covers the following aspects:

- The cost factors are taken from most of the processes across the value chain.
- The cost factors are easily measurable and are part of existing process / sub process measures.
- The cost factors focus on specific process measures and not generic.
- The measurements are mainly at the sub process levels and not generic.

The employees were trained for the current cost system and the data that was obtained from SharePoint uses the current costing method. The current cost system is susceptible to duplication of IOs. The duplication occurs when a new IO is defined for the COPQ to be added. The current method is said to be time consuming as the IO is redefined for the cost to be added.

5.3 RCA method

The current method of analysing root causes is the A3 brainstorming method which has been discussed in detail in the literature review. The A3 method allows PTT employees to follow up on the actions that are to be taken to eliminate the root causes. In general, this is a good method and it will be compared to other methods under the criteria that would be suitable for a manufacturing environment similar to PTT.

6. Project Data and Analysis

6.1 Case Study Analysis

A random sample of 13 cases was chosen from SharePoint for the purpose of analysis. The cases will be analysed to find trends, root causes, and the corrective and preventive action that will be suitable. The IO numbers, responsible department and the date that the IO was raised have been summarised in Table 3.

Table 3: IOs to be used for case study purposes

Case number	IO number	Responsible Section	Date Raised
1	1971	Production: Insulation	5/26/2011
2	2126	Production: Large winding	8/1/2011
3	2133	Production: Paper lapping	8/3/2011
4	2111	Production: Large winding	7/25/2011
5	2099	Production: Paper lapping	7/19/2011
6	2012	Production: Large winding	7/6/2011
7	1944	Production: Assembly line	5/12/2011
8	1907	Production: Small winding shop	4/19/2011
9	1840	Production: Assembly line	3/28/2011
10	1850	Production: Large winding	3/30/2011
11	1878	Production: Large winding	4/6/2011
12	1754	Production: Small winding shop	2/23/2011
13	2036	Production: Small winding shop	6/21/2011

The aim of the case studies is to illustrate the application of new techniques on a small scale. The results will be recorded and recommendations will be made. If the tools are effective on the sample of cases then the tools may be effective for larger samples.

6.2 Analysis of root cause trends

The following root causes have been obtained from the Quality Assurance Technician at PTT. The root causes were recently updated and new root causes were added. There was a problem initially with root causes that were repetitive and unclear to the users of SharePoint. In the revised root causes, this was rectified. A flow diagram for the manufacturing of a transformer, the windings department and the active parts department has been attached in Appendix A. The root causes are for the following sections of the company:

1. large windings and assembly,

2. medium windings and assembly,
3. small windings and assembly and
4. active parts assembly.

A sample of 100 non-conformances from 2009 and 2010 was taken from SharePoint to be analysed. The non-conformities were grouped by department, section and the root cause classification. Graphs and charts were plotted from this information. The IO data was collected at PTT for 12 months in 2010 from SharePoint. The data was grouped by the root cause classifications that were obtained from PTT. The main root cause classifications are stated below. The classifications provide an option to evaluate the root causes that have not yet been assigned by either the originator or the investigator.

1. Not Yet Assigned
2. Customer
3. Engineering
4. Environment
5. Knowledge / Training
6. Machinery /Tools /Equipment
7. Maintenance
8. Man / Human Error
9. Management
10. Material
11. Method / Procedure
12. Plant
13. Quality
14. Safety
15. Supplier
16. Systems
17. Force Majeure
18. Technology

The classifications are further broken down into more specific root causes. A pie chart, Figure 16, has been plotted with the root cause classifications to see which root cause is the most contributing to the total root causes.

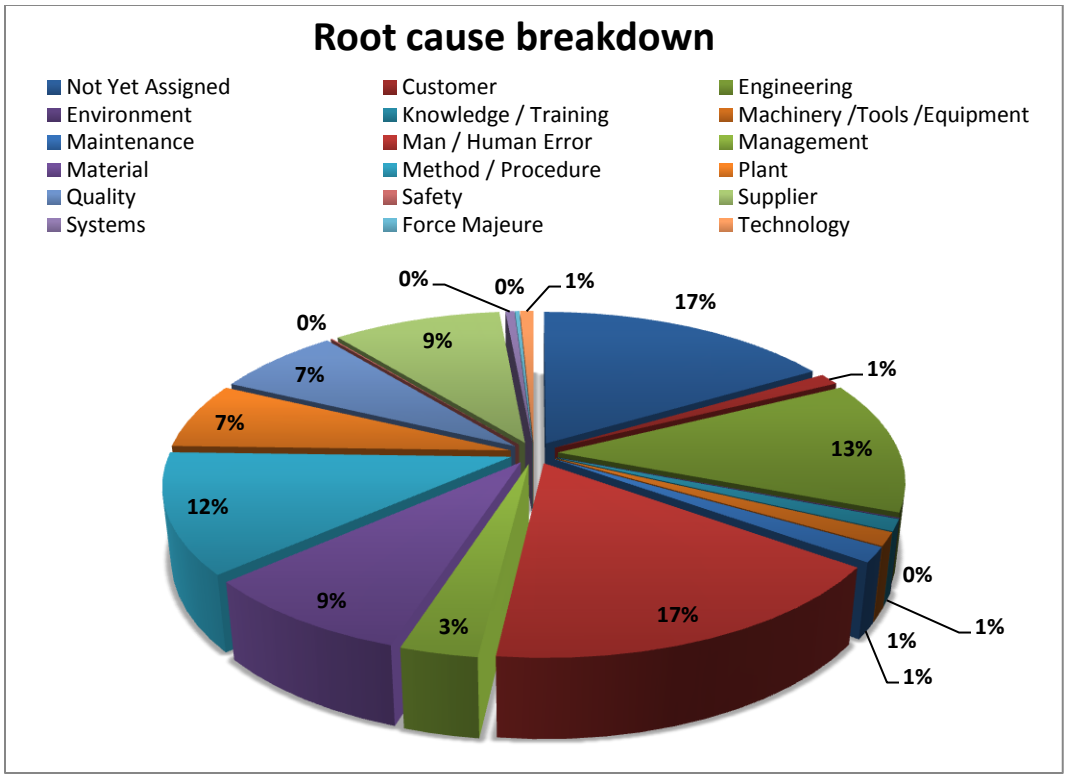


Figure 16: Root causes classifications

From the pie chart above it is clear that the most contributing root cause is human error. This root cause is one of the least understood root cause. The variation in human performance phenomena has been discussed in the literature review. The methods for analysing the variation in human will be used to further analyse the cases. The alarming discovery is that one of the major category of the root causes are the root causes that have not yet been assigned. This means that there 17% of all IOs found on the system have no root cause classification. This may be a problem if the root cause analysis was to be further investigated as the information is incomplete. Recommendations will be made to address this matter in the following sections.

6.3 Comparison and selection of the RCA tools

The tools and methods mentioned in the literature review have been categorized in Table 4 . The methods will score under each category and then ranked. The ranking is used as a method of selecting the best tool and method for RCA. The categories for ranking the methods and tools were obtained from journals based on comparison of RCA tools (Mahto & Kumar, 2008) and (Doggett, 2005). The categories that will be used for analysis are as follows:

1. the method/tool must define the problem clearly and concisely,
2. all the causal relationships should be defined,
3. the evidence to support the root cause is defined,
4. the causal path to the root causes must be traceable,
5. whether the method has a way to test its logic and accuracy,
6. whether the results from the technique are easy to document,
7. if the technique allows for categorising the root cause,
8. whether the technique is able find the specific root causes,
9. and the tool/method should explain how the solutions prevent the recurrence of the root cause.

The RCA tools and methods are compared in Table 4. The two highest ranking techniques will be used for the RCA of the cases.

Table 4: Comparison and ranking of tools and methods

Method/Tool	Type	Defines Problem	Defines all causal relationships	Provides a causal path to the root causes	Delineates evidence	Shows how the solution prevents re-occurrence	Easy to follow report	Has mechanism for testing logic	Indentify cause categories	Ability to find specific and reasonable root cause	Total Score
Ishikawa	Tool	yes	limited	no	no	no	no	no	yes	no	**2.5**
Pareto chart	Tool	yes	no	no	no	no	no	no	no	yes	**2**
Fault tree	Method	yes	yes	yes	no	yes	no	no	yes	yes	**6**
Affinity diagrams	Tool	yes	yes	no	no	no	no	no	yes	yes	**4**
Process failure mode effects analysis (PFMEA)	Tool	yes	no	limited	no	limited	no	yes	yes	yes	**5**
Process capability analysis	Tool	yes	limited	no	yes	no	no	yes	no	limited	**4**
Tree Diagrams	Method	yes	no	no	no	no	no	no	no	limited	**1.5**
5 whys	Method	yes	yes	no	yes	no	no	no	no	yes	**4**
Current reality tree(reality charting)	Method	yes	yes	yes	yes	yes	yes	yes	yes	yes	**9**
Change Analysis	Tool	yes	no	no	no	no	no	no	no	limited	**1.5**
Barrier Analysis	Tool	yes	no	no	no	no	no	no	no	no	**1**
Human Performance evaluation	Method	yes	yes	yes	no	limited	yes	no	yes	yes	**6.5**
A3 brainstorming	Method	yes	no	yes	yes	no	yes	no	no	yes	**5**

The comparison of the tools and methods yields results that will be used to select the best techniques that will be used for the analysis of the cases. The results of the RCA will be discussed and recommendations will be made thereafter.

The RCA techniques are fundamental for diagnosing problems in a process. In Table 4, the various RCA techniques have been analysed according to the criteria that have been discussed. The scoring is as follows:

1. Yes = 1 point
2. No = 0 point
3. Limited = 0.5 points

The scoring method was used and the results showed that the best method is the Reality chart and the second best method is the human performance evaluation. The least ideal method to be used for the root cause analysis is the tree diagram according to the criteria that was defined. The reality chart will then be used to analyse the 13 cases that will be used in the development of a solution.

6.3.1 Reality Charting

The Process of reality Charting consists mainly of seven steps and these have been outlined below:

1. The problem or effect is clearly defined.
2. The question," why?" is asked to the stakeholders.
3. The answers given by the stakeholders must consist of a condition and an action.
4. The answers that are given are plotted on the chart.
5. The supporting evidence to the causes is added to the chart.
6. The solutions are then examined for the causes and if they are in the control of the stakeholders then the action plan may be added.
7. All the stakeholders are involved therefore all the responsibilities are allocated during the analysis.

The software used for reality charting is called RealityCharting version 3 (Apollonian LLC, 2011) and it is the demonstration version that is downloadable from the website. The process of reality charting begins with following instructions from the wizard.

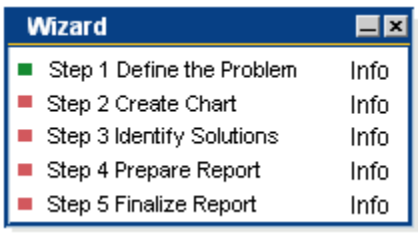


Figure 17: The wizard from RealityCharting (Apollonian LLC, 2011)

The wizard helps to guide new users with using the software. The first step, as shown in the wizard, is to define the problem clearly using the guidelines in the menu provided.

