MASTER

Analysis and improvement of the field quality and reliability information flows at Kinetron BV understanding and improving the No Fault Found problem

Vromans, F.

Award date:
2007

Analysis and improvement of the field quality and reliability information flows at Kinetron BV

Understanding and improving the No Fault Found problem

TU/e KINETRON

Frans Vromans

Monday, 23 July 2007

TU/e KINETRON

Author

Name F. Vromans
Student ID 500519

Supervisors

1st supervisor Prof. Dr. Ir. A.C. Brombacher

Eindhoven University of Technology
Faculty Technology Management
Section Quality and Reliability Engineering

2nd supervisor Dr. Ir. J.L. Rouvroye

Eindhoven University of Technology
Faculty Technology Management
Section Quality and Reliability Engineering

Kinetron supervisor Ir. J. Meijer

Kinetron BV
Jan Asselbergsweg 60
5026RR Tilburg

Abstract

Due to several trends in the industry a conflicting situation appears in the product development process. Products must have state of the art functionality, high quality and a low price and must be developed in the shortest possible time. The component based quality and reliability assurance methods are no longer sufficient to guarantee product reliability. There fore manufacturers must deal with products entering the market with an unknown reliability level, and it should be expected that a number of products will be returned which are according to specifications and No Fault can be Found (the NFF problem).

This means that manufacturers must focus on learning as fast as possible from the problems that occur in the field. To control product reliability manufacturers can get help from the customers that use their products. The manufacturers must use field failure information to improve product quality. Field failures must be analysed, root causes must be found, and recurrence of these failures must be prevented. The field quality and reliability information must be at the right place in the organisation, at the right time and must have the right quality.

To analyse if all information is at the right place, at the right time and of the right quality the MIR method is used. After analysis of the field quality and reliability information flows at Kinetron BV, it appeared that these information flows had high MIR scores for component related failures and low MIR scores for failures which result in NFF. To improve this situation Kinetron needs to improve the field quality and reliability information flows with low MIR values.

Executive summary

Introduction

Kinetron BV in Tilburg is a high tech, innovative development and manufacturing company of micro energy systems. Kinetron produces big series of water turbine generators (WTG). In the past Kinetron had field reliability problems in several categories. During the last few years more and more of these field quality and reliability problems were solved. Only one of the field problems remained unchanged in the absolute sense. Relatively the NFF problem increased from a few percent in the year 2000 till over 50% at the moment. The NFF problem relates to products returned by the customers that, when tested, comply with the specifications so no fault is found.

Trends and effects

Maybe the NFF problems at Kinetron are related to external trends and/or developments which influence the current market of innovative high volume products. The trends which influence the market of innovative high volume products are:

1. Influx of new technology
2. Reduction of time to market
3. Customer attitude towards reliability has changed
4. Primary business processes have changed

The trends cause a conflict in the main four business drivers. Customers expect state of the art functionality and product quality is taken for granted. Also the high innovation speed and price erosion put a high pressure on the Time To Market (TTM). This means that manufacturers must develop products with state of the art functionality, high quality and low costs, within the minimum amount of time. This leads to two kinds of risks: Technical risks and market risks. Unfortunately a decrease of one of the risks leads to an increase of the other.

At the moment manufacturers are not able to deal with this situation and the number of field reliability problems is increasing. Preventing all quality and reliability problems with quality systems or quality tools is not possible in these markets. Also testing the product reliability before market introduction is not possible. There is such a high pressure on the time to market that there is not sufficient time to perform tests. If tests are done it is still very difficult to develop tests for all product problems, all field situations and all customer actions. Finally the current test methods are mainly focussed on finding component related failures. Due to the trends a new type of failures occurs: the No Fault Found failure. This NFF failure will not be detected with the current test methods.

Reasons for the NFF problem are:

- Product does not meet customer expectations (non technical failure)
- Products are becoming more and more complex. It is possible that a product fails but the failure can not be detected by the tests performed by the service centre.
- Products have more and more interconnectivity. It can occur that two products function perfectly separately, but when connected together one or both products fail.
- Products are sold all over the world. It can occur that a product only fails in some field situations. And when the product is tested under other conditions the product works fine.
- Finally it is not possible to predict all customer actions. It can occur that a customer uses the product in such a way the product fails. But this failure can not be repeated by the service centre which analyses the returned product.
- Fault can not be found due to intermittent component problems
- The wrong part is replaced due to wrong diagnose of field engineer

Because it is no longer possible to prevent, predict, or test all product reliability problems with the current methods, manufacturers have to deal with products entering the market with an unknown reliability level, and it should be expected that a number of products will be returned which are according to specification and No Fault can be Found (the NFF problem).

To solve these problems manufacturers must use feedback information from the field. This means that manufacturers must focus on learning as fast as possible from the problems that occur in the field. Field failures must be analysed, root causes must be found, and recurrence of these failures must be prevented. Field failure information must be at the right place, at the right time, and must have the right quality. Besides these demands for field quality and reliability information it is of great importance in order to realise continuous improvement that there are closed field feedback loops. If the field feedback loops are not closed the process becomes unstable and no sustained improvement is possible.

Research questions
The problems at Kinetron combined with the information described in the literature led to the following research questions:

1. *Are the field quality and reliability information flows at Kinetron sufficient for root cause analysis and improvement of all the field returns?*
2. *If no, do the shortcomings in the field quality and reliability flows explain the number of NFF in the field returns?*
3. *How can the field quality information flows be improved so root cause analysis and reduction of the NFF field returns becomes possible?*

Analysis of information flows
To answer these questions the field quality and reliability information flows must be analysed. The analysis is done with the Maturity Index on Reliability (MIR) concept. The MIR model assumes that an organisation can only establish continuous improvement and solve and prevent failures as e.g. the NFF if a process has a level 4 on the MIR scale. The four MIR scales are:

Level 0: No information available
The manufacturer has no relevant quantitative evidence of the process output (e.g. number of field returns) of the products. Further there are no control loops back to production and development.

Level 1: How many problems?
The manufacturer has quantitative evidence of the process output in terms of number of failures in the field. This information is fed-back into the process, but the origin of the problems/deviations is unknown.

Level 2: Where do they originate?
The manufacturer has quantitative evidence of the process output, knows the origin of the problems (such as design, production, material or customer use), has the corresponding control loops, but does not know what actually causes the problems.

Level 3: What is the root cause?
The manufacturer has quantitative evidence of the field behaviour, knows the origin of the problems and knows what actually causes them, and has the corresponding control loops and is able to solve problems. The manufacturer is, however, not able to prevent similar events from happening in the future again.

Level 4: What can be done to prevent reoccurrence?
The manufacturer has quantitative evidence of the field behaviour, knows the origin of the problems, and knows what actually causes them and what to do about it. The level of knowledge is such that the manufacturer not only knows root causes of problems (technical and organisational) but is also able to anticipate and prevent similar problems in the future. All corresponding control loops are in function.

Influence of trends at Kinetron BV
After analysis of the situation at Kinetron it can be concluded that Kinetron is affected by the trends mentioned before. The products are complex, have more interconnectivity and more functionality. A high quality and reliability is expected by the customers. These complex and high quality products must be developed in a minimum amount of time and with the lowest product costs as possible. This leads to a conflicting situation. Reducing development time and product costs can lead to an increase of product quality and reliability problems (technical risks), but increasing the development time and product costs leads to lower sales quantities (marketing risks).

With the current quality systems, methods, tools and tests it is not possible for Kinetron and "Customer Company A" to prevent all reliability problems, or to find all quality and reliability problems by testing. This means Kinetron and "Customer Company A" will have to deal with products entering the market with an unknown reliability level, and it should be expected that a number of products will be returned which are according to specification and No Fault can be Found (the NFF problem).

Analysis of the field feedback information flows at Kinetron BV
To analyse the field feedback information flows an information flow model of the field feedback process is made and the MIR levels of the information flows are determined. This led to the following conclusions:

The field reliability information flows at Kinetron are influenced by the following factors:

1. The failure rate: High failure rates result in high warrantee cost and risks of claims, this leads to a high pressure on solving the problems and extra information flows arise.
2. Visibility and detectability of the failure by inspection of the returned product: If a failure is invisible and hard to detect by investigating the returned product, other field quality and reliability information flows can appear than when the failure is visible or easy to detect.
3. Origin and root cause can be found by analysis of the returned product: If the origin and root cause can be found by analysis of the returned product, other field quality and reliability information flows are used than when the failure is not visible or easy to detect.

Independent of the pressure on solving the problem, a problem is solved and prevented if the origin and root cause can be found by looking at the product only. In this situation the information flows with a MIR level 1 from the user till Kinetron Quality department where the product is analysed. Kinetron investigates the origin and the root cause and a solution to solve and prevent the problem. This information flows with a MIR level 4 to the relevant actors in the process and continuous improvement is enabled.

If the failure rate is high, the pressure on solving the problem builds up and the origin and root cause can not be found by looking at the returned product an additional information flow (MIR level 3) appears. Extra information is retrieved from the field engineer and the user. With this information the origin and root cause can be found. With this information Kinetron defines a solution and a preventive measure and communicates (MIR level 4) this with the relevant actors in the process. This again leads to a continuous improvement.

If the failure rate is low, the pressure on solving the problem is low. If the pressure on solving the problem is low and the origin and root cause can not be found by investigating the product only, the additional information flow does not appear and, the overall flow is degraded from a MIR level 4 to a MIR level 0. The result is that problems are ignored and stay unanticipated. This situation occurs in two situations.

1. The problem can be seen or detected by investigating the product, but the origin and root cause can not.
2. The problem can not be seen and not be detected by investigating the product, also the origin and root cause can not be found.

From experience in known that situation 1 doesn't occur very often. Situation 2 is responsible for the NFF problem.

Improving the information flows
Due to the trends and the consequences of these trends Kinetron and "Customer Company A" are not able to improve the failures in all categories of field reliability problems. Some categories of reliability problems are unanticipated and continuous improvement is not possible. To make the field return process suitable to deal with the two types of failures which are unanticipated in the current situation, Kinetron and "Customer Company A" have to improve the field quality and reliability information flows. Two solutions are presented both based on improving low MIR information flows.

Conclusions and recommendations
Kinetron can be categorized as an innovative mass production company which is influenced by the trends mentioned above. Due to the trends Kinetron is not able to prevent all reliability problems with the current quality and reliability methods and the NFF failure occurs.

After analysing the Kinetron field return process and the information flows through this process the following conclusion can be made: if the failure rate and the pressure on solving the problem are low and the origin and root cause can not be found by investigating the product only, not all information flows that occur in high pressure situations are present and the MIR level decreases from a level 4 to a MIR level 0. The result is that problems are ignored and stay unanticipated. This situation occurs in two situations.

1. The problem can be seen or detected by investigating the product, but the origin and root cause can not be found.
2. The problem can not be seen and not be detected by investigating the product, also the origin and root cause can not be found (NFF)

To make the field return process suitable to deal with the two types of failures which are unanticipated in the current situation, Kinetron and "Customer Company A" have to improve the field quality and reliability information flows.

Now the research questions can be answered:

1. *Are the field quality and reliability information flows at Kinetron sufficient for root cause analysis and improvement of all the field returns?*

   From the analysis of the field quality and reliability information flows at Kinetron BV it can be concluded that the field quality and reliability information flows are not sufficient for analysis and improvement of all field returns. In some cases the necessary information flows are not present, the origins and root causes of the problems are not found and the problems stay unanticipated.

2. *If no, do the shortcomings in the field quality and reliability flows explain the number of NFF in the field returns?*

The shortcomings in the field quality and reliability information flows do indeed explain the number of NFF in the field returns. The information which is necessary to solve reliability problems in the NFF category is not available. There fore the origin and root causes of this category of failures is not found and there is no continuous improvement possible. The NFF problem is one of the two field problems which stay unanticipated in the field return process at Kinetron BV.

3. *How can the field quality information flows be improved so root cause analysis and reduction of the NFF field returns becomes possible?*

The field quality and reliability information flows can be improved by increasing the MIR levels of the information flows with a low MIR level. This means that the quality of the information from the field must increase to enable finding the origin and the root causes of field problems. Another possible solution is to start a new information flow between the Kinetron Quality Department or "Customer Company A" Quality Department and the end user. If products are returned and No Fault can be Found Kinetron or "Customer Company A" contact or visit the field user and the service engineer to discuss and investigate the information. This will lead to high quality field feedback information which can be used to reduce the number of NFF problems.

Solving the NFF problem: a first start

The benefit of this study is proven by the fact, that already during this study, the first modifications to improve the NFF problem were implemented. Kinetron made two special multi meters to analyse rejected WTGs at the final inspection at the "Customer Company A". Also Kinetron is investigating methods to test the WTG and the electronic box together, to find and solve interconnectivity problems. Finally Kinetron is investigating a simple trouble shooting procedure which can be added to the gas water heater manual. All three solutions do not solve the problems, but a better analysis can be done, higher quality information is obtained, and several reasons for NFF can be excluded.

Generalisation

Most of the studies used to formulate and answer the research questions were performed in the innovative consumer electronics industry. The consumer electronics industry has the following characteristics: short time to market (short PCPs), increasing warranty time, and increasing rate of non-component related failures, globalisation and segmentation of the business process. This study shows that the characteristics of the consumer electronics industry are present in the gas water heater industry. The research method which is used to analyse the presents of the trends and to analyse the field feedback information can be used in companies with similar characteristics.

The conclusions of this research are related to the situation at Kinetron and don't have to be valid for other companies. Although the conclusions do not have to be valid for other companies, there is one conclusion that might be. The relation between the pressure on solving a reliability problem and the appearance of information flows which are necessary for solving the problem, is also present at other companies. To establish this relation at other companies, further research is necessary.

Acknowledgements

This report is the end of an eight month graduation project for my study Industrial Engineering and Management Science at the Eindhoven University of Technology. The research for this thesis is conducted at Kinetron BV in Tilburg. Because Kinetron is a supplier of "Customer Company A", this study also includes parts of the "Customer Company A" organisation. It would have been impossible to finish this project without all the help I received. So I would like to thank some people who have helped me a lot.

I did this study during the evening hours. During the day I worked at Kinetron. First of all I would like to thank the complete staff of Kinetron for their support during my study. I also would like to thank Marco Koningsberger (Director) of Kinetron who made this financially possible and my most appreciated colleague (actually my Boss) John Meijer for all his support during my study, even in times when things were difficult. John and Marco, Thanks!

Furthermore I would like to thank Aarnout Brombacher, my first supervisor, for his patience and the many conversations we had to push this research in the right direction. Also thanks to my second supervisor, Jan Rouvroye, for the time spent to read my report and view my presentations.

Other people who helped me during my study and who I need to thank a lot, are my fellow students. Rene Schroemges, Theo Rosendal and Eric van Roy. We were together for five years.

I also want to thank my father for correcting my thesis and my mother for her mental support.

Last but surely not least, I am thanking my girlfriend Ester. She supported me the entire period, she helped me understand the structure and contents of a scientific research project, even without knowledge of field reliability information flows. Finally she supported me by planning my study time and taking a lot of work out of my hands. She has been a great support!

Table of contents

Abstract 3

Executive summary 4

Acknowledgements 9

Table of contents 10

1. Introduction 12
   1.1 The company 12
   1.2 The product 13
   1.3 The initial problem description 14

2. Problem description 15
   2.1 Introduction 15
   2.2 Trends in industry 15
   2.3 Effects of trends on business drivers 17
   2.4 Effects of trends on Quality and Reliability 18
   2.5 Field feedback information 21
   2.6 Field feedback loops 23
   2.7 Conclusion 27
   2.8 Research questions 28
   2.9 Solution path 29

3. Methodology 30
   3.1 Introduction 30
   3.2 Information requirements 30
   3.3 Process requirements 31
   3.4 Criteria for the problem methodology 31
   3.5 The MIR concept 31
   3.6 Conclusions MIR 33
   3.7 Detailed solution path 33

4. Description of the situation at Kinetron 34
   4.1 Introduction 34
   4.2 Influx of new technology, functionality and complexity 34
   4.3 Pressure on Time to market 35
   4.4 Kinetron customers and pressure on quality 36
   4.5 Kinetron business creation process and globalisation and segmentation 36
   4.6 Effects of trends on business drivers 37
   4.7 Effects of trends on Quality and Reliability 38
   4.8 Conclusion: Need for fast and high quality field feedback 39

5. Field quality and reliability information flows at Kinetron 40
5.1 Introduction 40
5.2 Field return process Kinetron BV 40
5.3 Field return process activity model 42
5.4 Reactions on disturbances 43
5.5 Information flow models for three situations 49
5.6 Analysis of the information flow model 58
5.7 Possible information flow improvements 61
5.8 Solving the NFF problem at Kinetron: a first start 65

6. Conclusions and recommendations 67
6.1 Introduction 67
6.2 Conclusions 67
6.3 Generalisation 69
6.4 Recommendations for further research 70

References 71

Appendix A: Product return form 74

Appendix B: Trouble shooting procedure 76

1. Introduction

1.1 The company

Kinetron in the Netherlands is an innovative, high-tech organization specialized in the research, development, and manufacturing of micro (kinetic) energy systems. These systems convert (kinetic) energy into electricity and the other way around on a micro scale (see figure 1).

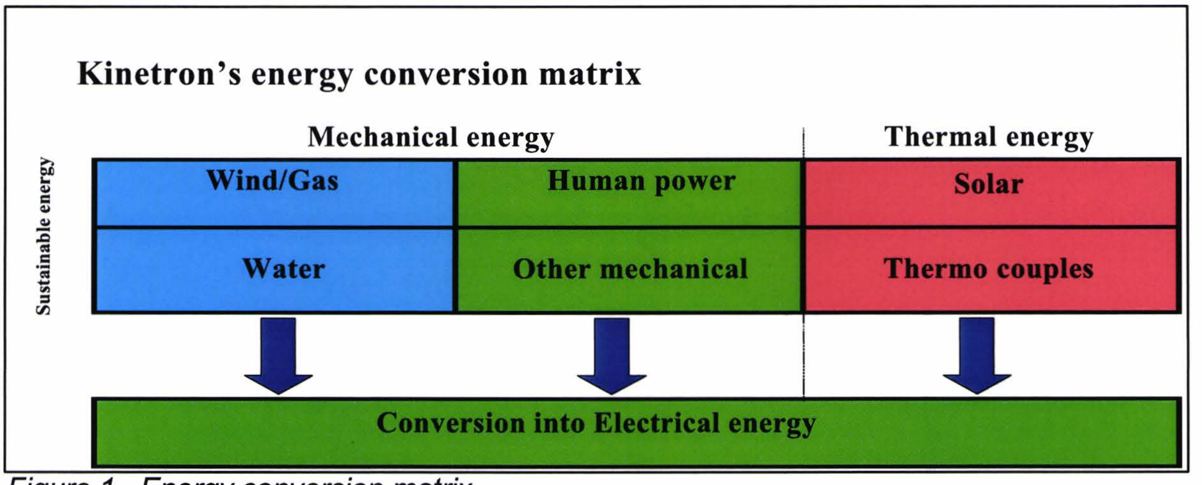


Figure 1. Energy conversion matrix

Kinetron is a project oriented, Business to Business, product and process development organization with in house prototype and production facilities. Kinetron organises the creation, production and distribution phase, or one of these, for their customers. New development projects are realized in global co-operation with industrial partners, research institutes, external experts and universities

Key technologies

- Micro generators
- Micro magnets
- Micro motors
- Micro gearboxes & micro mechanics
- Micro hydrodynamic systems

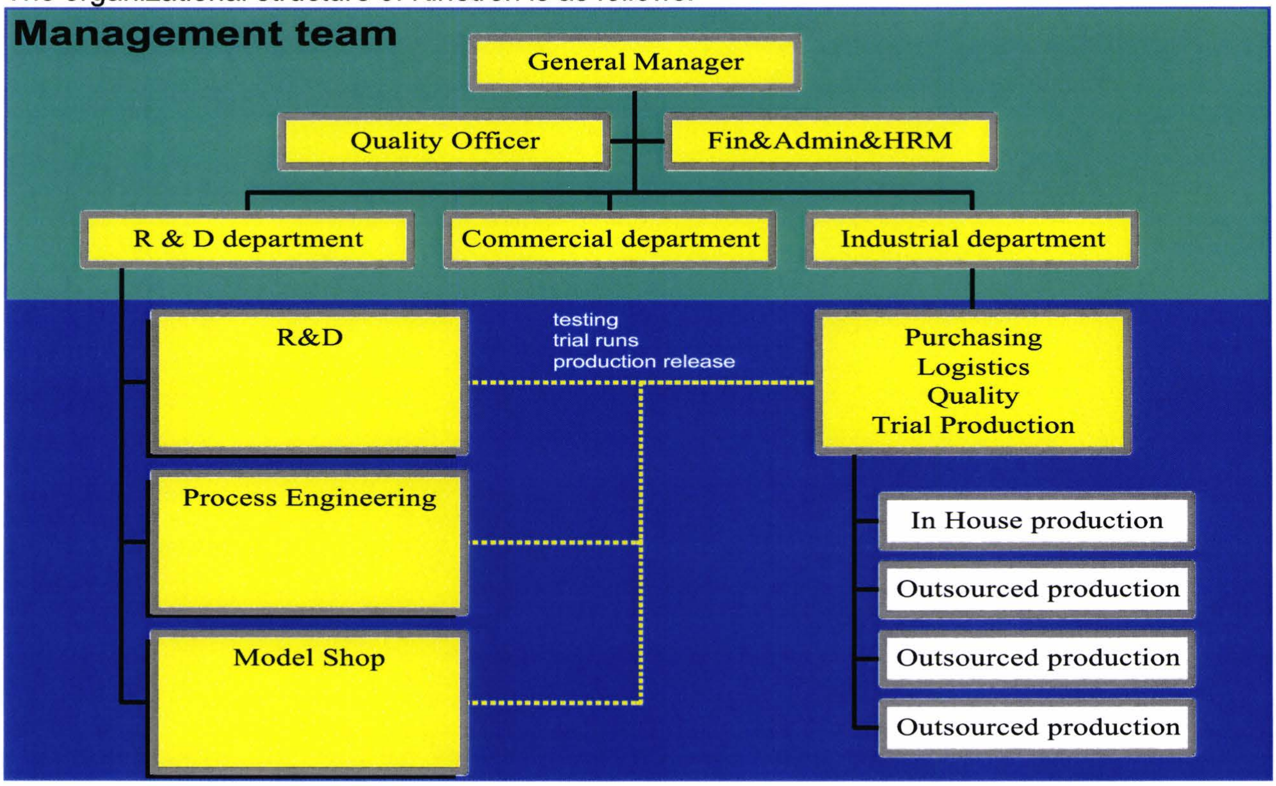
Kinetron holds a number of worldwide patents in the field of micro generators, hydro turbines and micro magnets.

