MASTER

The reuse of knowledge in a project based organisation

Brugman, L.S.

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The Reuse of Knowledge in a Project Based Organization

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Brugman, L.S.

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Supervisors:
Dr. Ir. J.J. Berends
Ir. I. Mols
Prof. Dr. E. J. Nijssen

Learning is not compulsory, neither is survival.
W. EDWARDS DENNING

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MANAGEMENT SUMMARY

This research has investigated knowledge reuse at Den Heijer Industries. At the moment Den Heijer Industries relies heavily on a people-based approach. This means they reuse knowledge by having the same persons doing the same job again. While this method has proved effective it is also vulnerable in the long term due to the dependence on individuals. When the research started three experienced employees where leaving the company, bringing this vulnerability to the attention of Den Heijer Industries.

A move away from people based methods seems the logical move. In order to do so several problems need to be countered. First of all Den Heijer Industries needs to deal with knowledge in a more structured fashion. Knowledge transfers and knowledge reuse should no longer be the effect of personal initiative but of organizational procedures. Secondly the underlying reasons, the so called "why", behind products and theories needs to be retained for the organization. This knowledge is crucial for Den Heijer industries to survive, grow and remain competitive. Finally knowledge that exists within the organization, codified or in peoples heads, needs to be traceable. Already a lot of documentation exists but at the moment only a person involved in the creation of the document can efficiently trace it.

A multitude of possible solutions were considered and evaluated during this research. It is advised to start with implementing the design preview solution. This solution entails the structural gathering of knowledge within projects at certain points. By doing so early on in the project and embedding it in the process knowledge reuse actually becomes part of the organizational way of working. This solution has several advantages. First of all the costs are low and no initial investments are needed. Furthermore it can be fitted into existing procedures making the changes required limited and the chances of success higher. The solution can be applied to all of the parts of Den Heijer Industries that are knowledge intensive. It also fits with the main strategic intent of Den Heijer Industries, to grow, because the solution is also perfectly applicable in larger organizations. Main drawback of the method however is that while it effectively addresses the structure problem it does less to counter the "why" and the traceability issues. However this method can be integrated with other solutions that do address those issues but might stumble upon higher resistance due to organizational inertia. The design preview may help pave the way for other measures to be taken with the regard to knowledge management.

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1. INTRODUCTION

Knowledge is a factor receiving more and more attention over the past few years (E.g. Hislop 2005). Attention that seems to come from management guru's like Peter Senghe and the world of academia alike. This research aims to contribute to the field of knowledge management by investigating the effects of different knowledge methods, codification, personalization, people-based and product-based, on knowledge reuse and on each other. The research specifically focuses on a knowledge reuse within a project-based environment.

As of yet very little research is done about the interactions between codification and personalization methods (with Crossan et al. 1999, Haas & Hansen 2007, Hansen et al. 1999, Song et al. 2007 as notable exceptions). With regard to people-based and product based methods and their interactions with codification and personalization even less has been written. Therefore an in-dept approach has been chosen that aims at uncovering the how and why behind these interactions. A case study is a well suited approach since it can provide the amount of detailed required for this research (Yin 2003, p. 13-18).

Company chosen for this research was Den Heijer Industries, a holding consisting of several small companies all involved in cryotechnology. Because several experienced people will leave the company within several years, awareness of the importance of knowledge has risen with the management. And while the fact that people are leaving is not a something that can be avoided, one can give attention to the retention, sharing and reuse of knowledge in the organization.

Their problems make Den Heijer Industries willing to cooperate in a research about knowledge management. On the other hand Den Heijer Industries has several characteristics making it well suited for research in this area. The company is knowledge intensive. It gains its competitive advantage form being to able to design and develop high quality products. The limited size of the company makes it possible to interview all of the relevant actors involved with knowledge reuse.

This research will first present the theoretical background used throughout this study. Then the approach taken, including the problem definition, research questions and research methods will be discussed. Then the analysis will be presented, this analysis will then form the basis for both the practical solutions that will be proposed to solve the problems of Den Heijer Industries as well as an academic reflection on the interactions between different knowledge management methods.

2. OVERVIEW OF THE LITERATURE

In this section the framework that will serve as a framework for the rest of the study will be presented. This will be done by defining knowledge and the important aspects of projects in relation to knowledge management first. Then four different methods of reusing knowledge will be presented. Finally the literature with regard to the interactions between those four different methods will be discussed.

2.1 Defining Knowledge

Knowledge will be defined as the *justified adequate beliefs of people in combination with their skills and abilities.* This definition uses both the epistemological definition that derives all the way back to Plato [2003] and the addition of their capabilities used by more recent researchers (e.g. Tsoukas & Vladimirou).

The classic definition of knowledge that could be traced back to Plato was "the justified true beliefs of people". Hereby justified refers to the extent it is reasonable to have the belief and true is about whether or not it agrees with the reality. Especially the later has countered considerable debate as it is hard, if not impossible, to define the reality. While a philosophical useful definition organizations rarely search for the absolute truth. Rather they have heuristics and beliefs that are adequate that allows them to operate efficiently. Therefore the classical definition was changed to "the justified adequate beliefs of people".

This definition was added upon with the skills and capabilities of people (done before by e.g. Tsoukas & Vladimirou 2001) for two reasons; knowledge can be so embedded in a person it is not a conscious belief and in this research at Den Heijer Industries it seems valuable to give special attention to this part. With people leaving that have done their jobs for years and no longer consciously performing certain activities it is hard to classify this part of the knowledge as belief. Thus the final definition used is the *justified adequate beliefs of people in combination with their skills and abilities.*

Within the definition of knowledge a separation has to be made between tacit and explicit knowledge (Polanyi 1958; 1968). Explicit knowledge is knowledge that can be described and formalized. Examples are textbooks, maps or patents. Tacit knowledge on the other hand is less tangible and cannot be captured that easily. It mainly exists in people's heads and what they can do. Examples of tacit knowledge are how to ride a bike, deal with foreign customs. While different forms of knowledge they do overlap to some extent, knowledge hardly ever is purely tacit or explicit. However it remains important that knowledge consists of both of them and both have specific characteristics when dealing with them.

2.2 Project Characteristics

By having a project structure knowledge management becomes more difficult and more important at the same time. More difficult due to the temporary nature of projects, and it is hard to gather knowledge for reuse from something that is not in place anymore. On the other hand this is also the reason knowledge management is more important as conscious action is needed to overcome that barrier.

One of the main issues regarding knowledge management in combination with projects is timing. Knowledge can be transferred in a concurrent, between projects tat are running at the same time, or sequential, transferring knowledge at the end to new projects, manner between projects. Concurrent is considered the more effective one according to Nobeoka (1995). However this way of transferring is not possible all the time because projects cease to exist at some point. Furthermore projects need to exchange knowledge with the routine organization and visa versa (Disterer 2002). This can be seen as an extra step in a process of sequential knowledge transfers between projects or simply as heaving knowledge to the rest of the organization and back.

Regardless of what kind of knowledge transfers are in order, when they involve projects they will likely encounter some specific problems. The following list gives an overview of the most dominant in the literature.

- The common belief that projects are unique (Cooper et al. 2002) and therefore knowledge useful for one project is not necessarily so for another one.
- Discovering what caused the performance (Cooper et al. 2002); it may not always be clear what actually leads to the success of a project and in order to do so the enormous amount of data generated needs to be reduced (Davenport et al. 2001).
- The temporary nature of projects (Cooper et al. 2002, Disterer 2002, Newell 2004, Zedwitz 2003), at the end of a project a new one will start and will force the employees to move on.
- Successful employees are promoted (Cooper et al. 2002) leaving a knowledge gap behind forcing their successors to reinvent the wheel (De Long & Davenport 2003). Also the requirements for these employees are high and their training requires special attention (Rees & Porter 2004).
- Employees are not willing to admit mistakes (Zedwitz 2003). Therefore they withhold knowledge that could help other projects to prevent them from making the same mistakes.

2.3 Knowledge Reuse Methods

In order to reuse knowledge within an organization four different methods can be used by an organization. The simplest is having the same people do the same job again. Almost just as straightforward is using the knowledge that is embedded in the product and recreating the product or parts of it. The other two have fostered more attention from literature and are personalization and codification methods. Personalization involves bringing people together and having them share knowledge by that personal interaction thus retaining it for the organization and further reuse. Codification on the other hand attempts to separate knowledge from individuals and store it in for example databases ready for later use. This section will shortly describe each method together with its main strengths and weaknesses. For a table summarizing more of the literature on each of them see *appendix I.*

The codification method focuses on separating knowledge from individuals and preserving it in other ways for the organization (Hansen et al. 1999). This may be done by databases but also more old fashioned paperwork. Greatest strength of this method is that an organization that has codified its knowledge is no longer dependent on individuals and is easier to hold on to. Furthermore codified knowledge in general is easier to transfer and distribute, especially when it has been done digitally. Main disadvantage is that some forms of knowledge seem hard to codify (e.g. Davenport et al. 2001) and that even when successful people seem reluctant to rely on this form of knowledge (e.g. Hislop 2005).

The personalization method aims at bringing people together and facilitating knowledge exchange between them (based on e.g. Bresnen et al. 2003, Hislop 2005, Newel et al. 2006 & Styhre 2003). Chief advantage here is that by not directly managing the knowledge itself but rather the carriers of the knowledge no parts will be overlooked and tacit knowledge will also be transferred. Simple measures like the co-location of people have shown great results (e.g. Hansen et al. 1999). Disadvantages are that it is hard for an organization to directly monitor, reward and further increase knowledge sharing and reuse (Alvesson & Kärreman 2001). Therefore it seems hard to control and this often makes managers choose for codification methods (Hislop 2005).

The people- based method is about having the same person or persons do the same job again. A practice that is natural in most organizations for most of the time. Probably because of this commonness of this practice it is the method least covered in literature. Advantage is that one cannot forget to transfer knowledge and that it involves no additional costs. In the long run however there is the danger of an organization becoming overly dependent on individuals or groups of individuals. Furthermore knowledge is not spread through the organization which limits knowledge reuse to the ones already possessing it.

The product-based method focuses on the knowledge inherently embedded in the product and reusing it by recreating the product. (e.g. Blackler 1995, Baldwin & Clark 1997, Muffato & Rovenda 2002). Give someone with general knowledge of mechanics a certain contraption and he might be able to figure out how it works (e.g. Buss 1994). The same goes for a programmer and a piece of software, the architect and a building and so on. If one takes this from a knowledge management perspective one can also use these products as a way of transferring knowledge or making transferring knowledge not necessary. One way of doing so is by creating modules that can be exchanged for other modules (Ulrich & Tung 1991). Different modules can be developed in different parts of the organization and then combined. The difficulty herein is twofold; first the interface in which the modules are used must be very narrowly defined thus lessening the flexibility of the product as a whole. The second difficulty lies in the risk of not optimizing the whole when just looking at single components. Another possibility is the creation of Platforms (Robertson & Ulrich 1998, Yang & Yiang 2006) where products are derived from a platform, a certain standard.

2.4 Interactions between Different Methods

A company does not need to choose either one of the four methods exclusively but can rely on a combination of them. Personalization and codification methods have received by far the most attention in the literature. Attention to a combination of both, let alone related to people and product methods, is rare. The literature also lacks regarding the coverage of people-based methods and product-based methods. Research that investigates the four of them as a whole was not to be found.

First of all it is possible that there will be negative effects when using both codification and personalization strategies at the same time. These methods could be redundant or partly redundant requiring a lot of effort for little extra gain. Also they draw time and energy from the employees, employees for who knowledge sharing is not a core business but more a facilitating activity. Hansen et al. (1999) state that depending on the company one of the two methods should become dominant. They even mention a division of 80 percent of the efforts on codification strategies and 20 percent on personalization strategies, or visa versa. Finally it can be the case that a company, a department or a person works with a specific type of knowledge that is suited for only certain methods, making other methods obsolete.

However using multiple methods can also be beneficial. The redundancy of the methods and the specific types of knowledge that require specific types of knowledge arguments may also be turned around. Methods may not be redundant and companies may deal with diverse knowledge types each asking for different methods. Furthermore according to some authors (Nonaka and Takeuchi 1995) a process of enlarging, sharing and justifying knowledge takes place in which both methods take their own role and are both needed for successful knowledge management. Last but not least, use of different methods may encourage users of one to start using others, thus creating synergy. Song et al. (2007) found that codification methods and personalization methods enhancing each other.

The last way the different methods may influence each other is if one enables the other. An example is that people are only willing to enter their information in a people finder system if the culture is positive towards knowledge sharing. If one looks at the interactions in this manner one actually creates priorities. It may not be useful to invest large amounts of money into IT-based systems or into arranging communities of practice without the willingness to actually commit to these things.

All together the literature can be summarized as is done in *figure 2.1*. The organization contains knowledge and transfers that within the organization and projects with four different methods. These four methods in turn also influence each other. For reasons of clarity only one project ahs been displayed but of course multiple projects can be present in the organization at the same time.

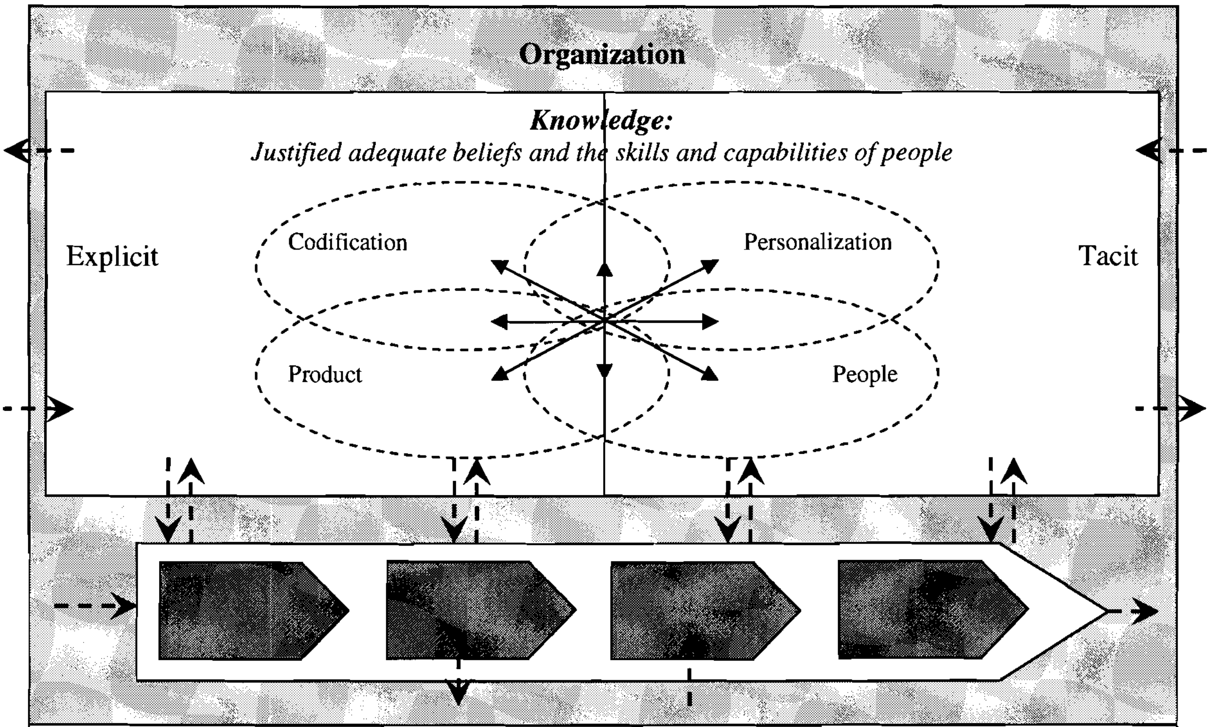

Figure 2.1: Interaction between different methods of sharing knowledge

3. RESEARCH APPROACH

As mentioned in the introduction this research was based upon a case study. This section will give more exact specifications as to the company where it was done, the exact problem definition and the research methods.

3.1 Company Description

Den Heijer Industries is a holding consisting of several companies of which the majority is located in the Netherlands but the service organization in India. All companies are involved in cryotechnology, technology that involves extreme low temperatures. The largest is Stirling, producing machines that create liquid nitrogen. Furthermore, while they serve a worldwide market, Den Heijer Industries is a rather small firm. This is mainly due to the fact that they do not produce their machines, but design them, order the parts and assemble them. Standard machines are used but always custom tailored for each customer, which can involve minor details and large changes. Despite their size they are market leaders in their specific area of liters per hour liquid nitrogen produced. There market mainly constitute of research institutions, either government controlled or company controlled, and KI-firms. The liquid nitrogen produced by the machines is mainly used for storing biological tissue and nuclear research but has also been applied in for example metal working or the development of space satellites. Furthermore their products are popular with institutions that want to either control their own production of liquid nitrogen or that are not connected to a good infrastructure that allows for regular deliveries of liquid nitrogen. For a more detailed description of the products of Den Heijer Industries see *appendices II* and *III*.

Den Heijer Industries aim to compete with high quality products in their current markets and to grow both in the current markets and into new ones. This high quality is best reflected in the large lifespan of their products, some of them being in the field for over forty years. Growth is achieved in several manners. First of all a new company was started within the Den Heijer Industries named CryoZone. CryoZone creates cryostats, spaces that preserve the cold. They aim at complicated situations in which the expertise of Den Heijer Industries can be used and in which profits are higher. Due to their size, three persons at the start of the research, they are not able nor do they want to produce simple standard cryostats. Aside from CryoZone they plan to increase their market with two different products. The first is the StirLab, a noiseless liquid nitrogen dispenser for laboratories that can produce liquid nitrogen in small quantities (two liters per hour). The main advantage is that it can easily be produced in larger quantities as it requires no customer specific tinkering. Finally Den Heijer Industries is developing the CryoSphere. Based on the same Stirling cycle principles this machine is created in such a manner it can work continuously for extreme long periods without maintenance. This product is aimed at the perceived future market of cooling electricity cables thus reducing resistance to zero. This market is potentially very large if, as of yet, still in the early stages of its development. For a more detailed description of Den Heijer Industries see *Appendix IV*.

3.2 Problem Definition

While the actual interest for this study was sparked at Den Heijer Industries due to the nearing retirement of three experienced employee's this is not the problem. Rather the fact that Den Heijer Industries has not secured the knowledge they posses for the organization and their inability to do so, is considered the problem.