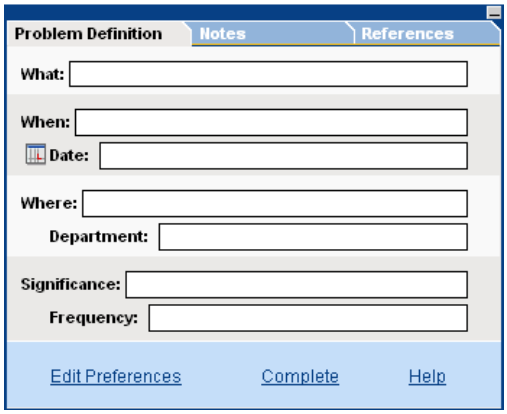


Figure 18: The problem definition (Apollonian LLC, 2011)

The preferences may be set by the user to make the problem definition close to reality. The next phase consists of drawing the reality chart. The chart draws the problem or effect onto the chart then the users are to insert the root causes and choose whether it is a condition or an action. The user also has an option to add the supporting evidence as the plotting progresses. If currently there is no supporting evidence that can be found then a question mark can be placed. The root cause with no supporting evidence should be avoided as valid root causes until the supporting evidence is added.

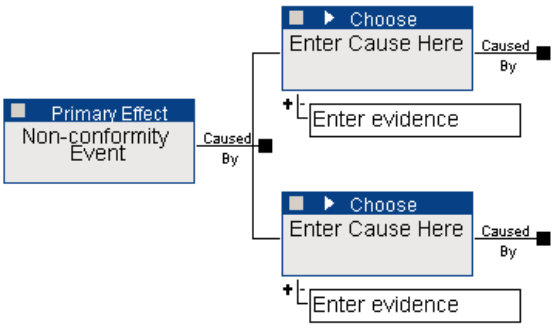


Figure 19: The structure of the Reality Chart (Apollonian LLC, 2011)

Once the chart has been drawn, the software tests the correctness of the chart before proceeding to the next phase. In the next phase the user inputs the possible solutions for each reason that has been defined in the chart. The solutions are then evaluated against the following criteria:

1. If the solution can prevent the re-occurrence of the same problem.
2. Whether the solution stated is in the control of the user or another supportive person.
3. Whether the solution meets goals.
4. If the solution may cause another unacceptable problem.

Once all the criteria for the evaluation of the solution are tested and the correct responses have been added, the solution is added as a valid solution. The solution may then be assigned to a stakeholder and the due date is set. A report is then generated by the software and the reality charting process is complete.

6.4 Human Performance Analysis

In the process of analysing human performance trends, data was be collected from the SharePoint system over a span of 3 years from 2009 to 2011. The data was analysed and plotted in a pie chart and bar charts. The steps that will be followed in this report are defined as shown in the figure that follows.

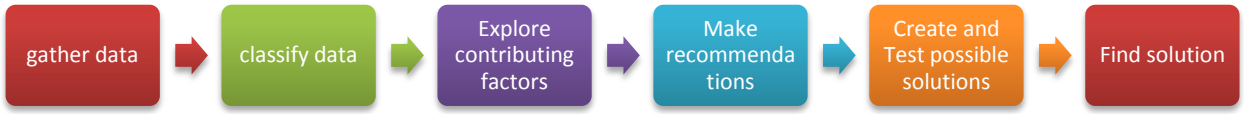


Figure 20: Human performance analysis procedure

For the purpose of this project, only the first four steps will be done then it will be left up to the company to formulate the solution from the recommendations and test the possible solution using the methods that would best suit the company.

6.5 Analysis of the Cost of Poor Quality

A sample of 340 cases were analysed and a pie chat plotted from the information. The sample consists of cases from the years 2009, 2010 and 2011.The costs were grouped by the departments of PTT. The departments are as follows: Production, Engineering, not allocated, Logistics, General Management, External Party, Finance and Admin, Project management, Supply chain, Technology, Powertech Transformers and Process Development.

There are some departments that were not clearly named such as the Powertech transformers department and the unallocated departments. The resulting pie chart is illustrated in the Figure 21 that follows. From, the chart, the most contributing department is the production department which

contributes 39% of the total costs of poor quality. Then the Engineering department follows with a contribution of 31%. The Engineering department consists of the mechanical and electrical engineering design section.

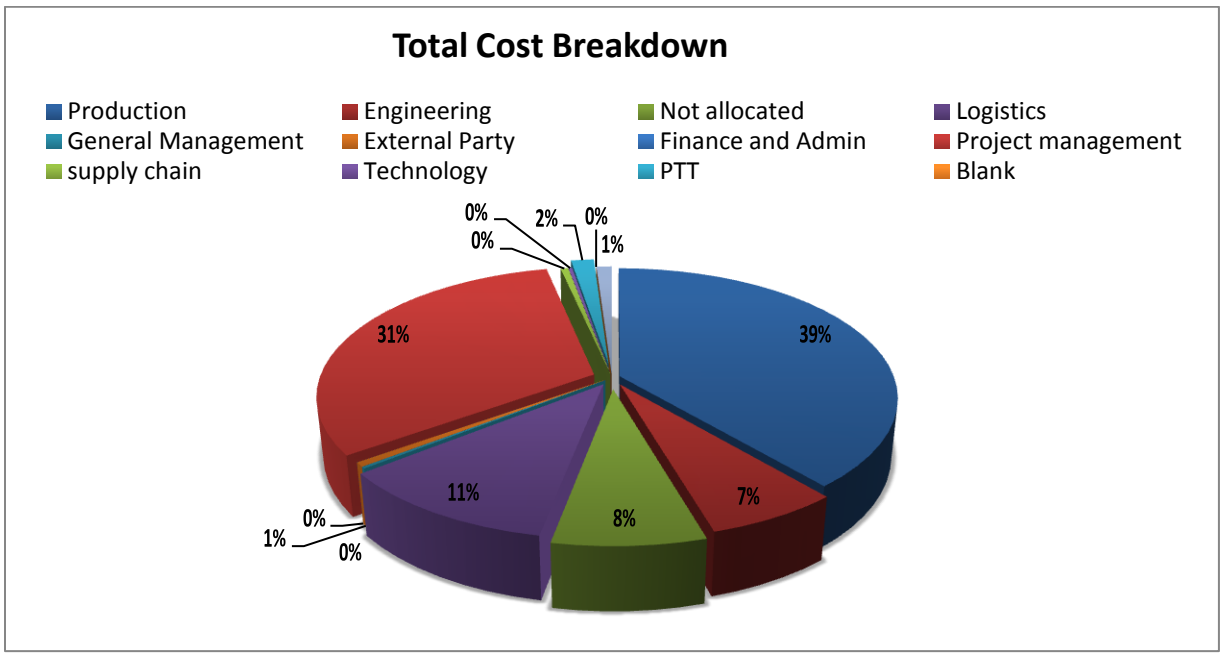


Figure 21: Summary of the total COPQ

The pie chart shows the percentages that each department contributes to the total cost of poor quality recorded on SharePoint. The Production department is divided into 18 other sections as shown the pie chart in Figure 22. The pie chart was plotted to show the distribution of cost is among the sections of the production department.

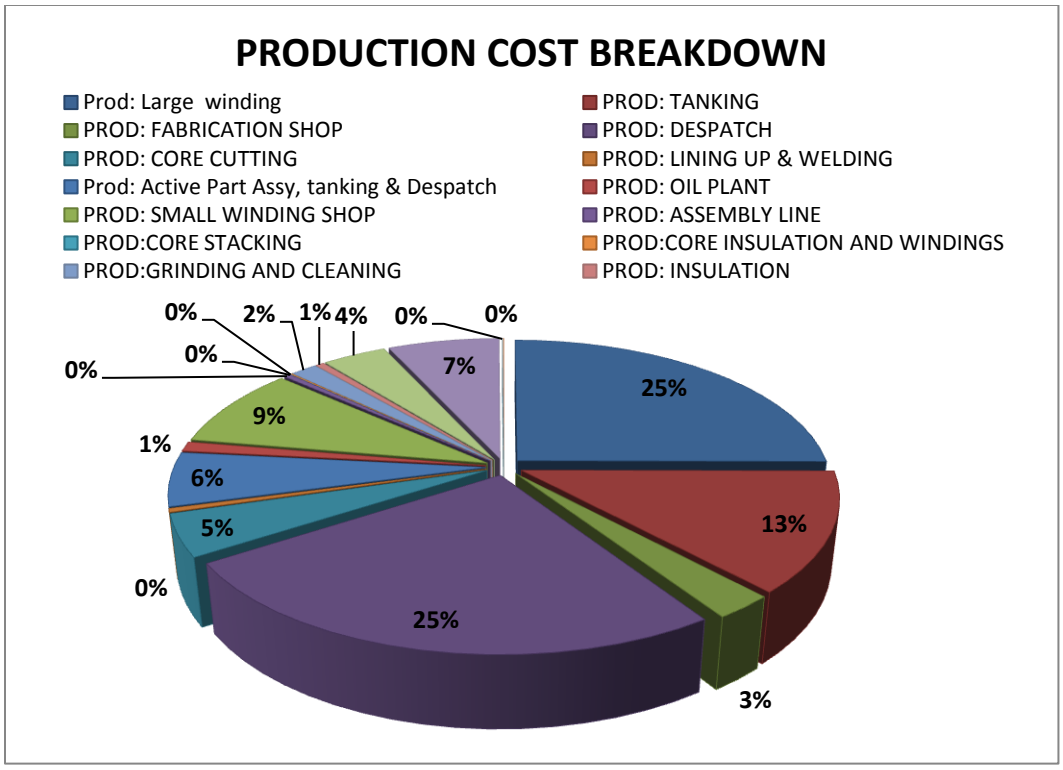


Figure 22: The cost breakdown of the Production department

The large winding section and the assembly line contribute to 25% of the total costs of poor quality. The analysis of data is essential for focusing efforts on the sections. The least contributing section is the core stacking section which virtually contributes 0% to the COPQ. Other similar sections appear to be well managed and maintained therefore efforts should not be focused on these sections.

6.6 The Quality Audit

The quality audit was conducted in the large windings and assembly, medium windings and assembly, small windings and assembly, and active parts assembly. The audit procedure was followed and the audit team consisted of two people. The audit was conducted for the following reasons:

1. to ascertain whether practice is in line with documented instructions,
2. to highlight any shortcomings within an area being audited,
3. and to ascertain to what extent ISO 9001:2008 requirements are met.

The notification was sent to the relevant departments a week prior to the audit. The audit was conducted in four days i.e. one day for each department.

The Auditing Technician inspected documentation and observed the work that was performed. The auditor interviewed some employees to test whether the employees had insight to the work that was performed. When an error was found, the auditor investigated the error further to try and resolve the matter immediately. The auditor furthermore asked the foremen for their insight about certain errors. The findings were written down in a notebook. The PTT formal Auditing Procedure and the formal Audit report have been attached to Appendix C. The findings of the Audit were then documented in a report. The findings will be presented to all relevant stakeholders and steps will be taken to address the findings. The findings will be analysed in this report and recommendations will be made.

7. Development of the solution

7.1 Root cause analysis

The root cause cases that were collected have been further analysed. The aim of the RCA is to observe and analyse the trends of the IO cases. In so doing the Quality Department may realise that the RCA methods may not be efficient. The cases have been sorted under the following categories:

1. **The IO status**

   This indicates the current state of the IO. There are mainly six states that an IO may be in and they are shown in Figure 15.