Main application areas/ markets:
Low power applications in areas where mechanical energy (movement) is available.

Main functions of Kinetron systems:

1. Power supply : Wiring or battery replacement
2. Power support: Accumulator recharge (capacity enlargement)

Corporate structure:
The organizational structure of Kinetron is as follows:



1.2 The product

The Kinetron products can be divided into four product groups:

1. Micro generators
2. Micro motors
3. Micro magnets
4. Water turbine generators

The research in this thesis is related to the water turbine generator production, therefore only the water turbine generator (WTG) will be discussed (figure 2 and figure 3).

Kinetron developed, in order of "Customer Company A", a Water Turbine generating system which uses the kinetic energy of running water in gas-water heaters to generate electricity for the power supply of the electronic system and to ignite the gas water heater. The gas-water heater with the Kinetron WTG has been successfully introduced to the market by "Customer Company A" in August 2000.

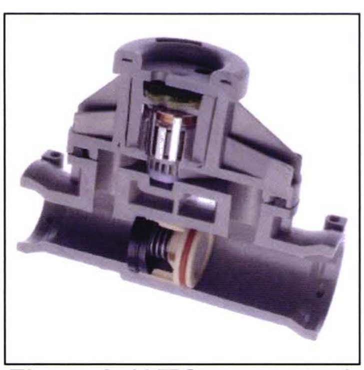


Figure 2. WTG cross section

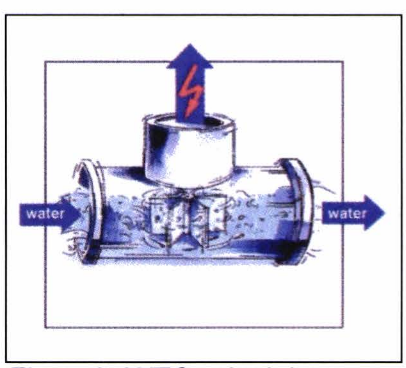


Figure3. WTG principle

1.3 The initial problem description

Unfortunately some of the WTGs have field problems and the gas water heater stops functioning according to customer expectations. The WTGs with field problems are returned to Kinetron by "Customer Company A". By analysis of the returned parts Kinetron solved almost all field problems. At the moment there is only a limited number of field problems left. Besides problems which can actually be detected and root causes can be found there is also a big part of returned products in which no fault can be found. This study is done because at Kinetron this problem is good for approximately 50% of the field returns. If Kinetron wants to reduce the field returns any further, this must be investigated.

The description above has led to the first global research questions:

- Why are products returned when no fault can be found?
- Why the root causes can not be found?
- What must be done to find the root causes of the NFF problem and to improve field quality and reliability?

As described above Kinetron is an innovative, high technological organisation. Also the products developed, manufactured and assembled by Kinetron can be categorised under the category high tech and highly innovative products for the mass market. If we assume that these NFF problems are not intentionally built-in by Kinetron it would be interesting to investigate if possible causes for these NFF problems are related to external trends and/or developments which influence the current markets of innovative, high volume consumer products. If the cause of these NFF problems is related to these trends, maybe the solution for the NFF problem can also be found in this direction. This report tries to analyse current problems at Kinetron and tries to establish a causal relation between the mentioned problems and the structure of- / developments in- modern business processes.

2. Problem description

2.1 Introduction

As discussed in chapter 1 the NFF problems could be related to external trends and/or developments which influence the current market of innovative products. Therefore in this chapter these trends and the consequences of these trends will be described. At the end of this chapter is discussed how quality and reliability can be controlled under the influence of the trends.

2.2 Trends in industry

2.2.1 Introduction

The last decades several trends influence the industry of innovative products. A study on trends impacting reliability of technical systems identified four major trends [Bro2005]:

1. Influx of new technology
2. Reduction of time to market
3. Customer attitude towards reliability has changed
4. Primary business processes have changed

2.2.2 Influx of new technology

Already in the year 1965 Dr. Gordon E. Moore (one of the founders of chip manufacturer Intel) published the law of Moore. This law stated that the number of transistors on a computer chip will double every 18 months for the same price [Moo65]. This law is still valid today. This increasing speed of technological change as well as the increasing depth of scientific and technological knowledge created more possibilities for new products [Wheel92]. Also the technologies become available at lower prices. Due to these lower prices new technologies and functionalities are being introduced in products for the mass market faster [Bro3]. These lower prices also lead to the combination of more functionalities in a single product [Bro3]. This again leads to products that are becoming more and more complex and have more interconnectivity with other products [Bro1].

Companies decide to implement new functionalities because of the following four reasons [Pet03]:

1. The customer demands a certain new functionality. These demands can be predicted by doing market research.
2. New technology becomes available and new product functions are possible. A company predicts that these functions are wanted by customers in the future. This is done because new technology becomes available and customers are not able to prescribe the possible new functions due to a new technology [Dem86].
3. To keep up with competitors. If the function is not implemented customers will be lost.
4. To make the product cheaper. New technologies can make the same functions possible, but for a lower price, e.g. software instead of hardware.

2.2.3 Time to market

The continuous influx of new technology always leads to a high pressure on time. This will be explained on the basis of the graph presented in figure 4. Company A introduces a product on the market with a memory of, for example, 10MB. If company B, which started development later than A, can introduce a product on the market with a memory 100MB for the same price, company A will not sell many products. So, to be able to make a profit company A must introduce his product with a memory of 10MB before company B. So to be able to have a reasonable market share and profit, companies must be the first (or at least one of the first) to the market with new products. Being late often results in competition from cheaper products with similar functionality or equally priced products with increased functionality [Bro3].

At the same time consumers adopt the products faster. E.g. it took the VCR over 15 years to reach commodity price levels and become a standard item in most households, whereas for DVD recorders this only took around 3 years [Bro3].

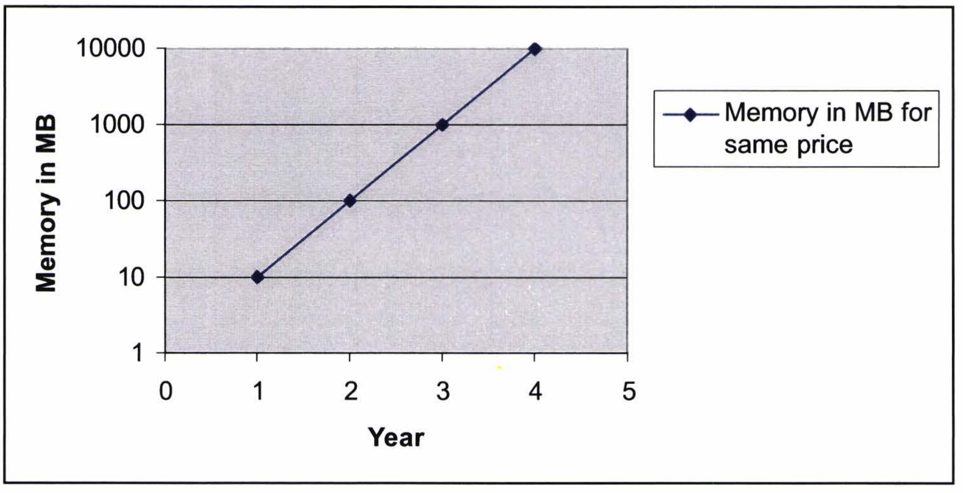


Figure 4. Example of the increase of MB for computer memories [Moore's Law]

2.2.4 Customer attitude towards product reliability

In the past, when products were not really complex, customers accepted a product to fail and to be repaired every now and then [Bro1]. In many cases the customer even knew what was wrong with the product and therefore accepts the failure. Now the products have become more complex and the customer is not able to understand what is wrong with the product when the product fails. The customer does not understand the complexity of the underlying systems and therefore he doesn't accept the product to fail [Bro3]. This is why product quality and reliability is not longer "nice to have, but it has become a prerequisite. Today customers expect a good quality and reliability even for inexpensive products [Bro1].

At the same time warrantee periods have increased and also the coverage on warrantee has increased. Warrantee periods of three years with an no questions asked policy are not uncommon these days. An unhappy customer can get a new product or his money back for whatever reason [Bro1]. In figure 5 the trends in quality and reliability are shown.

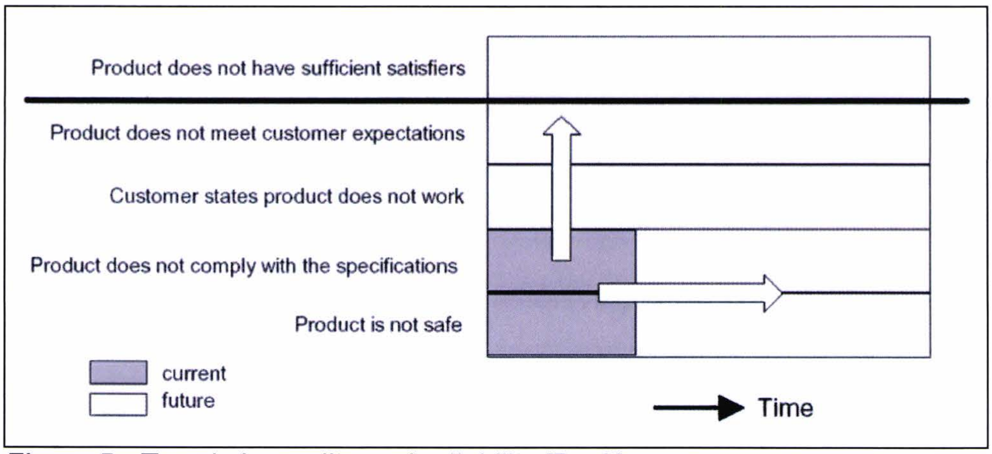


Figure 5.. Trends in quality and reliability [Bro2]

2.2.5 Trends in structure of the primary business processes

As stated before, technology innovations are taking place at high speed. As the product cycles and time to market are getting shorter, there will be an increasing pressure at the product quality and reliability. Researchers have stressed continuously that only organisations with the ability to develop a reliable product significantly faster than their competitors and also improve their production process continuously can have opportunity to occupy the leading position in the market [Sta90] [Whe92]. This strong competitiveness also leads to a high pressure on efficiency. To be more efficient manufacturers focus on their core activities and outsource other activities [Dij97],[Pet00b]. Increased international competition also forces companies to operate on a global scale. Globalisation combined with outsourcing leads to a segmentation of the business processes [Luy02] [Pet003]. In a segmented business process it is more difficult to know the contribution of all actors in the process and to communicate all information to the relevant actors in the business process [Pet03].

2.3 Effects of trends on business drivers

As a result of the trends described in the previous sections manufacturers of high volume consumer products are under pressure because the trends cause a conflict in their four most important business drivers [San00].

The four business drivers are [San00]:

1. Functionality: is the product able to fulfil its intended function.
2. Time: does the product reach the market at the required moment.
3. Quality / reliability: Does the product fulfil customer requirements at 'all' customers, not only at the moment of purchasing but also during the operational life of the product.
4. Profitability: Is the difference between product cost and sales price acceptable.

Today customers expect in new generations of products an ever increasing functionality. At the same time they take product quality for granted: Having it is not a strength, not having it is a fatal weakness [San00]. Connected with this are the increasing warrantee periods and the increasing warrantee coverage. If a manufacturer doesn't have an excellent knowledge about the quality and reliability of his products, warrantee claims may be much higher than expected [Bli96].

The high innovation speed has a consequence that products, from a sales perspective, become obsolete in months. The consequence is that development times must be reduced and that a strong price erosion occurs. If a manufacturer is late on the market it is almost impossible to sell big quantities and due to the price erosion it is almost impossible to make a profit on each product sold.

Both situations described above result in the following situations [San00]:
- The high innovation speed puts pressure on the time to market.
- Customers require excellent product quality

The product creation process must cope with these requirements and must be able to identify problems and risks before they happen [San00]. Risk for a design that find their roots in the development process can be divided into two types, technical risks and market risks. Technical risks are the risks of failing to meet technical targets, e.g. performance, reliability or producibility targets. Market risks are the risks of failing to meet market demands, e.g. time to market, costs of features. Unfortunately a decrease of one of these risks leads to an increase of the other and vice versa [The95]. If a lot of time is taken in the development process to reduce the technical risks the market risks increase and if development is rushed to shorten the Time To Market (TTM) the technical risks will increase. These uncertainties will have to be managed during the product development process. In the next section several methods to control quality and reliability are reviewed on their ability of dealing with these uncertainties.

2.4 Effects of trends on Quality and Reliability

2.4.1 Introduction

In the previous sections the trends and the effect on the main business drivers has been discussed. The conclusion is that it is becoming more and more difficult to make a product with excellent functionalities, high quality and low costs within the minimum amount of time.
This very complex task also has consequences for the reliability management processes. In the past reliability management processes were focussed on component related failures. Most information was collected for this purpose [Oud05], and quality and reliability problems were decreasing. The last decade the number of complaints on new products is rising again (figure 6). The cause for the rising number of complaints lays in the trends mentioned before.

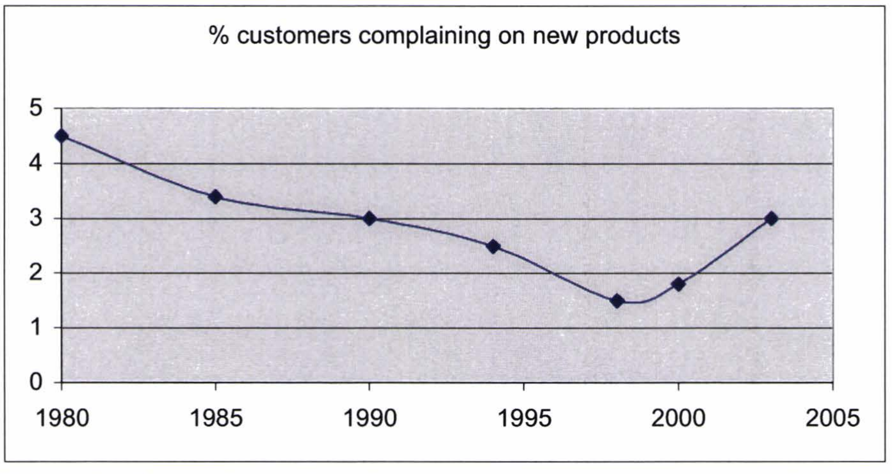


Figure 6. Percentage of customers complaining on new products [Oud05]

In the next sections there will be discussed why the most methods used to control product quality and reliability are not suitable anymore to control product reliability.

2.4.2 Quality and reliability control through implementation of quality control systems in the Business Creation Process

To improve product quality and reliability many companies have introduced ISO guidelines. To improve the quality of the organisation companies use Deming, Malcolm Baldrige or EFQM. Unfortunately this is not a guarantee for excellent product quality / reliability [Pet03]. Problems are often caused by a number of reasons [San99]:

- Obtaining quality certificates and awards becomes an independent goal, not connected to actual business operation.
- People have a tendency to focus mainly on nearby customers and forget, especially under pressure, the more remote customers. (Service helps the customer with a complaint, but it does not spend time in searching for the origin of the problem, it does not help two other customers of service, namely design and production).
- Companies are not sticking to the agreed procedure (for example under time pressure).

2.4.3 Quality and reliability control through tests in the Business Creation Process

Another way to control the reliability of a product is test the product reliability by the use of extensive test procedures [Pet03]. There are several problems which makes it difficult to make a good estimation of the product reliability based on tests. Tests are time consuming and are often on the critical path of the project schedule. Due to the ever decreasing time to market development teams may skip tests to meet the deadline [Min99]. Of course accelerated tests can be done to reduce the test time. But it is very difficult to translate the test results of an accelerated test to an actual reliability prediction about what is going to happen in the field [Pet03]. Due to the product complexity it is also very difficult to develop tests for all product problems that can occur. When the product reaches the market there will always be other reliability problems which were overlooked during development [Bro3]. Also these tests are mostly oriented towards finding component failures, but these failures make up only a minority of all product failures (figure 7) [Bro96].
Finally it is impossible to test all variations in consumers, products, applications and environments within the limited time available. As a result products are released to the market with an unknown reliability level [Bro3].

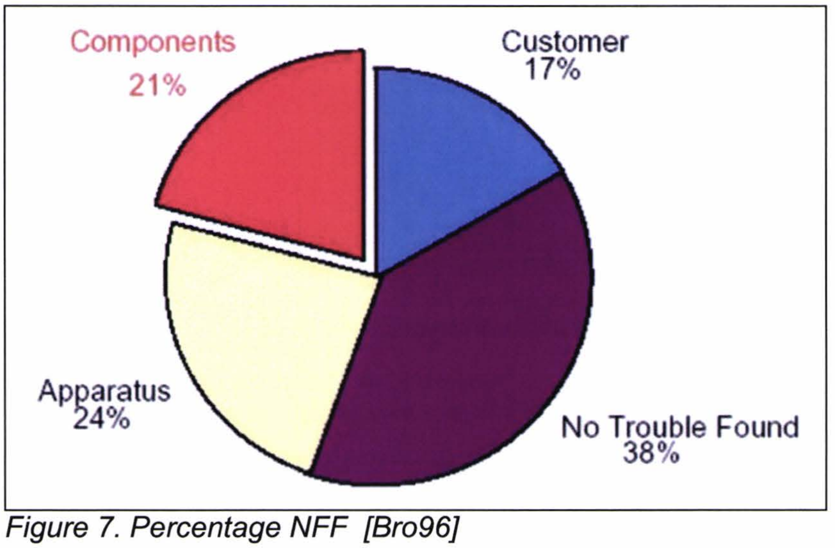


Figure 7. Percentage NFF [Bro96]

2.4.4 Reliability and new types of reliability problems

The definition of Reliability is: "The probability that a system will perform its intended function for a specific period of time under a given set of conditions (Lewis, 1996)". In the previous sections we have seen that it is no longer possible to predict, prevent or to test the product reliability sufficiently before the product is released to the market. The methods described before are not able to deal with the uncertainties embedded in the development (see section 2.3). Given the definition of reliability, this has a number of implications [Bro3]:

- To be competitive companies decide to introduce new technologies and features into their products early, even though they will not yet be proven mature: leading to higher technical uncertainties on the feasibility complying with the product specification. (Technical risks section 2.3)
- Globalisation and fast adoption leads to a wider range of consumers buying and using the products in a wider variety of environments. As products get more functions there are also more applications the products can be used in, and often more connectivity options. It is much more difficult to predict consumer expectations with all these parameters, leading to higher uncertainties on the specification and its coverage of expectations (market risks section 2.3).

Product reliability is usually measured by the number of products returned by dissatisfied consumers [Bro3]. For reliability these two risks lead to a number of new reliability problems. If we separate the problems in reliability problems due to technical risks and reliability problems due to market risks the following problems occur:

New reliability problems which occur due to high market risks:
Currently many companies in the consumer goods industry are facing an increasing number of product returns for non-technical reasons [figure 7]. Important reasons for consumers to return the products are that it does not meet their expectation, or that they are not able to get it working [Oud06]. In service centres or repair workshops the products are analysed to confirm the problem, but as there is no technical failure, this results in a growing number of "failure not found" classifications [Bro05b].

New reliability problems which occur due to high technical risks:
Besides the non technical reasons given above there are also several technical reasons why No Fault can be Found in the returned products:

- Products are becoming more and more complex. It is possible that a product fails but the failure can not be detected by the tests performed by the service centre.
- Products have more and more interconnectivity. It can occur that two products function perfectly separately, but when connected together one or both products fail.
- Products are sold all over the world. It can occur that a product only fails in some field situations. And when the product is tested under other conditions the product works fine.
- Finally it is not possible to predict all customer actions. It can occur that a customer uses the product in such a way the product fails. But this failure can not be repeated by the service centre which analyses the returned product.
- Fault can not be found due to intermittent component problems
- A good part is replaced due to wrong diagnose of the field engineer

2.4.5 Conclusions

The last few years an increase in complaints in new products can be seen (figure 6). The cause for this increase can be found in the trends described before. Due to the trends two conflicting uncertainties occur: Market uncertainty and technical uncertainty.

With all reliability methods described in the previous sections it is impossible to deal with both uncertainties at once. A decrease in the market uncertainty means an increase in the technical uncertainty and the other way around.

This conflicting situation makes that companies have to deal with products entering the market with an unknown reliability level, and it should be expected that a number of products will be returned as they are not fulfilling customer's expectations, although technically these products are according to specifications or the problem is hard to repeat [Bro3].

This means that other new ways to control product quality and reliability must be investigated.

2.5 Field feedback information

2.5.1 Introduction

In the previous section is concluded that companies have to deal with products entering the market with an unknown reliability level and that new methods must be found to control product quality and reliability. Petkova [Pet03] states that manufacturers can get help from the customers that use their product. These manufacturers must initiate projects to get field failure information as a means to improve product quality. [Dom01], [Hey02], [Fra02]. To reduce the field failures extra attention must be given to the back end of the PCP. Field failures must be analysed, root causes must be found and recurrence of this failures must be prevented [Pet03]. In other words if product reliability problems can not be prevented, predicted or tested before product introduction, it is necessary to learn as fast as possible from the product problems in the field [Bro4]. This must be done with field failure information.

With this field data the current product can be improved, but also the future products, the development process, reliability prediction methods and test procedures can be improved by the use of field data.