This problem definition widens the scope of the research from simply securing the knowledge of the people that are currently leaving to the complete organization. Therefore all departments using, reusing and creating knowledge fall into the scope of this research. For Den Heijer Industries this means the research department and the engineering department of Stirling and CryoZone. The knowledge reuse within and between these parts of Den Heijer Industries will be investigated.

3.3 Research Objectives

The objective of this research is to gain insight into how Den Heijer Industries currently reuses knowledge and how they can improve upon this. Specific attention hereby will go out to the different methods that are used now, the interactions between them and which methods should be used in order to remedy the current knowledge related problems at Den Heijer Industries.

Academically speaking the goal is to gain more insight in the interactions between people, product, codification and personalization methods.

3.4 Research Questions

In order to structure the research several questions have been formulated. The first two questions will determine whether there really is a problem and what causes that problem. Together the answers to these two questions will form the analysis phase. The third question will focus on possible solutions. The design part of the research will originate form these questions. Finally the last question will address the contribution to the literature that this research will try to make.

For the research to be justified it should be examined whether or not the problem really is a problem. In order to gain that insight the current way of working within Den Heijer Industries in relation to knowledge management should be know. The different sub-questions deal with how much knowledge is reused and how much could be reused. When answered it will be clear why Den Heijer Industries reuses knowledge and consequently the problem proposed in section 3.2 can be justified on the basis of those answers.

Research question 1: Is there really a knowledge reuse problem within Den Heijer Industries?
1.1: How much does knowledge reuse occur at the moment?
1.2: How is the knowledge reuse structured at the moment?
1.3: How much possible knowledge reuse does not occur at the moment?

If the answer to the first question is that it will be worthwhile to improve upon the current way of reusing knowledge within Den Heijer Industries the second question will address the reasons for why it is not done optimal. In order to do so the current way of reusing knowledge will be investigated in detail. Furthermore specific problems will be sought after.

Research question 2: What causes the knowledge reuse within Den Heijer industries to be not optimal?
2.1: What are the characteristics of the knowledge reuse process of Den Heijer Industries?
2.2: Which problems does Den Heijer Industries encounter when reusing knowledge?

Research question 3 aims at improving the situation in the different companies within the holding. In order to do so the limitations that are inherently present at Den Heijer Industries when implementing certain solutions should be known. Furthermore the different methods, people, product, codification and personalization, need to be evaluated and see to what extent they fit with Den Heijer Industries. This includes which methods are currently used, which should be used to deal with specific problems and whether or not the

Research question 3: Which solutions can one apply to Den Heijer Industries and how does one apply them to Den Heijer Industries?
3.1: Which limitations are present when trying to improve knowledge reuse?
3.2: Which methods fit best the situation at Den Heijer Industries?

The final set of questions is more theoretically focused and deals with the question how different methods interact with each other. By answering this research question it is meant to make a contribution to the literature. If these interactions are observed the sub-questions deal with what to do after this observation. First the question will be how these interactions can be controlled and the potential damage they do reduced or the potential benefits directed. On the other side it may be the case that certain methods are more useful in certain situations, and one of course wants to know which method fits which situation.

Research question 4: What are the interactions between different types of knowledge management, personalization and codification methods, in a project-based organization?
4.1: If present can these interactions be controlled and of value to an organization?
4.2: Which types of knowledge sharing fit in which types of situations and with what types of knowledge?

Answering these questions should both help solve the knowledge related problems Den Heijer industries faces as well as giving extra insights into the field of knowledge management.

3.5 Research Methods

In order to gain an in-dept understanding of the both the situation at Den Heijer Industries and the knowledge management methods used interviews will be held. Interviews are the best method to gain this thorough understanding (Yin 2003a). In order to do so the researcher however must have a grasp of the issues being studied (Yin 2003a, p. 65-66). The researcher therefore took several actions to gain an understanding of how people work at Den Heijer Industries and about the products they create. The researcher participated in large parts of a service course given to customers over the course of a week. This was for a large part to gain insight in the terminology used and to get a basic understanding of the Stirling machines. Without this knowledge the researcher would have been unable to grasp some of the stories gathered in later stages of the research. Aside from the more technical side the researcher was informed regarding the organizational side by management, staff of the different departments and documents regarding procedures and organizational structure.

Research question 1: Is there really a knowledge reuse problem within Den Heijer Industries?

Answering this question has been done in two steps. The first was to discover how the process of knowledge reuse occurred at Den Heijer Industries. The second was to look for incidents where knowledge reuse could have happened but did not.

Since the process of knowledge reuse is not formal at Den Heijer Industries the process used natural by individuals needed to be discovered. Semi-structured interviews were held in order to gain sufficient insight. During these interviews the interviewees were asked to support their words with proof in the form of drawings and other examples. The protocol for these interviews can be found in *appendix V*. Interviews were considered the best way to uncover this knowledge, partly because it was tacit (Schindler & Cooper, 2003, p. 319-335) and partly because the memory of individuals is the only place where it was stored.

Additionally closed-interviews, see *appendix V*, will be held regarding the knowledge needed to do their work. Every employee within the scope of the research will be asked which knowledge he or she posses and needs to do the job. Furthermore the each individual will asked which knowledge his or her department should posses to function effectively.

After the process of knowledge reuse has been mapped a search for failures to transfer knowledge was done. People were asked to remember problems that could have been prevented by reusing knowledge. Knowledge reuse that could have happened but did not lead to problems, but possibly to increased costs or lead-time, were not sought after. The reason is that when people were not able to identify these reuse opportunities then they will not be latter. These problems did not need to be recent. As the number of projects finished each year is limited, and the number of complicated projects even more so, the number of problems identified recently was small. Furthermore problems may not be recognized immediate and surface in the fields many months after the completion of a project. The protocol for these interviews is placed in *appendix V.*

Main issues will be the memory of the people involved. They however are the only ones able to identify whether or not they have reused knowledge and which knowledge they have researched. Furthermore during the second part people might be reluctant to admit to mistakes they made. This could have further limited the amount of problems as a result of failing to reuse knowledge.

Research question 2: What causes the knowledge reuse within Den Heijer Industries to be not optimal?

Where the first research question aimed to find out what was happening and how it was happening the second reason aims at why thins are happening in such a manner. This means processes and problems uncovered answering the first research question will be evaluated. Whenever it was necessary follow-up interviews were conducted. Phenomena leading to knowledge management problems or leading to current practices were uncovered.

Additionally a new employee that started during the course of the study was followed. By conducting interviews with him each week, knowledge related issues he faced were discovered. The protocol for these interviews can be found in *appendix V.* The new employee did not replace someone directly and therefore the situation will not be identical to the three people retiring. Nonetheless it will provide additional insight in how a new employee gathers knowledge within the organization and which problems he faces.

Research question 3: Which solutions can one apply to Den Heijer Industries and how does one apply them to Den Heijer Industries?

The problems and phenomena uncovered during the first two questions where used as a starting point for selecting possible solutions and evaluating them. These solutions were mostly obtained and adapted from the literature.

Several other companies will be visited. A part of these companies will be companies that can be used as a benchmark for Den Heijer Industries. Problems they encountered and solutions they have used serve as extra insights for evaluating the situation at Den Heijer Industries. Furthermore possible solutions can be judged by how well they, or similar solutions, performed in practice. Other companies that were visited were companies involved in knowledge management. This was mainly to get an insight in possible tools one could use to improve knowledge reuse.

Research question 4: What are the interactions between different types of knowledge management, personalization and codification methods, in a project-based organization?

This question will draw upon the information gained in order to answer the previous questions. By combining those findings and logic reasoning it should be possible to extend upon the current academic knowledge base. During the nature of a case study no definitive findings will be sought after. Rather new interactions between different ways of knowledge management will be explored.

4. ANALYSIS

Within this chapter the first two research questions will be answered. In the first section the reuse structures will be described on three different levels; within a technical field, within a department and between departments. The structure of reuse at each of those levels will be analyzed and when possible examples of actual reuse will be given. At the end of each subsection these structures will be coupled to the earlier presented methods of knowledge sharing; personalization, codification, product-based and people-based. Then those findings will be combined into an elaboration of the earlier presented problems. From this elaboration multiple core problems will be extracted and those will be placed in an organizational and theoretical context.

4.1 Reusing Knowledge

Reuse within Stirling exists within several different levels. There is reuse within the same technical function, within a department and within the organization. The first requires just a little sharing as most technical functions are covered by a limited amount of people within Den Heijer industries. But to reuse knowledge as a department or an organization knowledge needs to be available for others and thus needs to be transferred. *Figure 4.1* gives a graphical representation of the knowledge transfers that happen at the moment within Den Heijer Industries.For the reuse within a technical function of this is done by describing the general method that is used for reuse for three different technical fields; mechanical, technical and software, as well as examples in each of these three fields. This is done within the engineering department as technological functions here are clearly defined. This department also creates the drawings which will facilitate the mapping of reuse. For each technological field, mechanical, electrical and software, both the process as well as a concrete example will be given. Research, service and CryoZone will not be taken into account in this section. This is because of the limited reuse within a technical function, within research because as of yet it is too unstructured to talk about reuse, within service because they mainly reuse knowledge of the engineering department and within CryoZone they do not yet exist long enough to reuse their own knowledge.

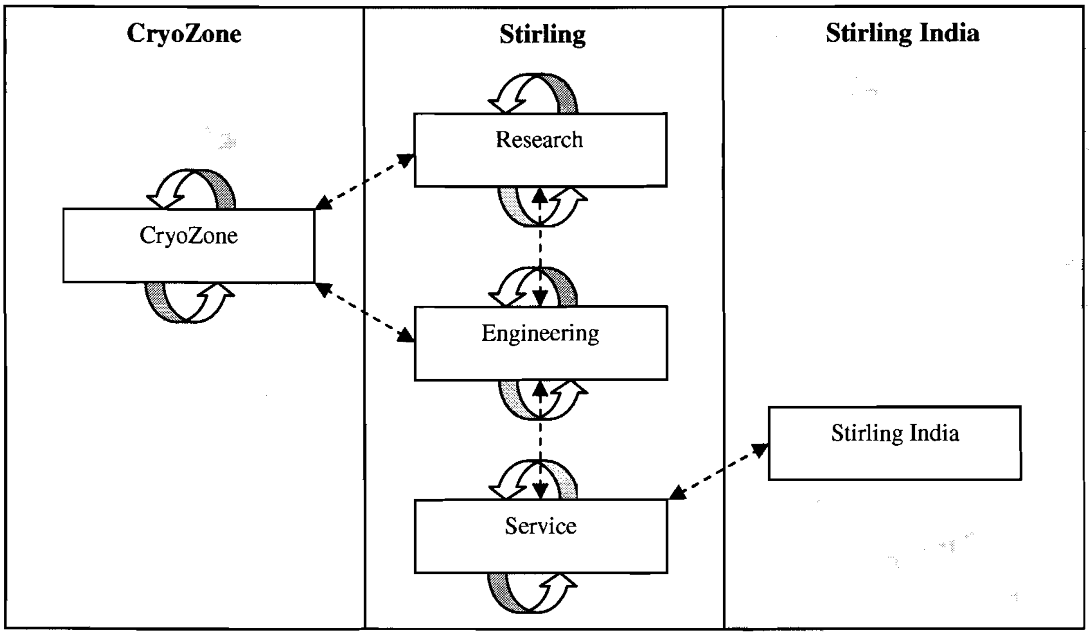

Figure 4.1: knowledge transfers between departments and companies

After that knowledge sharing within a department will be discussed. *Figure 4.1* displays which departments are of interest to this study. CryoZone will be considered as a department due to the small size of the company. Within Stirling attention goes out to the research, the engineering and the service departments. Finally Stirling India will not be considered due to earlier mentioned reasons of feasibility and added value.

The third part handles the remaining arrows in *figure 4.1*, namely the knowledge reuse and sharing between departments. Which barriers need to be overcome in and what problems are faced when stepping out of the boundary of the department or even the company?

The final part of this section concerns reuse not done. This is harder to do since there is no process for not using something. Therefore this will be done, with information gathered through interviews as described in *section 3.5*, by using a critical incident approach. This is not really exhaustive and will only highlight examples of not reusing knowledge that have lead to problems. Overall the goal is to get insight into how much knowledge reuse does occur at the moment and how it occurs and when it does not occur.

Reuse within the same function

Knowledge reuse within Stirling is relatively hard to trace. This is because it happens at a persons own initiative. Furthermore reuse is not registered and cannot be traced in a database. Therefore processes will be described for each technical field. These processes are not organizationally imposed but have emerged over the years as people wanted to reuse their own and others work. These process descriptions will be supported by concrete examples and images will be presented in order to illustrate these. Furthermore a distinction is made between special projects and regular projects. Regular projects mostly include the majority of both the StirLIN1 compact and the StirLIN1 economy but different technical fields can classify projects in a different manner. A rerouting of the piping for example influences the mechanical design but will have no impact at all on the electrical and software design. Everything in this section is concerned with the engineering department and almost all reuse is done by one person. Basically it closely analyzes how persons reuse their own knowledge although in some rare cases the work of others might be extracted from the archive.

Mechanical: Mechanically speaking projects of different complexity are handled by different project leaders. The project leader for the less complicated projects deals with the majority of the projects, see *appendix IX*. The main task here, except for actually realizing the projects, is keeping the designs for the basic machines up-to-date by dealing with change proposals. These proposals have different origins and can be due to changes by the supplier, a change of supplier, research, comments from the assembly crew or feedback from service. The actual changes that are made for the standard projects almost always involve process technical changes. An example is when the customer wants a cold gas as an end-product instead of a liquid substance. In order to produce such a machine heaters need to be integrated in the machine.

For the special projects large parts of projects are taken from previous designs. For certain parts, like fittings, it does not really matter from which projects these are taken since they are similar in most of the cases. For other parts it is necessary to compare multiple projects in order to see which can be adjusted with the least effort to the new situation or if it is possible at all to make the adjustment. This process of looking at multiple previous drawings and comparing them is highly experience dependent. This is not due to the nature of the task itself, a mechanical engineer with skill in CAD could accustom himself to the task, but due to the fact that the input is otherwise hard or impossible to retrieve. At the moment this is done purely on the basis of the memory of the respective employee. The large history of Stirling in combination with the fact that mechanically the core of the machines has not changed fundamentally makes the possible amount of data from which useful information is to be retrieved large. Examples were found of drawings that went as far back as 1990 but were still partly used for the creation of new machines now, eighteen years later.

In *figure 4.2* a more specific example is given for project J0505, a StirLIN4 that was produced recently. All of the reuse explained here was done on the basis of memories and reusing ones own work. This specific machine needed to have all its entry- and exit-points at one specific point. Furthermore it needed a certain height adjustments to make room for internal piping. The cap from project J0490 also was heightened and thus this was used as a basis and entry- and exit-points were adjusted. In turn, for project J0490 the cap was a heightened version of the cast-iron cap used in J0375. And finally the cap of J0375 was the result of a change in the machine that

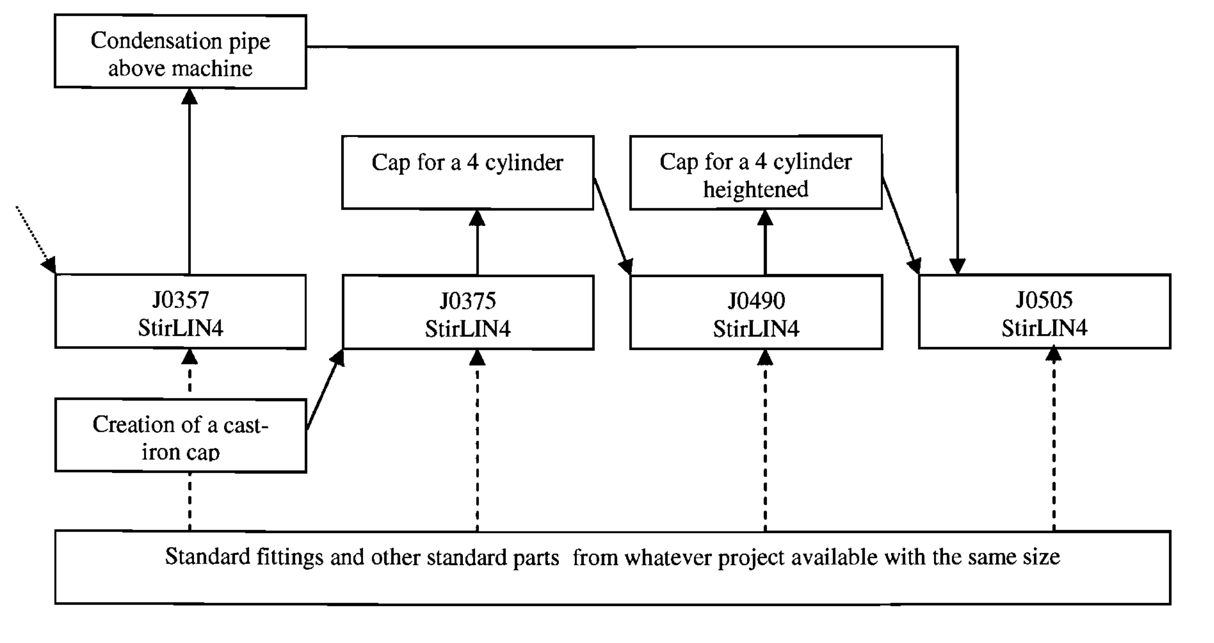

Figure 4.2: Reuse mechanical example for special project J0505

resulted in slightly larger different cap requiring a change in cap creation. Designs using folded plates were first tried but when that proved to be impossible cast-iron was used. Something similar happened regarding the condensation pipe that was placed above the machine. This happened before in project J0357. Which project provided the starting point for that specific design was no longer remembered by the project leader involved in all these projects. Furthermore all of these projects drew upon earlier designs with regard to fittings and the like. Because there is a multitude of potential sources for the design of those parts the project leader in question could not remember any specifics on those.

<u>Electrical:</u> There are two large differences between knowledge reuse regarding the electrical design and the mechanical design aside from the fact that it are two different fields of expertise. First difference is that while there are multiple engineers concerned with the mechanical design

there is only one for the electrical design. The other difference is that the size of machines or the number of turbines only has a minor effect on the electrical design. As a result it may happen that some parts of electrical designs from very large machines can be ported to machines that are completely different in size.