2. **The Problem description summary.**

   The problem that was obtained from the cases have been summarised to make it simpler. The problem descriptions tend to be long and detailed but this is not necessary for analysis.

3. **The summary of the corrective action.**

   The corrective action that was also obtained from SharePoint has been summarised. The corrective actions have been discussed in detail in the literature summary.

4. **The summary of the preventive action.**

   It is similar to the summary of the corrective action but it addresses the measures that will be taken to prevent future re-occurrence of the non-conformance.

5. **The Root Cause classification and root cause.**

   Each IO is associated to a root cause and the classification of the selected root cause. The classifications of the root causes were discussed in the analysis of root causes.

PTT uses the A3 brainstorming method to address the IOs that have high frequencies of occurrence and for high cost non-conformances. This technique was recently (2 years ago) implemented in the Quality Department and has been discussed in the literature review. The method is still relatively new to PTT and the employees are attempting to adjust to the change. The method and the other methods in this report are suitable for a manufacturing environment. The A3 method is currently used by PTT used as a tool to determine the preventive actions for IOs.

IO Number	IO status	Problem Description Summary	Summary of Corrective Action	Summary of Preventive Action	Root Cause Classification	Root Cause
2036	IO Accepted	Damaged winding	Winding replaced	Supervisor, inspectors are to verify sigma cards	Man/ Human Error	Lack of attention
1754	IO submitted for verification	Winding cylinder undersize	Ribs reduced	Diameter measurements are to be verified before transfer to Active Part	Man /Human Error	Process incorrectly followed
1878	IO Verified and closed	Winding undersize	Winding reduced as per deviation request	Diameter measurements are to be verified before transfer to Active Part	Method/ Procedure	Procedure Inadequate
1840	IO Verified and closed	Windings are oversize	Windings reduced to fit	A3 investigation in progress	Man/Human Error	Inadequate training
1850	IO Verified and closed	Cylinder could not fit over windings	Production must not over-rule quality	Quality must approve of the product	Management	Process incorrectly followed
1907		B winding undersize, D winding oversize	Deviation requested	A3 investigation in progress	Material	Procedure Inadequate
1944	IO Verified and closed	D winding undersize	Deviation requested	A3 investigation in progress	Material	Process incorrectly followed
1971	IO Verified and closed	Former cylinder undersize	Deviation requested	Avoid the use of poor quality material for former cylinders	Quality	Incorrect material
2012	IO Verified and closed	Copper shavings on the windings	Emphasize method provision during cleaning	Method provision to be followed by operators	Method/ Procedure	Process incorrectly followed
2126	IO submitted for verification	Disc joints unacceptable	New conductor used for the discs	Paper-lapping machines to be caliberated	Man/ Human Error	Bad packaging marking
2099	IO Accepted	Conductor insulated incorrectly	Send paper back to paper-lapping to be re-covered	Supervisors are to be trained for the department's products	Knowledge/ Training	Process incorrectly followed
2133	IO Allocated	Shortage in conductor	none taken yet	none taken yet	Not yet assigned	Not yet assigned
2111	IO submitted for verification	Former cylinder quality below specification	New cylinders ordered to replace rejected ones	A3 investigation in progress	Method/Procedure	Supplier late delivery

Table 5: The detailed IOs

Most of the IOs collected are verified and closed. Once an IO has been verified and closed then no further investigation is required to be done on the IO. The cases were also analysed to see the severity, chance of re-occurrence, risk priory and the type of event. This information was also obtained from

SharePoint excluding the type of event. The IOs are classified according to a scaling ranging from one till 5. The values are as follows:

- 1 = Rare,
- 2 = Unlikely,
- 3 = Possible,
- 4 = Likely
- and 5 = Almost certain.

The investigator assesses these values with the originator. The severity of the re-occurrence states the effect that the re-occurrence of the event would cause for the department. This section again requires the investigator to use a scale from one to five where one indicates an insignificant severity and five is a catastrophic effect. The risk priority amount illustrates the ranking of the risk relative to the other IOs on the system. Using the information from the literature review, the events were classified as either sporadic or chronic events. This classification was deduced from the value that indicates the chance of re-occurrence. If the chance of re-occurrence was greater than three then the event was classified as a chronic event, meaning that the event is considered normal by the investigator. As discussed in the literature review, sporadic events are usually catastrophic and unlikely to re-occur. This project will address the chronic events in details due to the frequency of their re-occurrence.

Table 6: Further analysis of the cases

IO Number	Chance of Re-occurrence	Severity of Re-occurrence	Risk Priority	Type of event(Sporadic / Chronic)
2036	1-Rare	1-Insignificant	Not Calculated	Sporadic
1754	4-Likely	4-Major	250	Chronic
1878	5-Almost certain	4-Major	300	Chronic
1840	3-Possible	1-Insignificant	Not Calculated	Chronic
1850	5-Almost certain	4-Major	300	Chronic
1907	5-Almost certain	4-Major	300	Chronic
1944	5-Almost certain	1-Insignificant	300	Chronic
1971	5-Almost certain	4-Major	280	Chronic
2012	3-Possible	5-Catastrophic	300	Sporadic
2126	5-Almost certain	1-Insignificant	Not Calculated	Chronic
2099	5-Almost certain	1-Insignificant	300	Chronic
2133	5-Almost certain	1-Insignificant	Not Calculated	Chronic
2111	5-Almost certain	1-Insignificant	Not Calculated	Chronic

The majority of the cases that were selected can be classified as chronic events. This is important for the assessment of the QMS as the chronic cases have lower costs but due to the frequency at which they occur they may contribute to large amounts in the costs of poor quality. A graph has been plotted to show the frequency of both kinds of events.

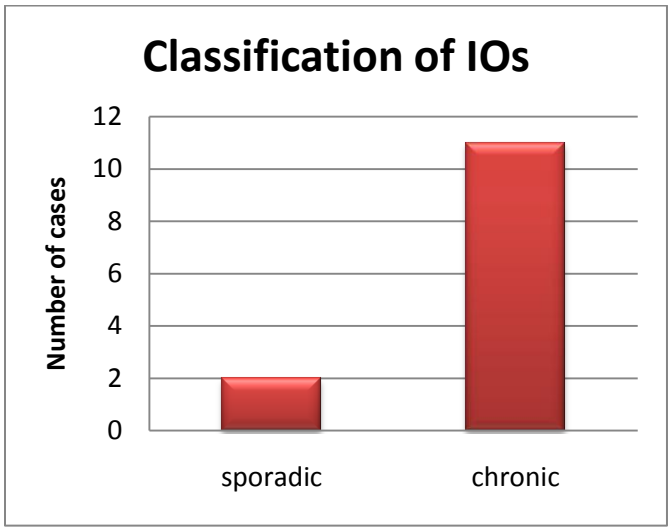


Figure 23: sporadic events compared to chronic events

The occurrences of chronic events are much greater than sporadic events. This implies that the errors that are considered normal in the QMS may be the cause of inefficiency.

8. Results

8.1 Results from the Quality Audit

The audit findings were obtained from the Quality Audit that was performed by the Quality Technician on the 16th of August 2011. The details and the audit procedure have been addressed during the analysis phase. The findings of the audit were recorded in the Audit report that has been attached to Appendix C. As discussed in the literature study, the findings were analysed and refined for the purpose of this report. The R-P matrix was used to classify the findings so that recommendations could be made from the findings. The findings were organised and similar findings were grouped together.

Table 7: The R-P matrix for the audit findings

		Reason/Cause			Pain/Effect			
No.	Findings	Design not adequate for control R1	Not implemented R2	Does not meet objectives R3	Cost P1	Opportunity lost P2	Risk P3	Comments
3.1	Red Triangle procedure was not available, on request, during the audit.							Risk of incorrect procedure followed
3.2	Red triangle cards were not placed on jobs.							Risk of the job being misplaced
3.3	Checklist does not have any business (PTT) identification .							Risk of incorrect checking
3.4	Sigma cards not signed off by the Supervisors.							Risk of no inspection performed
3.5	The bottom leads of C phase D/winding got damaged while rotating winding platform during winding.							Rework costs
3.6	Stack Iron as well as disc clamps(tools) not available during the winding.							Risk of damange to the clamps
3.7	Unmarked trolley with material was left on the walk way, not attended too during the whole shift.							Cost to trace and remarking. The risk of use
3.10	Travelling files not well maintained.							Control risk
3.11	Quality Objectives have not being adequately addressed within the audited area.							Risk that the product will not meet quality objectives
3.12	The vertical winding machines are full of dust on the top and material found on the floor with dust.							Cost of cleaning
3.13	Some trolleys of have broken collars and rings mixed with good material.							Cost of labour to sort the material
3.14	Sigma cards1ZXX209808 and 1ZXX209845 have common name							Risk of incorrect use of procedures
3.16	The sigma cards for clack have faded away and are found in various jobs such as travelling files							Increased risk of error during production
3.22	Certificate of calibration not available and does not indicate expiry date.							Risk of incorrect measurements
3.25	The leads of B and C Windings for #368 had carbon and were already crimped, C winding had a very sharp point just about 30mm below the ferrule							Risk of product failure

The matrix shows only a lesser number of findings (15 findings) when compared to the 25 findings that were recorded in the Audit Report. The findings were group together as follows:

1. Finding 3.2 was similar to the finding 3.18 because they both address the problem of jobs that are not marked with tags.
2. Finding 3.4 and 3.8 are grouped together because they are about supervisors not signing the sigma cards for various jobs.

3. Findings 3.10, 3.15, 3.17, 3.19, 3.20, 3.21, 3.23 are grouped as they are about the poor management of travelling files and procedures.
4. Findings 3.12 and 3.24 both state that the housekeeping and maintenance of materials is insufficient.
5. Finding 3.22 and 3.26 focuses on the calibration of machines.

By grouping the similar findings, the risk of repetition is largely reduced. The R-P matrix results reveal most findings were a result of the improper implementation of the procedures. This means that the quality system is defined well but the procedures are not being implemented correctly. The other majority of the findings indicate that the controls for the QMS are insufficient for the system. This implies that the QMS of PTT must be evaluated to identify the gaps in the system. There are processes that are insufficiently defined and the methods of controlling several processes are also insufficient. An example of this is the control of the travelling file which is required to be maintained but there are limited ways that this is ensured. In an attempt to assess the various features of the QMS, this is an important point that can be deduced from the R-P matrix.

The other trend that was observed is that the majority of the Audit findings arise from the Large windings sections. The table in Appendix C below shows the findings and the respective departments.

8.2 Results from the Root Cause Analysis

The reality chart selected after an analysis according to specific criteria. The method of constructing a reality chart has been thoroughly discussed in the root cause tool selection section. Firstly, to make the reality charting easier, the cases that were similar were grouped together. This was done to avoid repetition of the reality charts. The grouping was done for similar IOs as follows:

1. Type 1: Windings or Former cylinders that were found to be under/oversized. IO numbers 1754, 1840, 1907, 1850, 1944, 1971 and 2111.
2. Type 2: Windings that were damaged during manufacturing. IO number 2036.
3. Type 3: The disc joints that were found to be unacceptable. IO number 2126.
4. Type 4: A conductor that was used incorrectly therefore leading to shortage of a conductor. IO numbers 2033 and 2099.