Petkova [Pet03] distinguishes a number of problems that may occur regarding the collection of field feedback information:

- information comes in late
- the available information is not complete enough for quality improvement
- Information is not fed back to the right place in the PCP
- Information is often hidden in a huge amount of data that is difficult to analyse

This means that field feedback information must be fast and of the right quality. Important aspects of quality and reliability information are [Bro01], [Pet03] (section 2.5.2 till 2.5.4):

- The level of detail the information provides
- The deployment of the information to the relevant people in an organisation
- The time it requires to obtain and deploy this information

2.5.2 Quality of information / Level of detail of information

First of all quality and reliability information should provide sufficient information to determine further actions. The information must be able to tell if a problem is or can become a real quality and reliability problem or if the problem is highly unlikely ever to happen or to happen again. Second, the quality and reliability information must be detailed enough to identify the relevant actors in the business process. It must be clear who can act in order to resolve the problem. Finally the data must be detailed enough to identify root causes of a problem. For example, to identify root causes of NFF in field returns the quality and reliability information must be far more detailed [Bro01].

2.5.3 Deployment of information in an organisation

Not only must the root cause of a problem be known. The information about this root cause must also be deployed to the right people in the process to make continuous improvement possible. It is not uncommon that a service department has detailed information about important reliability problems but sees no use in communicating this information to other actors in the process. This is mainly due to local cost and time pressure. Sometimes a known (by the service department) field reliability problem can exist for several product generations. Hence it is necessary to communicate the information to the right actors in the process. The actors in the process can be divided into corrective actors (people with the ability to correct reliability problems in existing products) and pro-active actors (people with the ability to influence and/or prevent reliability problems in future generations of products). Research showed that reliability related information is mainly deployed to corrective actors and that the pro-active actors are not identified. The problem is corrected, but no preventive actions are taken [Bro01].

2.5.4 Time required for obtaining and deploying information

The modern time-driven product creation processes are under a strong time pressure. This resulted in new development models like concurrent engineering. But, for an development model like concurrent engineering to succeed timing of quality and reliability information is essential. Research shows that it is not uncommon for a company to obtain the information on actual field quality and reliability more than six months after product release. This can be too slow to use the information in this or even the next generation of products. Other companies which have a more aggressive way of gaining their information can retrieve the field quality and reliability information in less than six weeks. It is obvious that these companies have a big advantage, when developing the next generation of products [Bro01].

Petkova [Pet03] gives two requirements for the speed of field feedback:

1. The field feedback should be fast enough to be of use for necessary improvements in current generation of products.
2. In relation with the product road map, the field feedback should be fast enough to contribute to the prevention of recurrence of problems in new generations of products.

2.6 Field feedback loops

2.6.1 Introduction

As described before manufacturers have to deal with products entering the market with unknown reliability. To prevent the same problem from happening again in new products or new product generations it is important to detect and analyse the problems as experienced by the customer as soon as possible. First it has to be detected why the product did not do what the customer expected it to do. The reasons may be [Pet03]:

- The product was not designed to do what the customer expected, but the customer was not aware of this.
- The product was not compatible with the system in which it was used.
- The product was just not good enough; in reliability terminology: the load exceeded the capacity. The root cause may be in the design, in production, in the supplier, or in the material.

Because the output of the Business Creation Process (BCP) could not be predicted, collecting customer experience with the product and sending back this information to the PCP was found necessary. If the information is not of the right quality and send in time to right persons the BCP will become unstable and not predictable. This is considered to be an open loop process [Bro2].

In this section first the problem with open loop processes is discussed. Then some general approaches to control unstable (open loop) processes are discussed. Finally the importance of closing the field feedback loop is presented.

2.6.2 The open loop flaw

Benner [Ben83] gives the following practical example of the problems with open loop processes. “How would you like to compete in a bowling match where a curtain quickly drops down just in front of the foul line after you deliver your ball down the alley? You never know whether you scored a strike with the first ball, or whether you missed the pins completely. If you don’t find out how you score, what’s the sense of starting the ball rolling? That’s not the kind of game most of us would like to play. We much prefer a game in which we can follow our scores with each roll.” Could you possibly improve your game without knowing the scores? The answer is NO! This problem is referred to as the open loop flaw [Ben83]. In the system theory, a feedback loop is conceived as the information flow from the system output back to the system [Ben83]. This “feedback” is used to change the operation of the system, to correct undesired output. A completed feedback loop is often termed a “closed loop”. The article describes that many times the loop is closed too soon and can not be called a completed feedback or closed loop. For example, if prototype tests were successful the loop is closed and the product is released. Unfortunately this is no guarantee that the product will also react the same way in the field. So even if the prototype tests are successful it is necessary to look in to the actual behaviour of the product in the field and to feed back this information to the BCP [Ben83].

Benner [Ben83] has set up a number of questions to analyse if a system has an open loop flaw. The answers to the questions determine how the system reacts on unexpected events. For example, when was the last time the system was upgraded due to a failure report. Later in this report I will describe a more structured method to analyse the capability of a process to react on unexpected events.

2.6.3 How to close the loop

2.6.3.1 Introduction

The outcome of the open loop processes described in previous sections (with constant changes in technology, customer demands, field situations, etc) can not be predicted and will never be stable. In unstable processes important aspects like time, costs and quality are not always under control. In the next sub sections the following general approaches towards unstable processes are discussed [Bro2].

1. Inspection of the output
2. Local feed forward
3. Local feedback
4. Global optimisation

2.6.3.2 Inspection of the output

To check the actual output of a process with the planned output is called inspection of the output. Products that do not meet the planned specifications will be rejected (figure 8). Inspection of the output does not contribute to stabilising the process, but it generates information about the capability of the process and information for the next process.

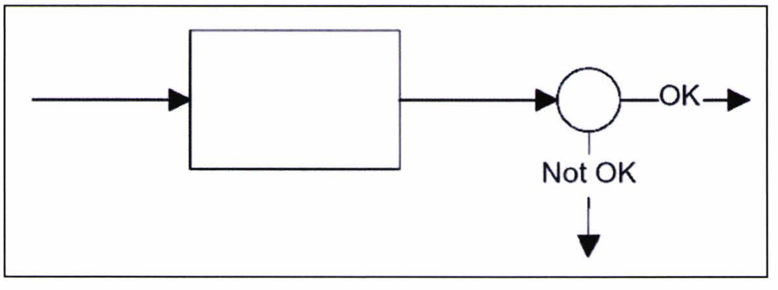


Figure 8. Inspection of the output

2.6.3.3 Local feed-forward

There are two possible local feed forward actions. The first is to adapt the subsequent process (improving the process capability, figure 9) and the second one is to adjust the parameters of the subsequent process (adjusting parameters / shifting targets figure10). In both situations the subsequent process is forced to deal with the output of the previous process. Both actions will not make the process more stable.

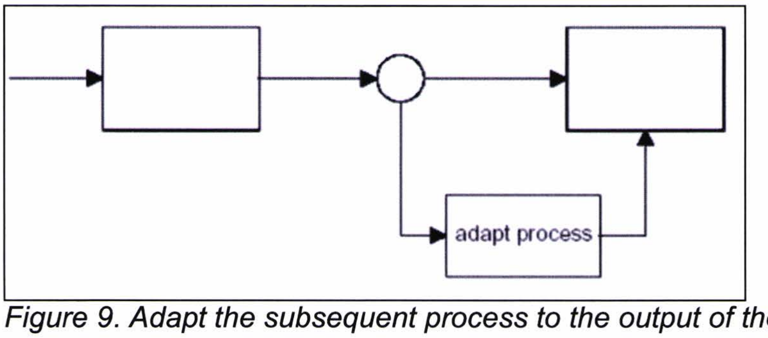


Figure 9. Adapt the subsequent process to the output of the previous process

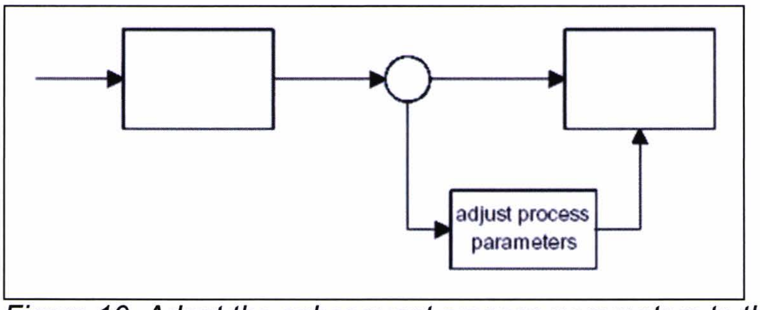


Figure 10. Adapt the subsequent process parameters to the output of the previous process

2.6.3.4 Local feed-back

In the case of local feed-back the output from the subsequent process is used to adapt the previous process or to adapt the input of the previous process (figure 11) or the parameters of the previous process (figure 12). From the literature about control theory one can learn that unstable processes require feedback. By verifying the outputs, feedback and adjusting the process inputs a process can be controlled and become stable.

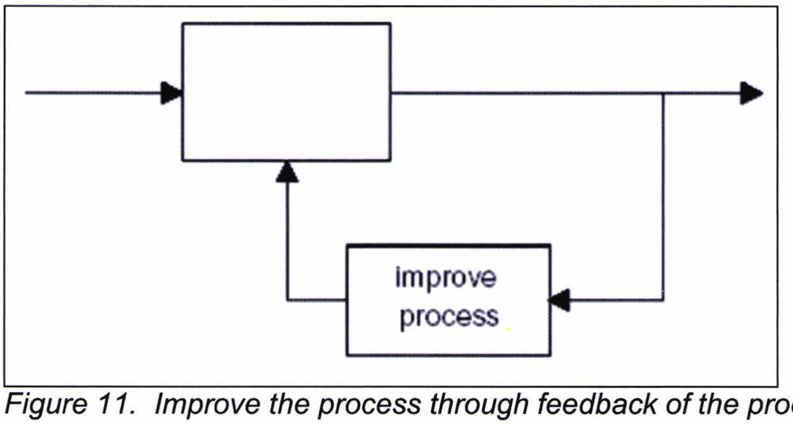


Figure 11. Improve the process through feedback of the process output

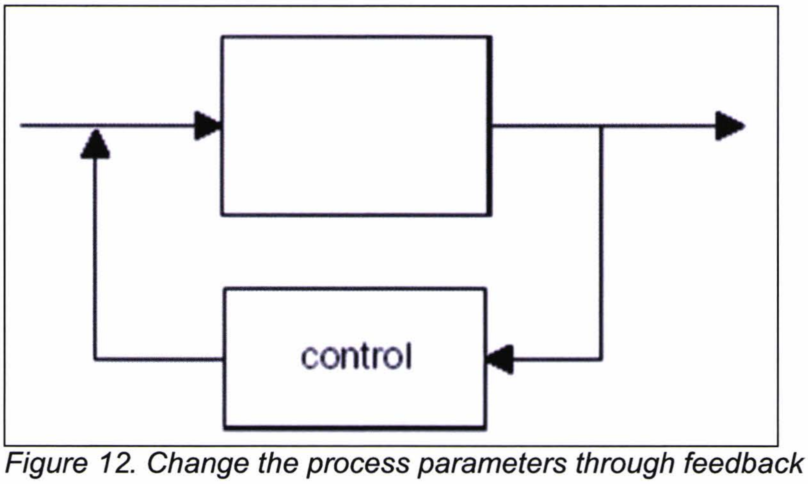


Figure 12. Change the process parameters through feedback of the process output

2.6.3.5 Global optimisation

Global optimisation can be reached by anticipating in the current process to the subsequent process and verifying the results (figure 13). To make global optimisation possible the subsequent process must be known very well. Also models of the subsequent process must be available. To keep these models up to date it is necessary to also measure the output of the subsequent process. An example of global optimisation anticipate in the development process to the requirements and constraints of the production process.

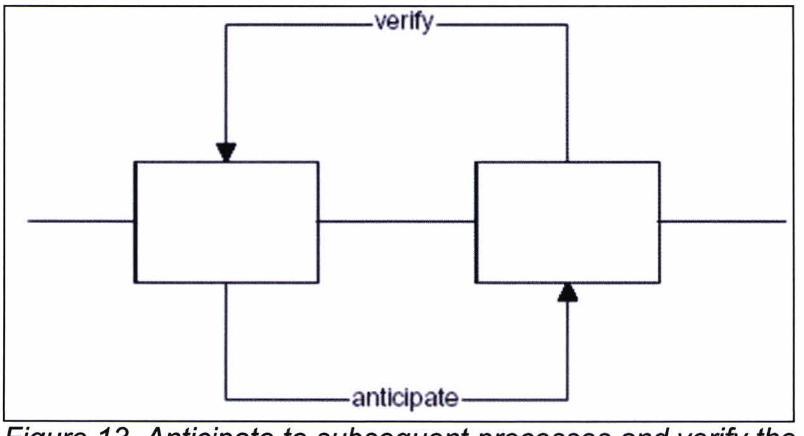


Figure 13. Anticipate to subsequent processes and verify the results: global optimisation

2.6.3.6 Closing the loop – field: field feedback

In the previous section some general approaches from the control theory were described to close the loop. In this section a description of closing the loop in the field quality and reliability process and the importance of closing the loop in the field quality and reliability process are described.

Quality expert Dr. Deming [Lat95] gives a practical example of the disadvantage of an open loop process by giving the well-known statement by Henry Ford 'You can have any colour car you want as long as it is black'. Due to this attitude there was no feedback loop from the customer to the manufacturer, and soon Ford lost many customers to competitors that offered choice. Deming presented the closed loop principle by using the so-called Shewhart cycle, later named Deming cycle. In figure 14 the Deming cycle is displayed.

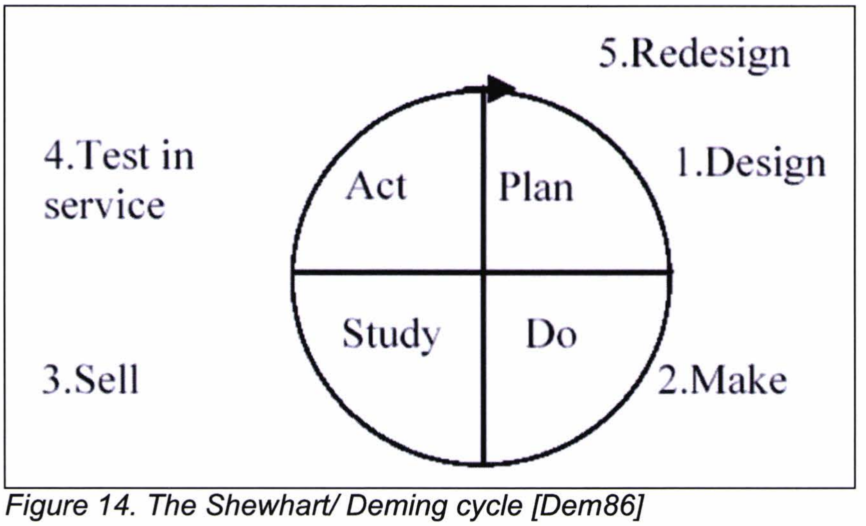


Figure 14. The Shewhart/ Deming cycle [Dem86]

The open loop in the field quality and reliability process can be closed by collecting field quality information from the customers. This is the most logical way to find out what is wrong with the product. The reasons for collecting field quality information are [Pet03]:

- It is the only way to find out whether the product does what it should do according to the end user.
- A product is designed for a particular function in well-specified circumstances. As the end user expects a particular function and decides himself about the circumstances in which he will use the product, the designer should be informed about what actually happens in the field•
- Tests are done under well-controlled laboratory conditions; it is not always clear that these laboratory conditions actually reflect the field conditions.
- Even if a product seems to be perfect at final inspection before it leaves the factory, it is not sure that it is still perfect when it arrives at the final customer (after transportation).

The field information that is collected should be targeted at clarifying [Pet03]:

- Whether it is necessary to take the product off the market immediately (e.g. for safety or reliability reasons).
- Whether the reliability is in line with the target, and if not, what has to be changed (root cause) and when.
- What customers expect of the product (e.g. design, functionality, interaction with other products, etc.).
- What the next generation should offer the end user.

All this is enough proof of the statement that manufacturers of high volume consumer products should have a field failure reporting structure.

2.7 Conclusion

There are four trends dominating the high volume consumer market.

1. Influx of new technology
2. Reduction of time to market
3. Customer attitude towards reliability has changed
4. Primary business processes have changed

These trends cause a conflict in the main four business drivers (section 2.3). Customers expect state of the art functionality and product quality is taken for granted. Also the high innovation speed and price erosion put a high pressure on the TTM. This means that the manufacturer must develop products with state of the art functionality, high quality and low costs, within the minimum amount of time. This leads to two kind of risks: Technical risks and market risks. Unfortunately a decrease of one of the risks leads to a increase of the other.

But how can manufacturers deal with these technical and market uncertainties? It seems that at the moment they can't. In section 2.4.1 we can see that the number of complaints on new products went down for years. At the moment the number of complaints is increasing again. Several methods to control product reliability were discussed and it was concluded that none of these methods are able to deal with the uncertainties described above.

Preventing all quality and reliability problems with quality systems is not possible in these markets. Also testing the product reliability before market introduction is not possible. There is such a high pressure on the time to market that there is not sufficient time to perform tests. If tests are done it is still very difficult to develop tests for all product problems, all field situations and all customer actions. Finally the current test methods are mainly focussed on finding component related failures.

Because it is no longer possible to prevent, predict or test all product reliability problems with the current methods manufacturers have to deal products entering the market with an unknown reliability level, and it should be expected that a number of products will be returned which are according to specification and No Fault can be Found (the NFF problem).

Reasons for the NFF problem are:
- Product does not meet customer expectations (non technical failure)
- Products are becoming more and more complex. It is possible that a product fails but the failure can not be detected by the tests performed by the service centre.
- Products have more and more interconnectivity. It can occur that two products function perfectly separately, but when connected together one or both products fail.
- Products are sold all over the world. It can occur that a product only fails in some field situations. And when the product is tested under other conditions the product works fine.
- Finally it is not possible to predict all customer actions. It can occur that a customer uses the product in such a way the product fails. But this failure can not be repeated by the service centre which analyses the returned product.
- Fault can not be found due to intermittent component problems
- A good part is replaced due to wrong diagnose of the field engineer

To solve these problems manufacturers must use feedback information from the field. This means that manufacturers must focus on learning as fast as possible from the problems that occur in the field. Field failures must be analysed, root causes must be found and recurrence of this failures must be prevented. Field failure information must be at the right place, at the right time and must have the right quality. Besides these demands for field quality and reliability information it is of great importance to realise continuous improvement that there are closed field feedback loops. If the field feedback loops are not closed the process becomes unstable and no improvement is possible.

2.8 Research questions

Due to the trends described before manufacturers of highly innovative, high volume consumer products, have to deal with products entering the market with unknown field quality and reliability. To control the product reliability manufacturers must learn as fast as possible from field reliability problems. Hence, fast and high quality field feedback loops are necessary. Although Kinetron develops and produces highly innovative products, Kinetron is a business to business supplier and does not supply consumer products. If the trends and conclusions till this far a valid will be investigated in chapter 4. Now the research questions for the Kinetron problem can be formulated:

1. Are the field quality and reliability information flows at Kinetron sufficient for root cause analysis and improvement of all the field returns?
2. If no, do the shortcomings in the field quality and reliability flows explain the number of NFF in the field returns?
3. How can the field quality information flows be improved so root cause analysis and reduction of the NFF field returns becomes possible?

2.9 Solution path

To answer the questions from the previous section the following solution path will be followed: The field quality and reliability information flows at Kinetron will be analysed and a quality information flow model will be made. If the field quality information flows are insufficient a proposal for improvements will be made.

Before the field quality and reliability information flows can be analysed literature about how to analyse field quality and reliability information flows will be discussed in chapter 3.

3. Methodology

3.1 Introduction

In the previous chapter is discussed that due to the trends, products enter the market with an unknown field quality and reliability performance. Preventing, predicting and testing product quality and reliability is not possible with the current quality and reliability methods. This means that manufacturers must accept that the products enter the market with an unknown field quality and reliability performance and that these manufacturers must focus on learning as fast as possible from the problems in the field. Hence, fast field quality and reliability feedback is necessary. The field information must be at the right place, at the right time and of the right quality.

As described above it is important to learn as fast as possible from field reliability problems. In section 3.2 the requirements for quality and reliability field information to learn from unexpected events (e.g. field quality and reliability problems) are discussed. In section 3.3 the requirements for a process to learn from unexpected events are discussed. In section 3.4 the criteria for the methodology are described. In section 3.5 the Maturity Index on Reliability is presented. At the end of this chapter a conclusion and a more detailed solution path is given.

3.2 Information requirements

To be able to learn from field reliability information the following characteristics are important [Bro4]:

- Speed; What is the time a company needs to detect a new unexpected field quality problem.
- Quality; What is the quality of this information that can be retrieved from this event.
- Deployment; How efficient is the deployment of this information to the relevant actors in the BCP.

The characteristics mentioned above were already discussed in more detail in section 2.5. Summarising can be said: "The field quality and reliability information must be of the right quality, at the right place and at the right time".

3.3 Process requirements

Besides the requirements for the field quality and reliability information there are also several requirements for the process. In order to be able to react and learn from undesirable deviations in a process the following four steps must be performed [San00]:

1. Measuring is the first step to make reaction possible. If the output of a process is not measured it is not likely that any corrective or preventive action will take place. Based on the simple fact that if there are no measurements it is hard to tell what the real problems are.
2. If a process is measured it is very important to communicate the results of these measurements to the relevant actors (see previous sections). So communication is the second step.
3. When the right information is at the right place it is still important that the information is analysed and root-causes are investigated. Now corrective actions can be implemented.
4. Although everything is done to correct the unexpected event, this process can still be categorised as "unintelligent". The problem is corrected, but no preventive measures are taken and the problem is likely to happen again. If preventive measures are taken the process is able to learn. The process or parts of the process is adapted to prevent that problems repeat themselves. This is what we call adaptation: the fourth step.