However what is the same for both a mechanical and an electrical viewpoint is that the majority of the standard projects are StirLIN1 machines in either the compact or the economy variety. For these two machines there are also versions that are kept up-to-date and used for each project that involves the machine concerned. At the moment there is no such basic design for other machines although the engineer involved is currently working towards such a design for the StirLIN2 machines. This process is hampered by the variety in other components due to changes imposed upon Stirling by the suppliers.

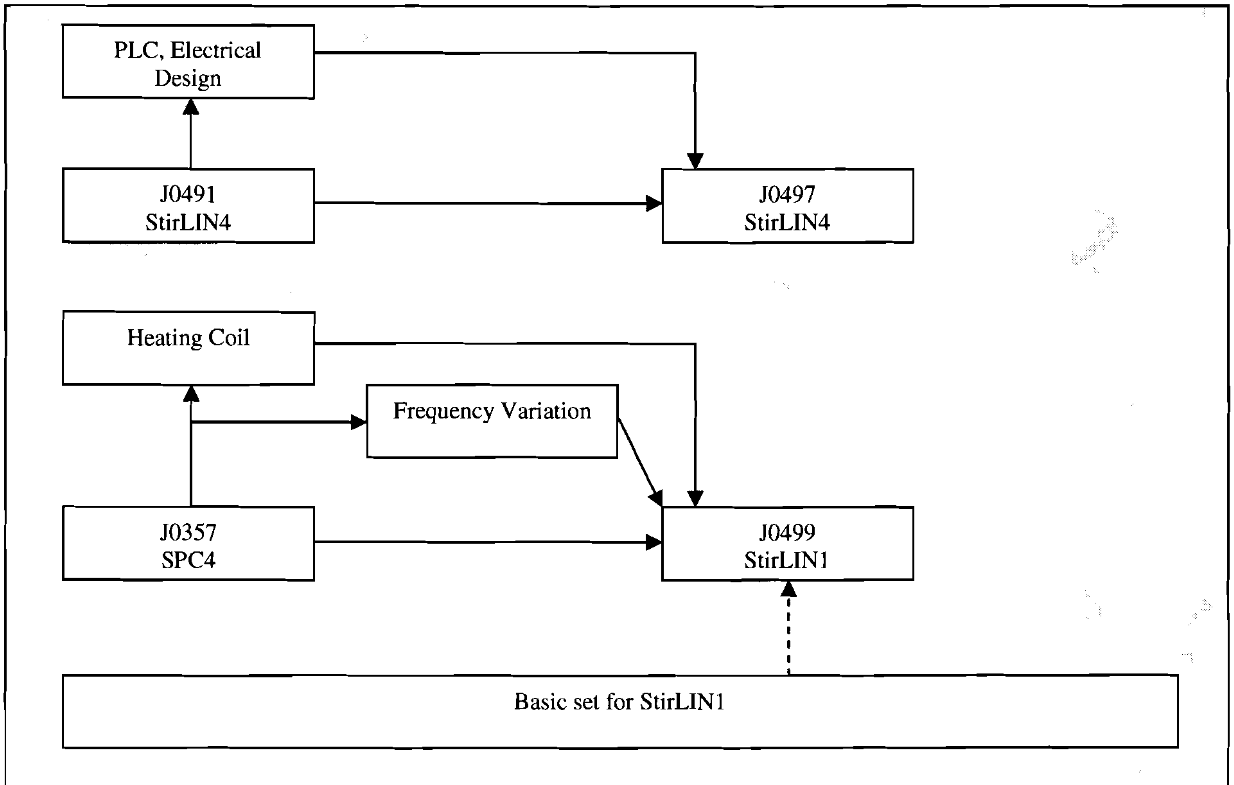

Figure 4.3: Reuse electrical examples for project J0497 and J0499

In *figure 4.3* two distinctly different examples are displayed. The first deals with the a StirLIN4 machine, J0497, whose design was so similar electrically speaking that it could be ported almost completely from a recent other project, J0491, also a StirLIN4. The second example may be more illustrative, here knowledge was reused from a project that was fundamentally different than the project it was used for. J0499 is a project that required a StirLIN1 with some modifications. Because it was a StirLIN1 the accompanying set was used as the basis for the electrical design. Following that two features were implemented from project J0357, a completely different machine. The two functions that were reused were a heating coil that prevents the liquid nitrogen from becoming solid and the possibility to adjust the frequency in which the turbine goes round thus controlling the quantity of liquid nitrogen produced.

Software: As with the electrical design the software design is created by one person. But even more than is the case for the electrical design the software design is reused intensively. Sometimes only certain variables have to be adjusted when a change occurs and often nothing has to be changed at all. Therefore there is basic software for the smaller standard machines that sometimes needs minor adjustment in the variables.

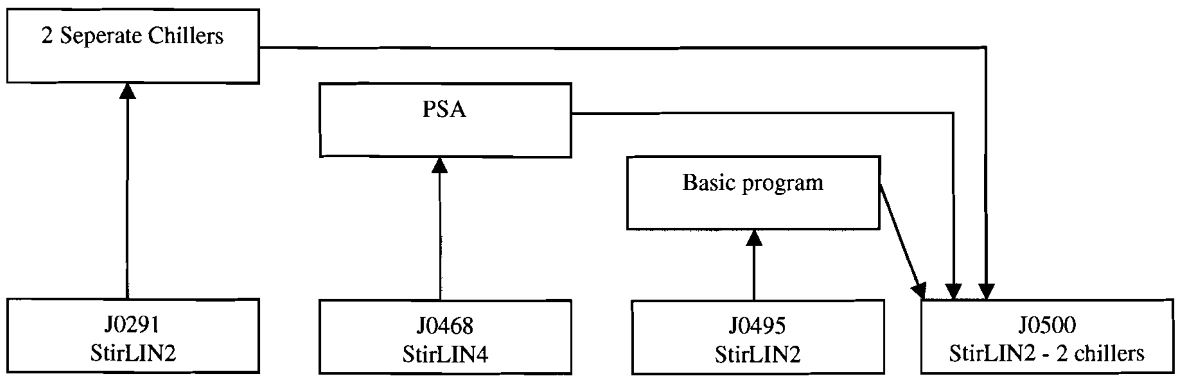

Figure 4.4: Reuse software examples for project J0500

For the more special projects a complete new program is created or parts are gathered from several previous projects. Of the former a very large unique project Stirling is currently working on is a good example. This project requires a completely new program with an underlying idea not present in any other machine previously created by Stirling. Of the latter an example is depicted in *figure 4.4*. This project was special because the customer already had a machine and wanted to order an identical one to the one they already had. That machine had two chillers that were controlled separately for each turbine in the machine, in this case two because it was a StirLIN2. However Stirling switched from that approach and adopted a way where the turbines are considered as one and controlled as one. This change was made quite some time ago and therefore the project used as a basis for this part, J0291, was from 2003. Furthermore the PSA, the pressure swing absorption, the device that separates the oxygen and the nitrogen from the air had been changed. The latest project using that specific PSA was J0468 and while the machines were different this makes no difference for controlling that specific part. Finally these two old parts of programming were implemented in the most recent program for a StirLIN2, project J0495.

	Mechanically	Electrical	Software
Codification	• Stored per project number • Memory of previous projects main method of locating previous projects for reuse • Basic designs available for some machines	• Stored per project number • Memory of previous projects main method of locating previous projects for reuse • Basic designs available for some machines	• Stored per project number • Memory of previous projects main method of locating previous projects for reuse • No basic designs available, pure iteration from previous projects
Product	• Large source of knowledge is stored in the product • Old solutions keep their relevance for a long time	• Large source of knowledge is stored in the product	• Large source of knowledge is stored in the product • Old solutions keep some relevance for a long time
Personalization	• People give each other help in finding correct documentation • Verification of solutions happens often • People are aware of each others expertise	• Not really happening due to the amount of people involved	• Not really happening due to the amount of people involved
People	• Specific jobs are almost always done by the same person • Some redundancy to a certain extent	• For a large part the work is done by one person • Some other persons in the organization are also capable of electrical work to some extent	• One person does all the programming • Highly dependent on that one person • Other persons do communicate regarding the software but not about the actual programming part

Table 4.1: knowledge sharing characteristics and problems within a function

As can be seen in this table reuse is mainly people-based within a technical function. For the mechanical part and, to a lesser extent, the electrical part the knowledge is present in multiple places in the organization. However for the software part Den Heijer Industries is solely dependent on one person. Furthermore it should be noticed that while both the product and codified knowledge is present and used as a source of knowledge this is mainly to support the people-based method. Personalization does happen for the mechanical part but in an uncontrolled manner.

Reuse within the same department

This section will address the storing, sharing and reuse of knowledge within the same department. For each department different methods of doing so will be discussed and like in the previous section characteristics and problems for each of them are summarized in a table at the end of this section.

Research: Researchers at Stirling have, to a certain extent, an overlap in expertise which allows them to easily share knowledge with each other. The main method of working however is still mainly people-based. Codification and product-based method are used to some extent but not intensively. Research seems the least structured part of Den Heijer Industries which can lead to neglecting possible valuable knowledge already present in the organization.

Stirling research uses so called R-numbers to denominate research projects and relevant information is allocated to these project numbers. However there is a division between "jobs", projects started by engineering which require research and that are customer driven and have a deadline and research driven projects. The division between these two kinds of projects is estimated to be 50-50 by the members of the research departments. Furthermore there exist documents containing a lot of knowledge regarding working with low temperatures and the Stirling cycle. However these documents are not kept up-to-date for many years and are at the moment only available in hard copy in a few different versions. At the moment when retaining knowledge no attention is given to how suitable for reuse the knowledge is. But also the products still contain knowledge relevant for research. This is due to the large history in which Philips had many more researchers and resources working on the Stirling engine. This resulted in machines being tested continuously for more than a year (Hargreaves 1995), practices that nowadays are unthinkable. An actual example observed was that one of the researchers was looking at the counterweights in all the cut open Stirling machines displayed throughout the building for aesthetic purposes. He wanted to know why there was a shift in size and first wanted to determine when this shift had happened. This is related to the phenomenon described in *section 7.2*, that the old reasoning is still valid but that the underlying reasons are not always remembered. In terms of personalization methods the only one that is, unconsciously, applied is co-location. Speaking in terms of people much more different strategies can be observed namely a high functional diversity, a culture that encompasses the willingness to share knowledge and a detailed and practical understanding of the field.

Engineering: The majority of the knowledge reuse at engineering is done using people-based methods, focuses on a technical field and was described in the previous section. There is however also knowledge exchange between the people and in such a manner knowledge is also reused. Because of the highly specialized way of working this happens only to a limited degree. At the engineering department of Stirling all documents are allocated to a project, a so called J-numbers or Job-numbers. Furthermore there are the standard-designs for the more frequently constructed machines as described earlier in this chapter. The reuse of previous products or projects is likewise described in that same section. Furthermore, like in the research department, all people working in the engineering department are, with exception of the software engineer, located in the same room. Due to this co-location no other personalization methods have been implemented. Also, to a lesser extent than the research department there is functional diversity. On the other hand it can be argued the phronesis, the detailed and practical understanding of the field, is even higher in the engineering department. And the culture is something that is present throughout the whole organization and not limited to a single department.

Service: Of all departments of Stirling that fall into the scope of the research the service department contains the least technical product related knowledge. They function as an in-between for the customers, Stirling's engineering department and Stirling India. The functional knowledge they possess on how to fix machines is completely derived from the engineering department. One can find an elaboration on this role as an information provider in the next section. The only part of knowledge that is stored and operated by this department consists of the manuals. Archiving is partly product and partly project-specific based. The more detailed manuals meant for answering specific customer questions are also managed by the service department but rarely reused.

CryoZone: CryoZone is such a young company that it has not yet generated enough knowledge to reuse itself. Projects are also fairly unique and therefore CryoZone tries to capture knowledge separate from projects rather than relying on past, customer specific projects. Furthermore personalization methods are shared intensively because every person works on each project. In combination with the specialized knowledge of each individual this often amounts to integrating knowledge rather than sharing it.

CryoZone has two main methods of codifying knowledge. The first is similar to that of Stirling and records project related information. Due to the uniqueness of the projects and the small amount of projects done at the time of this research their use for knowledge sharing is lower than for engineering. The chance that somewhere in the future the corresponding file for a project is used is not that large. This is also the reason products are not considered a source for knowledge sharing or storing at CryoZone. On the other hand more fundamental research is done at CryoZone and results are stored in documents and specifically computer programs that have a wide range. This wide range makes them applicable for future problems concerning the same variables. Personalization methods at CryoZone are used in the form of co-location. However due to the fact that the three persons presently working there each have their own field of expertise, and can even be considered as separate departments, only a limited amount of information needs to be shared. Finally they are currently attempting to gain extra knowledge through people methods, namely by hiring new people with expertise (3D-drawings) currently not available.

	Research	Engineering	Service	CryoZone
Codification	• Project-based • No clear structure • No distinction between types of	• Traceability • No explanation/ descriptions with drawings.	• Manuals, both specific and general	• Not really relevant yet due to relatively unique projects and short existence

	knowledge			• Programs contain fundamental knowledge
Product	• No complete understanding of the "why"	• Contains much relevant knowledge • Not always known • If known only by a limited group • Contains not only "why" knowledge but also "why-not"		• Previous projects/ products not relevant
Personalization	• Lack of structure • Ad-hoc basis	• Lack of structure • Ad-hoc basis	• Different persons have different tasks due to the small size • Experience from senior transferred	• Different scope of job per employee • More integrating than sharing
People	• Three new people and one with six years of experience • Each person has his own expertise	• Very dependent on one person doing the same work • Three persons retiring within three years	• Limited amount of people makes that the job is always done by the same person	• Each person doing the same job • Same persons working on all projects • Goal to attract a construction engineer

Table 4.2: knowledge sharing characteristics and problems within departments

Reuse within a department seems very people-dependent. Furthermore when personalization methods are used this happens in an unstructured and ad-hoc manner and there is no way of knowing for sure whether or not relevant knowledge is shared. When using codified knowledge people seem to run into traceability problems and need to rely on their own or other people's expertise to locate relevant documents. Finally especially research faces trouble when extracting relevant knowledge from codified data or products as they want not to replicate those data or products but rather benefit from the insights that lead to them.

Reuse between different departments

When looking at the different relationships in *figure 4.1* five different paths for transferring knowledge in-between departments and companies are shown. Of these five the two between CryoZone and Stirling will be discussed at the same time. As in the previous section the four different approaches of sharing knowledge will be evaluated. Following this the information exchange with the customers will be discussed, while this falls more or less outside of the scope of the research it still is interesting for the bigger picture. Finally, as in the two previous sections, characteristics and problems when transferring knowledge between departments and companies will be discussed.

Research-Engineering: Research and engineering each present considerable value to each other. Engineering has much experience with the old products and know "tricks" that can deal with certain problems. Research on the other hand has a more thorough scientific understanding of the process and more knowledge about the new products. Despite this interactions between the two happen on an unstructured basis do not seem really intensive.

While both have the same manager, engineering and research are situated in different rooms, albeit in the same building, and have different tasks. While these tasks are different they do share some common ground. And not only does engineering need information from research about new machines, research needs the expertise and experience of engineering for the old machines. Due to the organic growth of the company Stirling and because the core of the machines produced have not changed for quite a while, a lot of relevant product knowledge is located at the engineering department. So in developing products, an important source for research is the engineering department of their own company. Knowledge also flows the other way around as engineering consults the research department on certain topics, for example; advanced strength calculations, advanced thermodynamics and the newer product types. But the real issue is that knowledge needed for research is located at the engineering department and that it is not known what the limits to that knowledge are. That in turn results in an unstructured process when it comes to knowledge sharing. If one might think the other department knows something about the at that time relevant topic the person involved walks to the other department and asks for solutions or directions to old documents. This haphazard way of working does in no way ensure that the available knowledge is used when it is applicable. It is highly dependent on the insight people have in the amount of knowledge people at other departments posses.

CryoZone-Stirling: Between CryoZone and the research and engineering departments at Stirling there also are a lot of technical knowledge related transfers. The big difference between the link of research and engineering and CryoZone and Stirling is that the first is a more or less equal connection and in the latter CryoZone is receiving more knowledge than it is sharing. This information shared however is not always fully applicable to the issues faced by CryoZone. For example software simulations are redone or extended in order for them to have a broader scope. All exchanges go in an informal and personal way. Most of them concern checking or verifying certain solutions or information. And although CryoZone and Stirling are separate companies they are located in the same building and therefore employees treat each other as colleagues (with some jokes as exceptions). The researcher of CryoZone was in her first months even located in the same room as Stirling's research department facilitating personal contact. Occasionally projects are done in which both companies are involved blurring the boundaries even further. Finally an experienced technical sales employee from Stirling was moved from Stirling to CryoZone. While sales does not fall into the scope of this research this employee was technically competent which is why he is not only able to negotiate with customers about specification but even help to co-develop the products.

Engineering-Service: In order to provide customers with adequate service a certain amount of knowledge needs to be present at the service department. This does not mean that the full product and project knowledge is available at research and for specific or complicated problems they still will need to resort to engineering for assistance. The other way around service collects and categorizes information about the problems reported by customers. When structural or very critical problems surface they will inform engineering and further furnish them with extra details from the field when available. Even if the problem appears to be so complicated that research needs to be involved service will report to engineering and there the decision will be made whether or not to involve research.

Service-India: Communication between the service department in the Netherlands and the service company in India is limited to instructions and basic information. At the moment the only lines of communication present are those regarding when machines need to be installed and which need service. In other words, no technical knowledge is transferred. However the people involved in service within Stirling feel that it might very well be that service technicians in the field may have some know-how that is valuable to one or more departments of Stirling. As this link is currently non-existent nothing conclusive can be said here. While it does not fall into the scope of the research it is worthwhile to at least state that Stirling also transfers considerable amounts of knowledge to its customers. The service department benefits from customers who know their machines and can localize problems. Therefore training courses are offered on basic maintenance and the underlying principles of the Stirling cycle.