Trial software was obtained from the website of Reality Charting Software (Apollonian LLC, 2011)) and was used for a more accurate analysis of root causes. The software was used to make the case studies

more accurate and to add supporting evidence. The figures below only show a portion of the results from RealityCharting and the complete reality chart has been included in Appendix D along with the suggested solutions report. The resulting RCA from the 4 types of cases resulted in the following reality chart diagrams.

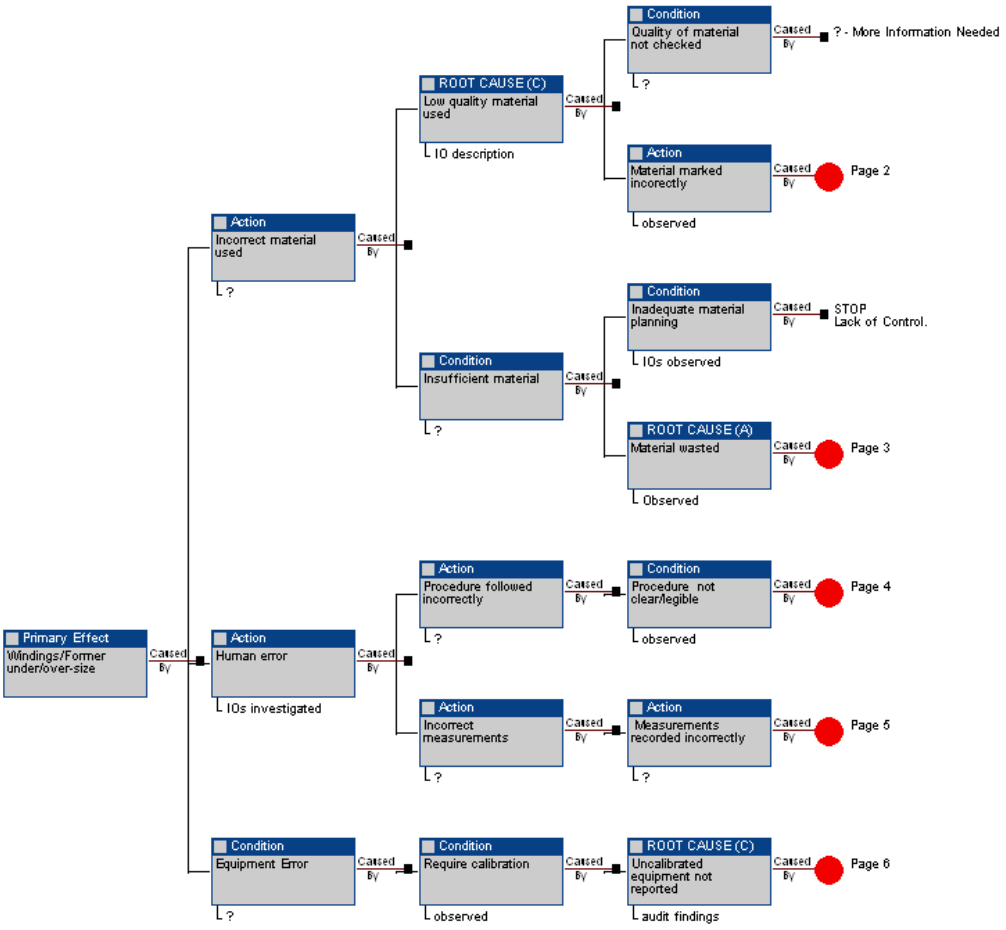


Figure 24: Reality Chart of Type 1 IOs

The results of the root causes were similar for the four types of cases. In the Reality chart the root causes have been identified using the criteria that were defined in the RCA section. The results from Type 1 IOs yield the following:

Action Root Causes	-Material wasted
	-Incorrect following of procedures
Conditional Root Causes	-Low quality of material used
	-Incorrect labels used
	-Low quality printing
	-Handwriting not legible

-Un-calibrated equipment not reported

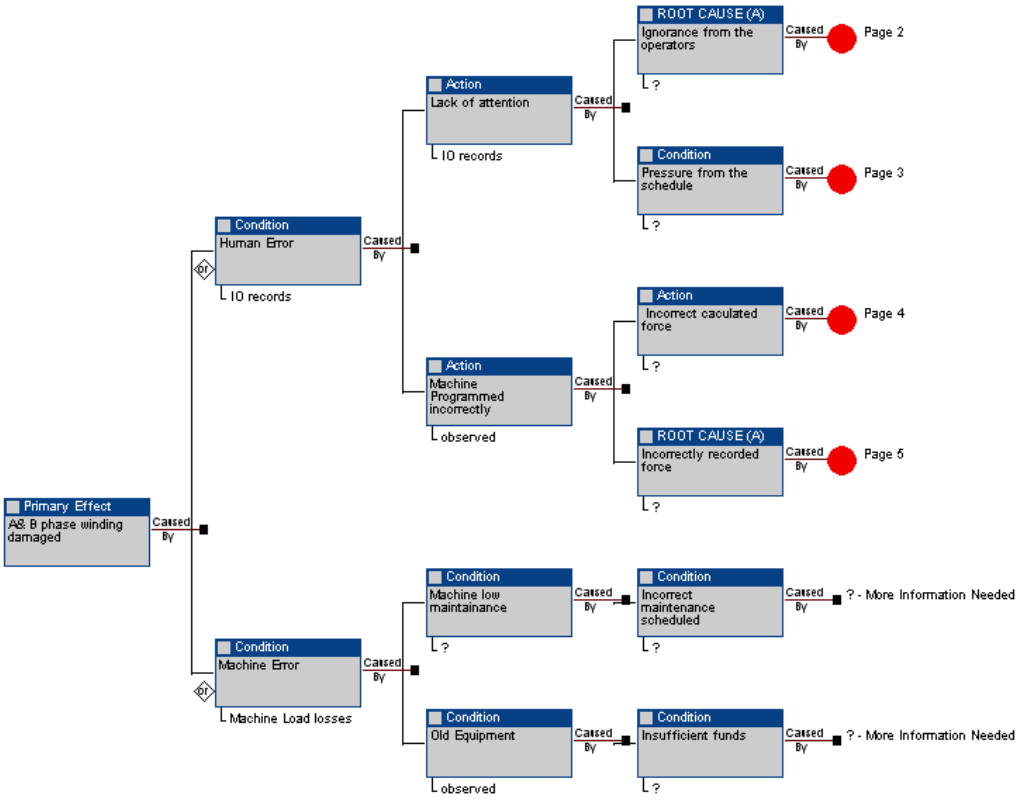


Figure 25: Reality Chart for Type 2 IOs

The results for Type 2 IOs that were defined as the windings that failed due to over-pressing. The Reality charting process yielded the following results:

Action Root Causes	-Ignorance from the operators
	-Incorrectly recorded forces
	-Handwriting not legible
Conditional Root Causes	-Low employee morale
	-Large number of delays
	-Production errors
	-Formulas not readily available
	-Procedure files not readily available
	-Lack of procedure file responsibilities
	-Formulas used incorrectly

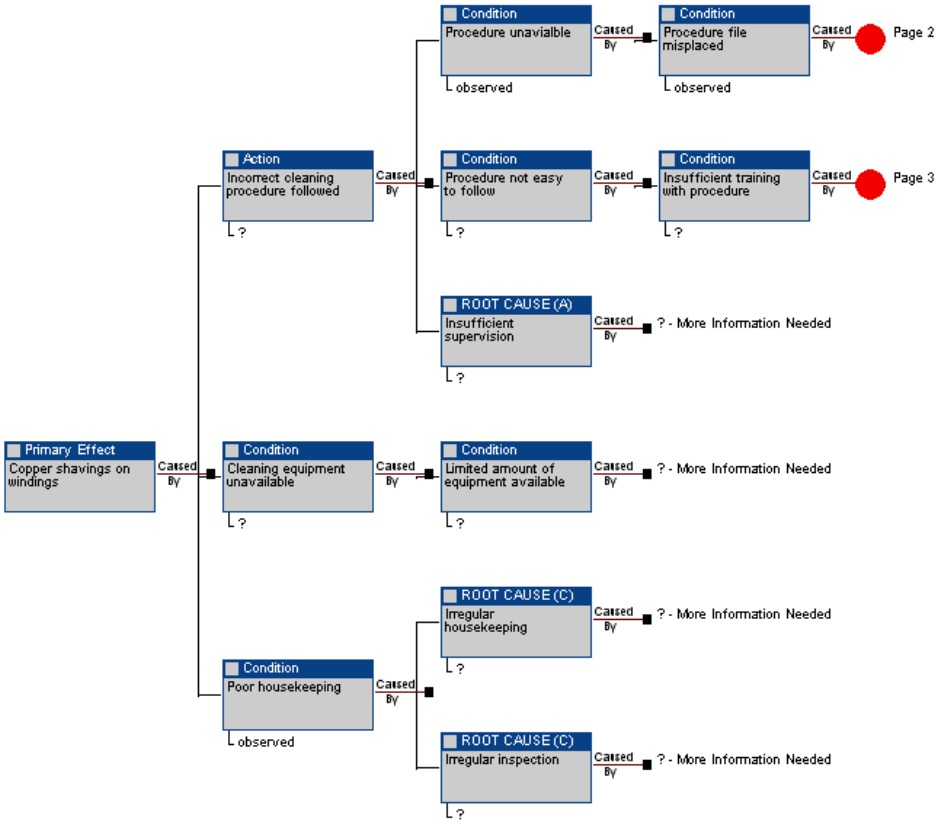


Figure 26: Reality Chart for Type 3 IO

The Type 3 IO yielded the following results

Action Root Causes	-Insufficient supervision
Conditional Root Causes	-Low employee morale
	-No accountable person
	-Irregular housekeeping
	-Irregular inspection

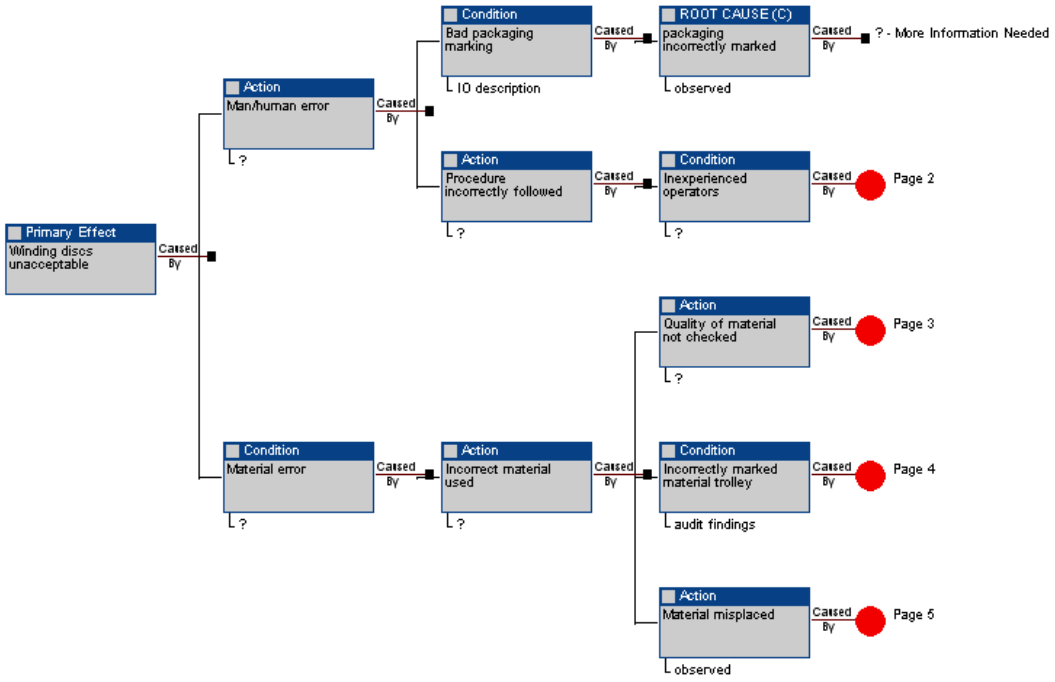


Figure 27: Reality Charting for Type 4 IO

Action Root Causes	-Insufficient supervision
Conditional Root Causes	-No accountable person for the file
	-Low staff morale
	-Insufficient training
	-Packaging incorrectly marked

The trends that have been observed in the case studies were that there appears to be a repetition of conditional root causes. The repetition may be caused by the similar nature of the non-conformities or the lack of evidence to support exploring other categories of root causes. The main root causes are as follows:

1. Insufficient training,
2. insufficient supervision,
3. low employee morale,
4. no accountability or responsibility for certain tasks and
5. the incorrect marking of materials.