If a process meets all four steps it highly likely that the field feedback loop is closed and that continuous improvement is possible (see section 2.6).

3.4 Criteria for the problem methodology

Summarising the previous sections: the methodology which will be used to answer the research questions described at the end of chapter two must be able to analyse:
- The speed of field quality and reliability information flows;
- The quality of field quality and reliability information flows;
- The deployment of field quality and reliability information flows;
- The reaction of the field quality and reliability process on unexpected events like field quality and reliability problems;
- Open loops in field quality and reliability information flows;

3.5 The MIR concept

In this section the Maturity Index on Reliability (MIR) concept is presented. The MIR concept meets the criteria to analyse the points mentioned in section 3.3 and will be used to answer the research questions mentioned in chapter 2. The Maturity Index on Reliability (MIR) concept uses the four steps in section 3.2 as a basis. With the MIR concept the reaction of processes on internal or external disturbances can be analysed. Also the related information flow through the process can be analysed. The MIR model assumes that an organisation can only act "intelligent" on disturbances as all four steps described above performed [San00]. This results in the following five levels of capability to analyse and control problems [San00].

Level 0: No information available
The manufacturer has no relevant quantitative evidence of the process output (e.g. number of field returns) of the products. Further there are no control loops back to production and development.

Level 1: How many problems?
The manufacturer has quantitative evidence of the process output in terms number of failures in the field. This information is fed-back into the process, but the origin of the problems/deviations is unknown.

Level 2: Where do they originate?
The manufacturer has quantitative evidence of the process output, knows the origin of the problems (such as design, production, material or customer use), has the corresponding control loops, but does not know what actually causes the problems.

Level 3: What is the root cause?
The manufacturer has quantitative evidence of the field behaviour, knows the origin of the problems and knows what actually causes them, and has the corresponding control loops and is able to solve problems. The manufacturer is, however, not able to prevent similar events from happening in the future again.

Level 4: What can be done to prevent reoccurrence?
The manufacturer has quantitative evidence of the field behaviour, knows the origin of the problems, and knows what actually causes them and what to do about it. The level of knowledge is such that the manufacturer not only knows root causes of problems (technical and organisational) but is also able to anticipate and prevent similar problems in the future. All corresponding control loops are in function.

These five levels will be called the Maturity Index on Reliability, in short MIR. The MIR principle is visualised in figure 15.

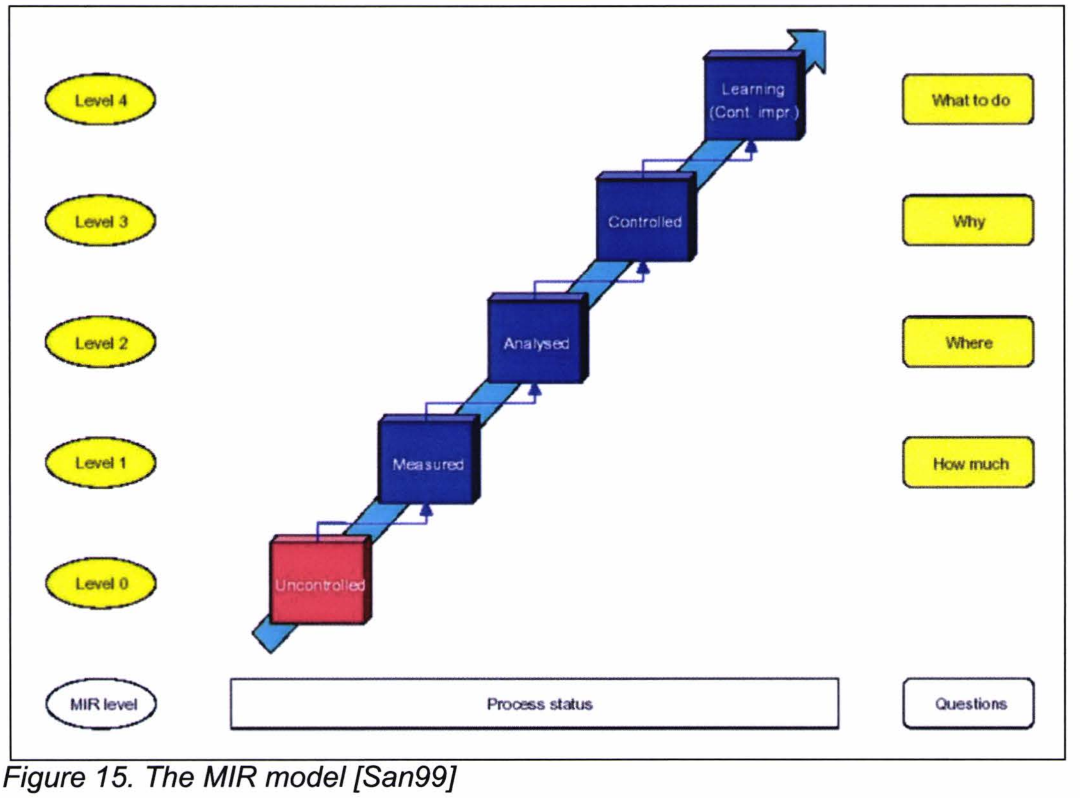


Figure 15. The MIR model [San99]

3.6 Conclusions MIR

Research in over 15 assessments in more than 8 business units or companies showed the following conclusions [San99]:

- Due to the big distances in time and place between development and service only few people have an idea of their role as actor in an information flow.
- Many attempts are done to speed up the upstream processes, e.g. concurrent engineering. Unfortunately when solving problems many companies still use classical, functional, structures. Problems are detected and resolved downstream, but little is done to prevent similar problems in the future (upstream).
- The predictive capabilities in the upstream process is very low due to the lack of relevant information about actual problems. 'Inventing' data on hearsay basis often compensates lack of relevant and valid in-process data.
- Many companies use a large number of tools to achieve product quality without considering the role of these tools in their essential processes.
- The MIR concept has proven to be a useful means to visualise, analyse and improve the role of information loops in essential business processes.

Other field experience in over 15 business units and companies in different parts of the world show that MIR assessment is a good first step to improve reliability. According to these studies a MIR assessment makes the following points clear [San00]:

- whether process output is measured,
- whether measurements are analysed and corrective actions implemented,
- whether there are any barriers between departments,
- whether departments get the right information from their suppliers (internal and external),
- whether the suppliers use that information,
- whether departments give the right information to their customers (internal and external),
- whether the customers use that information,
- whether information loops are closed,
- whether the organisation is learning from the past,
- and if not, what to do about it,
- what the time span is between improvement actions in a part of the PCP and the moment the results become visible in the field.

If these conclusions are reflected on the methodology criteria from section 3.4 it can be concluded that the MIR method seems an excellent method to analyse and improve the field quality and reliability process and the field quality and reliability information flows through this process at Kinetron BV.

3.7 Detailed solution path

An assessment of the company on a MIR scale uses the following steps [San99]:

- First all activities with relation to the field quality and reliability process are mapped in a activity model.
- The communication between activities is mapped and cross-checked. This can be done with interviews; off-process activities are removed and the resulting information flows and information loops are identified.
- Via documentation in actual events in actual projects the MIR level of the resulting information flows is determined.
- Priorities for improvements are the major bottlenecks determining the current MIR level.

4. Description of the situation at Kinetron

4.1 Introduction

To establish a possible relation between NFF and the Kinetron company structure first the relation between the earlier mentioned trends and Kinetron must be established. After that a model will be developed to analyse the relation between the quality and reliability information infrastructure at Kinetron and the possible occurrence of NFF.

In section 4.2 to 4.5 the trends are compared with the situation at Kinetron. In section 4.6 the effect of the trends on Kinetron business drivers is discussed. In section 4.7 the effect of the trends on Kinetron product quality and reliability is discussed. In the conclusions, at the end of chapter 4 it is analysed if the trends are present, if they affect Kinetron and if there is a need for fast, high quality field feedback.

4.2 Influx of new technology, functionality and complexity

As described in chapter 1 Kinetron is an innovative high technological organisation. The many patents of Kinetron indicate that Kinetron is an innovative company in an innovative market. Also the products developed, manufactured and assembled by Kinetron can be categorised in the category high tech and highly innovative products for the mass market. As mentioned in chapter 2 this is the category which is influenced most by the trends.

The WTG is one of these innovative products developed by Kinetron. The technology used in the WTG is a totally new technology and is patented "Customer Company A". The WTG is also a complex product with increasing functionalities.

The functionality of the WTG has increased since 2000 several times.

1. The WTG is only used to ignite the gas water heater.
2. The WTG is used to indicate if water flow is present (flow switch).
3. At the moment Kinetron is working on a WTG with built in flow measurement.

The WTG also has interconnectivity with other parts, e.g. the electronic box in the gas water heater. The WTG has to work with several different electronic boxes, which in the past has led to problems.

Also the gas water heater technology and functionalities are changing. A gas water heater in the past was equipped with a piëzo ignition, then with batteries and finally with the WTG. Also the technology to adjust the burner has moved from a steady flame to a complete electrical regulated water flow dependent burner. Also the gas water heater has more and more functionalities. Temperatures and water flows can be changed and a gas water heater with a display indicating the temperature and several other settings is the newest functionality.

All aspects related to the influx of new technology are present at Kinetron, the products are innovative, complex, have more interconnectivity and more and more functionality. Although all these aspects are present the remark must be made that the influx of new technology is less than in the high volume consumer electronics industry. New technologies and functionalities are added in a slower speed.

4.3 Pressure on Time to market

As discussed in the previous section all aspects of the influx of new technology are present at Kinetron, but the speed of introducing new technologies and new functionalities is lower than described in chapter 2. But when new technologies or new functionalities are developed there is a high pressure on time to market, to be on the market before any competitor. Another reason why there is a high pressure on time to market is the high pressure on decreasing the costs and increasing product quality and reliability of current products as fast as possible. If a new product is introduced and no new functions are added it is expected that the price of this product decreases every year and that the quality and reliability of the product is better every year.

The WTG has been redesigned several times to decrease price and increase quality. At the moment the second generation of the WTG is being developed (WTGII). The main reason for this is price decrease and quality improvements. Due to the promised price decrease and improved quality and reliability there is very high pressure on the time to market. "Customer Company A" wants to introduce this new WTG as soon as possible.

Kinetron develops the WTGII for "Customer Company A" and is there fore part of the "Customer Company A" development process. In figure 16 the development process for a new product is shown. The high pressure on time to market is also visible in this figure. First the title is "Time to Market – Process" which emphasis the pressure on time. Also this development process is a concurrent engineering process which is often used when there is a lot pressure on time [Pet03]. New activities start before the previous activity is finished. As can be seen there are already prototypes (A,B,C-samples) made and tested before the product development is finished.

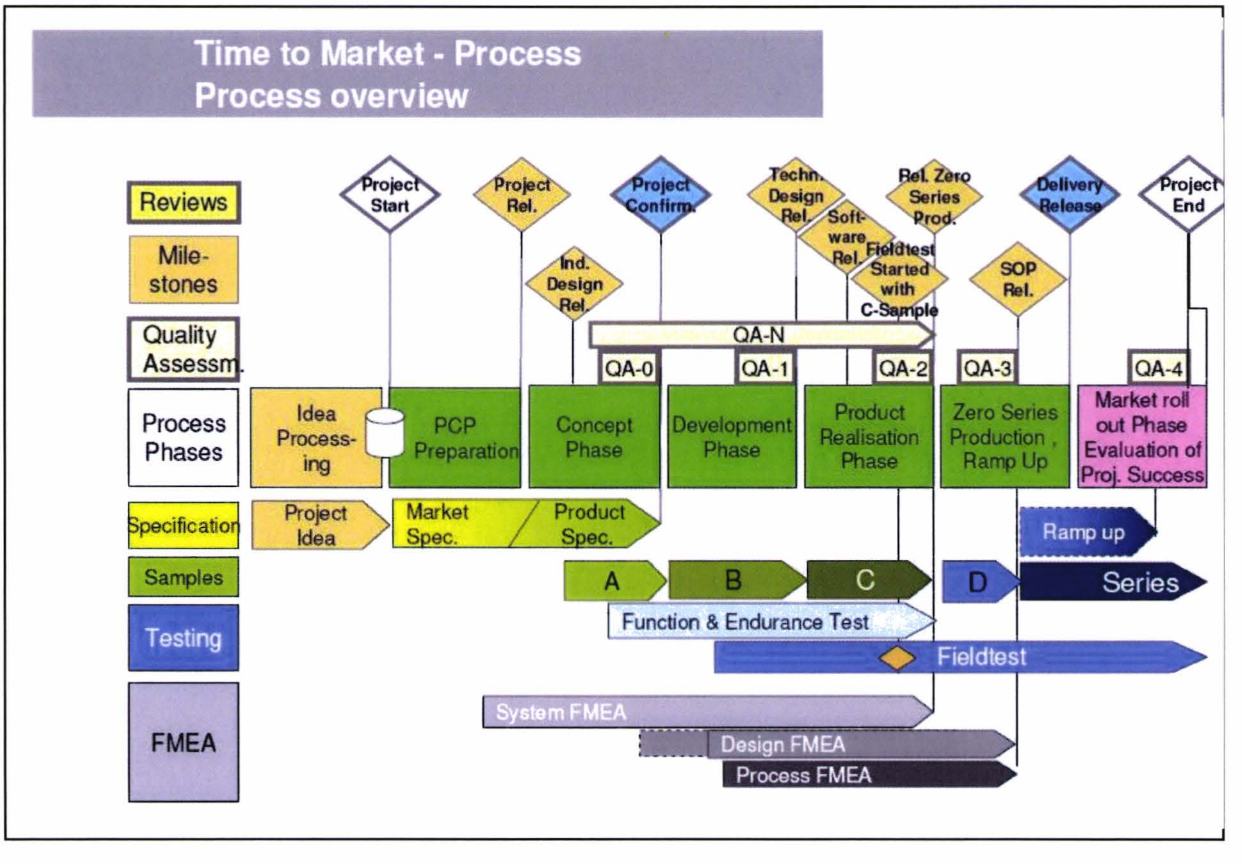


Figure 16. Time to market process

4.4 Kinetron customers and pressure on quality

Kinetron supplies the WTG to "Customer Company A". "Customer Company A" supplies the gas water heater to the end user. Both, "Customer Company A" and the end user must be kept satisfied, hence Kinetron has two customers: "Customer Company A" and the end user.

As mentioned in the previous section there is a high pressure on product quality and reliability. The end users are not able anymore to understand all technologies behind the cover of the gas water heater and there fore does not accept the gas water heater to fail. Besides this it is very inconvenient if the gas water heater fails and there is no warm water. If the gas water heater fails this can lead to an unhappy customer and loss of clients to the competitor.

Another very important reason for the pressure on product quality and reliability is the safety of the end user and their properties. A malfunctioning gas water heater can cause severe water damage or other risks. These problems can lead to high claims from customers and high costs for "Customer Company A". Also the gas water heater is delivered with a warrantee period of two or three years on parts and labour. All quality and reliability problems within this term lead to extra costs for "Customer Company A". The WTG is delivered with 3 years warrantee on not functioning according to specifications.

4.5 Kinetron business creation process and globalisation and segmentation

To analyse the segmentation of the Kinetron business process due to globalisation and outsourcing first the supply chain (figure 17) is analysed. Suppliers from all over the world supply parts to Kinetron in the Netherlands. Kinetron produces several extra parts and assembles the WTG. The WTG is delivered to "Customer Company A" who assembles the WTG and other parts from suppliers all over the world in their gas water heaters. The gas water heaters are delivered to distributors (worldwide) who sell the gas water heaters to the field engineers. The field engineers sell and install the gas water heater to the consumer.

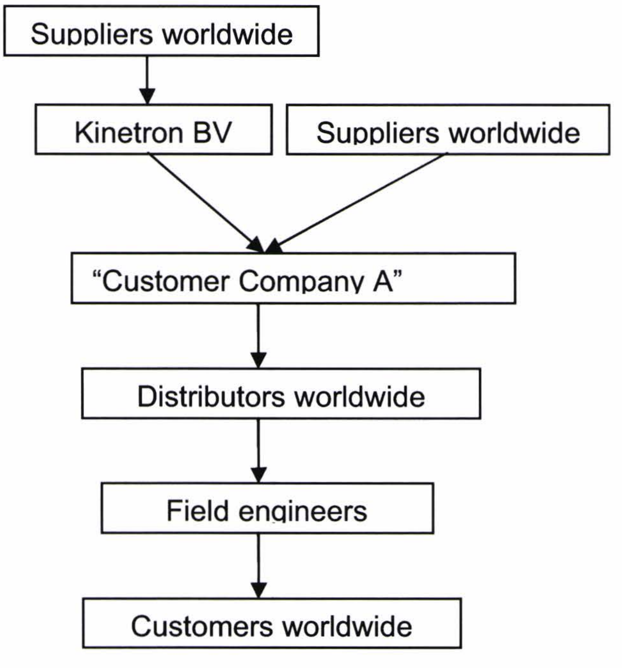


Figure 17. Gas water heater supply chain

When a new gas water heater is developed and produced “Customer Company A” sets up the specifications for all parts of the new gas water heater and discusses these specifications with the suppliers of the parts. Each supplier is responsible for his own knowledge and professionalism and each supplier develops (in cooperation with “Customer Company A”) and produces their own product. This shows that “Customer Company A” doesn't develop and produce all parts them selves, but much development and production is outsourced. Also the suppliers of “Customer Company A”, this includes Kinetron, outsource certain parts of their development and production. Kinetron for example outsources strength calculations of plastic parts and the theoretical design of the turbine shapes. The core design activities, like generator design and system design, are done by Kinetron. Kinetron also buys most of their parts externally, only the generator, which is Kinetron's core business is manufactured in house. Also the suppliers of Kinetron outsource several design and production activities. For example the plastic part supplier outsources the development and production of the tools which are needed to manufacture the plastic parts.

It can be concluded that the supply chain of the WTG is strongly affected by globalisation. Manufactures and customers are situated all over the world. Also can be concluded that suppliers focus on their core business and that outsourcing, in development and in production, is often done. This leads to a highly segmented business creation process.

Besides the fact that the business creation process is segmented, the Kinetron customers (end users) are segmented too. Kinetron customers (end users) are located all over the world, have different demands and live in all kinds of different situations.

4.6 Effects of trends on business drivers

With the information described in section 4.2 till 4.5 the influences of the trends on the business drivers of Kinetron can be discussed. The four business drivers as discussed in chapter 2 are [San00]:

1. Functionality: is the product able to fulfil its intended function.
2. Time: does the product reach the market at the required moment.
3. Quality / reliability: Does the product fulfil customer requirements at ‘all' customers, not only at the moment of purchasing but also during operational life of the product.
4. Profitability: Is the difference between product cost and sales price adequate.

The functionality of the WTG and the gas water heater is increasing. This leads to an increasing product complexity and increasing interconnectivity. At the same time, to avoid claims and to satisfy customers, product quality and reliability is very important. Connected with this are the 2 and 3 year warrantee periods. Kinetron and “Customer Company A” must have an excellent knowledge about the quality and reliability of their products, else warrantee claims may be much higher than expected.
The innovation speed at the gas water market is lower than the innovation speed in the high volume consumer electronics market, but innovation is present. Due to price erosion the WTG and gas water heater must decrease in price an increase in quality and reliability every year. This leads to a high pressure on time to market, not only with new products, but also with modifications on current products which must become cheaper and better as soon as possible.

Both situations described above lead to the following conflicting situation. Kinetron and “Customer Company A” must develop and manufacture complex products with more functionalities and more interconnectivity, higher quality and reliability in a shorter time and for lower costs. If development time and product costs are reduced it is likely that quality and reliability problems increase.

4.7 Effects of trends on Quality and Reliability

Kinetron and "Customer Company A" do a lot to prevent quality and reliability problems:

- Both companies are ISO9001 certified
- Prototypes are made and tested (A, B, C and D samples, see figure 18)
- A field test is performed with prototypes (see figure 16)
- FMEA is performed during development (see figure 16)

Unfortunately the quality systems, tools and tests are not sufficient to prevent all quality and reliability problems (see chapter 2). Figure 18 shows the results of Kinetron's latest investigation to field quality and reliability problems. A major cause of returned products lies within the category No Fault Found. In almost 50% of all returned products, No Fault Could be Found.

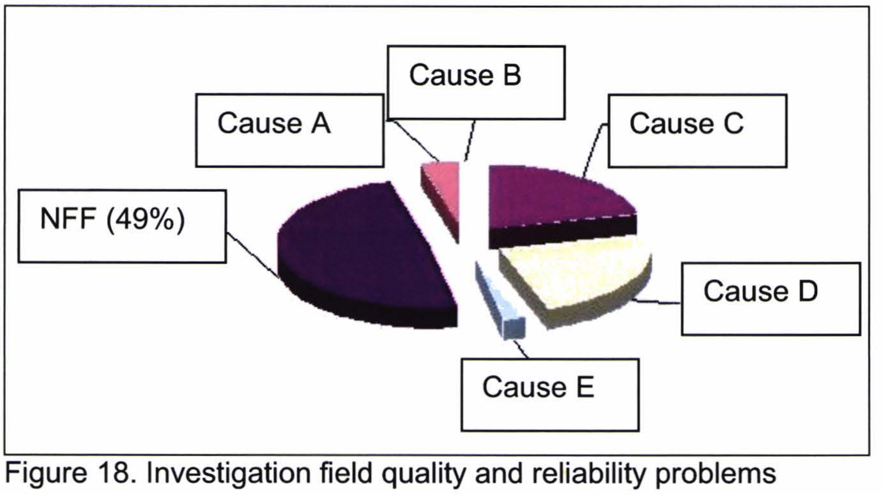


Figure 18. Investigation field quality and reliability problems

Reasons for these NFF could be (chapter 2):

- Product does not meet customer expectations (non technical failure)
- Products are becoming more and more complex. It is possible that a product fails but the failure can not be detected by the tests performed by the service centre.
- Products have more and more interconnectivity. It can occur that two products function perfectly separately, but when connected together one or both products fail.
- Products are sold all over the world. It can occur that a product only fails in some field situations. And when the product is tested under other conditions the product works fine.
- Finally it is not possible to predict all customer actions. It can occur that a customer uses the product in such a way the product fails. But this failure can not be repeated by the service centre which analyses the returned product.
- Fault can not be found due to intermittent component problems.
- A good part is replaced due to wrong diagnose of field engineer.