	Research – Engineering	**Stirling - CryoZone**	**Service - Engineering**	**Service - India**
Codification	• Research reports unstructured • Engineering archive hard to locate • Engineering archive hard to determine whether or not valuable knowledge is present	• One way, CryoZone absorbs and uses relevant documents of Stirling • CryoZone extends software simulations of Stirling research to a larger scope	• Feedback on customer complaints quantitative	• Relevant documents and drawings for machines are emailed when needed • Only descriptive feedback of what is wrong from India
Product	• Prototypes	• Parts that are relevant are shared, although relevance is sometimes hard to determine		• Errors are fixed in India, this knowledge is only shared to a certain level with the service department in the Netherlands
Personalization	• Lack of structure	• Lack of structure	• Collaboration when	• Not present but

	• Ad-hoc basis • References to codified knowledge • Checking and verifying • Skewed division of knowledge; research knows the new and engineering the old products	• Ad-hoc basis • References to codified knowledge • Checking and verifying • Sometimes collaboration • Some people at CryoZone first were located at Stirling's research department	trying to localize the problem • Assistance is rendered from engineering when solving the problem	potentially valuable
People		• Experienced technical sales manager moving from Stirling to CryoZone		• Not used and does not seem feasible in the current set-up

Table 4.3: knowledge sharing characteristics and problems between departments

Knowledge is shared between the different departments. People do not hoard there knowledge and are glad to share it. The problem however seems to be that there is no structured process for sharing knowledge and knowledge is not always shared. Furthermore the knowledge that is codified or embedded in products is hard to trace and requires assistance of persons intimately involved. This becomes exceedingly problematic when one does not exactly know what one is looking for. Furthermore a lot of sharing seems to occur after or during a project and not beforehand.

Reuse not done

If someone had the opportunity to reuse knowledge but did not recognize this opportunity at the given time chances are high that only failure brings to light this missed chances. When one could have copied a certain part of a machine, software or wiring but did not do so the lead-time may suffer but probably no one will notice. However if critical knowledge is not reused in a project this can lead to problems in the products and customers are bound to notice these problems. This section will give three examples of cases where knowledge not only could have been reused but should have. Key issue in all three of them is that the choice to not reuse the previous design or way of working was not a mistake. People consciously chose for a different solution because the "why", the knowledge so to speak, behind the original solution was forgotten and not recorded. So the last part of the first research question, how much possible reuse does not occur, is not answered completely, this section is not exhaustive in uncovering all the reuse that did not happen but could happen. However it does give an overview of the relevance of the knowledge not shared and supports that with several examples.

The first case came to light when multiple customers began complaining about oil coming up in the machine. There is oil present in the crank case to lubricate the crank shaft, when this oil gets to the upper part of the machine the regenerator is cluttered and will lose efficiency. (For more details on the workings see *appendix II.*) To prevent this, the cylinder through which the oil must, or rather must not, always used to be slightly conic. The margin by which the top of the cylinder needs to be smaller then the lowest part is miniscule. At a certain point in time the tolerances of the supplier became larger than the required margin thus leading to non-conic cylinders and oil contamination of the upper part of the machine.

Tie wraps form the center of the second example. At a certain point people started using them as opposed to the original silk thread to fasten isolation material in a vacuum. This was done because a tie wrap can be fastened quicker than making knots in the before mentioned silk thread. The problem here however is that tie wraps are made out of nylon and nylon consists for a large part out of water. When placed into a vacuum nylon starts to dry and becomes brittle. As a result the tie wraps lose their strength and after a year no longer will keep the isolation material in place. The silk thread may take more time to knot but when used it will last for a far longer time.

The final case also deals with isolation material, this time wrapped around the piping that transports the liquid nitrogen from the cooling head to the storage vessel. This aluminum-like foil used to be crumpled for two reasons; crumpled layers of isolation material contain pockets of air and when crumpled the amount of heat radiated is reduced both improving the isolation qualities. These underlying ideas were forgotten and people started to wrap the foil tightly around the piping, simply because that looked neater. And indeed if one does not know that crumpling has certain benefits why should someone make an effort to make things less orderly looking.

These were just three examples but they all serve to state the same point. As one of the employees formulated it; "Back in the days when Philips had far more people working in their cryogenic research apartment than we now have, and none of those people were idiots and they designed things in specific ways for specific reasons. We still have the designs but miss out on those reasons.".

The core of the problem is that for knowledge sharing Den Heijer Industries is highly person-dependent. This has two underlying reasons; the first is that archive is not really accessible and second that each task is handled by one person. People reuse their own extensive knowledge they gained through years of experience. Much of this knowledge is still relevant now because the core of the products manufactured at Stirling has not changed much mechanically throughout the years. This means the constructions and "tricks" incorporated in the design are there for a reason. These designs are in turn stored in the archive but the reasoning behind the designs is not preserved. Furthermore it is hard, if not impossible, to find something in the archive when one is not intimately familiar with Stirling's history.

New Employee

The new employee did face some problems when starting at Den Heijer Industries. The main issues he faced were related to a large project of which the previous project leader was hired on a temporary basis. Only part of the information regarding the project was documented. The lack of structure he faced in projects made it harder for him to gather the knowledge he needed.

On the bright side He found everyone more than helpful in assisting him. Furthermore it was very easy to define which person possessed the knowledge he required. This might also be due to the small size of the company but both things made it easier for him to find his way at Den Heijer Industries

4.2 Benchmarking

During the course of the study several other companies were visited, see *appendix VI* for a table summarizing the characteristics and the more detailed findings at those companies. In general two important findings were done during those sessions. First of all everyone acknowledge the importance of retaining knowledge for the organization. Furthermore both codification methods and personalization methods were used consciously. Product-based and people-based methods were not considered management tools.

Personalization methods were used and in general received praise. One of the interviewees even stated retaining knowledge was a matter of having enough phone numbers and making phone calls. Most interesting example of a personalization method used was removing the most experienced service engineer from service. This forced the less experienced service engineers to face the more difficult problems and learn. The experienced service engineer however was still available for support thus transferring his knowledge to the new generation.

Codification strategies were used also and deemed valuable but at the same time less successful. Support was needed from all the layers of the organization. While meeting with varying degrees of success codification of knowledge was still considered vital to preserving knowledge in the long run. Efforts that were only partly successful were still considered better than nothing.

4.3 Problem Elaboration

Now that the problem has been analyzed on a very detailed level the previous sections can be used to create a justified overview of the situation at Den Heijer Industries. First a cause and effect diagram will be presented in order to define the main problems. After that the problems will be located both with regard to the organizational structure of Den Heijer Industries as well as with regard to the four different knowledge management methods; Personalization, codification, people-based and product-based methods.

Main Problems

The previous sections have been the basis for the extended cause and effect diagram presented in *figure 4.5*. The majority of these blocks do not present problems at all. If one looks for example at the diagram it can be seen that the majority of the blocks situated at the left side are things that the company cannot or does not want to change. Or more concrete, the increase in sales and the large project are just the things the company wants. That as a side effect they negatively impact knowledge sharing and retention should be taken as a given. Something similar goes for the service department being located in India. While from a knowledge management perspective this has certain disadvantages, it makes sense from an economic perspective, wages are lower, and a logistic perspective, a lot of customers are located in India. Finally the large history and the organic growth of the company are also things that have positive side effects, the large history is even one of the reasons there is a lot of knowledge to share. But regardless of how beneficial or not these two factors are, more important is that they cannot be changed.

Den Heijer Industries fails to capture the "why" behind the designs in any other than a heavy person-dependent way. The capturing knowledge itself does not seem to be a problem at first sight for Den Heijer Industries. Every project needs to produce a number of drawings and standard documents in order to be completed. However these drawings and documents tend to emphasize *what* was done and not *why* it was done or *why* it was done in such a manner. Also the product itself exhibits this quality; one can see what was done but not why it was done. However not only documents, archives and the product itself seem to be inadequate, also the memory of people involved does not seem sufficient. Related blocks in *figure 4.5* include; "archiving has low priority", "large history", "relevance of old solutions", "no reviewing of the project" and perhaps the most obvious "Underlying reason not captured or lost". In the end of *section 4.1* examples were given of cases where this *why* was not captured and knowledge sharing did not occur when it should have. These examples also show that not only did codification and product based methods fail when the job is transferred from one person to another, also personalization methods failed in transferring the *why*.

The second of the problems is the lack of traceability, or findability, of knowledge. This problem can be found in the bottom of *figure 4.5*. Doing so would seem feasible, at least in the sense of not being completely impossible like, for example, denying the organic growth of the company. Furthermore it is something that has no unpleasant side effects like decreasing the work

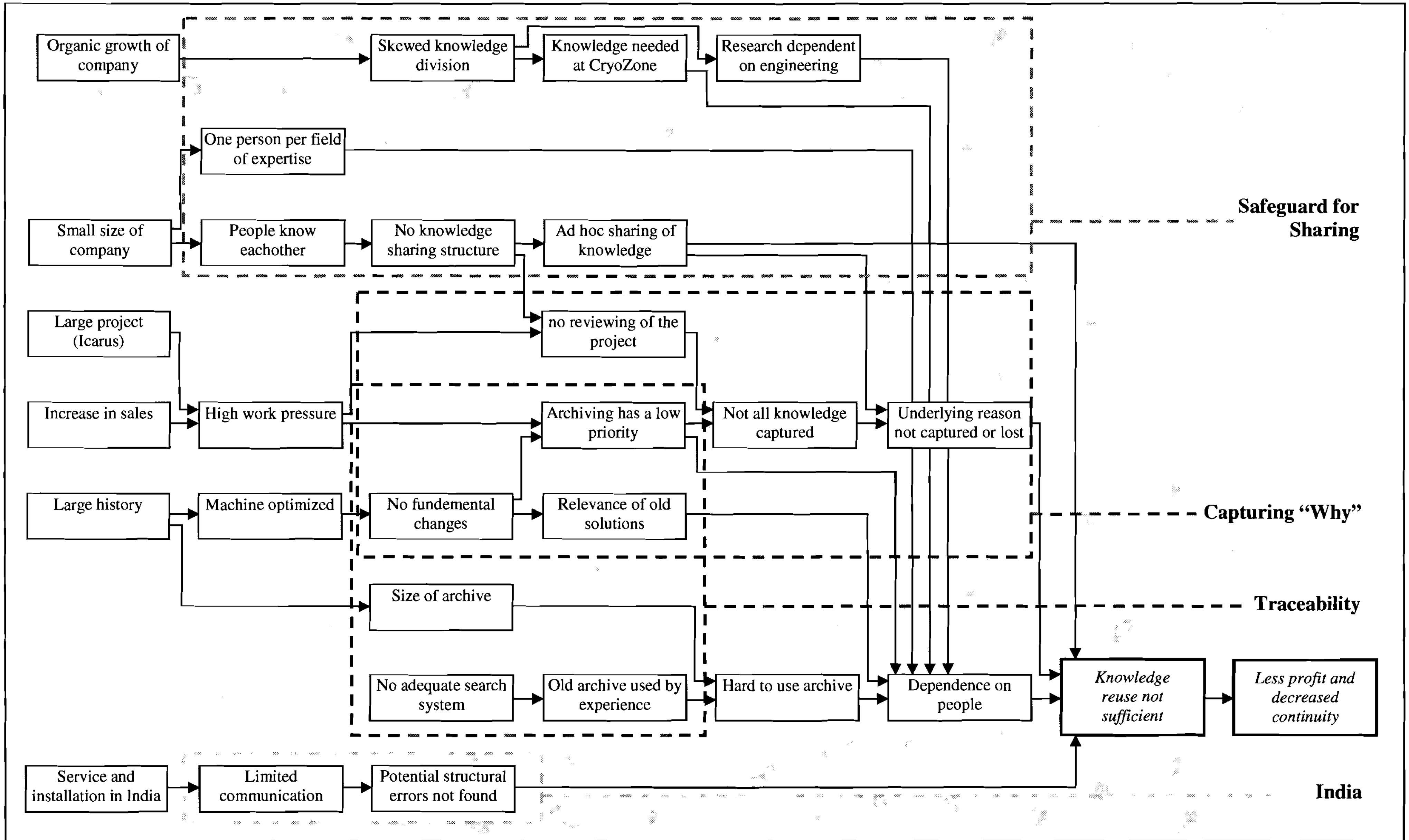

Figure 4.5: Cause and effect diagram

pressure, which would either require less orders and income or more employees and more expenses. On the other hand the traceability of archived documents has a direct impact on the knowledge reuse. Substantial amounts of information are automatically archived, when creating a Stirling machine drawings have to be created thus generating documents. These are attached to a project number so if one knows which project is needed it is easy to find. However when one is looking for a certain characteristic of a project the only way to easily find one or more corresponding projects is to be familiar with the projects.

The final problem that is considered central is the fact that there is no complete sharing of the relevant knowledge due to the lack of structure. Because everyone knows everyone else within the company no need for formalization or institutionalizing is observed. This does not mean people do not communicate; on the contrary people know each other quite well and willingly share knowledge. It does however mean they do so in an unstructured manner and might oversee certain things because they simply assume that a certain topic is already known throughout the organization. The need for this kind of sharing is further increased by the skewed division of knowledge between the different departments and company. This means that relevant knowledge is located at different locations. CryoZone needs knowledge from Stirling and also between research and engineering within Stirling sharing is needed. Because of the close personal contacts the people sharing the knowledge may get the illusion that everything is shared while in reality certain issues are overlooked. For a summary of the problems and their relations to the different knowledge management methodologies see *appendix VII.*

One part of *figure 4.5* has not yet been discussed. This is the part relating to the service department in India located at the top of the diagram. The reason for this is that though it was noteworthy enough to mention it falls outside of the scope of the project and therefore is not further evaluated during this study.

Problem Localization

Three problems have been defined now, but where do they manifest themselves? That question can be answered by stating in which department a problem is occurring but also in a more abstract manner, namely by relating them to the theory presented in *chapter 2*.

Losing the reasoning behind previous designs is the most prevalent problem in the research department. This is due to the nature of the deliverables they need to produce. A research department does not want to reuse products and preferably does not even want to reuse knowledge all the time. Rather, old knowledge or old knowledge in combination with new knowledge is used to create new solutions or products. Thus the why of previously created solutions or products are the most important part of knowledge that needs to be available for the research department because instead of recreating a solution they want to know why the solution was created in such a manner. Due to a number of factors displayed in *table 4.4*, this is not always possible within Den Heijer Industries. But also CryoZone, due to the uniqueness of their products, have a need for capturing not only the "what" but also the "why". Their products differ to such an extent that blueprints from previous projects are not useful and instead the knowledge used to create them is needed. At the moment this really is not much of an issue yet due to small size and the small number of projects completed but in the longer run the lack of adequate attention of storing the underlying knowledge of projects can be quite harmful.

The lack of structure and the accompanying problems are most prevalent within the engineering department and between the engineering department and the research department. Within the engineering department this is caused by a high degree of specialization among the people working there. Because of this people are more narrowly focused on their own job since that does not require them to interact much with others. Between the research and the engineering department roughly the same problem can be observed. Knowledge is distributed between the two departments but no structural interaction during either a research project or an engineering project is embedded in the processes at Den Heijer Industries. Each party may however possess knowledge valuable to the other and therefore a more structured way of sharing knowledge and reusing it as a company rather than as an individual or a department is valuable. It should be noted that knowledge is shared to a certain extent, just not always and not always at the optimal moment. Creating a more structured way of sharing knowledge is thus meant to complement the more informal and unstructured knowledge sharing processes at Den Heijer Industries.

Finally the problem of the traceability of knowledge can be found throughout the organization. A distinction however is made between the service part, both in the Netherlands as well as in India, and the rest of the organization; engineering, research and CryoZone. Within engineering, research and as of yet to a lesser extent CryoZone an enormous body of knowledge is present and is generated in codified form. This knowledge is actively used at the research department and the engineering department, and indirectly by CryoZone. The method of finding the required knowledge however is based on the memories of the people working at Den Heijer Industries. If one has not worked on a certain project that could be relevant it will be hard, not feasible or even impossible to find. As can be seen in the first sub-section of *section 4.2* examples have been found of reusing knowledge from projects from 1990. Increasing the traceability of this knowledge by having people independent search methods will improve the reuse of knowledge and sustain it in the future. On the other hand there is the issue of tracing knowledge from the service department in India. This is more an issue of communication since knowledge gained in India is not shared within Den Heijer Industries as a whole. The reason that it is still grouped under the traceability problem is because potential solutions need to span half the globe and therefore will rely on codification methods. In other words, Stirling India should be able to tap from the codified knowledge generated in the Netherlands and also should be able to add to it.

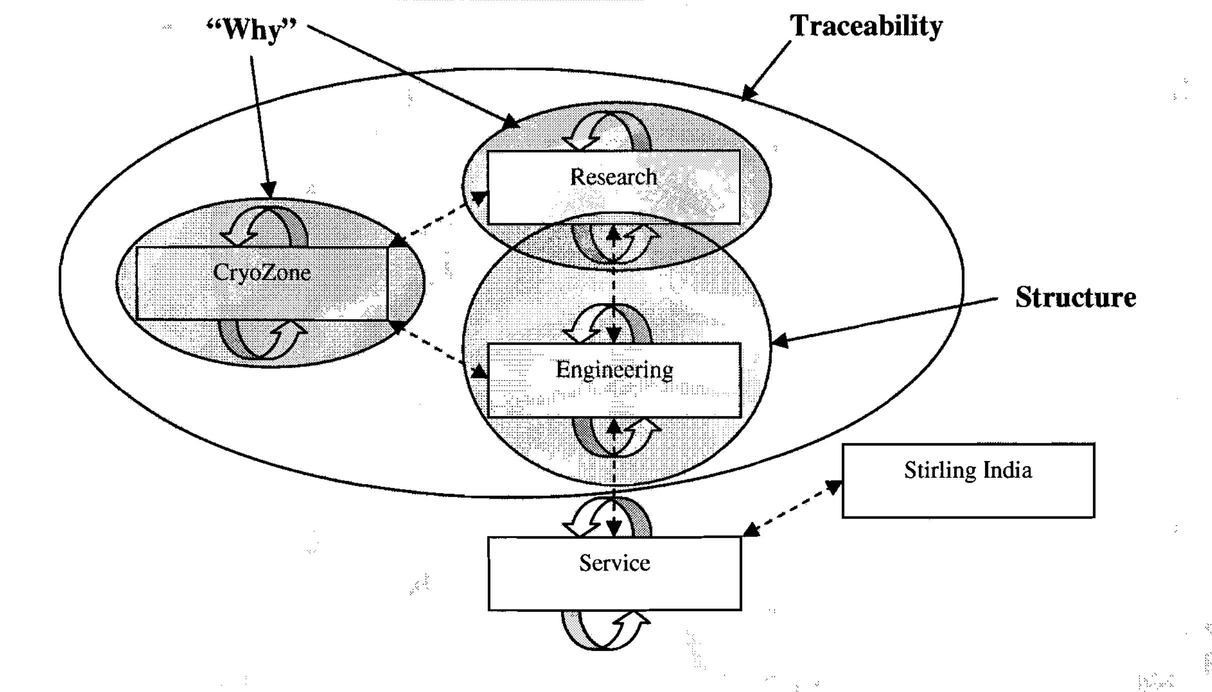

Figure 4.6: Localizing knowledge reuse problems within the organization

In *figure 4.6* the three different problems are placed within the organizational framework. For reasons of clarity the traceability issues regarding Service and India are not displayed. This is because these parts of the organization are mainly reusers of information, not knowledge. Now that the three problems are placed in their organizational context they need to be placed in a theoretical context. In order to do so, a part from the framework presented in *section 2.4* is used. Goal is not only to define the current situation of Den Heijer Industries but also to serve as a starting point for the solution design and where they should move to.