The main recommendation is that PTT must assess these root causes in more detail in an attempt to eliminate them.

8.3 Results human performance analysis

The IOs obtained from SharePoint we analysed. A sample of 120 cases was taken from IOs over three years i.e. 40 IOs from 2009, 40 IOs from 2010 and 40 IOs from 2011. The IOs were then filtered to find the IOs that were caused by human error. From the 120 IOs collected, 23 were caused by human error. It can then be estimated that 20% of all IOs are caused by the different categories of human error as shown in the diagram that follows. The categories of human error under the Quality Assurance Department are as follows:

1. QA - Missing / Incomplete Information,
2. QA - Drawing Interpreted Incorrectly,
3. QA - Lack of Attention,
4. QA - Process Incorrectly Followed,
5. QA - Inadequate Handling / Transport,
6. QA – Misplaced Stock,
7. QA: Engineering Design,
8. And blank entries.

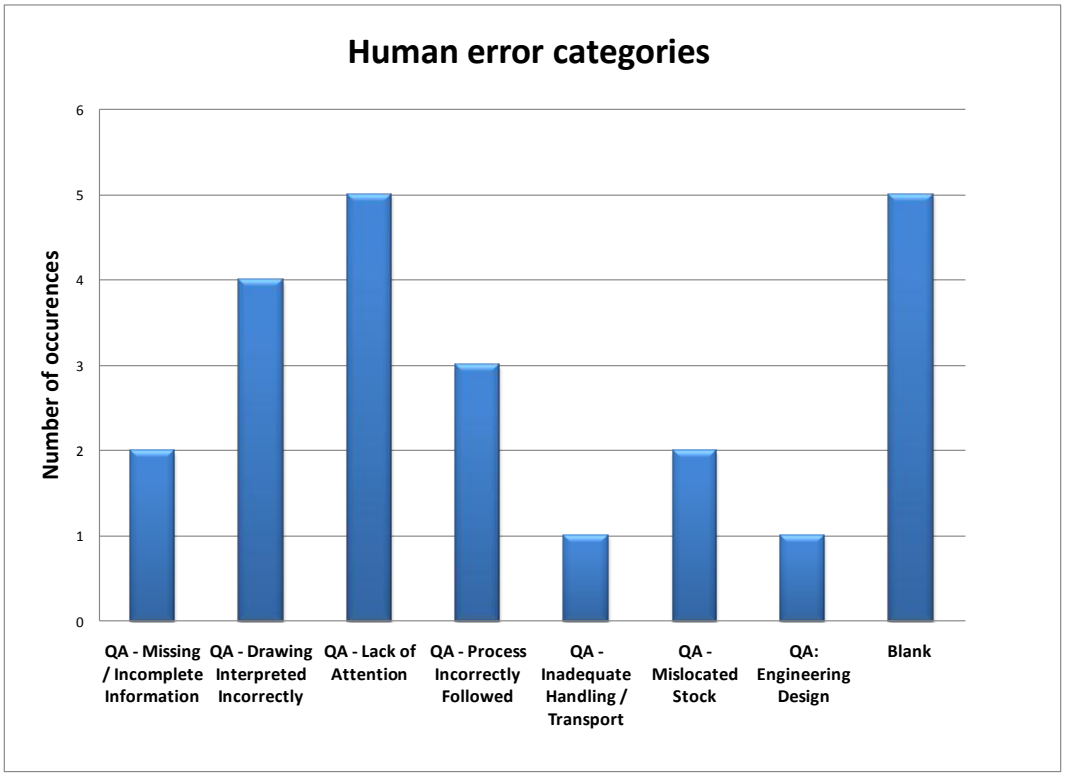


Figure 28: Human error categories

The blank category IOs only classified the root cause as human error but the investigator and originator did not specify the category of human error. The IOs were also investigated for human error trends over three years.

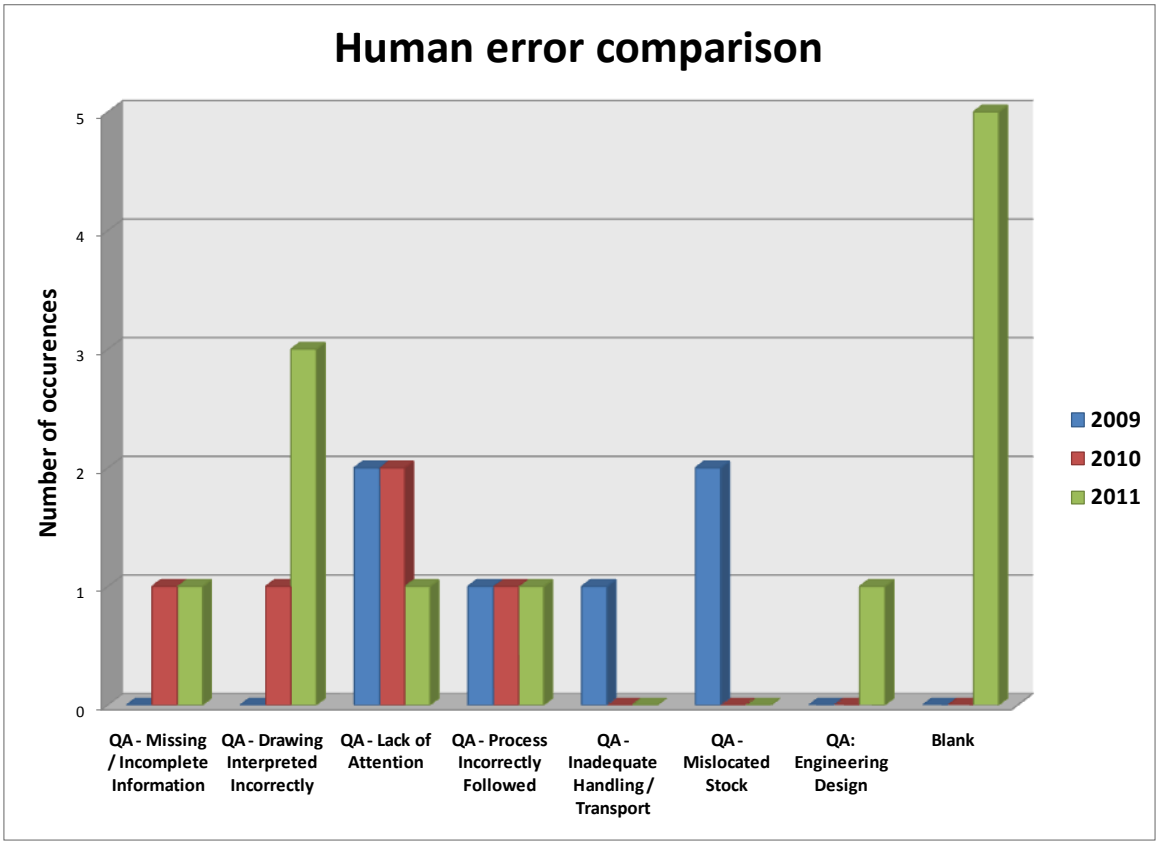


Figure 29: Human error comparison over three years

Due to the inconsistency in the capturing and recording of IOs, there are many cases observed in 2011 that have no specific root cause added to them .This makes it difficult to find the trends if the information is incomplete therefore extra cautions are to be taken by the investigators and the originators during the completion of the IO. The highest and the most re-occurring trends in Figure 29 is that the drawing is regularly interpreted incorrectly. The least occurring of incidents are the inadequate transport and engineering design. The incident of inadequate transport seems to have been permanently eliminated by a corrective and a preventive action. The most constant IO cause is that the process was followed incorrectly; this may mean that this problem is seen as normal and that it does not need immediate attention. In the recommendations the following human errors have been addressed:

1. The blank root cause,

2. drawing interpreted incorrectly,
3. missing or incomplete information and
4. the process incorrectly followed.

The trend of the blank root causes has been encountered in this section for 2011. The possibilities for such trends are as follows:

1. The investigators and originators have a limited time to complete the IOs in time.
2. The IOs are checked for completeness at the end of the year and throughout the year they are left incomplete.
3. There is no time limit set between the time that the originator raises an IO and closing date of an IO.

9. Key performance indicators (methods to testing)

In this section, the current state of the QMS will be analysed using the performance indicators that were obtained from the Key Performance Indicators (KPI) library (Mirror42, 2004-2011). Currently there are no clearly defined KPIs for PTT and by defining the indicators on a dashboard would make the maintenance of the system easier. The KPIs are obtained from the balanced scorecard as shown in Figure 30. The indicators are based the categories shown in the scorecard. The KPIs have been defined under each perspective on the Balanced Scorecard.

Figure 30: Balance scorecard categories (Kasselman G, 2011))

Financial Perspective

1 Cost of poor Quality are the costs incurred by PTT due to the non-conformances. These costs have been discussed in-depth in the literature review.

2 Cost due to delays are the costs that are encountered by PTT due to the number of delays in the production system

Internal Business Processes

1 Number of certifications obtained includes certificates such as the ISO 9001 and ISO 14000 certificates that a company receives accreditation.

2 Percentage of efficiency of the process measures the overall efficiency of the system. This is a comparative indicator as the efficiency of the systems will continuously be measured.

3 Percentage of Products delayed due to non-conformances. This percentage reflects the time used for rework and solving all the non-conformances of an item.