4.8 Conclusion: Need for fast and high quality field feedback

From the information discussed in section 4.1 till 4.7 can be concluded that Kinetron and "Customer Company A" are affected by the trends mentioned in chapter 2. The products are complex, have more interconnectivity and more functionality. A high quality and reliability is expected by the customers. These complex and high quality products must be developed in a minimum amount of time and with the lowest product costs as possible. This leads to a conflicting situation. Reducing development time and product costs can lead to an increase of product quality and reliability problems (technical risks), but increasing the development time and product costs leads to lower sales quantities (marketing risks).

As shown in section 4.7, the current quality systems, methods, tools and tests it is not possible for Kinetron and "Customer Company A" to prevent or test all product reliability problems. This means Kinetron and "Customer Company A" will have to deal with products entering the market with an unknown reliability level, and it should be expected that a number of products will be returned as they are not fulfilling customer's expectations, although technically these products are according to specifications or the problem is hard to repeat (NFF problem).

Kinetron and "Customer Company A" have to focus on learning as fast as possible from the problems that occur in the field. To control product reliability Kinetron and "Customer Company A" can get help from the customers that use their product. They must use field failure information to improve product quality and reliability. Field failures must be analysed, root causes must be found and recurrence of this failures must be prevented. As discussed in chapter 2 field feedback information must be at the right place, of the right quality and at the right time. To realise continues improvement it is important that that there are closed field feedback loops.

In the next chapter a model will be developed to analyse the relationship between the quality and reliability information infrastructure at Kinetron and the possible occurrence of NFF.

5. Field quality and reliability information flows at Kinetron

5.1 Introduction

In the previous chapter is shown that the trends mentioned in chapter 2 are present at Kinetron. Also the need for fast and high quality field feedback is established. In this chapter a model will be developed to analyse the relation between the quality and reliability information infrastructure at Kinetron and the possible occurrence of NFF.

To develop the model first the field return process is described. From this description a field return process activity model is made. After this, the field return statistics and the reactions of the field return process on disturbances are described. Both sections (statistics and reactions) will be used later to determine the information flows and the MIR levels of these information flows. This information will be used to make separate information flow models for three groups of field reliability problems. At the end of this chapter the complete field information flow model is analysed and a conclusion is given.

5.2 Field return process Kinetron BV

The Turbine Generator is manufactured by Kinetron and delivered to “Customer Company A”. “Customer Company A” assembles the Turbine Generator in the Gas Water Heater and supplies it to distributors all over the world. The distributors deliver the Gas Water Heater to a field engineer, who installs it in the home of the end user / field user. If the end user has a complaint about the Gas Water Heater the defective product and all available information has to travel back in the opposite direction. On the next page the field return process is described step by step.

Because of the limited time and resources it was not possible to visit: “Customer Company A” in the south of Europe, the distributors all over the world and the field users which are mainly in South of Europe, South America and Australia. This is why most of the information is retrieved out of documentation, registrations of earlier field problems available at Kinetron and communication with the quality department of “Customer Company A”. Unfortunately I was not able to retrieve all necessary information from field users and distributors. This is why the research border is limited to the field return process and information flows between “Customer Company A”, Kinetron and the suppliers of Kinetron. The field return process from end user to distributor to “Customer Company A” is described as accurate as possible, unfortunately some assumptions must be made in this part.

Step 1: User → Field engineer

User has complaint and calls the field engineer and explains the problem.

Step 2: Field engineer → Distributor

The field engineer visits the user and repairs the gas water heater. The defective parts are replaced and a product return form (appendix A) is filled in. The defective part and the form is sent to the distributor.

Step 3: Distributor → "Customer Company A" quality department

The distributor receives the defective part and the product return form and forwards this information to "Customer Company A".

Step 4: "Customer Company A" quality department → "Customer Company A" production V "Customer Company A" development V suppliers V Kinetron quality department

"Customer Company A" receives the defective part and the product return form from the distributor. "Customer Company A" delivers new spare parts to the distributor and updates the spare parts database. Also the field return statistics are updated. There are statistics about Gas Water Heaters and statistics for parts, e.g. the Turbine Generator. Every few months and in special cases (e.g. a sudden increase or new causes of field returns) "Customer Company A" analyses a batch of returned products and determines the origin and root cause of the returned products. The results are communicated with the "Customer Company A" development department, "Customer Company A" production department and Kinetron quality department. Depending on the origin and root cause of the field complaint (design, production, field conditions or customer use) the product, the product specifications or the production process must be modified to prevent this problem in the future. Because Kinetron has more knowledge about the Hydro Generator also 50% of all returned WTGs is sent to Kinetron for analysis. The parts are sent together with a return document which mentions the type of Turbine Generator, the quantity and the description "Parts rejected by customer".

Step 5: Kinetron quality department → Kinetron production V Kinetron development V suppliers

Kinetron receives 50% of all WTGs from "Customer Company A". These WTGs are analysed by Kinetron. Depending on the origin and root cause, the product specifications or the production process must be modified to prevent this failure in the future. Also Kinetron updates the field returns statistics and makes quality reports.

5.3 Field return process activity model

From the information in section 5.2 the following activity model of the field return process is made.

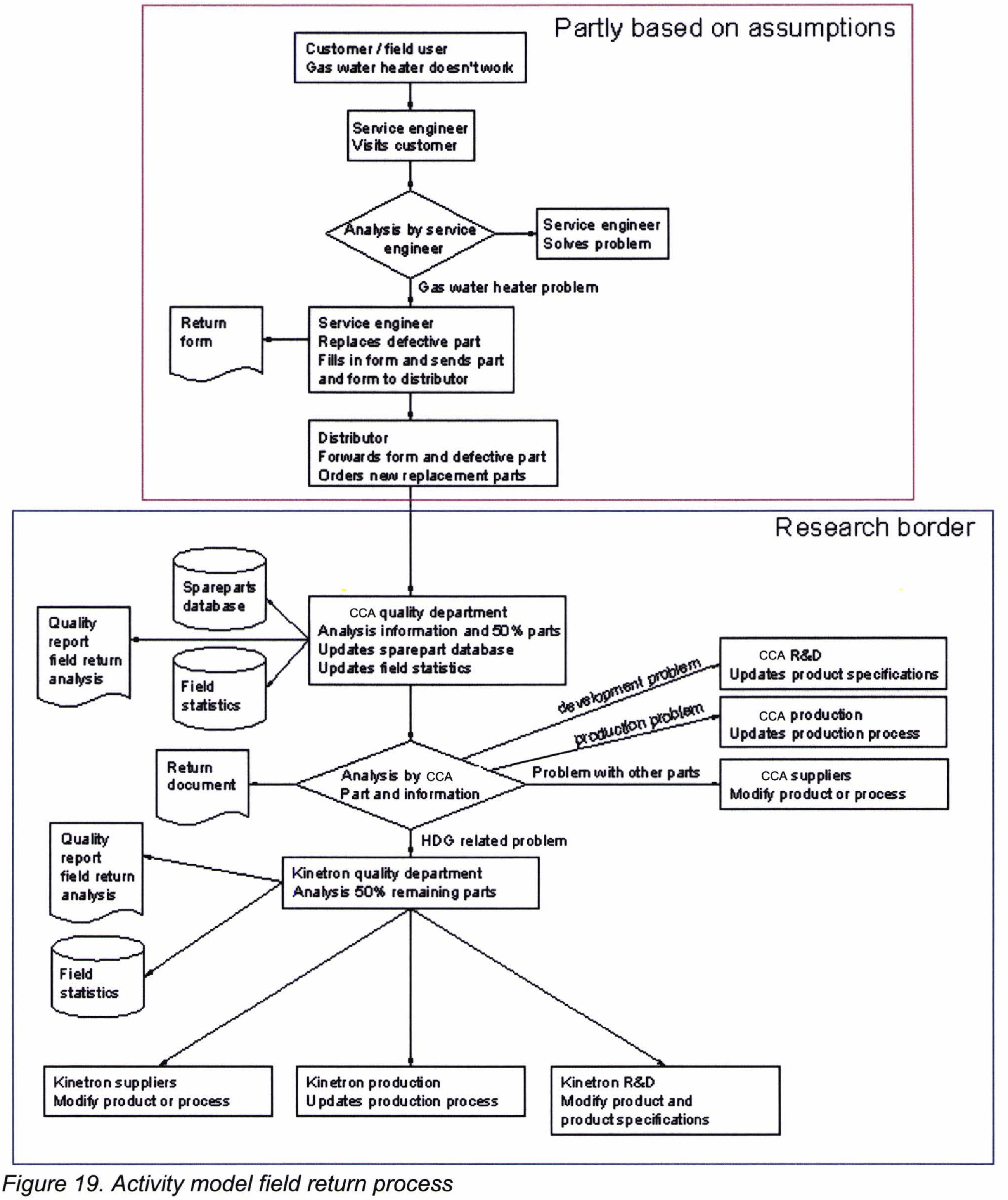


Figure 19. Activity model field return process

5.4 Reactions on disturbances

5.4.1 Introduction

In the previous section the activity model of the field return process is discussed. The activity model presents the ideal situation of the process if all information is at the right place, at the right time and of the right quality. In the real situation this will probably not be the case. In the next sections the real reactions on disturbances (field problems), based on a number of practical examples, is discussed. This information will be used to make field return information flow models for several kinds of field failures.

5.4.2 Reactions field user and distributors

As mentioned in section 5.2 the field user contacts the service engineer and explains the problem. The service engineer visits the field user and analyses the gas water heater. The service engineer replaces the defect parts and fills in a return form (appendix A). Both the defective part and the return form are sent to the distributor. The distributor only forwards the form and the parts to "Customer Company A" and supplies the service engineer with new parts. Now the form and the defective product reach the volcano quality department. What is done from here will be discussed in the next sections.

5.4.3 Field return statistics

Both "Customer Company A" and Kinetron use statistics to monitor the number of field complaints. Each WTG is printed with a production date and a type number, so the products are traceable per product type and per day. Kinetron keeps statistics per type of WTG. Each WTG that is returned from field is analysed and the root cause is added to the statistics of the corresponding product type. The Kinetron statistics focus on the division of the different failure types, not on the number of returned products. Each design modification, or each new generation product, Kinetron tries to solve several field quality problems. In the statistics of a new type WTG can be seen if the modifications have reached the intended goal. In figure 20 and figure 21 the difference between the "WTG type A" and "WTG type B" can be seen. In the "WTG type B" a modification is done to reduce failures with cause 1. This resulted in a decrease of cause 1 problems from 41 till 0%.

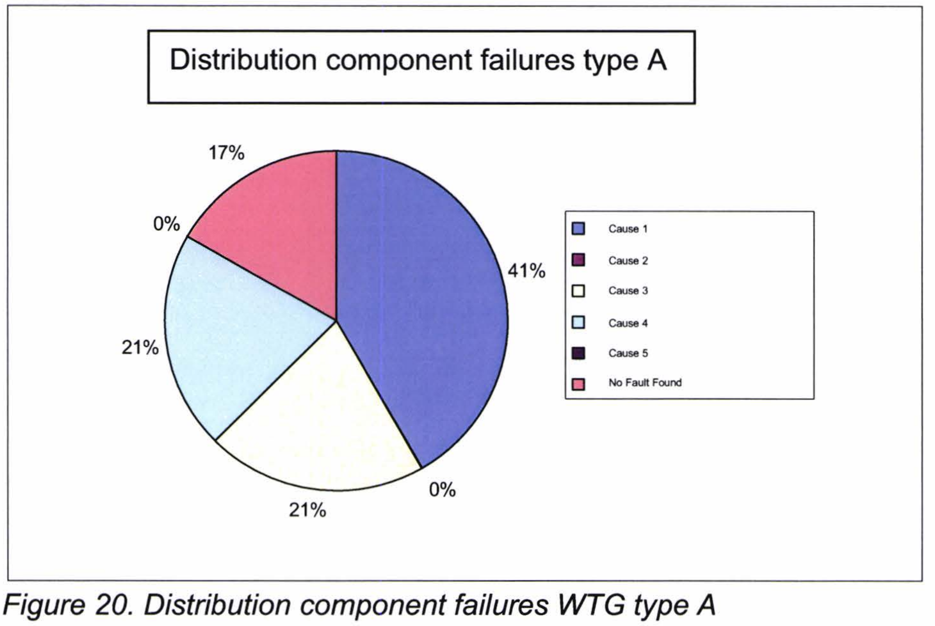


Figure 20. Distribution component failures WTG type A

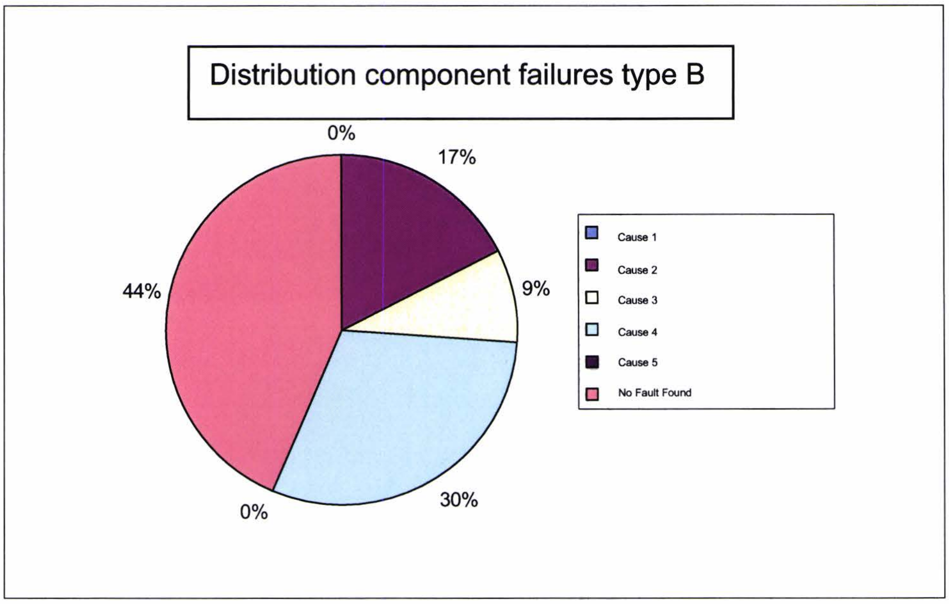


Figure 21. Distribution component failures WTG type B

In the "Customer Company A" statistics the emphasis lies on the number of products returned from the field, within a certain period after production date. The reason for this is to monitor the warrantee costs which are related to the failure of products within the warrantee period. The statistics are made by counting the number of warranty reports made by the field engineers and by counting the returned parts which arrive at "Customer Company A". Not all parts are returned, if a part is returned depends on the quantity, the severity of the failure, the country, etc. The time is determined by the difference between the production date (product stamp) and the field complaint date. In figure 22 the percentages of field problems within 0 till 15 quarters after production date are given.

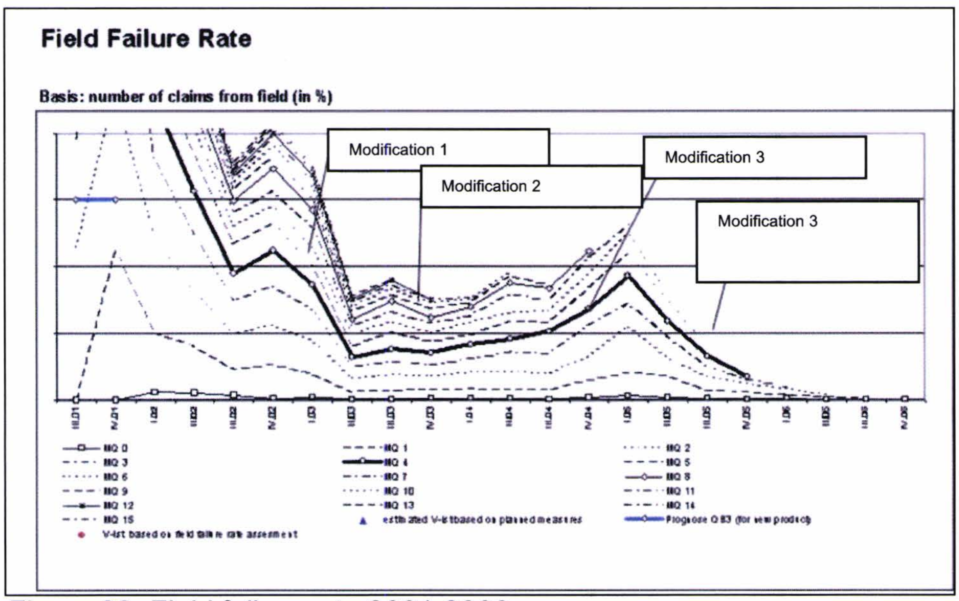


Figure 22. Field failure rate 2001-2006

5.4.4 Reactions on field return investigations "Customer Company A" and Kinetron

Approximately every half year "Customer Company A" analyses a number of returned WTGs and makes a field return quality report (figure 23). Also Kinetron investigates all returned products and makes quality reports per type of WTG (figure 21 section 5.4.3). The purpose of these reports is to identify the main causes of the field problems and to set targets to solve and prevent these problems. In this section the reactions on these field return investigations are discussed.

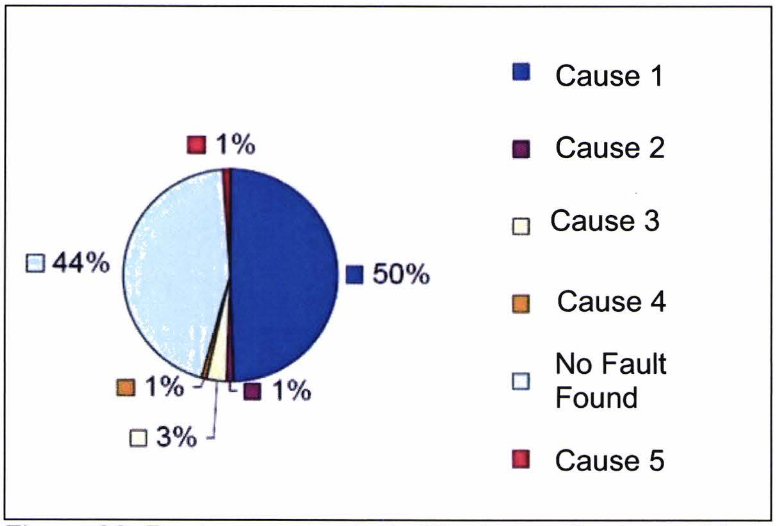


Figure 23. Root cause analysis "Customer Company A"

To investigate the reaction on this field return analysis' a number of problems and the reactions on these problems are investigated. A summary is given in table 1.

Description	Origin	Root cause	Preventive measure
Leakage at high pressure	Field	Pressure specifications too low / wrong market information.	Modified product, updated pressure specifications, build test equipment to simulate field behaviour with high temperatures and higher pressures.
Dirt problems	Field	Dirt resistance was not specified / wrong market information.	Modified position of product in the gas water heater, modified design, add filter, specified dirt resistance and build test equipment to simulate field behaviour with dirt.
Noise in bypass valve	Design	A standard bypass valve was used which was not designed for flow regulation.	Modified bypass valve design.
Rotor stuck on shaft	"Customer Company A" production process	A certain action after the Turbine generator was built in caused the rotor to get stuck on the shaft.	Modified design and production process.
Rust on axle	Material	Material is not corrosion resistant enough.	Selected a higher grade stainless steel and Updated product specification.
No Fault Found	Origin is unknown	Root cause is unknown	No preventive measures are taken since the yr 2000.

Table 1. Selection of field return problems and the reaction on these problems

By studying the reactions on these field return analysis' it became clear that almost no additional field information is used. The only information available is the defective product and the return form. The form only has limited possibilities to really explain the problem the field user experienced, or to explain the result of the analysis the field engineer performed. All information is retrieved from the analysis of the returned parts. If the problems are component related and the origin and root cause can be found by investigating the product, most of the times a good preventive measure is implemented. The preventive measures solved the problem and prevent it from happening again. There were also preventive measures taken which prevent the same problem to happen in new generations of products. More and more component related market and field information is added to the product specifications. These specifications will be used during the development of new generations of WTGs. Also test equipment is built to simulate the extreme field conditions which cause products to fail. All new developed products must pass these tests before the product is released. The process has proven to be very effective on component related problems. None of the solved field return problems from the first generation of WTGs has appeared in the modified versions of the WTG. Also during the development of the second generation WTGs a good estimation for the expected number of field returns could be given.

Unfortunately the NFF problem remains the same in the first and second generation of WTGs. In these investigations only products are investigated and origins and root causes can only be found if the problem is component related. There is not enough information available to find root causes of problems in the NFF category. The result is that not all origins and root causes of the problems can be found and the NFF problem occurs. In the "Customer Company A" investigation from the yr2005 44% of all products have the no fault found problem. In the Kinetron investigation which is continuously updated this is 49%.

It is remarkable to see that the NFF problem could be seen in all field investigations since the yr 2000 and never anything was done to solve this problem. This is mainly due to the fact that people think it is not a real problem, because nothing is wrong with the product. Also the people don't know how to solve the problem and rather focus on the component related problems were the root causes are clear. From the yr 2000 till now a great number of field problems is solved, more is known about the market and the field behaviour of the product. Because most problems are solved the percentage of NFF in the field returns has increased (figure 20 and 21 section 5.4.3) and the problem became more visible. Now people are starting to realise that it is indeed a big problem.

5.4.5 Reactions on sudden increases in field returns or new problems

Besides the normal field return problems, also two other situations are investigated. The first one is a sudden increase of a known field problem. The second one is the occurrence of a new field problem. To investigate the reactions on these situations two important field problems from the past were investigated.