Goal is to localize sub-problems and to characterize each of the relevant departments and connections between those departments in terms of codification, personalization, people and product. For Den Heijer industries this gives a relatively clear picture, as can later be seen in *figure 4.7*. All different departments, and the main connections to be investigated, can be described as heavily people influenced. There are however subtle nuances which will be elaborated on the rest of this section.

First of all, engineering is the most person based department within Den Heijer Industries. This does not mean that people do not talk to each other, work together or dislike each other. It means that everyone has their own, often quite narrow field of expertise that might interact but barely overlaps with that of others. This results in work being done by the same person over and over again with very little exchange of knowledge. It might be argued that also the products do contain knowledge at the engineering department. *Section 4.2* even provided examples of knowledge that was extracted from projects. However the method of extraction plus the fact that the old projects were often done by the person using the old knowledge ensures that the knowledge reuse is still heavily person dependent.

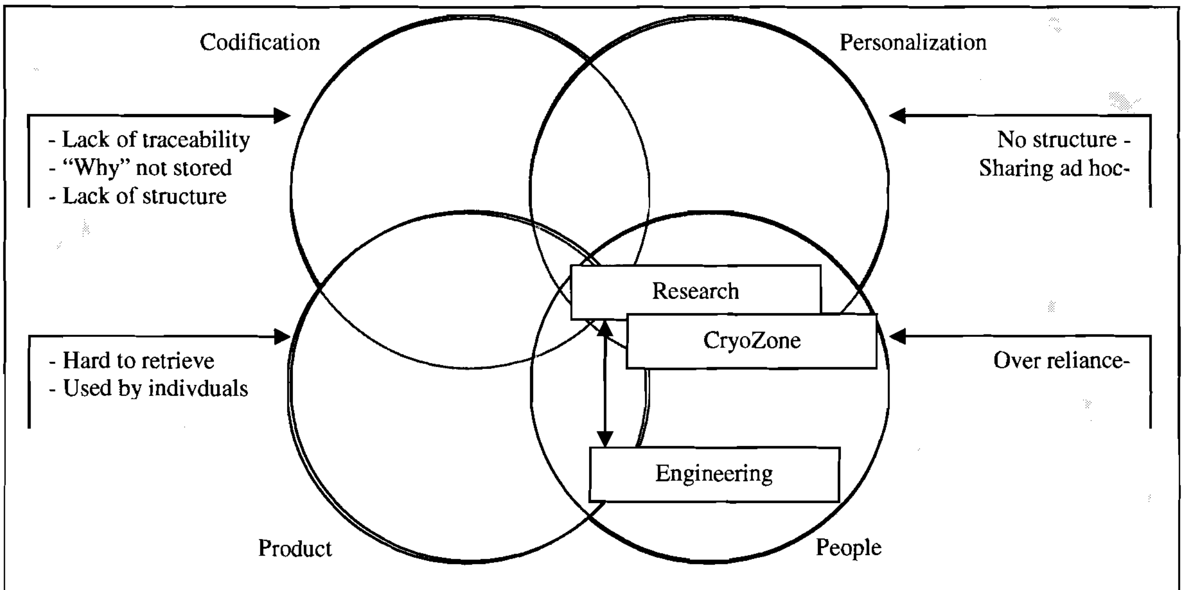

Figure 4.7: Characterizing the knowledge reuse within the departments

The research department is placed higher, on the overlap between people and personalization. This is because the knowledge of the people working at the research department overlaps, at least to a much larger extent than in the engineering department. Therefore knowledge exchange is already more feasible. However this still does not result in a very high lever of personalization since everybody is still working more or less on their own field of expertise. No structural ways of consulting each others knowledge are present and thus while interactions are more frequent than in the engineering department, they still occur on an ad hoc basis.

In between the previous two departments is CryoZone. On the one hand they all have specializations when working on a project. On the other hand everybody works on each project facilitating interaction and knowledge exchange even though the overlap in knowledge is not that great. So while there is a high degree of specialization, which comes naturally for a small company dealing with complicated matters, the way of working still forces people to work together. Therefore CryoZone has been placed in between the research and the engineering department in terms of people dependency.

Finally the connection between research and engineering is located in the person section. This might seem strange since interactions between departments cannot be done by one person. However since the interactions are heavily people dependent, the connection is still categorized as being a people method. Certain persons know how they should contact who. In turn these person contacted use their own knowledge to, for example, locate something in the archive. So while the process itself is naturally an interaction between persons and thus a personalization method the conditions in which this happens are quite people dependent.

4.4 Problem Interactions

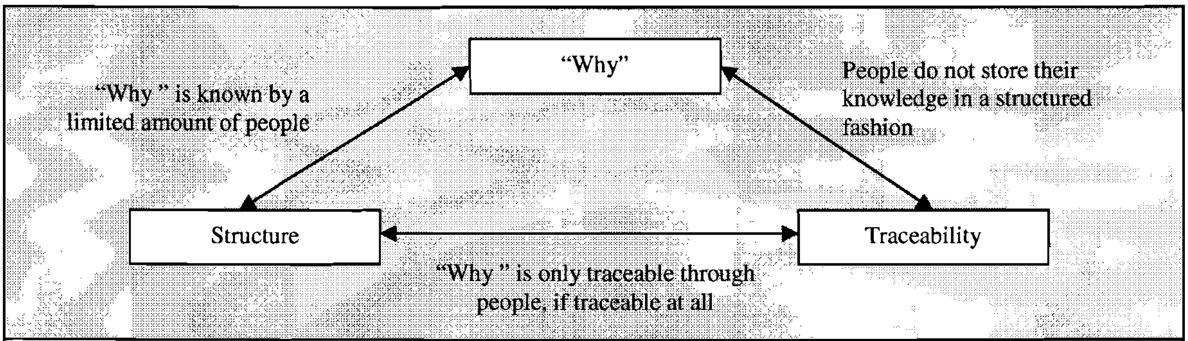

Figure 4.8: Engineering direction

While three different, but related, problems are presented and deal with similar issues. This section will briefly discuss what these relations are and how each problem affects the others. *Figure 4.8* shortly summarizes the interactions between these problems.

First of all the lack of structure and the importance of the underlying "why" both are a results from, for example, the organic growth which lead to the current state of Den Heijer Industries. These factors have created a system where informality rules and the need for structuring knowledge exchange is not perceived. Furthermore the intimate knowledge about the workings of the machine or certain parts of the machine lies with a certain number of experienced people or is completely lost. The part that still is remembered needs to be shared in a concise manner which is hampered by the lack of structure.

The traceability and the "why" issue both originate from the problems of correctly storing the underlying reasons. As far as these reasons are stored they cannot be retrieved easily thus further aggravating the problem. So while the traceability problem concerns all data stored this specifically affects the "why" part because of the great importance of that piece of knowledge. The main problem however that makes the reason behind certain designs untraceable, is it simply is located within people's heads rather than in archives. Even when a database search yields the name of a person that should have the necessary knowledge it may very well be that he or she no longer works at Den Heijer Industries.

The last relation, the one between structure and traceability mainly focuses on lack of structure leading to a lack of traceability and, visa versa, a lack of traceability leading to a need for structure. As long as there is no structured way of codifying knowledge it becomes increasingly hard to actually locate the required knowledge at a later point in time. The other way around it is now hard to make a search of the archive for relevant information hard, if not impossible. One can say that when starting on a project the first thing to do is a database search for relevant information, but without a good structure underlying the codified knowledge in an organization this is not feasible.

One can thus conclude that the three problems in the organizations overlap for a certain part. This is not a problem since solving one of them may thus help in dealing with the other two. Reasoning the other way around however this means that one cannot solve one of the problems without dealing with the other two. Therefore it is mandatory that when trying to solve the current problems regarding knowledge management, attention is given to the field as a whole and that all three defined problems are dealt with.

5. SOLUTION DESIGN

The design of the solution can be divided in a few distinct parts. First of all the context in which the solutions will have to be implemented will be given. Then a general direction in which Den Heijer Industries will need to move to improve upon the current situation. In *chapter 4* problems were already defined and localized. This chapter will give answers to which methods one should use in what kind of manner to solve which problems. After that somewhat abstract description of several solution directions more concrete examples of solutions will be given. Each of these solutions then will be ranked according to their costs, their chance of success (or failure) and the potential impact they have on knowledge management issues. Finally one of these solutions, the choice based on the previously mentioned rankings, will be further developed.

5.1 Specifications

Before starting with thinking about a solution three things have to be defined. First of them is what one wants to achieve by implementing these solutions. This includes not only what one wants to achieve but also where one wants to achieve the given goals, in other words, the scope of the solutions. Secondly, there are all kinds of factors that influence or might influence the final design. And last but certainly not least there is the strategic context that has to be taken into consideration in order to see to which factors the solutions have to conform in order to be useful in the future.

Goals

The main goal is to *improve knowledge reuse within Den Heijer Industries*. In order to do so, knowledge must be available, so the sub-goals are to *retain* and to *share* knowledge within the organization. Subsequently when knowledge is available the organization must be *stimulated* to actively use the knowledge available.

The solutions will concern the research department and the engineering department of Stirling, the link between them and CryoZone. The archive will receive special attention as it spans the entire organization. Service will be excluded from the solution design because, as could be seen in *figure 4.6*, the main problems found do not relate to that department. Furthermore the service department does not reuse knowledge but rather supplies feedback and reuses information. The reuse should improve for the everyday knowledge for regular activities as well as the more specific knowledge that is used in rare situations are of importance. This does include both tacit and explicit knowledge and focuses on technological issues.

Boundaries

Den Heijer Industries has a few characteristics that limit the options to choose from, and affect the effectiveness of solutions chosen. The most obvious is the small size of the company. In the financial sense this means less room for investments. In terms of knowledge management this means that a lot of codification techniques aimed at bringing back large groups of people and spanning geographical boundaries are not necessary.

Furthermore Den Heijer Industries deals with technologically, and specifically mechanically, advanced machines. Also the machines have been perfected over the course of many years. Furthermore few institutes in the world work with either the Stirling engine or in cryotechnology so outside knowledge is relatively hard to come by. This means internal knowledge is very important and might be critical for the survival of the company. Already a lot of knowledge is codified thanks to the way of working at Den Heijer Industries. Drawings need to be made of machines and research reports have to be written. Therefore there are large quantities of documents available that need to be dealt with.

Finally regarding the IT-infrastructure no new investments are likely to be done again in the future. This is because recently an upgrade for Exact, eSynergy, has been bought and this is the system that should used to implement any codification solutions suggested. eSynergy is a tool for helping to access the already existing database and is well suited for several solutions discussed later in this section.

Strategic Context

It is important that the solutions chosen will remain valuable in the future. In order to do so they have to be in line with the strategic intentions of Den Heijer Industries. And since the most important strategic goal is to grow considerably, all solutions must not only be feasible for the current small organization, but also adequate or adjustable for a larger organization. Since this growth should not only be the organic growth of already existing products, but also should flow from new products that might be more standardized. Any solution implemented should also be applicable for these products.

In order to achieve the organic growth there are also some mid-term strategic objectives to be addressed. These mainly are a better control of the costs and a higher percentage of delivering projects on time. This should be done without decreasing the quality. Effective knowledge reuse can be helpful both by decreasing the lead time of a project as well as decreasing the costs made.

Finally one of the main strategic considerations of Den Heijer Industries, like every other organization, is their continued existence. Their knowledge about cryotechnology and the Stirling refrigerator is crucial to do so. Therefore all solutions should be aimed at retaining this knowledge for and spreading it through the organization. Additional issues may involve the protection of their knowledge from competitors. For their current market this is not an issue but when venturing into new markets it may become one.

5.2 General Direction

The analysis revealed that knowledge reuse within Den Heijer Industries is highly people-based. This does not need to be a problem in the short run but with people leaving, it makes the company overly dependent on individuals in the long run. This section will provide directions to which methods one should turn in order to solve the problems earlier presented. This will partly be done from the viewpoint of the departments where the problems occur rather than the viewpoint of the problems themselves. Reason is that different departments may face the same problems but in slightly different ways which can lead to different solutions. Some of the reasoning however is similar and to prevent redundancy, departments that will be discussed later will refer to earlier discussed subjects. The exception is the issue of traceability that is present in all departments and therefore will be discussed for all the departments of interest. For all of the solutions it goes that the proposed changes do not completely move away from knowledge reuse by having people doing the same work again. That is a natural way of working and certainly valuable albeit vulnerable if it is the only method used.

Engineering

Engineering at the moment reuses knowledge mostly through people based methods. Codification methods and product-based methods are used but seem more like a supporting tool for person-based reuse and sometimes for personalization methods. It is proposed to move away from people-based methods and to personalization methods by introducing more structure. *Figure 4.1* summarizes the changes that are proposed.

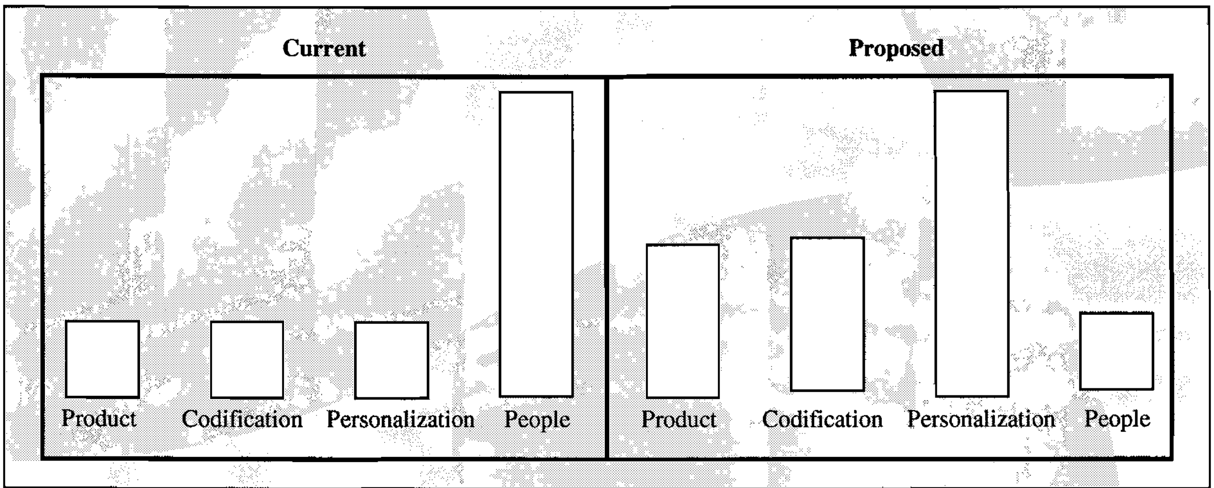

Figure 5.1: Engineering direction

Den Heijer Industries should rely less on people. As said in chapter 2 this can have certain advantages but at the moment Den Heijer Industries relies on it too much. A move to mainly personalization methods is proposed. In a project organization social processes often play an important role (Bresnen et al 2003) and Den Heijer Industries is no exception. Since these social processes are already in place and of value, one should use the basis for knowledge sharing that they provide. Furthermore these social processes should help in the more unique situations that are encountered as this is were personalization methods excel as opposed to codification methods (Haas & Hansen 2007, Hansen et al. 1999). Personalization methods have the advantage that they can easily transfer tacit knowledge (e.g. Davenport et al. 1998, Hislop 2004, Styhre 2003). Finally these methods may contribute to increasing the shared understanding on the engineering department (Nonaka & Toyama 2007, Zackariasson et al. 2006) which is a part of retaining knowledge for the organization (De Long & Davenport 2003, Tsoukas & Vladimirou 2001). While already in place these personalization activities should be more structured to ensure that they are happening at the right time (Newell 2004).

Furthermore Den Heijer Industries should retain knowledge for the organization in the long run, a strong point of especially codification techniques. Therefore an increase in codification and product based methods is also proposed, especially regarding the traceability of the efforts already done within those methods. By structuring the way products are created and basic models are stored, they can become available to all as a source of knowledge. Codifying knowledge for direct reuse can be very effective and direct reuse is the situation in which codification strategies excel (Haas & Hansen 2007). This knowledge has to be understood very well before it can be codified to a greater extent (Crossan et al. 1999, Nonaka 1994 Zietsma et al. 2002). Furthermore platforms are already being used which can be quite profitable (Yang & Yiang 2006) but adding upon this with modules might further increase potential benefits (Baldwin & Clark 1997, Ulrich & Tung 1991). However codification and product based-methods should not be the prime focus point for several reasons. First of all some of the advantages of codification methods do not apply. Transferring knowledge over large distances and making it available to large groups of persons is such an advantage (e.g. Hislop 2005) but also one not needed. Furthermore codification is more suitable when the knowledge is intimately known and easier to reuse (e.g. Crossan et al. 1999, Haas & Hansen 2007, Hansen et al. 1999) but the personalization strategy proposed is aimed at specific situations that require not everyday knowledge. And these are the areas where codification techniques might fall short (e.g. Haas & Hansen 2007, Hansen et al 2007, Hislop 2005, Newell et al. 2006.)