Learning and Growth

1 Number of training hours per employee for the full-time employees.
2 Number of certifications per employee.

Customer Perspective

1 Number of customer complaints this also includes the number warranty claims after the delivery of the products.
2 Number of products rejected by the customers.
3 Percentage of customers lost every year

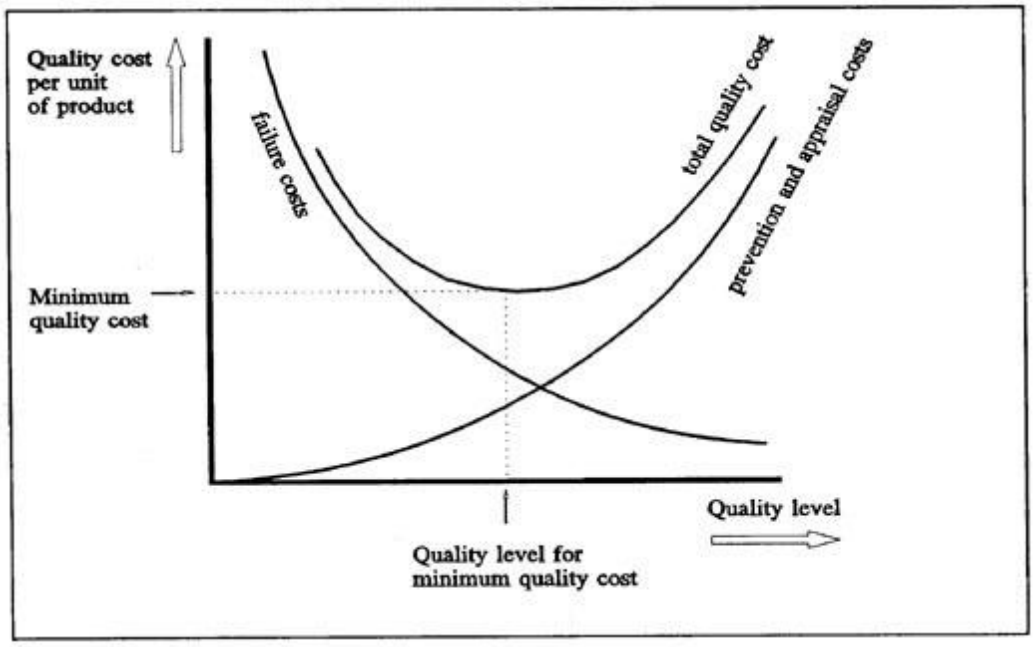
The indicators are methods of testing the efficiency of new techniques in a system. The indicators may be used by PTT the tools suggested in this report will be implemented in the Quality Department. Production data containing 70 products in the main assembly line was obtained for 22nd of October 2010. From the sample of 70 points, 58 products were late and 12 were early or on-time. The average was calculated as 5.3 weeks, this implies that the average product is late by 5.3weeks i.e. 26.5 days. A dashboard is a platform where key performance indicators may be represented in their categories. A dashboard has been created for the purpose of observing the performance of the QMS system. The dashboard will summarise the performances and changes in some of the KPIs. Screenshots of the Dashboards have been added to Appendix E.

10. Recommendations

At the end of the analysis of the different aspects of QMS the following recommendations could be made. With regards to the trend analysis that was done for the root causes, it is clear from the results that production and engineering are the largest contributors to the root causes. The following recommendations were made from the results:

1. According to the first objective, the trends in the root causes were analysed graphically represented and the Reality Charting Method was selected as the best RCA method that would be suitable to the PTT environment. RealityCharting is the recommended method to be used for RCA but further analysis must be done to test this method. The trends from the root cause analysis have been extensively discussed in the results section of the report.
2. For the second objective the trends in the costs of poor quality were graphically represented and the trends were found from the data obtained from SharePoint. The recommendation is for PTT to adopt a Benchmarking strategy to manage the COPQ. This means that PTT should test the

relative costs of poor quality with leading worldwide and similar companies like Rotek. This would set the minimum in the performance and further strategies can be discussed to manage the improvements to be made. A further recommendation would be that due to the complex nature of the products (transformers) the best cost method is the P-A-F model. The challenge is to find the shape of the COPQ curve and from there an optimal costs curve can be obtained. An example of the cost curve is as follows



3. The results of the analysis of human performance variation highlight important aspects that need to be further addressed by the company. It is recommended that the company re-evaluates the training process and the frequency of the training provided to the operators and supervisors. The evaluation of the human performance requires that PTT further investigate the underlying causes of human performance variation such as
    a. Causes of low staff morale.
    b. Errors in the monitoring of the operators.
    c. Errors related with tools and equipment and the maintenance of them.
    d. Errors in the staffing system such as staff sizes and the method of staffing.
    e. Errors in the supervision procedures that lead to insufficient supervision.
4. The common root causes that were identified in the RCA must be categorized and methods on how to address the root causes must be explored in an attempt to eliminate the causes. The possible solutions to the root causes have been added to Appendix D.

5. The Quality Audit yielded results that would be useful in finding the major problem section in the Production department. The recommendation for the Quality Audit Process is that there should be regular follow up meetings to ensure that the findings are investigated thoroughly and to avoid the re-occurrence of the findings.
6. A dashboard was created for the purpose of observing the key performance indicators which were defined and customised for PTT. The dashboard should be regularly maintained to find the trends of the data that is obtained from SharePoint.

11. Conclusion

The results of the project has shown that the there are aspects of the QMS that require immediate attention before further losses occur. The importance of preventive action was also highlighted as the reactive methods may have a higher costs associated to it. The QMS is a system that requires constant assessment and it is fundamental that companies invest time and resources to reduce the occurrences of non-conforming products. The ultimate costs of an inefficient QMS may be the loss of customers and to recover from such losses takes more effort therefore it is better to address the loss of quality in the final product. This report assessed a small portion of the QMS, it is now the responsibility of PTT to assess and keep track of the other features of the QMS.

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Appendix A

Figure 31: Product manufacturing Process

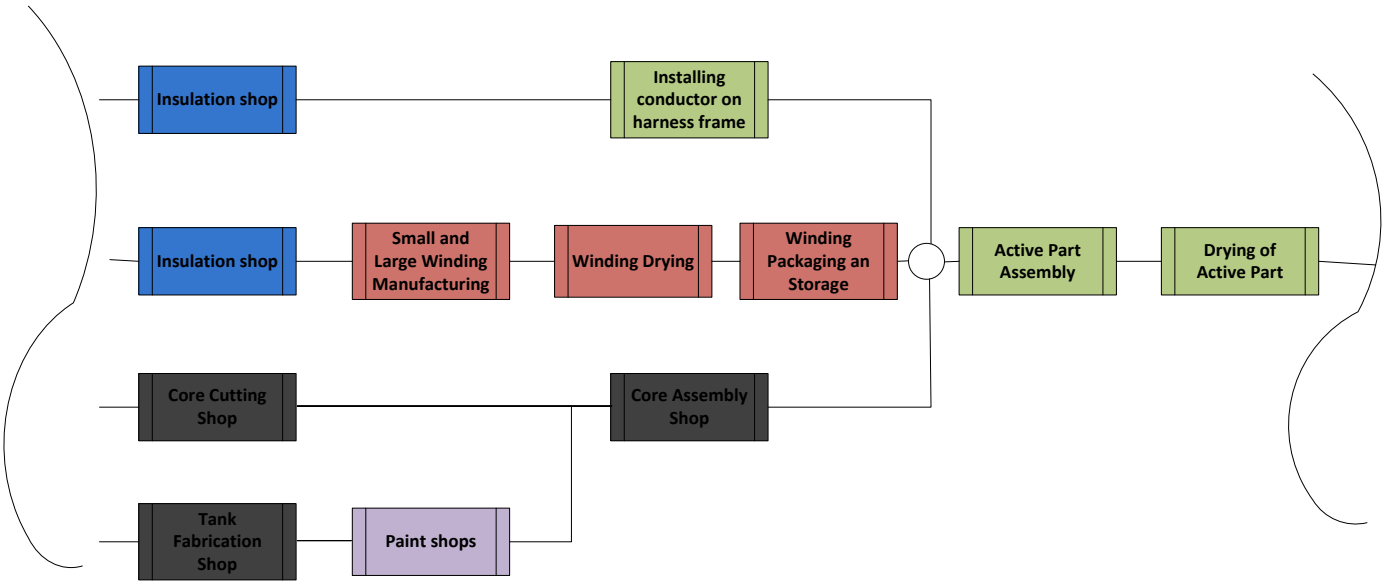
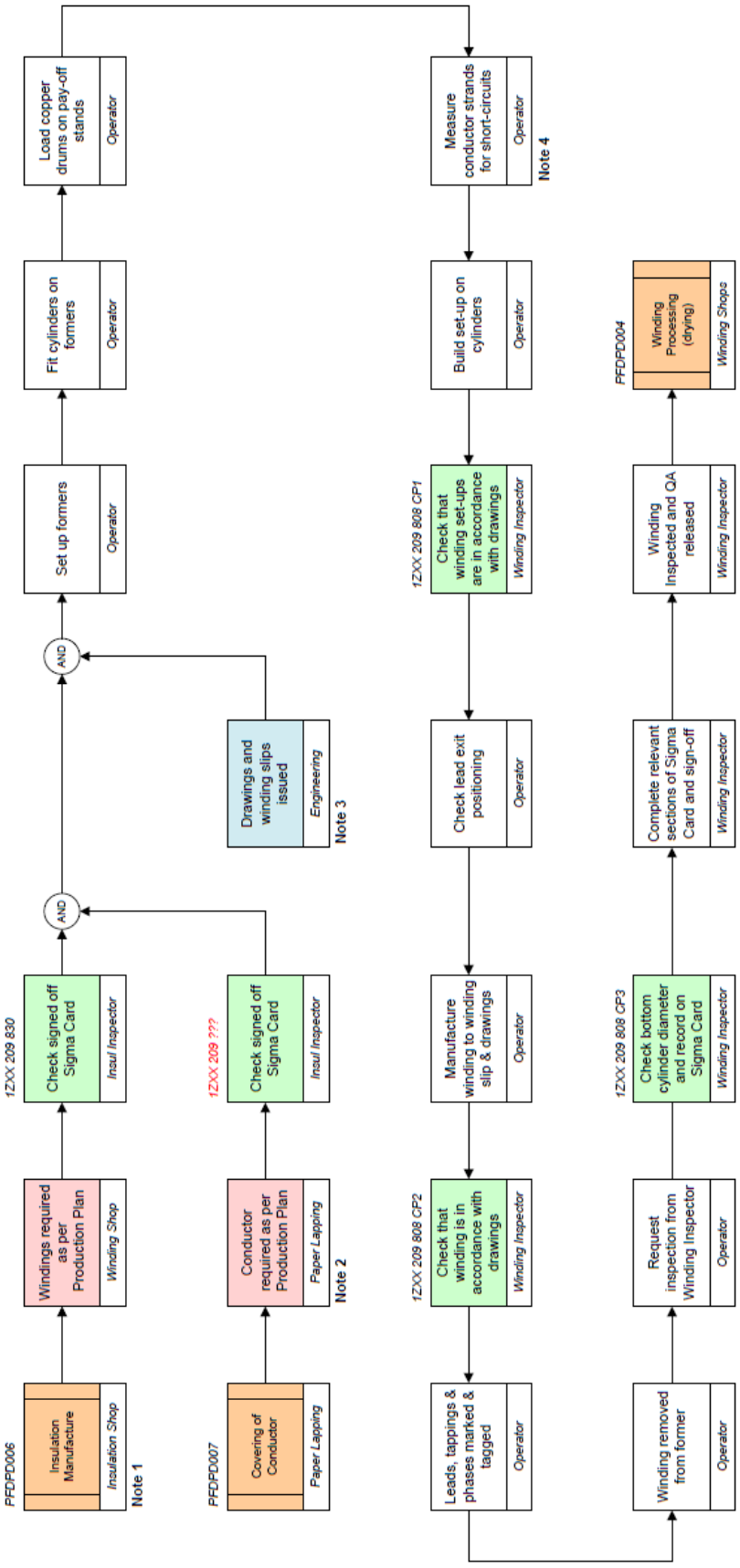