1. Sudden increase of field returns after product introduction in a new country
2. New field problem after product introduction in a new country

In both events the quality department of "Customer Company A" detected the situation and informed Kinetron about the problem. The products were returned to Kinetron for investigation.

In the first case Kinetron was informed by "Customer Company A" that there was a sudden increase of field returns after the product introduction in Poland. The field returns from Poland were separated from other field returns and sent to Kinetron for analysis. Kinetron detected that all WTGs had iron particles on the magnet which blocked the magnet. To solve this problem and to prevent this problem in the future Kinetron developed a filter and reduced the size of the magnet. Kinetron and "Customer Company A" updated the product specifications and described the dirt resistance of the WTG. Kinetron built test equipment to test a WTG on dirt resistance. From then on the WTGs dirt resistance has improved. Even now there are several projects defined to increase the WTGs dirt resistance.

In the second case a new field problem arose after the product introduction in Austria. Again "Customer Company A" detected that there was a new field problem and that this field problem mainly appeared in one country. Several WTGs had broken and severe leakage had occurred in some houses. The defective products were separated and immediately returned to Kinetron. Kinetron had no idea what happened to the products. All products manufactured by Kinetron had passed a 10 second pressure test at 15 bars and during the design of the product, the product could resist a pressure of 35 Bars before breaking. So how could this leakage occur? Kinetron expected that the water pressure in Austria must be too high for the product and asked "Customer Company A" about the water pressure at the houses were the product was broken. "Customer Company A" contacted the distributor in Austria to find out the water pressure in the houses. After investigation the distributor could tell that the water pressure was approximately 12-15 Bars. Although this pressure was a little higher than in other countries the problem was not solved. Kinetron could not break a product at 12 Bars, so there must be something else. Kinetron decided to send the broken product to the supplier of the plastic part. After his analysis it became clear that the product was broken due to creep and that the burst pressure of 35 Bar doesn't mean that the product could resist 35 bars for a longer period. But still the problem was not solved. Although the pressure which the product could resist for a longer period is lower than 35 Bars the 12 bars in Austria shouldn't be a problem. Also there were thousands of products in other countries which were installed much longer ago and had no problems. In the mean time Kinetron had also learned that the effect of creep increases with temperature increase. So Kinetron asked "Customer Company A" what the temperature is in the room where the gas water heater is installed in Austria. Again the distributor started an investigation and soon the cause of the problem became clear. The distributor made pictures of the gas water heater installations in Austria and he mentioned that the temperature in Austria could rise till 40 degrees Celsius. At first Kinetron thought that 40 degrees is not that high so there must be another cause, but when the pictures arrived it all became clear. The gas water heaters in Austria are mounted outside the house in metal boxes (figure 24). Sometimes the metal cases were in direct contact with the sunlight and the temperature in the boxes could rise very high. Also if the gas water heater was burning the metal boxes became hotter than when the gas water heater is installed normally. After the cause became clear Kinetron modified the design to resist higher pressures and higher temperatures. The new design was much stronger and was made from more temperature resistant material. The product specifications about pressure resistance were upgraded and tests were designed to test the pressure resistance of the WTG under high temperatures. Because this modified design was based on the original WTG design of the first generation, it still was not as strong and temperature resistant as Kinetron wished. The tests and pressure resistance at high temperature are now a standard at Kinetron development. The second generation of the WTG can resist such high pressures and temperatures that this field problem must be solved for ever.

Another reason for broken WTGs in Australia was the use of the gas water heater in combination with a solar booster (figure 25). Normally the running water cools down the WTG. If the WTG is used in combination with a solar booster, the incoming water of the WTG is pre heated. The temperature in the WTG can become too high which causes the WTG material to weaken. Finally in combination with a continuous water pressure, the WTG can break and leakage will occur. Kinetron did a study to the WTG in high temperatures and advised "Customer Company A" not to use the WTG in solar applications. In the future a new WTG for solar applications will be developed.

Figure 24. Gas water heater placed in metal box in the sun

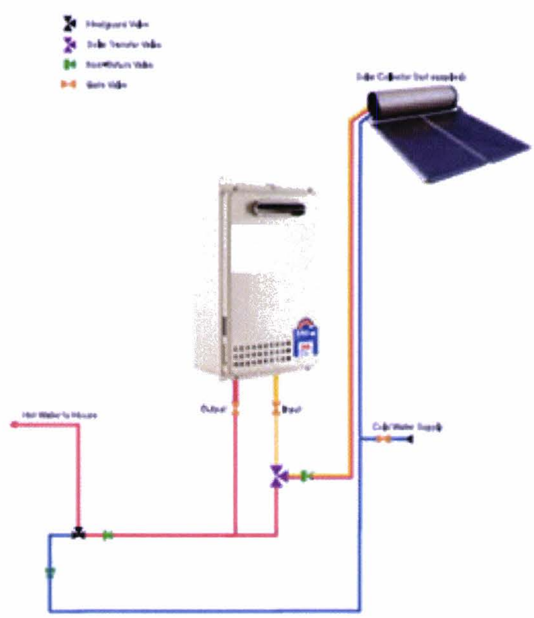


Figure 25. Gas water heater in combination with solar system

In both situations the quality department of "Customer Company A" detected the special cause (new failures or a sudden increase of failures) and informed Kinetron. Extreme field conditions and interconnectivity with solar applications caused the WTG components to fail. In both situations the failures lead to a visible and detectable WTG failure, but in contradiction with the failures presented in the previous section, the origin and the root cause of the problem could not be found by analysing the returned products only. Because both problems lead to high costs (warrantee and leakage claims) there is high pressure on finding the root cause of the problem, which led to a new communication flow. Extra information was retrieved from the distributor, the field engineer and the user to solve the problem. After this Kinetron and "Customer Company A" implemented preventive measures to prevent the problem in the future.

5.5 Information flow models for three situations

5.5.1 Introduction

In the previous sections it became clear that the reaction of the field return process depends on several factors. The dominating factors are:

1. The failure rate: High failure rates result in high warrantee cost and risks of claims, this leads to a high pressure on solving the problems and extra information flows arise.
2. Visibility and detectability of the failure by inspection of the returned product: If a failure is invisible and hard to detect by investigating the returned product, other field quality and reliability information flows are used than when the failure is visible or easy to detect.
3. Origin and root cause can be found by analysis of the returned product: If the origin and root cause can be found by analysis of the returned product, other field quality and reliability information flows are used than when the failure is not visible or easy to detect.

All variations of these factors are presented table 2 on the next page. A combination of these factors can lead to three different information flow models, information flow model 1, 2 and 3. These information flow models and the MIR levels of the information flows are presented and discussed in the next sections.

Failure rate	Failure visible and detectable at the returned product	Origin and Root cause can be found by analysis of the returned product	Has this problem already occurred in the WTG?	Examples	High pressure due to high costs.	Information flow 1, 2, or 3
Low and constant	Yes	Yes	Yes	Standard field returns e.g. dirt in WTG	No	1
Low and constant	Yes	No	Yes	Sometimes WTGs return with burnt cables. The origin and cause are unknown and no preventive measures are taken.	No	3
Low and constant	No	No	Yes	NFF, intermittent component problems, interconnectivity problems, problems due to extreme field conditions, problems due to unexpected user or field engineer actions, hard to find component problems, product returned due to wrong diagnose of field engineer, non technical problems (e.g. customer not satisfied)	No	3
High and constant	Yes	Yes	Not any more	During introduction of the WTG there were several problems with high failure rates.	Yes	1
High and constant	Yes	No	Not any more	In the beginning there were many WTGs with leakage due to a broken cap. Additional field information was necessary to find out that the pressures in the field were higher than specified.	Yes	2
High and constant	No	No	This situation hasn't occurred till now	NFF, Intermittent component problems, interconnectivity problems, problems due to extreme field conditions, problems due to unexpected user or field engineer actions, hard to find component problems, good product returned due to wrong diagnose of field engineer, non technical problems (e.g. customer not satisfied)	Yes	2
Sudden increase of known failures or a sudden appearance of a new failure at a high rate	Yes	Yes	Yes	A few years ago there was a sudden problem with broken magnets. The magnets were weaker due to a bad injection moulding process.	Yes	1
Sudden increase of known failures or a sudden appearance of a new failure at a high rate	Yes	No	Yes	Dirt problem in Poland, leakage problems in Australia, interconnectivity problem with solar system.	Yes	2
Sudden increase of known failures or a sudden appearance of a new failure at a high rate	No	No	This situation hasn't occurred till now	NFF, Intermittent component problems, interconnectivity problems, problems due to extreme field conditions, problems due to unexpected user or field engineer actions, hard to find component problems, product returned due to wrong diagnose of field engineer, non technical problems (e.g. customer not satisfied)	Yes	2

Table 2. Type of information flow depending on several failure aspects

5.5.2 Information flow model 1

On the next page information flow model 1 is presented. In this section the information flows and the MIR levels of the information flows in this model will be discussed step by step. Because the information flow from the user till the "Customer Company A" quality department (Flow A orange) is the same in all three information flow models, this information flow will only be discussed in this section.

Flow A, from user till "Customer Company A" quality department, MIR level 1 (orange):
As described in the activity model, a user has a problem with the gas water heater and calls the service engineer. The service engineer analyses the gas water heater and replaces the defective parts. Also a return form for these parts (appendix A) is filled in. Both the defective part and the form are sent to the distributor, who forwards the parts and the form to "Customer Company A" quality department. Also new spare parts are ordered. "Customer Company A" keeps statistics about the field return rates and the spare parts (section 5.4.3). This information flow can be defined as a MIR level 1 information flow. Statistics are kept, but it is not clear what the origin and the root cause of the problem are.

Flow B, from "Customer Company A" quality department to Kinetron quality department, MIR level 1:
"Customer Company A" receives the parts and the return forms and updates the statistics and forwards the parts to Kinetron. The "Customer Company A" quality department is at this moment not able to detect the origin of the problem and all parts are sent to Kinetron. It can happen that the problem in the WTG is caused by, for example, the "Customer Company A" production department, and the part is sent to the wrong party. This can de defined as a MIR level 1 information flow.

Flow D, from Kinetron quality department to "Customer Company A" quality department V Kinetron suppliers V Kinetron production V Kinetron R&D, MIR level 4 (dark green):
Now Kinetron receives the defective WTG and analyses the part. As mentioned in the table the problem is visible or easy to detect and also the origin and the root cause of the problem can be found by analysing the returned product. The problem information is communicated to the origin of the problem and effective preventive measures are taken. Kinetron also updates the statistics. This information flow can be defined as a MIR level 4 information flow, which leads to a continuous improvement.

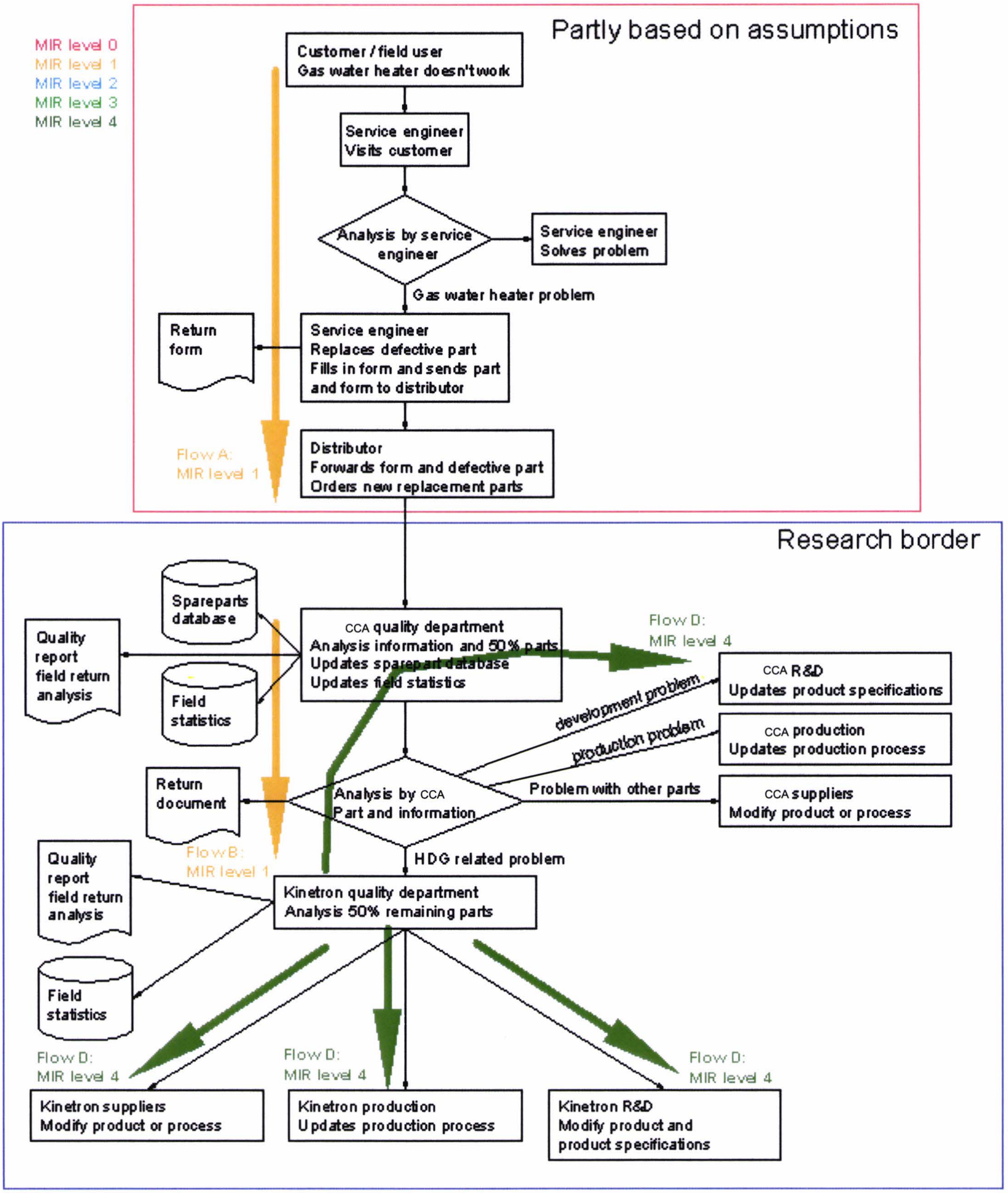


Figure 26. Information flow model 1: Origin and root cause can be determined by investigating the returned product

5.5.3 Information flow model 2

On the next page information flow model 2 is presented.

Flow C, from Kinetron quality department to "Customer Company A" quality department • distributor • service engineer • field user, Mir level 3 (light green)
Again Kinetron receives the defective WTGs from "Customer Company A" quality department and analyses the part. As mentioned in the table a precondition for information flow C (model 2) to appear is a high pressure on solving the problem due to high warrantee and claim costs. A second precondition for information flow C to appear is that the root cause can not be found by investigation of the returned product only. If this was possible information flow model A can be used. Taken into account these two preconditions two situation can occur: the failure is visible or not visible. In both situations an information flow between the Kinetron quality department and the field user (including all parties in between) appears and additional information is retrieved. This will continue until the origin and root cause are known. This information flow can de defined as a MIR level 3 information flow. Origin and root cause are known, but no preventive measure is taken.

Flow D, from Kinetron quality department to "Customer Company A" quality department V Kinetron suppliers V Kinetron production V Kinetron R&D, MIR level 4 (dark green):
Now the problem information is communicated to the origin of the problem and effective preventive measures are taken. Kinetron also updates the statistics. Now the information flow can be defined as a MIR level 4 information flow, which leads to a continuous improvement.

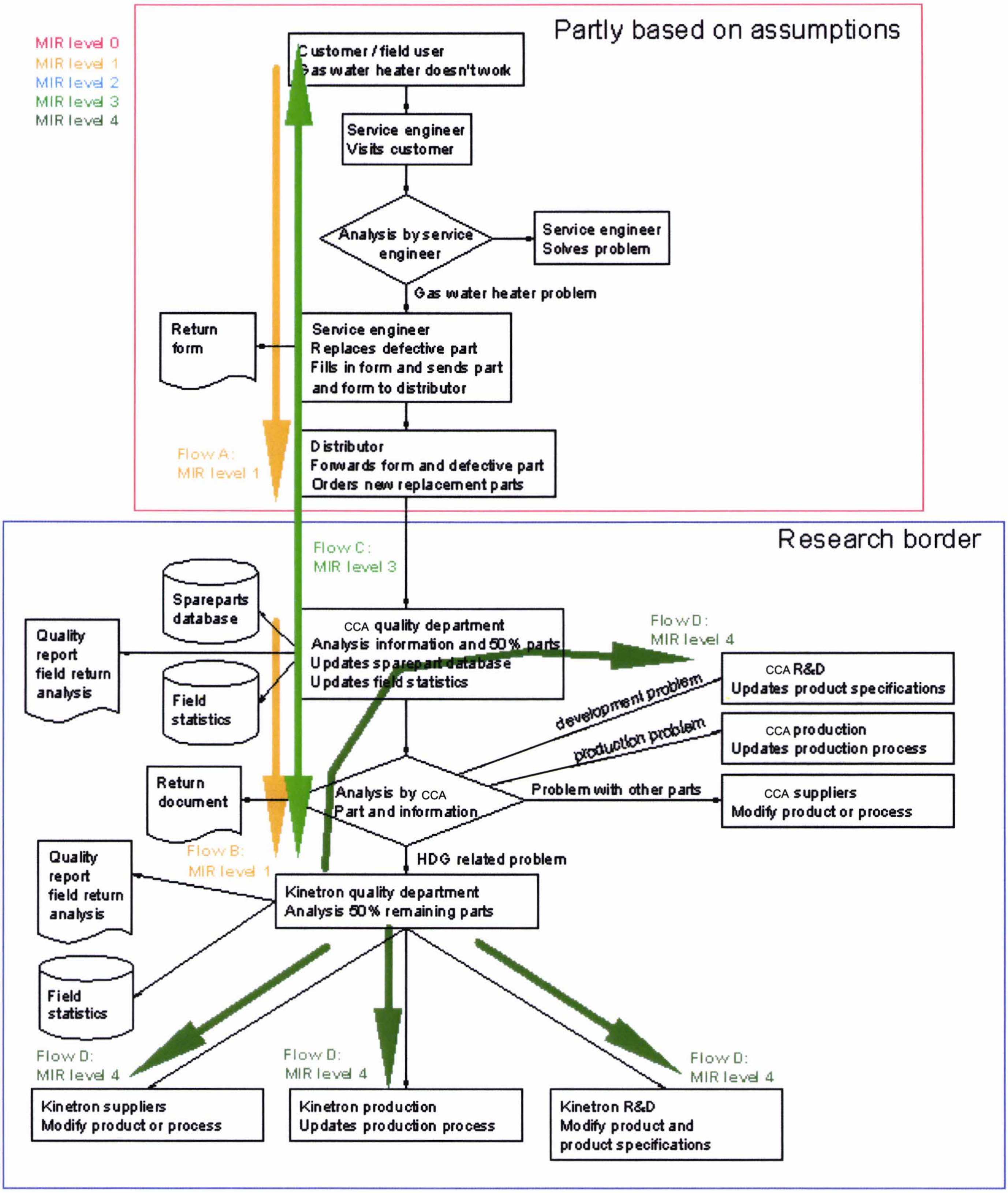


Figure 27. Information flow model 2: Important failures were origin and root cause can not be determined by investigating the returned product

5.5.4 Information flow model 3

On the next page information flow model 3 is presented.

Flow C, from Kinetron quality department to "Customer Company A" quality department • distributor • service engineer • field user, Mir level 0 (red)
Again Kinetron receives the defective WTGs from "Customer Company A" quality department and analyses the part. As mentioned before, for flow C to appear there are two preconditions, a high pressure on solving the problem and the origin and root cause can not be found by investigation of the returned product only. In information flow model 3 the pressure on solving the problem is too low and flow C does not appear. The result is that flow C doesn't appear and has a MIR level 0.

Flow D, from Kinetron quality department to "Customer Company A" quality department V Kinetron suppliers V Kinetron production V Kinetron R&D, MIR level 0 (red):
If flow c doesn't appear and has a MIR level 0, also flow D doesn't appear. The result is that also flow D has a MIR level 0 and that nothing is done to prevent this problem.