Research

Research main problem is that certain relevant knowledge is not captured or was not captured in the past. Therefore a selective codification of the knowledge generated and used by the research department is proposed. Research, as opposed to engineering, is not too person dependent and persons already work together to a certain degree. No changes are supposed in that area. Research does extract knowledge from products but since these are not created by themselves but rather are or were created by engineering they are dealt with when discussing the relation between engineering and research. *Figure 5.1* summarizes the current and proposed situation.

Since the focus of research is on creating completely new products the knowledge required differs from that other parts of the organization need. Rather then needing to know what was done before one needs the reasoning behind the design. What also is important that as opposed to engineering there is already more interpersonal interaction. This is due to the greater overlap in knowledge and activities that increases the potential for easy communication (Bechky 2003, Nonaka & Toyama 2007). And because of the creativity needed at a research department one does not want to formalize these interactions any further (McGrath 2001). Knowledge at the research department is crucial for the organization and thus needs to be retained(De Long & Davenport 2003).

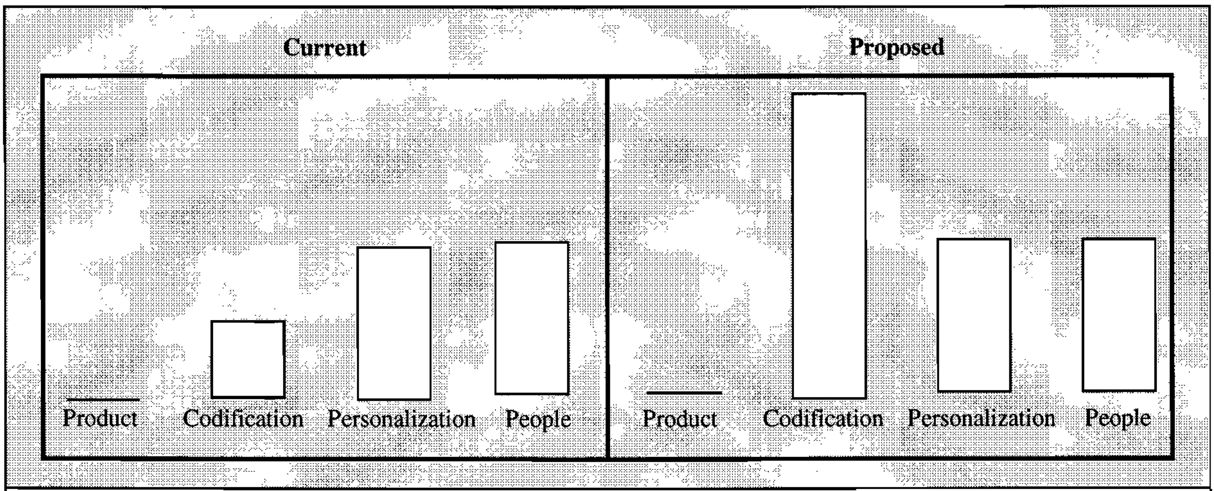

Figure 5.2: Research Direction

It is proposed that, despite well known problems (e.g. Alvesson & Karrmeman 2001, Hislop 2005, Polany 1966), a codification approach is partly taken in order to preserve the knowledge for the company. While codifying the knowledge will not be easy, it is not deemed impossible (e.g. Crossan 1999, Hansen et al. 1999, Nonaka 1994) and more importantly it can be seen as a process of learning in itself (Prencipe & Tell 2001). A heavy reliance however, can very well damage the performance of the research department (e.g. Haas & Hansen 2005, Hall 2006) because it may inhibit researchers to "think outside the box". However it should be clear that codification only should be used as a supporting tool and one should not shift completely towards a reliance on databases. This combination of, already present, personalization methods like co-location and codification has the highest chance of success because it avoids pitfalls that a pure codification strategy would face (e.g. Gammelgaard & Ritter 2005, Newel et al. 2006, Song et al. 2007).

Engineering/Research

The interaction between engineering is present but at the moment not structured enough. This lack of structure leads to potential valuable knowledge not being shared between the departments or not at the right time. Motivation or willingness to share knowledge that could be a potential problem (Haas & Nohria 2004, Hauschild et al. 2004) is not the issue. Therefore personalization methods are proposed. They can transfer the knowledge needed and if necessary can be easily supported by codified knowledge. This furthermore is a feasible option because of the physical nearness of the two departments. Over reliance on people cannot be considered an issue here since communication between the two departments always will involve multiple people and thus always will spread knowledge through the organization. *Figure 5.3* illustrates the proposed move to more structured personal contact between the two departments.

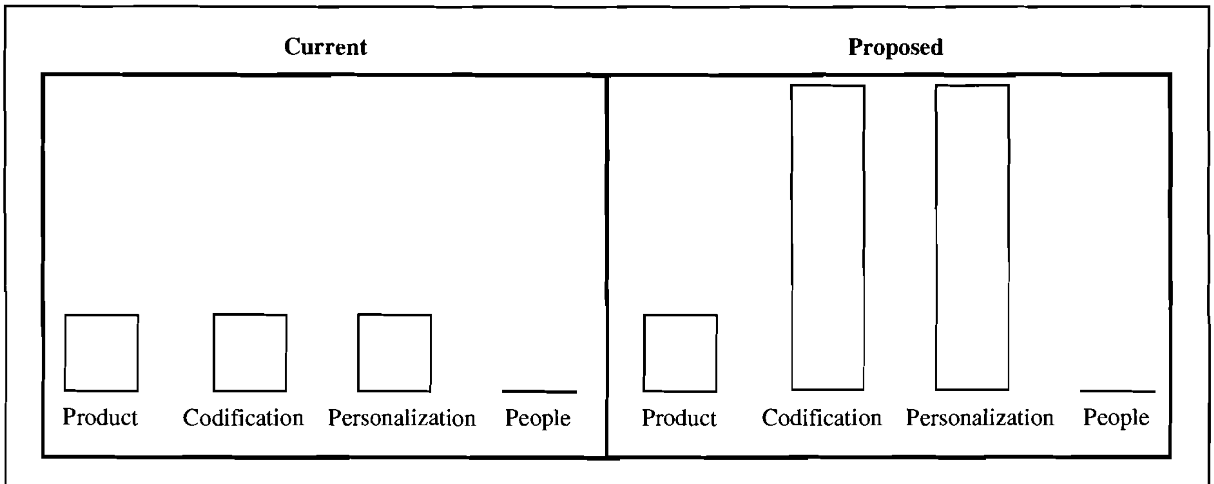

Figure 5.3: Engineering/Research Direction

The increased use of codification methods does not seem necessary. Engineering departments need help for very advanced projects or very rare problems. On the other hand the research department will want to use the vast practical, often tacit, knowledge and experience of older product types at the engineering department. Personalization methods are the most efficient at transferring this kind of in-dept specific knowledge (Haas & Hansen 2007, Hansen et al. 1999). Structuring this exchange and probably intensifying it is more efficient than replacing or partly replacing this with codification methods. Furthermore personalization methods will lead to a greater shared understanding (Nonaka & Toyama 2007, Zackariasson et al. 2006) which will only increase the effectiveness of knowledge exchange in the future. Additional benefit is that because more people share knowledge more often in a more conscious manner the knowledge is easier retained for the organization (De Long & Davenport 2003, Tsoukas & Vladimirou 2001)

CryoZone

CryoZone faces both the problems of the research department and that of the link between the research and the engineering department. Thus the problems and proposed solutions are also similar. The similarities with the research department come from the technologically advanced products they create. While they differ because the research department actually does not create products, CryoZone is still more alike with Stirling's research department and not the engineering department. Their products are so specific and require such a high level of specific technological knowledge that the previous designs, while still used as a basis, are not that important in comparison with the theory that lies behind it.

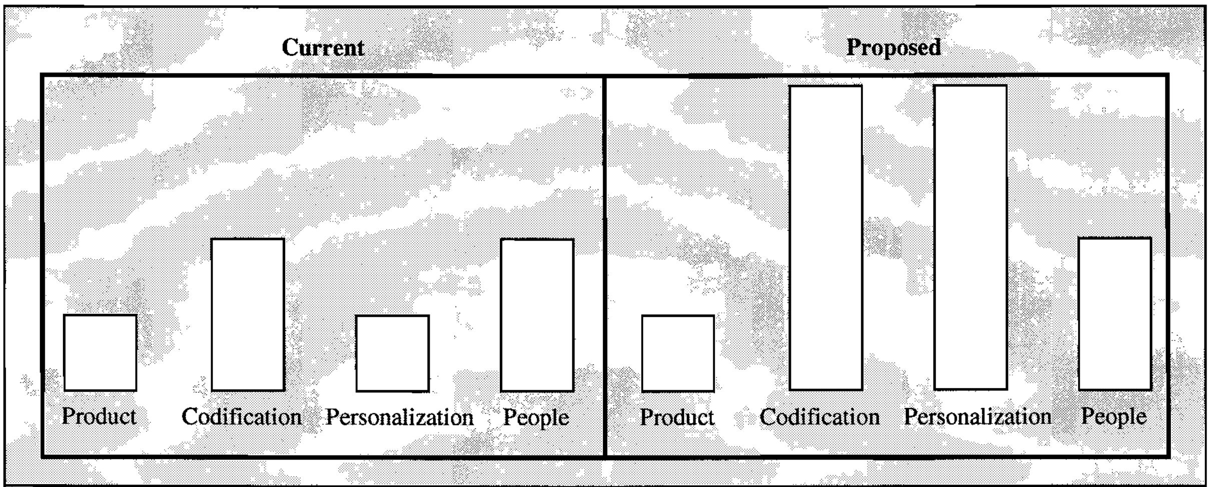

Figure 5.4: CryoZone Direction

Because of the extremely small size of CryoZone it is not possible to have all required knowledge, or even capacity, internally and they need to really heavily upon Stirling for support. This link needs to be restructured in a similar fashion from the perspective of CryoZone. This is the case because in the current situation Stirling will not have needs that CryoZone will need to fulfill. Later on when growth has taken place and more knowledge and manpower have been acquired the link might become more one of equals.

Archive

To describe an archive in any other way than a codification method seems strange. At Den Heijer Industries however use of the archive is highly people dependent. It is proposed to make the traceability of knowledge within the archive less person dependent.

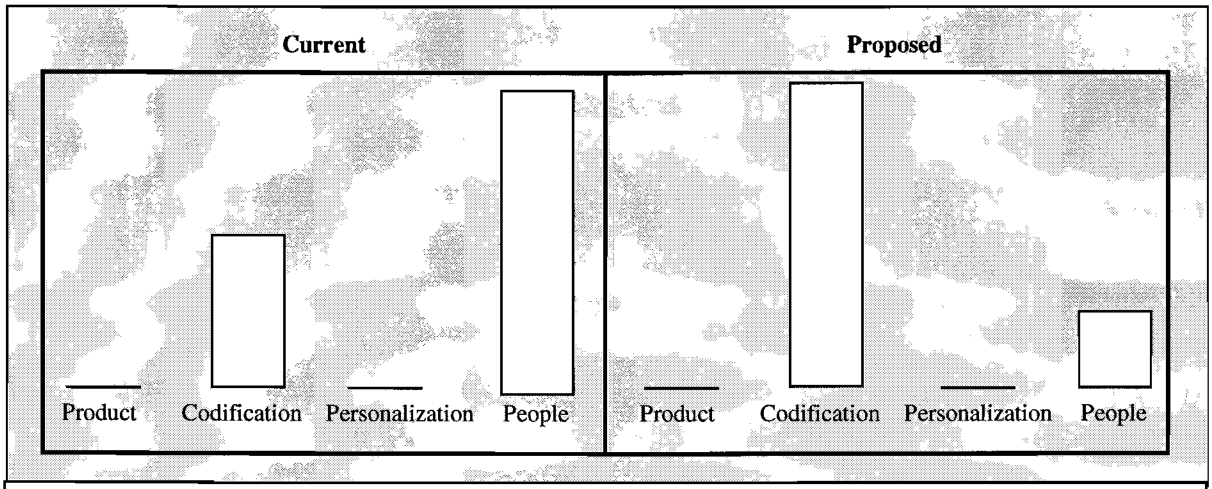

Figure 5.5: Archive Direction

This codified knowledge has been accumulating for the last years until the point that only the person who knows where to look will find the required document in the archive. This way the value of this abundant knowledge source amounts to nothing as one cannot find the required piece when needed (Davenport et al. 2001, Haas & Hansen 2001). That knowledge residing in the archive can still be of use as was already concluded in *section 4.4* where it was shown that people navigate through this archive using experience and sometimes finding useful knowledge dating a long way back. And while codifying knowledge itself is a problem, the goal is not to actually codify knowledge. It is to employ a strategy that makes the already codified knowledge, or the knowledge that will be codified, during everyday work accessible and thus more valuable.

5.3 Solutions

By now it has been stated that Den Heijer Industries should change the way they deal with knowledge, the direction they should move in and it has been argued why this is the case. So the starting point and the destination have been defined and now this section will describe how to get from the one to the other. For each problem one or more solutions will be given. Each solution will be assigned to the problem it is best suited for. This does not mean a solution cannot have an impact on multiple problems. The solutions will be described shortly but a more extensive description including strengths and weaknesses can be found in *appendix VIII*. At the end of this section an overview will be provided ranking all solutions based on costs, benefits and risk. Finally, issues regarding interactions between the different solutions like redundancy or synergy will be discussed.

Structure

As can be seen in *section 5.1*, in order to solve the problem regarding structure a move towards personalization and one towards products/codification has been proposed. This move resulted in three different possible solutions of which two are directed at the personalization approach.

By previewing what to come in a *design preview* and then actively looking for knowledge before it is needed may solve problems before they become problems. This solution is applicable for all departments and can be integrated into already existing meetings. *Exchange sessions* are a solution where the different departments meet at a regular basis, for example three months. During these meetings ideas, problems and project information are exchanged with as goal to create synergy and help people discover relevant knowledge that otherwise would have gone unused. Finally *modularity* may be used as an extension to the platform approach Stirling currently uses. By dividing the products into modules and organizing documentation accordingly knowledge that would have otherwise been restricted to a platform now spreads over all products that make use of that module.

"Why"

In order to store the reason behind the techniques used within Den Heijer Industries two strategies are proposed. These two strategies are closely related and support each other. The first is a pure codification strategy aimed at storing the relevant knowledge in such a manner that it is retrieved easily. The second is far more related to personalization strategies and can be seen as supporting the first solution.

One way of storing the reason of a design is by creating a *compendium of knowledge*. Such a compendium would either be a, digital, book or a wikipedia-like website that contains relevant knowledge about topics that are critical to the organizations survival. For Den Heijer industries this would for example mean cryotechnology but also knowledge about specific parts like the regenerator or the storage vessels. This compendium should continuously be updated by research, engineering and CryoZone as more insight is gained in certain areas. Furthermore *technology owners* are a tool for assigning responsibilities for certain technologies to certain individuals. This responsibility entails different things like keeping up-to date within that field but also updating documentation. If it was implemented in combination with the compendium certain parts of that could be assigned to certain technology owners.

Traceability

As stated in the previous section large amounts of codified knowledge are generated and it is essential that everyone has access to the documents they need when they need them. Three related codification methods are proposed in order to establish this.

First of all one could better benefit from what already is codified by implementing a *search system,* a *storage structure* or both. A search system should have to deal with multiple keywords that have the same meaning and English and Dutch language being used in different but relevant documents. In order to make documents without text, like drawings and designs, traceable they either should be assigned keywords or linked to other documents. For a storage system these links are vital. By creating a network between documents it will become easy to find related projects or research rapports by simply clicking on links. By relating documents in many different ways and not only assigning them project-numbers or research-projects but also customer, specific solutions used and technological fields traceability will be hugely improved. In order to provide research projects with adequate information to make them traceable *after-project reviews* could be held. In these meetings that would occur after finishing a project documentation would be created that would summarize project findings and redirect to relevant documents.

Ranking

Each of these solutions has been judged in three different manners and in *figure 7.6* the results have been graphically displayed. The separate axes represent the costs and the potential benefits of each solution. However since one cannot be sure of the benefits the risk factor has also been included. The largest oval represents the most likely amount of benefits that the solution will yield. The line or lines attached to the larger oval represent the range of possibilities that may occur in terms of profitability. If one looks at, for example, the compendium one can see that most likely the result is highly beneficial. While that is the most likely situation it may very well be only a marginal beneficial. Search systems on the other hand are almost just as beneficial and have the additional advantage that the minimum expected benefits are much higher.

In the figure one group of attractive solutions seem to arise. The most attractive seems the group composed of modularity, after-project-reviews and design reviews. They all feature low costs and high expected benefits. What is less attractive however is that two of the three might not turn out that beneficial. Still one would not be spending large amounts of money and even when only partly successful they can still be worth their while. The design review is the one of the three that seems the most lucrative because, although slightly more expensive, features the highest potential benefits in combination with the least risk. The other solutions all involve either higher costs, lower benefits, higher risk or a combination of the before mentioned. The compendium for example might yield superior benefits in the long run but is expensive, and since the large amounts of discipline and codification involved, can just as well fail within the organization. Technology owners are a completely different matter but still less attractive. While not that costly, the potential benefits are not as high when compared the other solutions. The remaining solutions all are in betweens of these two extreme examples and thus it seems that they have less value than incorporating a knowledge perspective in modularity, after project reviews and design reviews.

Overall it can be seen that design reviews and after-project reviews seem like the best choices. They are closely followed by the incorporation of a knowledge aspect into a modularization approach. The remaining other options seem to have a trade-off between the potential benefits and the amount of risk one takes when implementing them. To consciously make a choice which solutions to implement one needs to consider them in a strategic context as well as judge how they influence each other.