Figure 32: Winding manufacturing process


PFDPD006
Insulation Manufacture
Insulation Shop
Note 1
1ZXX 209 830
Check signed off Sigma Card
Insul Inspector
Windings required as per Production Plan
Winding Shop
PFDPD007
Covering of Conductor
Paper Lapping
1ZXX 209 ???
Check signed off Sigma Card
Insul Inspector
Conductor required as per Production Plan
Paper Lapping
Note 2
AND
AND
Drawings and winding slips issued
Engineering
Note 3
Set up formers
Operator
Fit cylinders on formers
Operator
Load copper drums on pay-off stands
Operator
1ZXX 209 808 CP2
Check that winding is in accordance with drawings
Winding Inspector
Leads, tappings & phases marked & tagged
Operator
Manufacture winding to winding slip & drawings
Operator
1ZXX 209 808 CP1
Check that winding set-ups are in accordance with drawings
Winding Inspector
Check lead exit positioning
Operator
Build set-up on cylinders
Operator
Measure conductor strands for short-circuits
Operator
Note 4
1ZXX 209 808 CP3
Check bottom cylinder diameter and record on Sigma Card
Winding Inspector
Request inspection from Winding Inspector
Operator
Winding removed from former
Operator
Complete relevant sections of Sigma Card and sign-off
Winding Inspector
Winding Inspected and QA released
Winding Inspector
PFDPD004
Winding Processing (drying)
Winding Shops

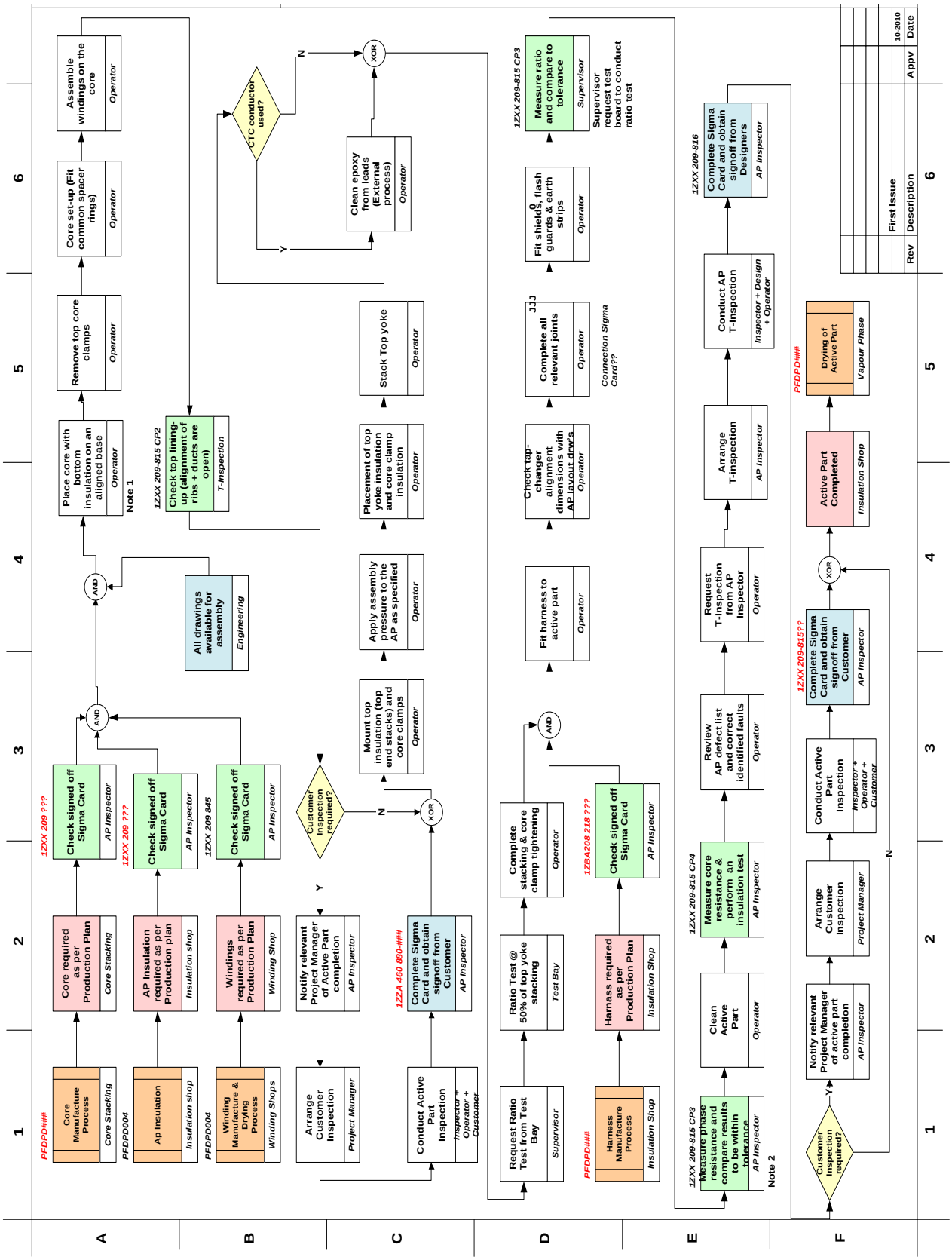


Figure 33: Manufacturing process for Active Parts department

Appendix B

Table 8: Root cause classifications

Section	Generic root cause	Section Root cause
➢ **Small and medium windings** ➢ **Large windings**	➢ Drawing Interpreted Incorrectly ➢ Incorrect Material/Parts used ➢ Process Incorrectly Followed ➢ Lack of Attention ➢ Material not Ordered ➢ Supplier Problem ➢ Inadequate Training ➢ Planning not Issued ➢ Procedure Inadequate ➢ Lack of Attention ➢ Material not Planned ➢ No Procedure to Follow	➢ Cylinder damaged at the bottom due to hooking ➢ Cylinder undersize ➢ Conductor not finishing the job ➢ Conductor undersize ➢ Incorrect covering dimensions ➢ Clacks shortage ➢ Transposition not positioned correctly by design ➢ Oil guides not fitting/sealing ➢ Close fitting collars not equal size with conductor ➢ Bad joints from paper lapping ➢ Tails not insulated according to drawing
➢ **Small and medium winding assembly** ➢ **Large winding**		➢ Cylinders warped and undersize ➢ Cylinder bursting open ➢ Cylinder having oil bubbles ➢ Cylinder damaged at the bottom due to hooking ➢ Bad joints ➢ Tails not lining up ➢ End insulation collapsing under pressure ➢ Bottom end stack not lining up ➢ Transposition not marked ➢ Transposition on an incorrect position ➢ Conductor tilting under pressure due to loose discs
➢ **Large Active Parts assembly** ➢ **Small Active Parts Assembly**		➢ Drawing not having measuring dimensions ➢ Incorrect ratios on windings ➢ Core plates stacked incorrectly ➢ Connection staggering not conforming due to space constraints ➢ Yoke bolts not flashing after lock nuts ➢ Windings not fitting over another (ID undersize) ➢

Appendix C

Internal Audit Company Procedure

Procedure

6.1 Selection of auditors

The internal auditors shall ensure that audits are conducted as per internal audit schedule. They act as lead auditors and may co-opt additional personnel to assist with audits as they deem necessary. External consultants may also be used to perform or assist in performing quality audits. As a minimum requirement, the following personnel will be trained as internal auditors:

- Q Manager
- Q Technicians
- Q Inspectors
- Environmental Manager
- Safety Manager
- QA & Environmental Assistant
- Occupational Health Practitioner

When an integrated audit is performed in a certain area, the audit team shall be selected to cover all areas to be audited. The objective should be to train auditors in all four disciplines (multi-skilling).

6.2 Scheduling of audits

Internal quality audits are scheduled by the Q Manager or his assistant. The frequency of audits is adjusted on the basis of the current situation or when significant changes have been made to the organisation or system function elements. A schedule showing the status of internal quality audits is kept electronically in "Sharepoint".

In some cases additional audits may be required where new contracts have been awarded or where customer requirements or trends indicate that an audit should be performed. Where possible, internal system audit schedules are adhered to unless particular circumstances prevent the conduct of the audit on the specified dates.

Continuous trend analysis are conducted on IO's raised relating to the product / service and customer/supplier related, internal audit findings as well as external audit findings.

Where trends are evident, additional ad hoc internal quality system audits are carried out. The 4 – Q Model approach could be utilised to investigate the trends.

The method and format used for conducting and reporting audits must however, ensure that the end results meet the requirements of raising audit non-conformances and follow-up action to confirm their clearance and closure.

6.3 Preparation for company QA audits

As per scheduled on the “Sharepoint”, e-mail is sent to the relevant department manager(s) of the system functions to be audited prior to the planned audit and should include:-

a) Audit Date;

b) Area to be audited.

c) Other Information as Required.

If needed and where applicable, checklists could be prepared and duties assigned to assistant auditors.

If required, a meeting could be held (pre-audit meeting) with the manager (and possibly the foreman as well) to discuss any particular aspects or functions to the internal audit.

6.4 Performance of the Audit

If the audit team consist of more than one auditor, a pre-audit meeting could be held to assign tasks and discuss the audit areas. Checklists may be used if required.

An IO is raised, referring to the audit report, for follow-up purposes.

Where applicable and deemed necessary, arrangements are made to have responsible contact persons from the relevant system functions available to provide information and answer questions during the audit.

Internal audits are carried out using the criteria specified in SABS ISO 9001.

ISO 19011: Guidelines for quality may be used as a guide.

The foreman or departmental manager of the area must agree upon audit findings.

Once the findings had been agreed upon the findings are captured on Sharepoint

Referencing to the audit report numbers.

6.5 Reporting of Audits

Upon completion of the audit, a meeting may be held (post audit conference) if deemed necessary by the auditor and / or manager. An audit report is then generated and distributed by the auditor within 1 week from date of audit. This report must reflect at least:

(a) Purpose of the audit;

(b) Scope;

(c) Summary;

(d) Conclusion

(e) Reference number of the IO raised

The audit report is circulated electronically to all responsible department heads. A copy of the audit report is also sent to the CEO, and the report is also made available on Sharepoint

6.6 Audit follow-up activities

A response to the Audit Report and Audit Findings is requested as per agreed target date, not exceeding one month. Managers are responsible to ensure that agreed target Dates for the finding(s) closure are met.

When deemed necessary, a follow-up audit could be scheduled to investigate audit findings, which are overdue.

1. Records

The Audit Report, together with all relevant documentation is retained as a quality record.

Audit reports are filed electronically in a Sharepoint programme under "PTT/Engineering/Quality Department; Audit Schedule/year and are kept for a minimum period of five years.