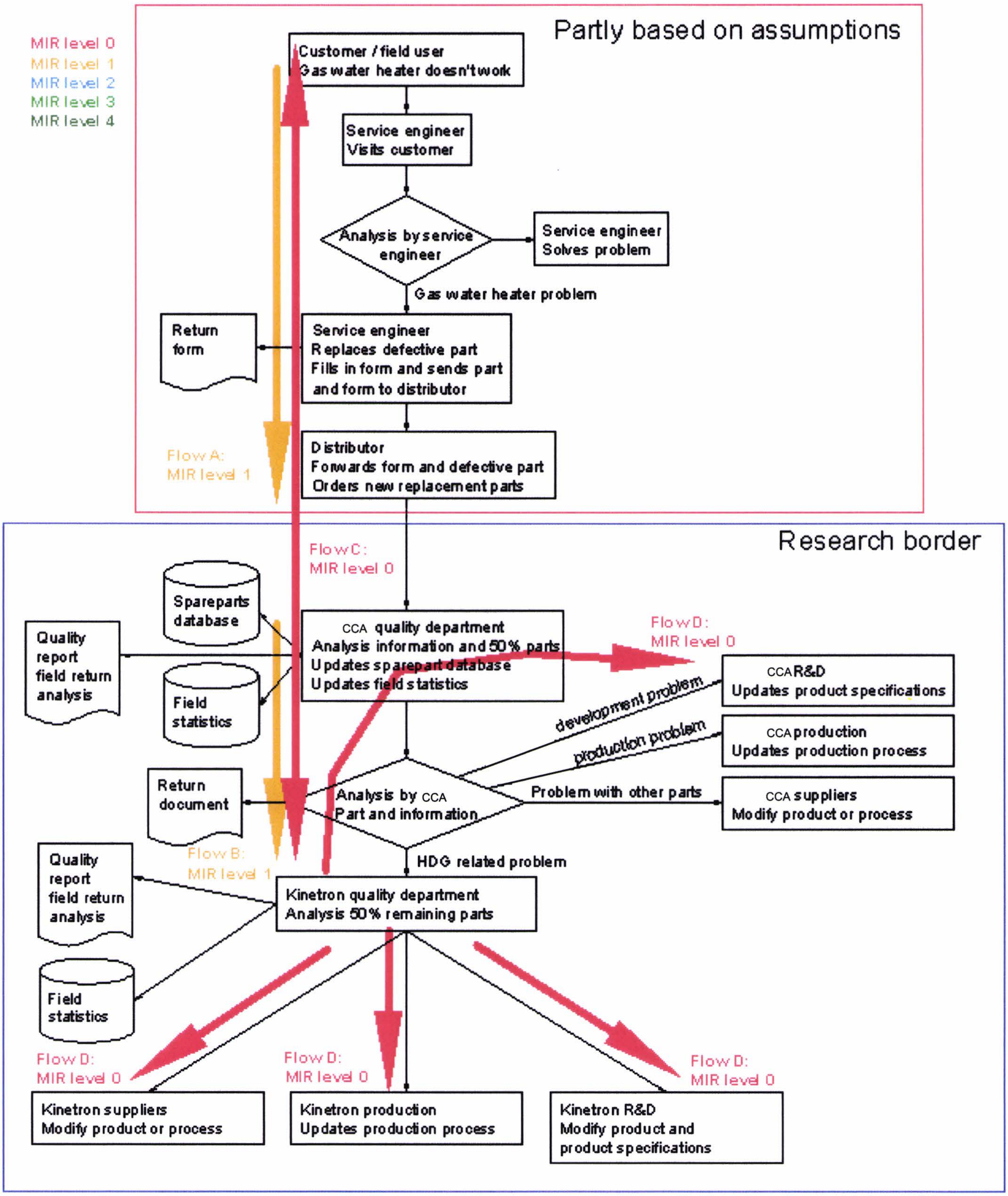


Figure 28. Information flow model: Low rate failures were origin and root cause can not be determined by investigating the returned product

5.5.5 Information flow model field return process

In the model below all models described before are combined to one model. This model will be analysed in the next section.

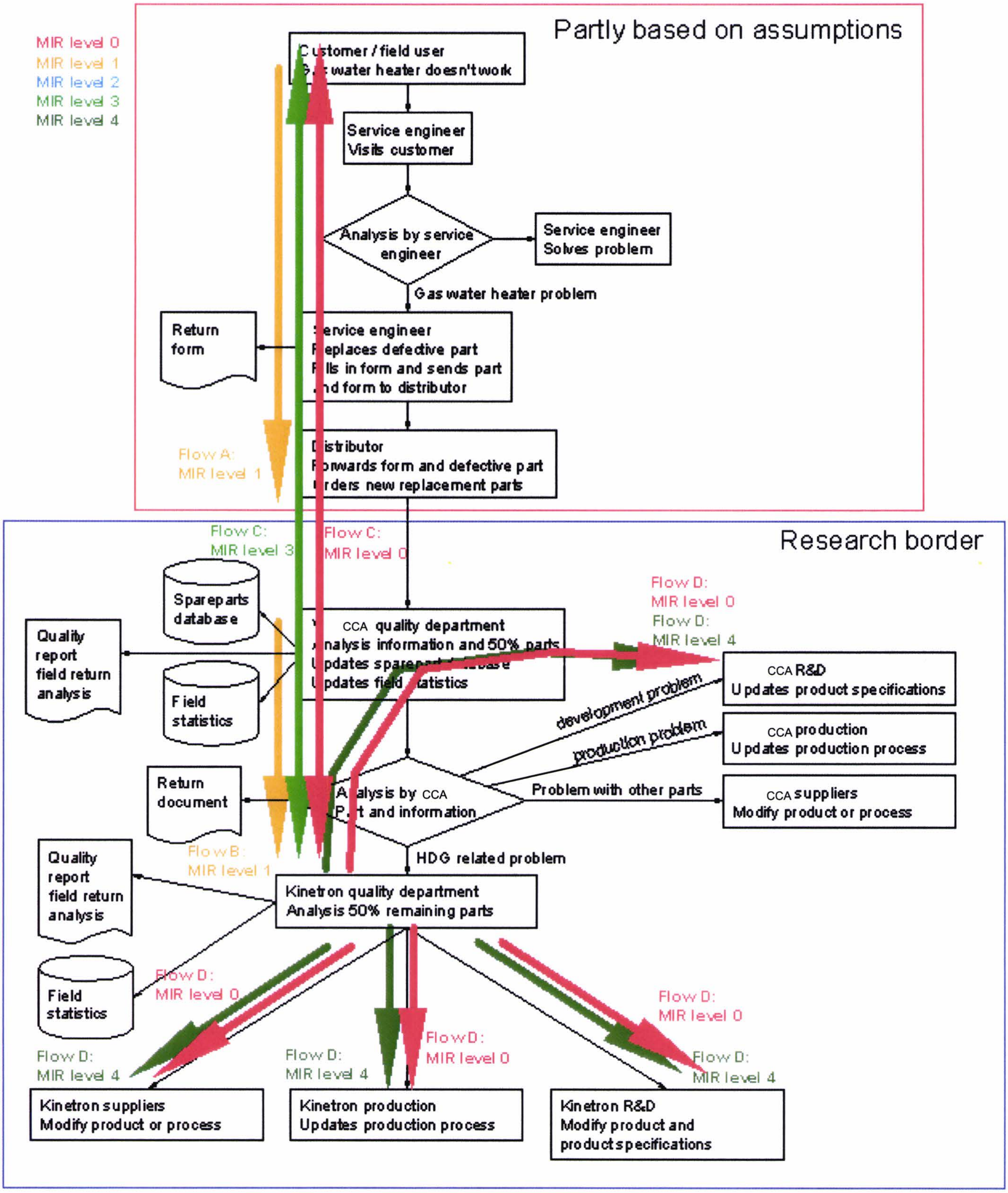


Figure 29. Information flow model field return process

5.5.6 Feedback time

In the statistic information of "Customer Company A" indicate that there is a number of products that is returned within the first quarter after production. This means that these parts are, delivered to "Customer Company A", kept on stock, delivered to distributor, delivered to service engineer, sold to end user, installed by service engineer and failed, within three moths after production date. This indicates that at least in some cases the field information (product and product return form) arrives at "Customer Company A" within 3 months. The WTG changes approximately every one or two years, so the field feedback should be fast enough to improve the current product and to prevent the same problems from happening again in the next generations of products.

Further research to the field feedback speed is necessary. The field feedback can be determined and analysed for each information flow model presented in the previous sections. Unfortunately this couldn't be done with the information available at the moment.

5.6 Analysis of the information flow model

Depending on the three factors mentioned in section 5.5.1 information flows appear or do not appear and continuous improvement is possible or not.

Independent of the pressure on solving the problem, a problem is solved and prevented if the origin and root cause can be found by looking at the product only. In this situation the information flows (flow A and B) with a MIR level 1 from the user till Kinetron Quality department where the product is analysed. Kinetron investigates the origin and the root cause and a solution to solve and prevent the problem. This information flows with a MIR level 4 (flow D) to the relevant actors in the process and continuous improvement is enabled.

If the failure rate is high, the pressure on solving the problem builds up and the origin and root cause can not be found by looking at the returned product an additional information flow (flow C, MIR level 3) appears. Extra information is retrieved from the field engineer and the user. With this information the origin and root cause can be found. With this information Kinetron defines a solution and a preventive measure and communicates (flow D, MIR level 4) this with the relevant actors in the process. This again leads to a continuous improvement.

If the failure rate is low, the pressure on solving the problem is low. If the pressure on solving the problem is low and the origin and root cause can not be found by investigating the product only information flow C does not appear and is degraded from a MIR level 4 to a MIR level 0. The result is that problems are ignored and stay unanticipated. This situation occurs in two situations.

In table 2 the table of section 5.5.1 is repeated, now including the MIR levels. The two situations in which the problems stay unanticipated are marked red. These situations are:

1. The problem can be seen or detected by investigating the product, but the origin and root cause can not.
2. The problem can not be seen and not be detected by investigating the product, also the origin and root cause can not be found.

From experience is known that situation 1 doesn't occur very often. Situation 2 is responsible for a major part (50%) of the field returns at the moment. This situation is responsible for NFF. Failures that belong to this category are:

- Product does not meet customer expectations (non technical failure)
- Products are becoming more and more complex. It is possible that a product fails but the failure can not be detected by the tests performed by the service centre.
- Products have more and more interconnectivity. It can occur that two products function perfectly separately, but when connected together one or both products fail.
- Products are sold all over the world. It can occur that a product only fails in some field situations. And when the product is tested under other conditions the product works fine.
- Finally it is not possible to predict all customer actions. It can occur that a customer uses the product in such a way the product fails. But this failure can not be repeated by the service centre which analyses the returned product.
- Fault can not be found due to intermittent component problems
- The wrong part is replaced due to wrong diagnose of field engineer

Due to the trends and the consequences of these trends Kinetron and "Customer Company A" are not capable of improving all categories of field reliability problems. Some problems are unanticipated and continuous improvement is not possible. To make the field return process suitable to deal with the two types of failures which are unanticipated in the current situation, Kinetron and "Customer Company A" have to improve the field quality and reliability information flows. In the next section two possible solutions will be discussed.

Failure rate	Failure visible and detectable at the returned product	Origin and Root cause can be found by analysis of the returned product	Has this problem already occurred in the WTG?	Examples	High pressure due to high costs.	Information flow 1, 2, or 3	MIR level
Low and constant	Yes	Yes	Yes	Standard field returns e.g. dirt in WTG	No	1	4
Low and constant	Yes	No	Yes	Sometimes WTGs return with burnt cables. The origin and cause are unknown and no preventive measures are taken.	No	3	0 / 1
Low and constant	No	No	Yes	NFF, Intermittent component problems, interconnectivity problems, problems due to extreme field conditions, problems due to unexpected user or field engineer actions, hard to find component problems, product returned due to wrong diagnose of field engineer, non technical problems (e.g. customer not satisfied)	No	3	0 / 1
High and constant	Yes	Yes	Not any more	During introduction of the WTG there were several problems with high failure rates.	Yes	1	4
High and constant	Yes	No	Not any more	In the beginning there were many WTGs with leakage due to a broken cap. Additional field information was necessary to find out that the pressures in the field were higher than specified.	Yes	2	4
High and constant	No	No	This situation hasn't occurred till now	NFF, Intermittent component problems, interconnectivity problems, problems due to extreme field conditions, problems due to unexpected user or field engineer actions, hard to find component problems, product returned due to wrong diagnose of field engineer, non technical problems (e.g. customer not satisfied)	Yes	2	4
Sudden increase of known failures or a sudden appearance of a new failure at a high rate	Yes	Yes	Yes	A few years ago there was a sudden problem with broken magnets. The magnets were weaker due to a bad injection moulding process.	Yes	1	4
Sudden increase of known failures or a sudden appearance of a new failure at a high rate	Yes	No	Yes	Dirt problem in Poland, leakage problems in Australia, interconnectivity problem with solar system.	Yes	2	4
Sudden increase of known failures or a sudden appearance of a new failure at a high rate	No	No	This situation hasn't occurred till now	NFF, Intermittent component problems, interconnectivity problems, problems due to extreme field conditions, problems due to unexpected user or field engineer actions, hard to find component problems, product returned due to wrong diagnose of field engineer, non technical problems (e.g. customer not satisfied)	Yes	2	4

Table 3. Type of information flow depending on several failure aspects, including MIR levels. Low MIR levels indicate unanticipated failures.

5.7 Possible information flow improvements

5.7.1 Introduction

To enable the field return process to deal with the two failure types described in the previous section the field quality and reliability information flows must be improved. In this section two solutions will be presented. First the ideal solution is presented. Secondly a more practical solution is presented. Of course a combination of these solutions is also possible.

5.7.2 Solution 1: The ideal situation

The ideal solution would be to increase the MIR level of flow A and B to a minimum level 3 figure 30). This enables the "Customer Company A" quality department to find the origin and root cause with help of the field information from the user and the service engineer. "Customer Company A" knows the origin and distributes the defective product and the field information directly to the relevant actors in the process. Because "Customer Company A" already knows the origin and the root cause of the problem there is no longer need to retrieve field information afterwards and information flow C becomes obsolete. Kinetron can directly work on a solution and a preventive measure.

Possible problems with this solution are:

1. To increase the MIR level of flow A from 1 to 3 a great part of the responsibility for analysis of the gas water heater and finding the origin and the root cause of the problem lays by the service engineer. The service engineer must be trained to analyse the gas water heater and the WTG.
2. The service engineer is not equipped to perform a full analysis of all WTG specifications.
3. If the service engineer is not able to find the origin and the root cause of the problem the service engineer must retrieve and communicate all relevant information to the "Customer Company A" quality department. At the moment there is no possibility to communicate all information on the return form (appendix A). There is no space available for free text. This can be important for finding causes of NFF. Also it is difficult to prepare the return form for determining the origin and root cause of all sorts of failures. Every failure needs other information to solve the problem. For the WTG it would be very helpful if the WTG voltage is determined before the WTG is returned. This makes possible to distinguish technical and non technical failures already in the real field situation. This also prevents wrong analysis by the field engineer.
4. The service engineer gets paid to solve the problem with the gas water heater. At this moment the service engineer has no incentive for solving the reliability problems with the gas water heater.

How to solve these problems is subject of further research. A start would be to modify the return form with an open text space for explanation of the problem and the analysis which was performed to find this problem. Further it would be helpful if the service engineer is obligated to measure the WTG voltage and to note the Voltage on the return form before returning the WTG. This enables Kinetron to distinguish technical and non-technical failures.

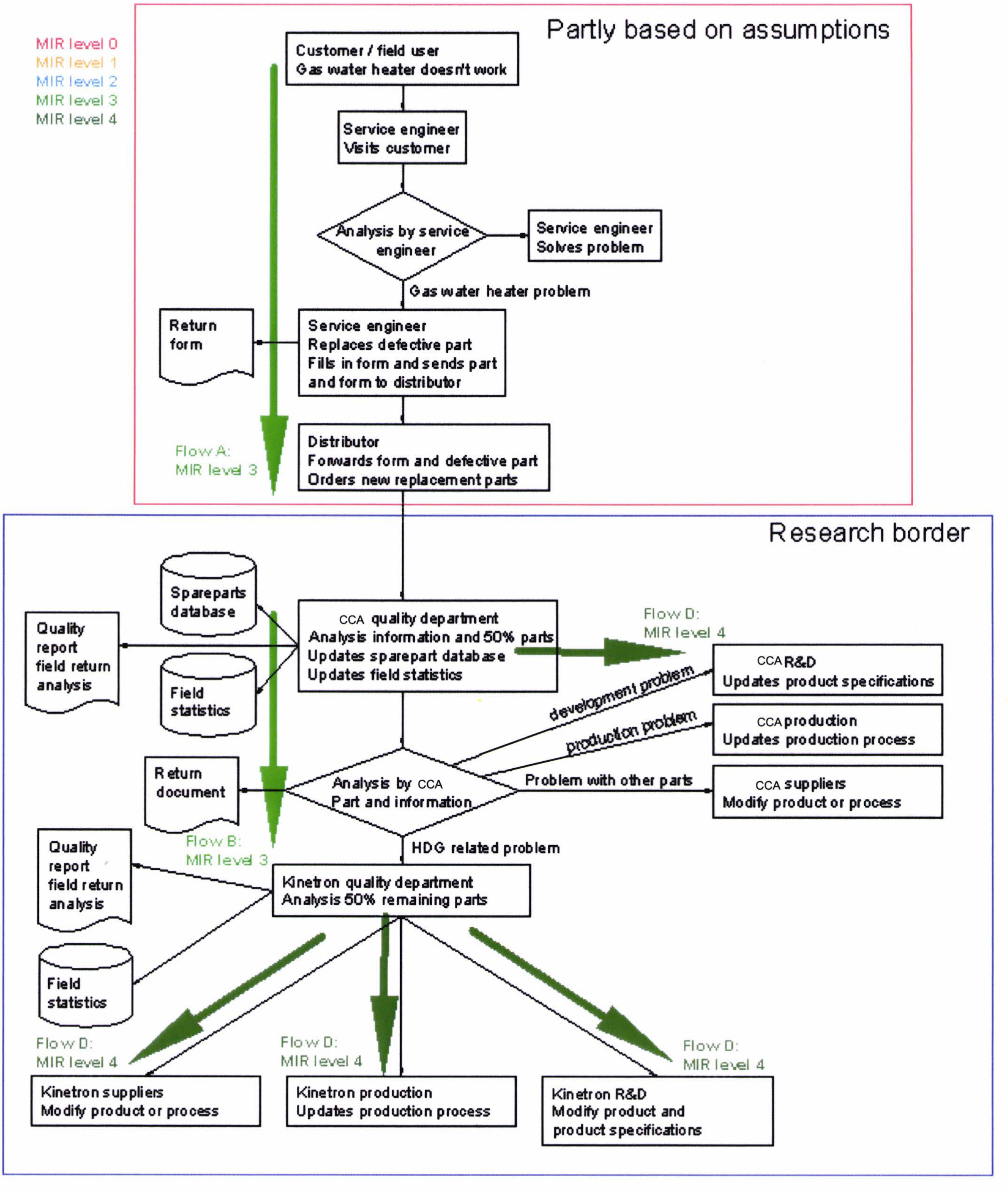


Figure 30. Information flow model solution 1: The ideal situation

5.7.3 Solution 2: A more practical solution

A more practical solution is to start a new information flow between the Kinetron Quality Department or "Customer Company A" Quality Department and the end user (similar to the incidental flow c). This information flow is successfully used in situations were the pressure on finding and solving the problem is high, but this information flow doesn't appear when the pressure is low. If products are returned and No Fault can be Found Kinetron or "Customer Company A" contact or visit the field user and the service engineer to discuss and investigate the information. This will lead to high quality field feedback information which can be used to reduce the number of NFF problems.

Of course it is possible to plan this action for example once a year on a number of WTGs, in stead of contacting all customers with a NFF problem.

This solution leads to several questions:

1. How can the product return forms be kept by the returned WTG, so the name and address of the user of this product and the field engineer who repaired the gas water heater are known.
2. The origins and root causes of the NFF must be found by interviewing field engineers and end users and by analysing user actions and field situations. What is the best way of doing this? Which information is necessary? What equipment is necessary? Who is responsible for this? Which customers are visited? Etc.
3. If the origin and root cause are found the information must be discussed with the Kinetron quality department and a solution must be found. How is made sure that Kinetron receives all information necessary for solving and preventing the problem?

How to answer these questions is subject of further research. A first start could be to start small and to visit for example 10 users and field engineers who returned a WTG with the NFF problem. Perhaps this can be done close to Kinetron or "Customer Company A", so no long travelling is necessary. If the project leads to a success the project can be expanded to more visits and more countries.

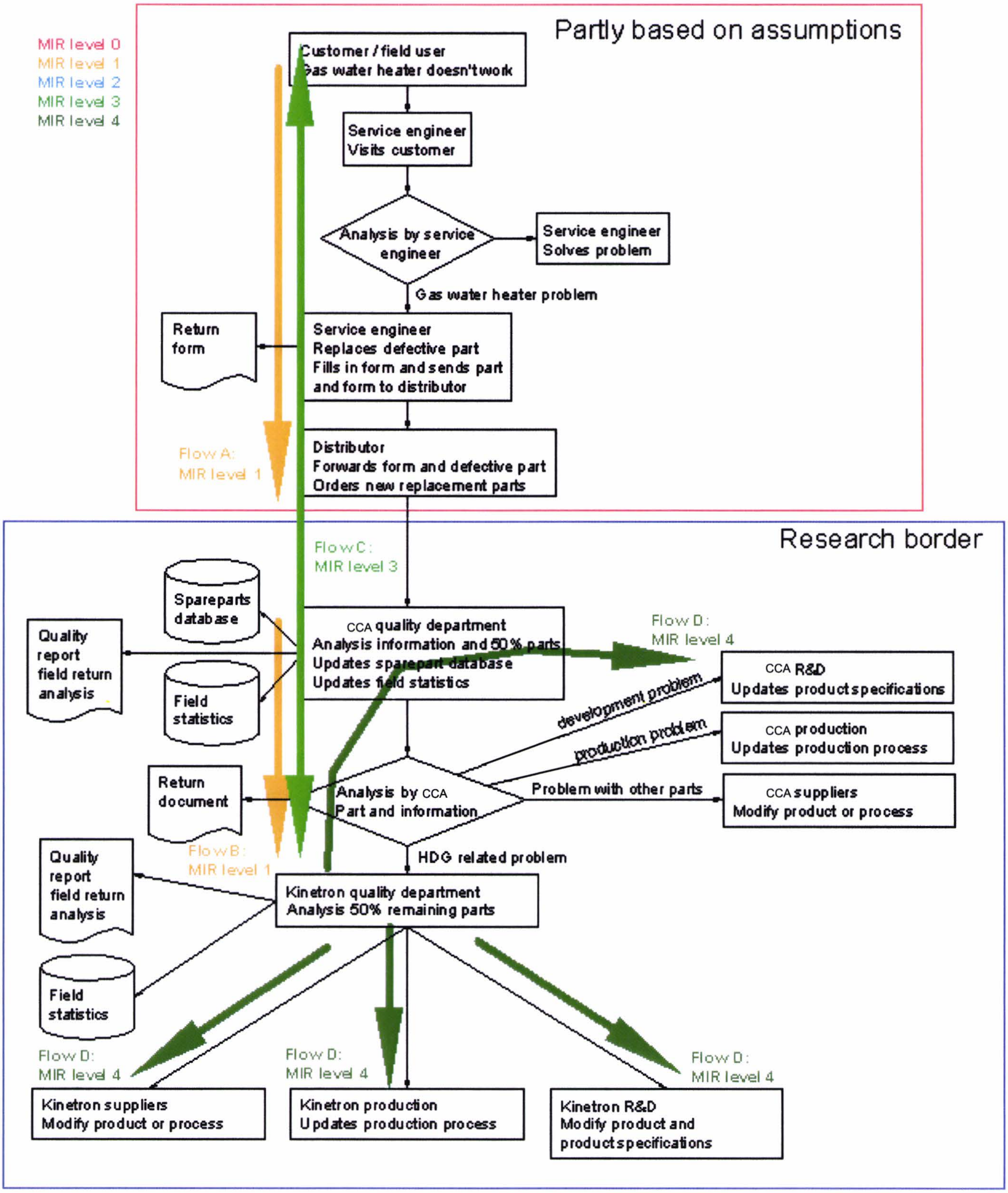


Figure 31. Information flow model: a more practical solution

5.8 Solving the NFF problem at Kinetron: a first start

5.8.1 Introduction

At the moment Kinetron and "Customer Company A" have started to implement small changes in the processes to improve the NFF problem. Although the research is done in relation to NFF in field returns, the NFF also occurs in the final inspection at the "Customer Company A" assembly line. Products are rejected at "Customer Company A" (South of Europe) and are sent to Kinetron (Netherlands) for analysis. In the next sections the first implementations in the assembly line are presented. Then the first possible implementations to reduce the number of NFF in the field returns are presented.