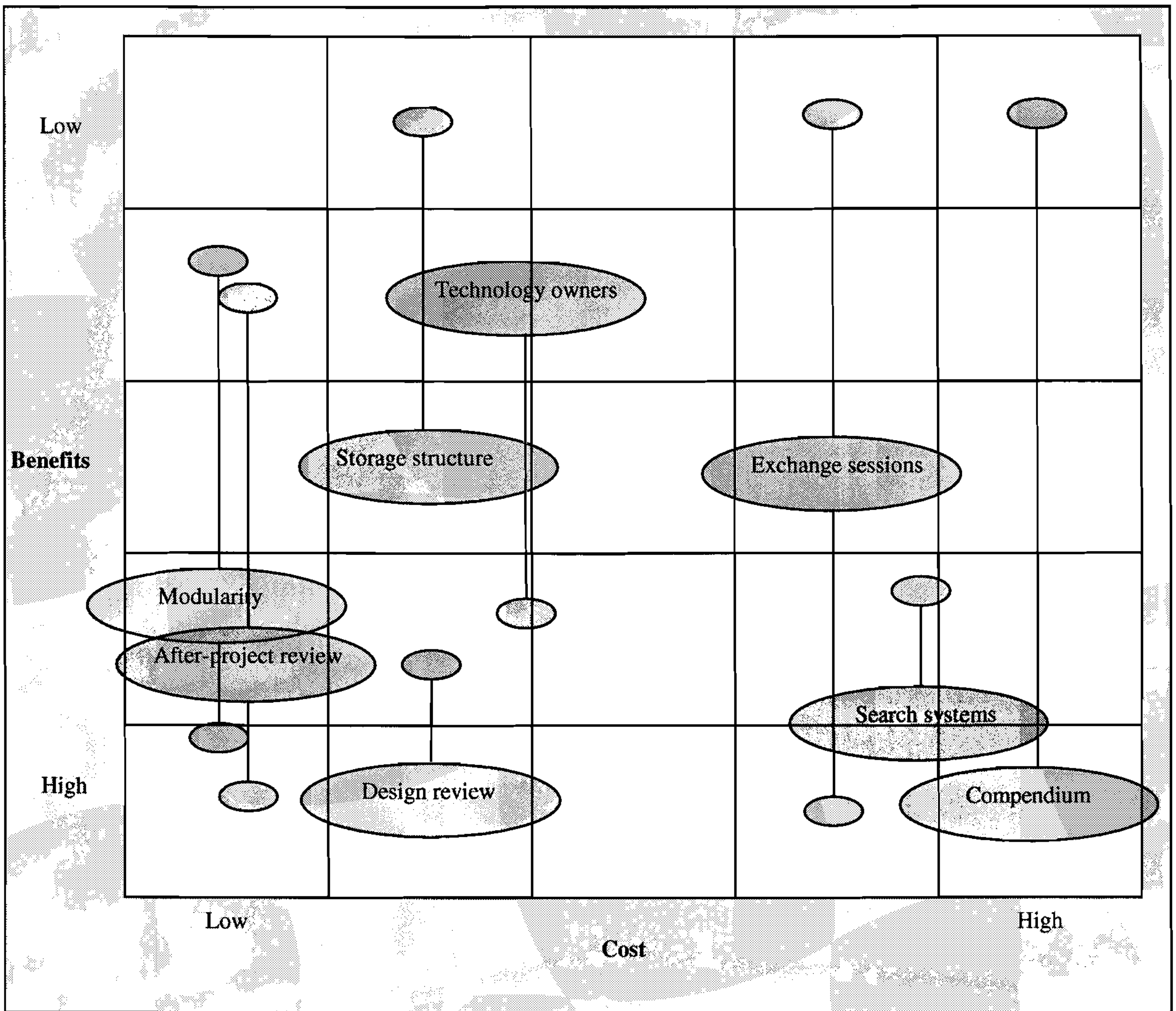

Figure 5.6: Value

Strategic Value

While all solutions have been ranked it is also important to consider how well, or how bad, they fit within the strategic goals of Den Heijer Industries. As the main strategic goal of Den Heijer Industries is growth they should be judged on how valuable each solution will be when the organization increases in size. And if one judges each solution as to its relevant worth depending on the size of the organization three categories can be discerned.

First of all there are the solutions that become less practical or valuable when the organization increases in size. The exchange sessions are fall into this category. As the size of the organization increases it becomes less and less feasible and more and more costly to arrange meetings between departments. Eventually only meetings with parts of each department will be possible and exchange sessions will lose at the very least some of their relative value. Also when one regards after-project reviews as a stand alone solution they will lose value as the number of projects reviewed increases. Looking for knowledge using after-project review is possible only if the generated amount is not too large. To a lesser extent this also seems to be the case for the storage structure. A storage structure however can show such interactions with the search system that these might negotiate the effect, this will be elaborated on in the next section.

Then there are solutions that become more valuable for den Heijer Industries as the organization grows. This seems beneficial but does also imply that at smaller sizes relative benefits are less. Therefore maybe these solutions can be implemented later. Technology owners and the compendium both fall into this category. With a limited amount of people some individuals would "own" too many different technologies. Furthermore the compendium might at the moment take up too much time from regular work for the researchers. If they spend just an amount of allotted time on the compendium would not be up-to-date and irrelevant. The search system on the other hand seems valuable already but will even increase in value when the amount of data dealt with increases.

Finally there are solutions that seem to retain their value regardless of the size of the company and this is the most beneficial category for an organization that is changing in size. Modularity is at the moment already applicable and will retain its worth even if the organization increases in size. The second is the design preview, this process of looking for knowledge early on in the process is valuable no matter what size the organization is.

Interactions

Each implementation of a solution may affect another solution to a smaller or larger extent. Beside the obvious common denominator, that they all draw upon the same resources like time and money there also may be more complicated interactions. First of all the after-project review and the design preview and the exchange sessions can be redundant or observed to be redundant. While the design preview and the after-project review might be seen as complementary, to be done during and after the project respectively, this does not hold for the exchange sessions. Usage of the exchange sessions might be unnecessary with the other two in place and visa versa.

For the storage structure and the search system one can also argue that they are redundant; when the search system is good no storage structure is required and when one can find everything thanks to a good structure no one needs a search system. The other way around may also be true, if neither of the two is perfect they may complement each other and so provide the quickest way of finding something. If a search yields results that are not exactly what one was looking for the structure might direct the searcher to the correct document, and the other way around the structure may help to narrow down the field before the actual search. Technology owners on the other hand are supposed to improve both and benefit from both. This solution is somewhat the opposite of the storage system and the search system in terms of risk, benefit and costs. The costs will not be reduced by increasing using both

5.4 Specific Application

It is both infeasible and undesirable to implement all proposed solutions. Therefore this section starts with choosing the solution most attractive based on the before mentioned interactions and rankings. This solution will be further refined with respects to both the content and the implementation. Finally some recommendations will be given on which solutions to implement in the future, in what time span and in what order.

Choice

The solution of choice has become the design preview. The design preview is not too expensive to implement. Furthermore it addresses the most acute problem of Den Heijer Industries. People have left and this method helps in spreading the knowledge throughout the organization as quickly as possible. Codification strategies might seem more ideal for this in the long run but one cannot codify the past that simply, codification needs to happen when the knowledge is relevant (e.g. Prencipe & Tell 2001, Nonaka 1994). All in all, this tool seems the best to start with to move toward a conscious knowledge management strategy for Den Heijer Industries.

As could be seen in the previous section chances of failure are low, benefits are high and costs are low. It can be integrated into existing meetings and the creation of documentation can also be combined with current efforts. This makes the observed changes minimal and the chance for success high. It also means that no additional meetings are needed so costs will be minimal. Finally benefits of reusing knowledge that otherwise not would have been reused or transferred too late are potentially large (e.g. Hislop 2005, Newell 2004)

This solution has the advantage being beneficial to the engineering department and the research department as well as CryoZone. Thus implementing this solution can garner improvements over the whole organization.

Furthermore the design preview has the advantage it has considerable worth for Den Heijer Industries already and will probably retain that as the organization grows.

A design preview improves should improve the structure and the timing of knowledge transfers and thus enhance knowledge reuse. Furthermore by looking for knowledge people gain more awareness of the knowledge available in the organization, increasing the traceability of knowledge. By looking for knowledge one also may be forced to unearth the reasoning of previous designs and rediscovering the "why". By creating documentation one can backlog some of the knowledge present in Den Heijer Industries. While the design preview is not the perfect solution for increasing the traceability nor capturing the "why" it can serve as a starting point for other methods. By having people looking for knowledge and searching for the reasons behind designs they will be more inclined to see the value of more and more structured storing of knowledge. Cumbersome solutions like a storage structure or a compendium of knowledge will get more support when people have seen the possible benefits it will yield.

Description

The design preview has been chosen. This approach focuses on gathering knowledge that in the beginning of the project. The overall goal herby is to increase knowledge reuse within Den Heijer Industries. Design previews will do this by focusing on concurrent transfers (Nobeoka 1995) and exchange with the routine organization (Disterer 2002). More specifically, the goal is to identify and procure knowledge from outside of the project early. Furthermore extra previews might be conducted when problems are encountered. In order to describe how design previews go about, three questions need to be answered; when do they need to occur, what should they try to transfer and how should they be executed? Finally the focus of the design preview is on engineering and the link between engineering and research. This means that both engineering and research will have to use them and also both can be identified as a knowledge source due to a design preview.

Timing is crucial for the design previews, discovering knowledge afterwards improves nothing. But since constant checking is not feasible, moments need to be picked at which design previews are executed. These moments should not differ too much from normal practice in order to easily integrate them into normal working routines. For engineering this will result in the normal meetings, described in the flowchart in *appendix XI, figure III*, being extended with design previews. The kick-off meeting, the checking of the basic design and the verification of the different technical fields always should include these design previews. Since only the blocks in the workflow will be adjusted the workflow itself will not change.

Important is that the design previews should be focused on the work that still needs to be done. When work done proved to be insufficient another design preview may be applied when looking for new solutions. Somewhat similar goes for the final preview that should only include a design preview when work was rejected. Important is to always remember that design previews should be aimed at being preventive and thus not focused on the past of the project. Whenever a problem arises however, a design preview may also be valuable. But one does not want that every minor setback provokes a meeting. Therefore the responsibility of starting an additional design preview will lie with the project leader. Things he or she should consider are naturally impact the lead-time and costs that the setback might have. The larger these are the relatively smaller the exercise of an additional design preview is. Furthermore the capability of the people to already deal with the problem or locate the required knowledge should be taken into account.

For research the situation is a little bit less clear-cut since the research projects do not always follow predefined schedules. Because of the more uncertain nature of the work that is done and sometimes even the uncertainty about the results research represents a less structured environment. What they do have in common with every other project is that they start, so at least at the beginning of each project a design preview should be done. For the very small projects this may just be an individual doing a small archive search and asking around a bit. For the larger projects a more formal approach should be taken. Later on design previews should be done when predefined milestones, if defined at all, are reached or large problems are encountered.

A design preview should always be aimed at the work to be done and try to get the answers to three questions; what knowledge do we need, have we got this knowledge and if we do not where should we look or who should we ask? The structure should conform to these questions and this does not differ between engineering and research. The first question involves qualifying the more unique and problematic aspects of the project. If such aspects indeed exist the group should consider whether or not they are capable of dealing with them. This should be done on the basis of technological field and experience with similar projects. If the result of this evaluation is that the team lacks knowledge or that it is likely that there already exists valuable knowledge outside the project-team, a systematic check of the archive and the people not on the project is required. The archive is as of yet quite problematic to consult extensively without the aid of memory but this should still be done. At the same time people are identified that worked on similar projects or can be considered experts in the fields that are related to the problems identified. This can latter on be combined with the technology owner solution if and when that solution is also implemented. While clear cut solutions will not always be the result people are forced to challenge their own ideas by gathering input from others. By reflecting and reviewing their own approaches and notions, new insights are gained and the knowledge reuse potential of Den Heijer Industries is used more effectively. Finally by structuring the interactions one becomes less dependent on hunches and individual action.

The design preview should take place when all the different team members are present. This is different for each project but should not deviate from a normal team setting. For the engineering department this would most of the time this would result in the project leader, a mechanical responsible, a process designer and an electric designer being present. When projects are larger naturally more people will be involved and for small projects less. In the latter case the electric designer for example may be excused as there is only one at Stirling. For research projects the group simply the different researchers involved and for CryoZone everyone. This way knowledge and awareness of problems is created in the project. By actively looking for knowledge throughout the organization and discussing problems, solutions and theories knowledge or at least the awareness will spread. This may help in securing the "why" for Den Heijer Industries thus also contributing to solving that problem.

Finally there is the issue of codification, does one want to store the results of a design preview or can it be assumed that those findings become an integral part of the project and do not have to be documented separately? Because it can be assumed that relevant knowledge is indeed largely stored and codification requires high amounts of discipline, decreasing the chance of success of the design previews. On the other hand certain documents are already required for quality justification purposes. Therefore documentation already is created and a design preview can build o that. Still it is advised to keep the codifying to a minimum and limit documentation to references to documents, projects and persons consulted. These should be in the form of links, which are supported by eSynergy, and are aimed at strengthening the structure of the archive. This way the design preview contributes to solving the traceability of knowledge.

Implementation

The actual implementation should be done by the project leaders, as they have responsibility over how projects are carried out. In order to ensure however that the design preview is something they can agree with pilots should be done. These pilots have as a goal to fine-tune the process of design previewing and should start with fresh projects. In the beginning they should only be done at the predefined points mentioned in the previous section. Input from every employee involved in the design previews should at least be considered. Furthermore these pilots will be the final test in order to see whether or not they are beneficial in practice. Gathering knowledge early in the project seems beneficial but with the pilots it can be justified in practice.

Main resistance factors would seem to be the lack of cooperation from the employees. This resistance will surface if either the process of previewing and informing is troublesome or if the immediate use is not apparent. Therefore the amount of work that should be done in terms of codification should be minimal. Only simple notes should taken regarding the design preview and those should be integrated in existing projects documentation. The perceived use is not something that can be influenced that easily. Project leaders should do their best to convince everyone of their use. When a design preview leads to actually useful preemptive knowledge sharing this should be recognized and word should be spread through the organization. Additional disciplinary action might be taken when this is not sufficient.

In order to start with the design review first awareness of the problem needs to be created. It should not be simply be introduced with an "as of tomorrow" announcement. Rather the reasons should be given and the benefits people performing the previews will get need to be stressed. The pilots will then furthermore ensure that the preview gradually becomes a part of the normal way of working. A design review will become more efficient when the search system and storage structure also implemented but for a start this is not necessary.

6. ACADEMIC REFLECTION

Main observation seems to be that two of the four methods, people-based and product-based, were least dominant in literature but very prevalent in practice. Furthermore all four of the methods seemed to strengthen each other. In fact they sometimes overlapped rather than interacted. Codified documents were used by the individuals who created them for people-based knowledge reuse. Personalization methods were used to gain insight into products. In other words, rarely was an approach taken by an individual based on purely one of the methods.

People-based methods were the most prevalent method at Den Heijer Industries and the one receiving the least attention from the world of academia. Having one person doing the same job again, however appeared to be the most practical and easiest way to do so despite its dangers in the long run. Since by default almost every organization would be expected to use this method, unless they hire new staff for each job, it should receive more attention. At den Heijer Industries it proved to be the most natural way of working and it became dominant over the years making the organization vulnerable to the weaknesses of the method.

Product-based methods furthermore were not really used at Den Heijer Industries although knowledge was stored in products and people are aware of that. The knowledge however is hard to extract and also for future products documentation is not created in such a manner that this will be the case for future products. That knowledge is stored in products however seems undoubtedly so therefore they may very well serve as the basis for a knowledge management method.

Furthermore literature has tried to define two separate strategies in codification and personalization methods (e.g. Haas & Hansen 2007, Hansen et al 1999, Hislop 2005, Song et al. 2007). These have gathered more attention in the literature than people-based and product-based methods. While both indeed have different characteristics they also can also work together blurring the borders between them. This was observed in this case study but also in a limited amount of academic papers (e.g. Song et al. 2007). So aside from also taking into account people-based and product-based methods it is advised to look at the whole spectrum of knowledge management methods as a whole and not as separate entities.

Aside from knowledge management methods not being pure in the sense of the methods they apply they often their goals are also not purely aimed at knowledge management. Within Den Heijer Industries this was observed as for example knowledge needs to be codified in order to guarantee quality. Without documentation Den Heijer Industries has no way to prove the quality but at the same time that documentation serves as a way of storing knowledge. Modularity is one of the solutions that also illustrate this point. While possibly very beneficial for knowledge management purposes it is also aimed at certain benefits for production, easy to create customizable products and cost control (Baldwin & Clark 1997, Ulrich & Tung 1991).

Not all interactions described in literature however did fit the situation at Den Heijer Industries. Some authors have proposed a way of working featuring several steps ranging from the identification of knowledge, when it is still tacit, to the codification of knowledge when it is thoroughly known (Crossan, et al. 1999, Nonaka 1994, Zietsma et al. 2002). What was observed at Den Heijer Industries was that the most important knowledge that was thoroughly known was still mainly located with people. Furthermore there is no structured way of working to process the knowledge into codified form or heuristics. This may be due to the before mentioned size of the organization or to other factors but what remains is that codified knowledge does not represent the knowledge Den Heijer Industries is most intimately familiar with at the moment.

While the theoretical reflections are based on a case study and thus the specific situation at Den Heijer Industries there are reasons to assume there are still some characteristics of this situation that are quite common. For a start there is a high reliance on informal methods and a focus on tacit knowledge that is usual in small firms (Anderson & Boocock 2002, Meroño-Cerdan et al. 2007, Nunez et al. 2006). Furthermore organizational learning is perceived to be secondary to individual learning, like Anderson and Boocock (2002) also found. Furthermore both Meroño et al. (2007) and Nunez et al. (2006) found that barely any knowledge management tools were implemented, just as with Den Heijer Industries. What did differ from the literature is managerial awareness of the issue of knowledge management, something often lacking in small firms according to Nunez et al. (2006). Whether or not this managerial awareness is a result of this study or if it will continue after its completion remains to be seen. Also narratives exists in such a manner that they show striking likeness with the literature (Orr 1990, Patriotta 2003). Stories about the great minds in cryotechnology like Haarhuis and Rinia (Hargreaves 1991) still exist and contribute to both knowledge exchange and organizational identity.

While Den Heijer Industries conforms to the literature for a large extent there is one aspect that differs enormously from the literature. Hoarding knowledge and the lack of willingness to share it which can be quite prevalent (Hansen & Nohria 2004, Hauschild & Stein 2001, Simons & Peterson 2000) is non-existent. People are proud of their products and love to tell and learn others about them. This facilitates, among other beneficial effects, the informal exchange of knowledge and might help in the implementation of future knowledge management tools.