This procedure, together with any amendments or revisions is a permanent record kept by the document co-ordinator.

Internal Audit Report

[1]**Prepared By:** E Dikobe		**Assisted By:** N P Ngomane	**Date:** 16/08/2011
Approved By: HJH Pieterse	**Department:** Quality		
Department: Large & Medium Windings and their Assemblies	**Process(es):** Quality Management System		**Report No. :**ED/IA/11-04 **No. of pages:** 7

Revision	Description	Date
1	Observation changed to minor finding	03/09/2009

3 Minor and Major Findings

No	Findings	Action	Completion date
3.1	Red Triangle procedure was not available, on request, during the audit. (ISO 7.5.1; b)	Riaan	
3.2	Red triangle cards were not placed on W1063037 jobs during the audit. (ISO 7.5.1; b)	Riaan	
3.3	Checklist (appendix 7) does not have any business (PTT) identification nor neither is part of our QMS.(ISO 4.2.1; c and d)	Riaan	
3.4	Sigma card no. 1ZXX209808; page 1/16, 5/16 not signed off by the Supervisor. (ISO 4.2.4)	Riaan	
3.5	The bottom leads of C phase D/winding got damaged while rotating winding platform during winding. (ISO 7.5.5)	Riaan	
3.6	Stack Iron as well as disc clamps not available during the winding of seq #370 D winding (ISO 7.5.1; c)	Riaan	
3.7	Unmarked trolley with material was left on the walk way, not attended too during the whole shift. (ISO 7.5.3)	Riaan	
3.8.	New sigma Cards for the repair of # 182 C phase C/W were not signed off by the Supervisor during the audit, the inspector signed on the 29th July 2011. (ISO 4.2.4)	James	
3.10	Pages 3/16 to 16/16 found in the travelling file of # 182 are not identified for which unit are they for. (ISO 4.2.3; e)	Paul	
3.11	Quality Objectives have not being adequately addressed within the audited area. (ISO 4.2.1; a)	James	
3.12	The vertical winding machines are full of dust on the top(ISO 4.2.3 e)	Riaan	
3.13	The trolleys of #358 and 373 have broken collars and rings mixed with good material.(ISO 7.5.5)	Riaan	
3.14	Sigma cards1ZXX209808 and 1ZXX209845 have common name(ISO 4.2.3 e)	James	
3.15	Some of the sigma cards of #'s 185 and 972 were found in the	James	

[1]

	travelling file of # 182(ISO 4.2.3 e)		
3.16	The sigma cards for clack have faded away and are found in various jobs such as travelling of (ISO 4.2.3 e)	James	
3.17	An IO was not found in the travelling file of the failed winding for #182, as per the index file.(ISO 4.2.4)	James	
3.18	Failed winding found without any identification.(ISO 7.5.5)	James	
3.19	1ZBA 462002-1 (Tolerances) and 1ZBA 208001-33 (Winding adjustment) were not available in the file though called in the index of the Procedure file (ISO 4.2.3 e)	James	
3.20	1ZBA202001-1 (Qualifying process for HF brazing of copper) and 1ZBA 202001-6 (HF brazing at Interleaved windings) not indexed but are in the Procedure file. (ISO 4.2.3 e)	James	
3.21	There are two revisions of TPR 4628 0235-05(Pressing of Power Transformer windings) dated the 5th/07/2000 and the 25th/07/2008 in the Procedure file. (ISO 4.2.3 e)	James	
3.22	Certificate of calibration no. 2332 SABS AFS 436-1, Page ½ (page 2 is not available) was calibrated on the 23th May 2007, and does not indicate expiry date. (ISO 7.6c)	James	
3.23	Annexure 7.10 of TPR 4628 0235-5 has been filed in the area within the Safety Section in the Procedure file. (ISO 4.2.3 e)	James	
3.24	Vertical Winding Machine No. 1 does not have a material trolley. “Ramp” was found on the ground collecting dust and iron fillings.(ISO 7.5.5)	James	
3.25	The leads of B and C Windings for #368 had carbon and were already crimped, C winding had a very sharp point just about 30mm below the ferrule. (See photos)(ISO 7.5.2 c)	David	
3.26	The gauge on Hydraulic Press Machine no. 2 is not calibrated (ISO 7.6 a)	Peter	

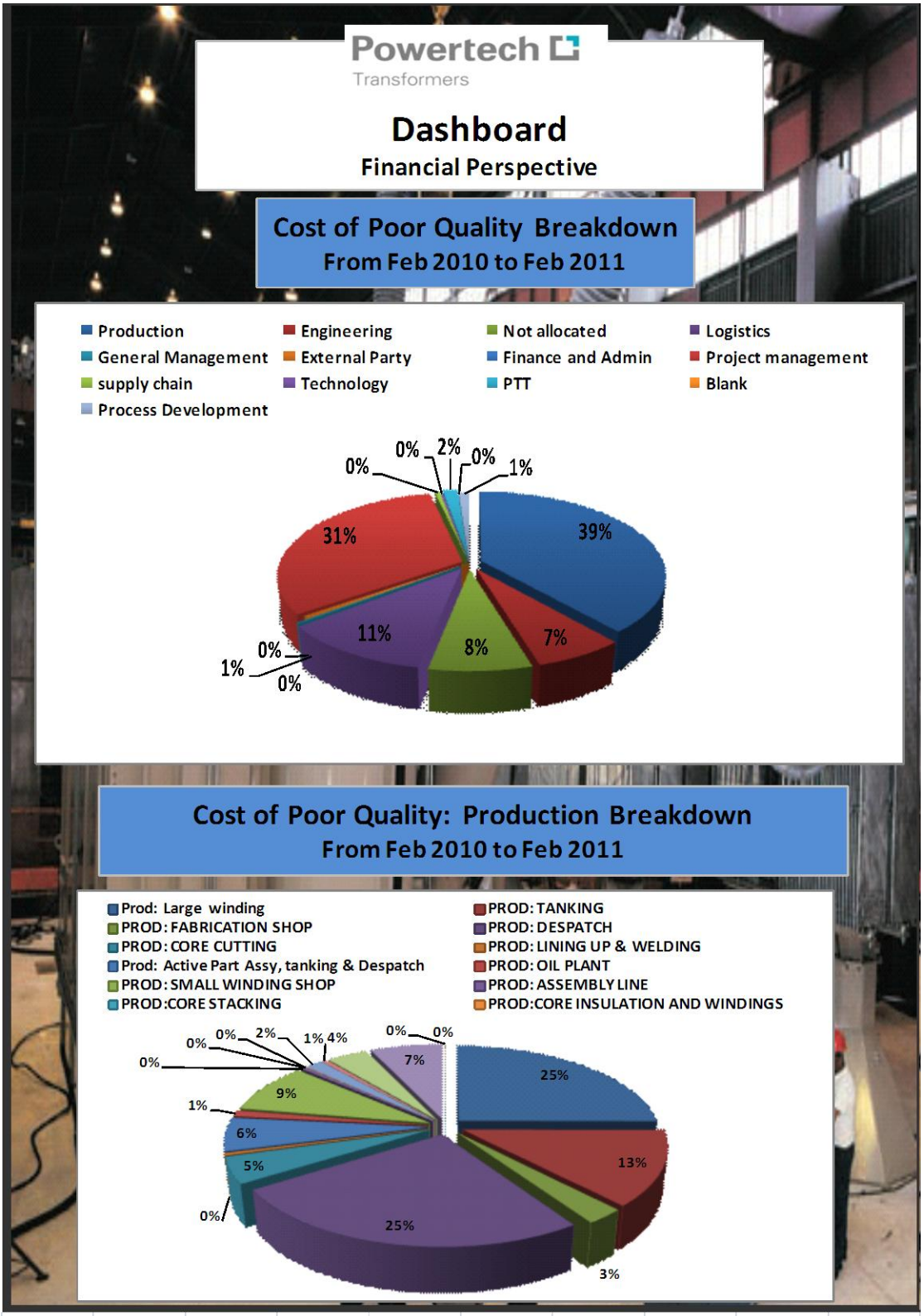
Table 9: The classification of the Audit findings as per department

Finding No	department
3.1	Large windings and Assembly
3.2	Large windings and Assembly
3.3	Large windings and Assembly
3.4	Large windings and Assembly
3.5	Large windings and Assembly
3.6	Large windings and Assembly
3.7	Large windings and Assembly
3.8	Medium windings and Assembly
3.9	Medium windings and Assembly
3.1	Medium windings and Assembly
3.11	Medium windings and Assembly
3.12	Large windings and Assembly
3.13	Large windings and Assembly
3.14	Medium windings and Assembly
3.15	Medium windings and Assembly
3.16	Medium windings and Assembly
3.17	Medium windings and Assembly
3.18	Medium windings and Assembly
3.19	Medium windings and Assembly
3.2	Medium windings and Assembly
3.21	Medium windings and Assembly
3.22	Medium windings and Assembly
3.23	Medium windings and Assembly
3.24	Large Active Part Assembly
3.25	Medium Active Part Assembly

Appendix D

This Appendix has been attached to the disc on the back cover of the document.

Appendix E


Powertech
Transformers
Dashboard
Financial Perspective
Cost of Poor Quality Breakdown
From Feb 2010 to Feb 2011
Production
Engineering
Not allocated
Logistics
General Management
External Party
Finance and Admin
Project management
supply chain
Technology
PTT
Blank
Process Development
0%
0%
2%
0%
1%
31%
39%
11%
8%
7%
0%
1%
0%
Cost of Poor Quality: Production Breakdown
From Feb 2010 to Feb 2011
Prod: Large winding
PROD: TANKING
PROD: FABRICATION SHOP
PROD: DESPATCH
PROD: CORE CUTTING
PROD: LINING UP & WELDING
Prod: Active Part Assy, tanking & Despatch
PROD: OIL PLANT
PROD: SMALL WINDING SHOP
PROD: ASSEMBLY LINE
PROD:CORE STACKING
PROD:CORE INSULATION AND WINDINGS
0%
0%
0%
2%
1%
4%
0%
0%
0%
7%
25%
9%
1%
6%
13%
5%
0%
25%
3%

Powertech
Transformers
Dashboard
Internal Business Processes
Delay Summary
Date: 22/10/2010 to 01/06/2011
16
14
12
10
8
6
4
2
0
PROD: CORE CLAMP & DRILLING
PROD: CORE STACKING
PROD: FABRICATION SHOP
PROD: GRINDING & CLEANING
PROD: LINING UP & WELDING
PROD: MACHINE SHOP
PROD: PAINTSHOP
PROD: PAPER LAPPING
PROD: SMALL WINDING SHOP
PROD: STEELYARD
PROD: SUB ASSEMBLY
PROD: TANK FABRICATION
Prod: Tank Manufacturing
PROD: TANKING
Blank
Root cause Breakdown
From Feb 2010 to Feb 2011
Not Yet Assigned
Customer
Engineering
Environment
Knowledge / Training
Machinery /Tools /Equipment
Maintenance
Man / Human Error
Management
Material
Method / Procedure
Plant
Quality
Safety
Supplier
Systems
Force Majeure
Technology
0%
0%
1%
0%
9%
17%
1%
7%
13%
7%
12%
0%
9%
3%
17%
1%
1%
1%