5.8.2 NFF in production process "Customer Company A"

The NFF in the assembly line can have the following reasons:

1. WTG has interconnectivity issues with the electronic box. It can occur that both products function perfectly separately, but when connected together one or both products fail.
2. Products are tested in Portugal and returned to Kinetron in the Netherlands for analysis. It can occur that the WTG fails in the Portuguese final inspection, but when the returned product is measured at Kinetron in the Netherlands it works fine. The cause can lay in the different simulated field or test conditions.
3. Fault can not be found due to intermittent component problems.
4. A good part is replaced due to wrong diagnose of field engineer.

To gain more insight in the origin and the reasons for NFF, Kinetron modified two multi meters (figure 32), which can be used at the final inspection in the assembly line of "Customer Company A". If a gas water heater fails the test engineer has to disconnect the WTG, connect the multi meter, and test again. If the measured Voltage is high enough, the WTG is not the problem. If the Voltage is too low, the test engineer replaces the WTG, writes the Voltage level on a sticker and places this sticker on the WTG. Now Kinetron can see the Voltage level at witch the WTG was rejected. Also Kinetron is investigating the possibility to test the WTG and the electronic box together, to find interconnectivity problems. Although both solutions do not solve the problems, insight is gained in the origin and the causes of the problems, a higher information quality in obtained and several reasons for NFF are excluded.

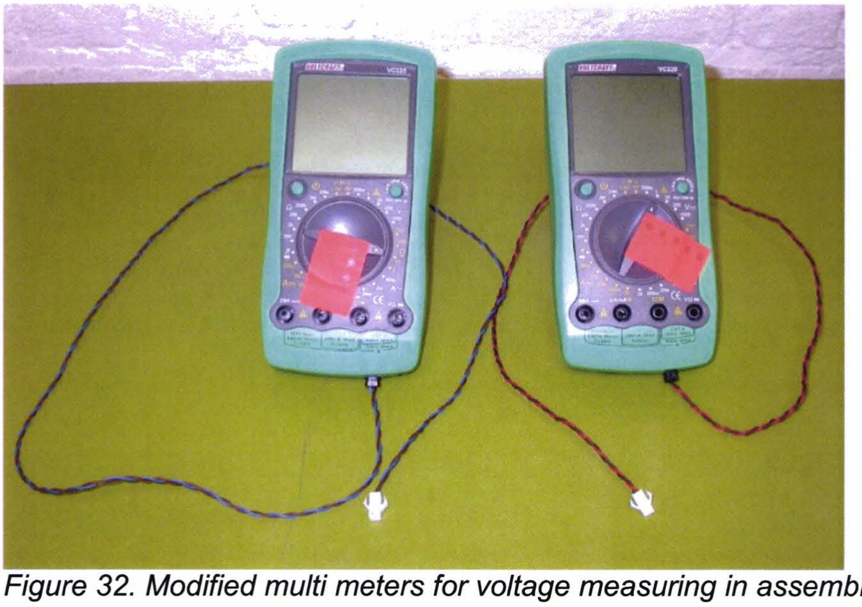


Figure 32. Modified multi meters for voltage measuring in assembly line

5.8.3 NFF in field returns

To reduce the number of NFF in the field returns Kinetron is studying the trouble shooting manual (Appendix 2) of a gas water heater with WTG. It seems that no trouble shooting procedure is available to analyse and solve a problem with the WTG. Maybe a simple procedure can be added to this manual to analyse and solve problems with the WTG. For example, if the gas water heater doesn't ignite, the display doesn't work and the water flow is sufficient the problem must be located in the WTG. Measure the WTG voltage. If the Voltage is too low, write down the Voltage on the product return form and replace the WTG.

With this procedure a number of the above reasons for NFF are excluded, the field engineer is capable to perform a better analysis and higher quality information can be obtained.

6. Conclusions and recommendations

6.1 Introduction

This chapter describes the main conclusions of the research as well as answer the research questions. Also the generalisation of the research and recommendations for further research are presented.

6.2 Conclusions

Manufacturers of innovative mass market products are faced with four trends:

1. Influx of new technology
2. Reduction of time to market
3. Customer attitude towards reliability has changed
4. Primary business processes have changed

These trends cause new failure types, e.g. NFF failures, which can not be prevented by the current quality and reliability methods and tools. Manufacturers have to deal with products entering the market with an unknown quality and reliability level and it should be expected that a number of products is returned which are according to specification and No Fault can be Found.

Kinetron can be categorized as an innovative mass production company which is influenced by the trends mentioned above. Kinetron is not able to prevent all possible reliability problems with the current quality and reliability methods and tools and the NFF failure occurs.

To solve these problems manufacturers most use field feedback information. This field feedback must be fast, at the right place and of the right quality. To enable continuous improvement it is necessary that there are closed field feedback loops. To analyse field feedback information flows the MIR method can be used. With the MIR method the reaction of processes on internal or external disturbances can be analysed. Also the resulting information flow through the process can be analysed.

After analysing of the Kinetron field return process and the information flows through this process the following conclusion can be made. If the failure rate is low, the pressure on solving the problem is low. If the pressure on solving the problem is low and the origin and root cause can not be found by investigating the product only, not all information flows that occur in high pressure situations are present and the MIR level decreases from a level 4 to a MIR level 0. The result is that problems are ignored and stay unanticipated. This situation occurs in two situations.

1. The problem can be seen or detected by investigating the product, but the origin and root cause can not.
2. The problem can not be seen and not be detected by investigating the product, also the origin and root cause can not be found.

To make the field return process suitable to deal with the two types of failures which are unanticipated in the current situation, Kinetron and "Customer Company A" have to improve the field quality and reliability information flows.

Now the research questions can be answered:

1. *Are the field quality and reliability information flows at Kinetron sufficient for root cause analysis and improvement of all the field returns?*

From the analysis of the field quality and reliability information flows at Kinetron BV it can be concluded that the field quality and reliability information flows are not sufficient for analysis and improvement of all field returns. In some cases the necessary information flows are not present, the origins and root causes of the problems are not found and the problems stay unanticipated.

2. *If no, do the shortcomings in the field quality and reliability flows explain the number of NFF in the field returns?*

The shortcomings in the field quality and reliability information flows do indeed explain the number of NFF in the field returns. The information which is necessary to solve reliability problems in the NFF category is not available. There fore the origin and root causes of this category of failures is not found and there is no continuous improvement possible. The NFF problem is one of the two field problems which stay unanticipated in the field return process at Kinetron BV.

3. *How can the field quality information flows be improved so root cause analysis and reduction of the NFF field returns becomes possible?*

The field quality and reliability information flows can be improved by increasing the MIR levels of the information flows with a low MIR level. This means that the quality of the information from the field must increase to enable finding the origin and the root causes of field problems. Another possible solution is to start a new information flow between the Kinetron Quality Department or "Customer Company A" Quality Department and the end user. If products are returned and No Fault can be Found Kinetron or "Customer Company A" contact or visit the field user and the service engineer to discuss and investigate the problem. This will lead to high quality field feedback information which can be used to reduce the number of NFF problems.

The benefit of this study is proven by the fact, that already during this study, the first modifications to improve the NFF problem were implemented. Kinetron made two special multi meters to analyse rejected WTGs at the final inspection at the "Customer Company A". Also Kinetron is investigating methods to test the WTG and the electronic box together, to find and solve interconnectivity problems. Finally Kinetron is investigating a simple trouble shooting procedure which can be added to the gas water heater manual. All three solutions do not solve all the problems, but a better analysis can be done, higher quality information is obtained, and several reasons for NFF can be excluded.

6.3 Generalisation

Most of the studies used to formulate and answer the research questions were performed in the innovative consumer electronics industry. The consumer electronics industry has the following characteristics: short time to market (short PCPs), increasing warranty time, and increasing rate of non-component related failures, globalisation and segmentation of the business process.

This study is performed in the gas water heater industry. Although the time between product introductions on the market is longer than in the consumer electronics industry, there is a high pressure on time to market. This is mainly due to the high pressure on price reduction and quality improvements. This study shows that the characteristics of the consumer electronics industry are present in the gas water heater industry. The research method which is used to analyse the presents of the trends and to analyse the field feedback information can be used in companies with similar characteristics.

The conclusions of this research are related to the situation at Kinetron and don't have to be valid for other companies. Although the conclusions do not have to be valid for other companies, there is one conclusion that might be. The relation between the pressure on solving a reliability problem and the appearance of information flows which are necessary for solving the problem, is also present at other companies. To establish this relation at other companies, further research is necessary.

6.4 Recommendations for further research

The following recommendations for further research can be identified:

Further research for Kinetron BV:

- First of all the activity model and the information flow models must be validated with the real situation. The first steps of the process and the first steps of the information flow models (from field user till "Customer Company A" quality department) are based on assumptions. It is important to replace these assumptions for the real situation.
- The feedback time for the three presented information flow models can be investigated in more detail.
- The solutions presented to improve the field quality and reliability of the WTG in relation to the NFF problem introduce reasons for further research. What information is necessary to find the origins and root causes of the NFF problems? What is the best way to gather and communicate this information?
- Can the product return form be used to gather high quality field information? If yes, what must be modified in the product return form?
- How can the knowledge of the field engineer be improved?
- Does the field engineer have the right tools to analyse a defective gas water heater properly?
- Can the trouble shooting procedure be modified to decrease the number of NFF problems?
- How can the service engineer be motivated to help improving the gas water heater reliability?
- Is it possible to deliver the defective WTGs including product return form to Kinetron?
- If the origins and root causes of the NFF must be found by interviewing field engineers and end users and by analysing user actions and field situations. What is the best way of doing this? Which information is necessary? What equipment is necessary? Who is responsible for this? Which customers are visited? Etc.
- If the origin and root cause are found, the information must be discussed with the Kinetron quality department and a solution must be found. How is made sure that Kinetron receives all information necessary for solving and preventing the problem?
- Can Kinetron and "Customer Company A" modify the development process and introduce early field tests to prevent the NFF problems?

Further research for TUE:

- This study has found a relation between the pressure on solving a problem, the possibility to find the origin and the root cause by investigating the returned product and the appearance of an information flow between the manufacturer and the field user. Besides the lack of field quality and reliability information to solve the NFF problems it can be that more companies are faced with the fact that the pressure to solve these problems isn't high enough and no effort is done to start the information flow with the field user or field engineer. This can be subject of further research.
- The conclusions of this research are valid for companies with the same characteristics. It would be useful to study in which other industries the trends occur.
- At the moment the NFF problems can not be prevented with the quality and reliability methods and tools. It is interesting to investigate if new quality and reliability methods and tools can be developed to cope with the trends. Maybe the introduction of early field tests and customer interaction tests can help preventing the NFF problem?

References

[Ben83] Benner L., Sweginnis R. (1983); "System safety's open loops"; A paper published in Hazard Prevention, 19:6, November/December 1983

[Bli96] Blischke W.R., Murthy D.N.P. (1996); "Product warrantee handbook"; Marcel Dekker, New York.

[Bro1] Brombacher A.C.; "Product reliability and quality of business processes: requirements for developing reliable products"

[Bro2] Brombacher A.C.; "The building bricks of product quality: an overview of some basic concepts and principles";

[Bro3] Brombacher A.C.; "Reliability of consumer goods with fast turn around" A contribution to the "encyclopedia of quantitative risk assessment", Eindhoven University of Technology

[Bro4] Brombacher A.C., De Graef M.R. (2001); "Betrouwbaarheid van technische systemen: anticiperen op trends";

[Bro05] Brombacher A.C. (2005) "Reliability in strongly innovative products ; a threat or a challenge?" Reliability Engineering and System Safety

[Bro05b] Brombacher A.C., Sander P.C., Sonnemans P.J.M., Rouvroye J.L. (2005); "Managing product reliabilty in business processes 'under pressure"; Reliability engineering and system safety 2005 88:137-146

[Bro94] Brombacher A.C. (1994); "Will it really work? Some critical notes on current industrial design processes"; Inaugural lecture, Eindhoven University of Technology

[Bro96] Brombacher A.C. (1996); "Predicting Reliability of High Volume Consumer Products; Some experiences 1986 – 1996"; Symposium "The Reliability Challenge" organised by Finn Jensen Consultancy, London

[Bro99] Brombacher A.C. [1999]; "MIR: Covering non-technical aspects of IEC61508 reliability certification"; Reliability Engineering and System Safety, Elsevier

[Bur07] (Article: Overhaul & Maintenance's February 2007 issue By Bill Burchell)

[Dij97] Dijkstra, L., Dirne, C.W.G.M., Govers, C.P.M. & Sander, P.C. (1997): Samenwerking in Ontwikkeling (in Dutch). Kluwer, Deventer.

[Dom01] Dommelen, W. van (2001): Fast Field Feedback. Eindhoven University of Technology.

[Eva93] Evans, J.R. & Lindsay, W.M. (1993): The management and control of quality. West Publishing Company, St. Paul, MN

[Fra02] Franken, B.F. & Hendriks, M.M. (2002): Fast Field Feedback. Eindhoven University of Technology.

[Hen81] Henley, E.J. & Kumamoto, H. (1981): "Reliability Engineering and risk assessment" Prentice-Hall, Englewood Cliffs.

[Hey02] Heynen, E.W.H.P. (2002): Fast Field Feedback: a field study. Eindhoven University of Technology.

[Kra83] Kraljic, P. (1983): "Purchasing must become supply management" Harvard Business Review, September-October, 61, 109-117

[Luy02] Lu, Y.(2002); "Analysing reliability problems in concurrent fast product development"; PhD thesis, Eindhoven University of Technology

[Mey97] Meyer, C. (1997); "Relentless growth: how Silicon Valley's innovation strategies can work for your business"; Free Press, New York.

[MIL65] US MIL HDBK 217 (1965): Reliability Prediction of Electronic Equipment.United States Department of Defence.

[Min99] Minderhoud S. Quality and reliability in product creation: extending the traditional approach. Quality and Reliability International 1999 15(6):417-425.

[Moo65] Moore G.E. (1965); "Cramming more components onto integrated circuits"; Electronics, Volume 38, Number 8, April 19 1965

[Oud05] Den Ouden, E., Lu, Y., Brombacher, A.C. (2005); "Customer oriented product quality: Why available approaches are no longer sufficient"; Article in review, Journal of product innovation Management, 2005

[Oud06] Den Ouden E., Lu Y, Sonnemans P.J.M., Brombacher A.C. (2006) "Quality and reliability problems from a consumer's perspective: an increasing problem overlooked by businesses?"; Quality and reliability engineering international (in press)

[Ove06] (Article: Investigating the mobile 'No Fault Found Phenomenon' – July 2006 By Dough Overton)

[Pet00b] Petkova, V.T. and Sander, P.C. (2000): Structures for internal and external cooperation. In: ISA EXPO 2000 Update IV, Management issues in Manufacturing, 65-77, ISA.

[Pet03] Petkova, V.T. (2003); "An analysis of field feedback in consumer electronics industry"; PhD thesis, Eindhoven University of Technology

[San00] Sander P.C., Brombacher A.c. (2000); Analysis of quality information flows in the product creation process of high volume consumer products"; International journal of production economics 67, p.37-52

[San99] Sander, P.C. & Brombacher, A.C. (1999): MIR: The use of Reliability Information Flows as a maturity index for quality management. Quality and Reliability Engineering International, 15, 439-447.

[Smi98] Smith, P.G. & Reinertsen, D.G. (1998); "Developing products in half the time: new rules, new tools"; Van Nostrand Reinold, New York.

[Sta90] Stalk G., Hout T.M. (1990); "Competing against time: How time based competition is reshaping global markets", The free press, New York 1990

[The95] Theije, S.M., de (1995); "Design and reliability: reliability control through reliability tests in the design process of monitors"; Eindhoven University of Technology

[Val99] Petkova V.T., Sander P.C., Brombacher A.C.(1999); "The role of the Service Centre in Improvement Processes"; Quality and Reliability Engineering International

[Wheel92] Wheelwright S.C. Clark K.B. (1992); "Revolutionizing product development: Quantum leaps in speed, efficiency and quality", Free press, New York

Appendix A: Product return form

RETOURFORMULIER
garantie onderdelen

- ☐ **Is uw zending boven de 10 kg?**
  De zending wordt bij u opgehaald als u dit formulier invult en faxt naar
  Daarna het formulier svp bij uw retourzending voegen.
  U verleent (hierbij) opdracht voor het afhalen van _____ pakket(ten)/pallet(s) op onderstaand adres.

- ☐ **Is uw zending beneden de 10 kg?**
  Dan graag dit formulier ingevuld bij uw retourzending voegen en dit sturen naar:

	Uw adres	Afhaaladres (indien afwijkend)
Naam	....	....
Contactpersoon	....	....
Straat	....	....
Postcode, Plaats	....	....
Telefoonnummer	....	
Faxnummer	....	
Opmerking	....	
Uw referentienummer	....	

Voor een correcte en snelle afhandeling van uw retouren verzoeken wij u vriendelijk doch dringend om gegevens op **beide pagina's** van dit formulier volledig in te vullen.

Bewaar het afgetekende afhaaldocument van de vervoerder als bewijs van retourzending.

LET OP!
Bij een ontbrekende installatiefactuur is de productiedatum van het toestel of onderdeel bepalend. Voor verdere garantiebepalingen verwijzen wij u naar de garantievoorwaarden van het toestel.
Voor de goede orde maken wij u erop attent dat creditering achterwege kan blijven indien essentiële informatie voor de beoordeling van uw retouren ontbreekt.

Indien de onderdelen zijn aangekocht anders dan bij kunnen er verschillen optreden t.a.v. de creditering. Om deze verschillen uit te sluiten adviseren wij u om de onderdelen daar te retourneren waar u ze heeft ingekocht.

1 / 2

RETOURFORMULIER
garantie onderdelen

Afzender: .... d.d. ....

Reden uitval ?
aankruisen wat van toepassing is

Referentie	Artikelnummer	Benaming onderdeel	Type toestel	FD-nummer	Serienummer	Postcode plaatsingsadres	Huisnummer plaatsings-adres	O.G.P. / T.O.P. contract	Kopie van installatiefaktuur toegevoegd?	Gescheurd	Lawaai	Lek	Geen functie	Regelt niet	Overige, n.l.
1								o	J / N	o	o	o	o	o	
2								o	J / N	o	o	o	o	o	
3								o	J / N	o	o	o	o	o	
4								o	J / N	o	o	o	o	o	
5								o	J / N	o	o	o	o	o	
6								o	J / N	o	o	o	o	o	
7								o	J / N	o	o	o	o	o	
8								o	J / N	o	o	o	o	o	
9								o	J / N	o	o	o	o	o	
10								o	J / N	o	o	o	o	o	
11								o	J / N	o	o	o	o	o	
12								o	J / N	o	o	o	o	o	

2 / 2

Appendix B: Trouble shooting procedure

7 Problems

7.1 Problem/cause/solution

Assembly, maintenance and repairs must be performed by qualified technicians only. The following chart offers solutions to possible problems (solutions followed by an * must be undertaken by qualified technicians only).

Problem	Cause	Solution
The heater does not ignite and digital display is turned off.	Switch turned off.	Check switch position.
Slow and difficult ignition of the burner.	Reduced water flow.	Check and correct.
Red LED in switch flashes.	Reduced water flow.	Check and correct.
Water at low temperature.		Check the temperature selector position and adjust it according to the desired water temperature.
Water is not heated, no flame.	Insufficient gas supply.	Check reducer, and if inadequate or malfunctioning, replace it. Check if the bottles (butane) freeze during operation, and if so, move them to a warmer place.
The burner turns off the heater is operating.	Temperature limiter has tripped (digital display shows "**E9**").	Wait 10 minutes and restart the heater. If the problem persists, call a qualified technician.
	Flue gas safety device has tripped (digital display shows "**A4**").	Vent the area. Wait 10 minutes and restart the heater. If the problem persists, call a qualified technician.
Incorrect temperature information in the appliance digital display.	Insuficient contact of the temperature sensor.	Check and correct the temperature sensor assembling.
Digital display shows "**E1**".	Water temperature sensor has tripped (outlet water temperature above 85 °C).	Reduce the water temperature using the power and/or temperature adjustment selector. If the problem persists, call a qualified technician.
Digital display shows "**A7**".	Temperature sensor incorrectly connected.	Check and correct connection.
	Temperature sensor defective.	Replace the temperature sensor.
Blocked heater.	Digital display shows "**F7**" or "**E0**".	Turn the heater off and on, if the problem persists, call a qualified technician.
There is spark but the main burner does not ignite, heater blocked.	No ionisation probe signal (digital display shows "**EA**").	Check: • Gas supply. • Ignition system (ionisation electrode and electrovalves).

Tab. 7