7. CONCLUSION

While knowledge reuse was found to be not optimal at Den Heijer Industries, there seem more than enough possibilities for improvements. Knowledge management has the explicit attention of the management, facilitating changes and the implementation of new tools. Several problems were identified as well as general changes that should be made and tools that can be used to achieve these changes.

7.1 Managerial Implications

The management of Den Heijer Industries should take action in order to preserve knowledge for the company in the long run and to reuse it more effectively in the short run. In order to do so three problems need to be dealt with; the current unstructured way of sharing knowledge, not capturing the underlying reasons and the traceability of knowledge. In the short run the application of design previews is proposed. After that several of the other solutions may be implemented.

7.2 Recommendations for Further Research

For Den Heijer Industries it is advised to further delve into the breadth of knowledge management. That means that while this study addressed knowledge reuse within the organizational boundaries, attention should also be given to acquiring knowledge from outside these boundaries. This may be in the form of partnerships with suppliers or customers, co-development with universities or more even fleeting relationships.

Furthermore it was observed that the process of reusing and sharing knowledge rarely consist of one method. Practices usually seem to combine at least one or more of the methods distinguished throughout this research. Even codification and personalization methods are highly entwined as documents may be refer to people and people to documents.

Regarding the more academic venues for further research the synergy or lack thereof between different methods seems a worthwhile pursuit. Not only personalization and codification methods should gain attention but also people-based and product-based methods should get more attention. By looking at these four methods as a whole, rather than separate entities, new and more thorough insight in the field of knowledge management will be gained. This seems not only interesting issue in a theoretical sense but can also prove to be highly valuable in practice. How can one identify these interactions? Can they be used to make otherwise unattractive tools attractive? In what sense are different methods already an integral part of each other and can they be separated? Answers to these kind of questions will provide further insight in the field of knowledge management

7.3 Limitations

Since this research is a case study the results should be generalized to other situations with caution. This is even more so the case because of the in-depth nature of the study and the small size of the company.

Furthermore the research was based on qualitative data and lacks an empirical basis. Also assessment of the different solutions proposed are more educated guesses based upon interviews and generalized findings from the literature.

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9. APPENDICES

I. Knowledge sharing methods

Methods

Topic	Sharing, Quantitative	Sharing, Qualitative	Knowledge Reuse
Codification methods			
IT-tools (databases, computer-mediated communication)	(0/+) Haas & Hansen (2001) (+) Hansen et al. (1999) (+) Gammelgaard & Ritter (2005) (0/+) Hislop (2005) (+) Song et al. (2006) (+) Song et al. (2007)	*(-) Bresnen et al. (2003)* *(-/0) Davenport et al (2001)* *(-) Newel et al. (2004)* (-) Haas & Hansen (2005) (-/0) Haas & Hansen (2007) (-) Hall (2006) (-/0) Hislop (2005) (+) Song et al. (2006)	(+) Hansen et al. (1999) (0/+) Haas & Hansen (2007) (+) Song et al. (2006)
Heuristics (centers of excellence, best practices, technology rules, Justification)	*(+) Prencipe & Tell (2001)* *(+) Walker & Cristensen (2005)* (+)Crossan et al. (1999) (0) Szulanski (1996) (+) Zietsma et al. (2002)	*(+) Prencipe & Tell (2001)* (-) Crossan et al. (1999) (0) Szulanski (1996) (+) Tsoukas & Vladimirou (2001) (+) Nonaka (1994) (-) Zietsma et al. (2002)	(0) Denyer & Tranfield (2005)
After-project reviews	*(-) Newel et al. (2006)*	*(+) Zedwitz (2003)* *(-) Newel et al. (2006)*	*(+) Zedwitz (2003)*
Personalization methods			
Co-location (job rotation, face-to-face communication, mentors)	(0) Haas & Hansen (2007) (+) Hansen et al. (1999) (+)Gammelgaard & Ritter (2005) (+) Hansen & Nohria (2004) (+) Song et al. (2006)	(+) Haas & Hansen (2007) (+) Hansen et al. (1999) (+) Hansen & Nohria (2004) (+) Hauschild et al. (2001) (+) Song et al. (2006) (+) Song et al. (2007)	(0) Haas & Hansen (2007) (+) Song et al. (2006)
Communities of practice	(+) Brown & Duguid (2006) (+) Gittelman & Kogut (2003) (+) Hislop (2005) (+) Milne & Callahan (2006)	(+) Brown & Duguid (2006) (+) Gittelman & Kogut (2003) (+) Bechky (2003) (+) Hislop (2005) (+) Milne & Callahan (2006)	(+) Hislop (2005)
People finder (knowledge mapping)	*(0/+) Berg, van den & Popescu (2005)* (+) Hellström & Husted (2004)	*(0/+) Berg, van den & Popescu (2005)* (+) Hellström & Husted (2004)	
Story telling (narratives)	(+) Orr (1990)	(+) Orr (1990) (+) Patriotta (2003)	
Leadership (autonomy, goal setting, competition)	*(-/0) Katz (1985)* (0/+) Alvesson & Kärreman (2001)	*(-/0) Katz (1985)* *(-) McGrath (2001)* *(-) Szarka et al. (2004)* (+) Hansen & Nohria (2005) (0/+) Alvesson & Kärreman (2001)	*(+) Szarka et al. (2004)*
People			
People dependence	(-) Hatch & Dyer (2004)	(-) De Long & Davenport (2003) (-) Hatch & Dyer (2004)	(+) De Long & Davenport (2003) (+) Hatch & Dyer (2004)
Products			
Embedded			(+) Blackler (1995)
Modularity			(+) Baldwin & Clark (1997) (+) Ulrich & Tung (1991)
Platforms	(+) Muffato & Rovenda (2002)		(+) Muffato & Rovenda (2002)

	(+) Robertson & Ulrich (1998)		(+) Yang & Yiang (2006)

Table II.I: Literature on different knowledge management methods

Influences

Influence	Codification	Personalization	People	Product
Firm size	(-) Anderson & Boocock (2002) (0/-) Nunes et al. (2006)	(+) Anderson & Boocock (2002) (0/+) Meraño-Cerdan et al. (2007)	(+) Anderson & Boocock (2002)	
Work pressure	*(-) Zedwitz (2003)* (-) Huber (1991)	*(-) Zedwitz (2003)* (-) Huber (1991)		
Time	*(-) Katz (1982)* *(-/0)Newel (2004)*	*(-) Katz (1982)* *(-/0)Newel (2004)*	*(-) Katz (1982)*	
Motivation	(+) Hauschild et al. (2001)	(+) Katz (1998)	(+) Hauschild et al. (2001) (+) Katz (1998)	
Quantity of knowledge	(-) Davenport et al. (2001) (-) Haas & Hansen (2001)			
Tacitness (causal ambiguity, Knowledge type)	*(0) Leseure & Brookes (2004)* *(-/0) Newel (2004)* (-/0) David et al. (2000) (-) Hansen (2002) (-) Hislop (2005) (-) Polanyi (1966) (-) Szulanski (1996)	*(0) Leseure & Brookes (2004)* *(-/0) Newel (2004)* (0/+) Styhre (2006) (+) Hansen (2002) (+) Hislop (2005) (+) Polanyi (1966)		
Measurability	(+) Lettice et al. (2006)	(0) Lettice et al. (2006)		(+) Lettice et al. (2006)
Functional diversity	*(-/0) Keller (2001)*	*(-/0) Keller (2001)* *(-/0) Lovelace et al. (2001)*		
Trust	*(+) Foos et al. (2006)* *(+) Lovelace et al. (2001)* (+) Hislop (2005)	*(+) Foos et al. (2006)* *(+) Lovelace et al. (2001)* *(0) Bakker et al. (2006)*		
Culture (climate for learning/sharing)	*(+) Davenport et al. (1998)* (+) Zackariasson et al. (2006) (+) Nonaka & Takeuchi (1995) (+) Reich (2007)	*(+) Davenport et al. (1998)* (+) Hauschild et al. (2001) (+) Nonaka & Takeuchi (1995) (+) Oliver & Kandadi (2006)		
Phronesis	(+) Nonaka & Toyama (2007)	(+) Zackariasson et al. (2006) (+) Nonaka & Toyama (2007)		

Table II.II: Influences

For both tables goes that when the names of the authors are printed in italic the research focused on knowledge management in projects. When underlined it means the research was conducted in an organization that works on a project basis, e.g. consultancy firms. A minus (-) stands for a negative impact, a zero (0) stands for either no observed impact or no conclusive statement at all and a plus (+) stands for a positive impact. Positive impacts on learning and the success of the knowledge exchange have been shared under the heading of qualitative sharing, dissemination a under quantitative sharing and better project performances have been put under knowledge reuse.

II. The Stirling cycle

The Stirling engine was patented by Robert Stirling in 1816. The principle of this engine was to have heat as an input and movement as an output. Unfortunately for Robert Stirling the engine based on this principle never became a success. Years later, in 1930 Philips started working with this engine but also never achieved commercial success. A quote from the book *The Philips Stirling Cycle* from Hargreaves (1991) clarifies why, Philips continued developing the enginedespite failure after failure.

> *"Certain is it that the unbridled optimism of the post-war years was not entirely the fault of the commercial spirits. The engineers had a hand in it too. Of course there was no conscious attempt to present the engine in a better light than the facts justified; nevertheless, great efforts were made to ensure that every demonstration worked well, even if the engine did have to be dismantled afterwards to clean the regenerator or repair some critical component. Because of the many successes and the continuing stream of improvements, it was felt that such problems were just passing difficulties, soon to be overcome like so many others. But it was disconcerting to find after each step forward it was always the same problems that seemed to be left over."*

In 1945 the principle was reversed, now movement was the input and temperature difference was the output. In 1955 the first cryogenerator based on the Stirling cycle was put onto the market and opposed to the engine they became a success.

The Stirling cycle involves alternately compressing and expanding a fixed quantity of a nearly perfect gas. The engine was based on a closed cycle, which means no gasses are exchanged with the outside environment. The gas that is compressed is kept at room temperature in order to cool that part. The expansion however is performed at low temperatures.

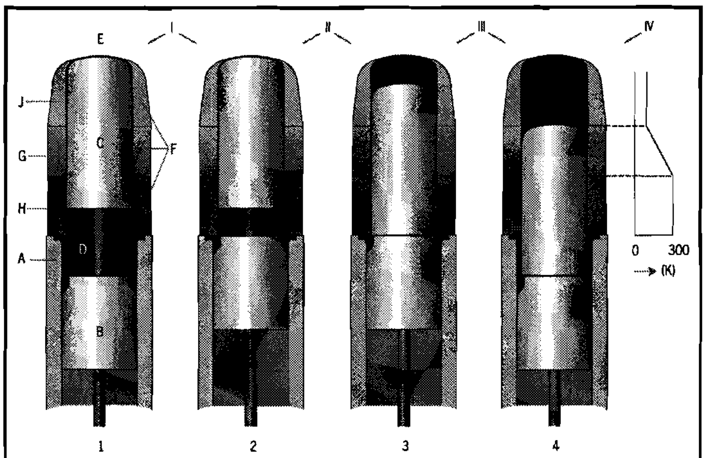

Figure II.1:four phases

This proces has four distinct phases; these are illustrated in *figure II.I*, which shows the four different piston positions, each indicated by a Roman numeral. The cylinder A is closed by the piston B, and contains a certain amount of gas. The space inside the cylinder is divided into two sub-spaces, D and E, by a second piston C, the so-called 'displacer'.

The annular channel F connects spaces D and E, and contains three heat exchangers: the regenerator G, the cooler H and the freezer J. In position 1 most of the gas is in space D and at room temperature. During phase I this gas is compressed by piston B. In phase II the gas is displaced by means of the displacer from space D to space E, which is already at a low temperature. During this displacement the gas passes through the heat exchangers. The cooler dissipates the heat caused by compression through cooling water. The regenerator cools the gas almost to the temperature prevailing in space E.

Phase III is the phase during which actual cold production takes place, namely by expanding the gas through movement of the displacer and piston together. Finally, by moving the displacer (phase IV), the gas is returned to space D. While passing the freezer its cold is dissipated to the ambient environment, and in the regenerator it is reheated to nearly room temperature. The initial situation has now been restored, and the cycle can be continuously repeated.

The PV-diagram of the Stirling cycle is shown in *figure II.II*, and comprises the following four phases:

Phase I: Isothermal compression

Phase II: Isochoric displacement and cooling

Phase III: Isothermal expansion

Phase IV: Isochoric displacement and re-heating

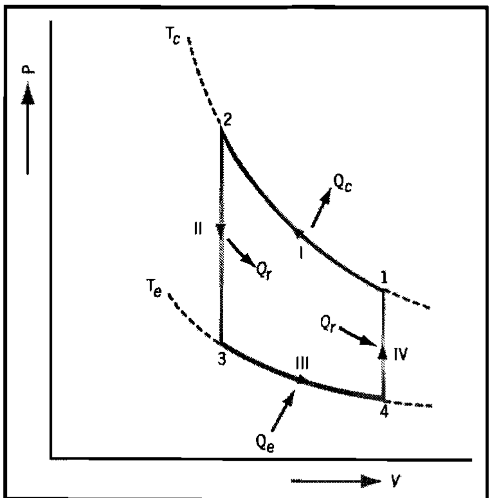

Figure II.II:PV diagram

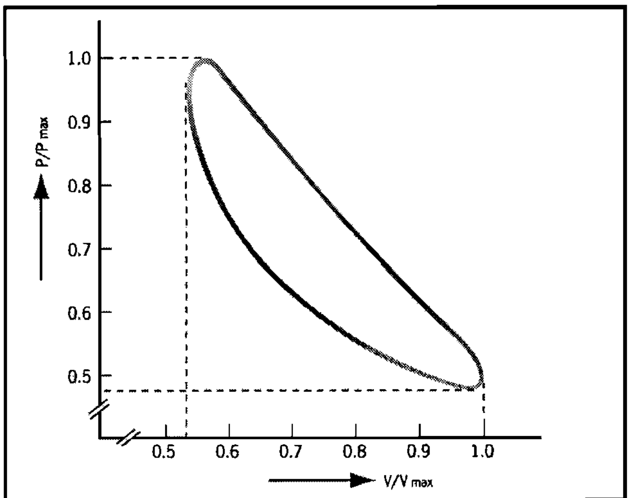

Figure II.III: PV diagram harmonic movement

In practice, however, this diagram is much smoother than shown in *figure II.II*, because of the harmonic movement of the piston. There is a phase shift between the displacer and the working piston, causing the expansion space to lead the compression space by about 90°. The actual situation is shown in *figure II.III*.

It is clear that a large temperature difference will occur between the compression space and the expansion space. The way in which this temperature difference is established, and what influence the regenerator has in this, is shown in *figure II.IV*. The working gas in both the compression and expansion space is initially at ambient temperature. During the first working cycle the gas is successively cooled by the water cooler and by the expansion to temperature T1. When the expanded gas returns to the compression space, a temperature gradient is established in the regenerator. This means that, after the second compression stroke, the working gas is slightly pre-cooled in the regenerator before it is expanded in the expansion spaces to reach temperature T2. After a significant number of strokes the temperature gradient in the regenerator reaches equilibrium, which means that the working gas reaches its lowest temperature, TN, after expansion. It is obvious that the regenerator is the most important component in this cooling process.

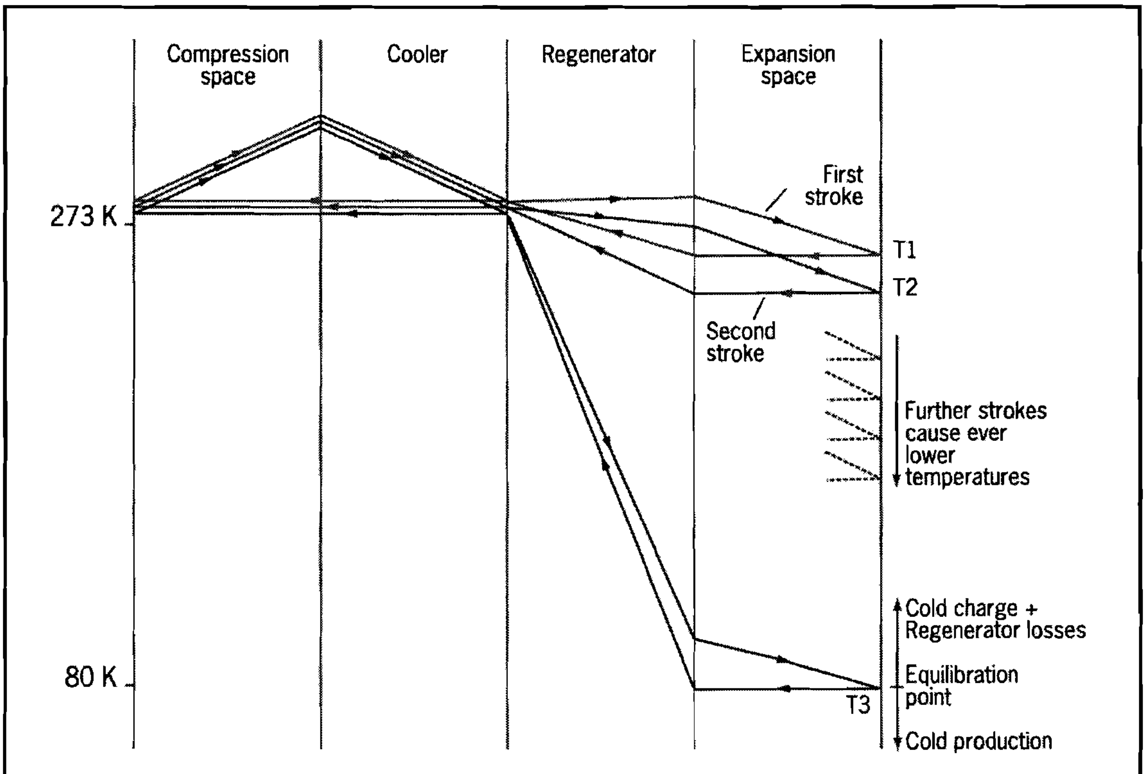

Figure II.IV: PV diagram harmonic movement

III. Products Stirling B.V.

All the products created by Stirling are more or less based on the head displayed in *figure III.I.* Some models designed for even lower temperatures have two heads thus going through the Stirling cycle two times.

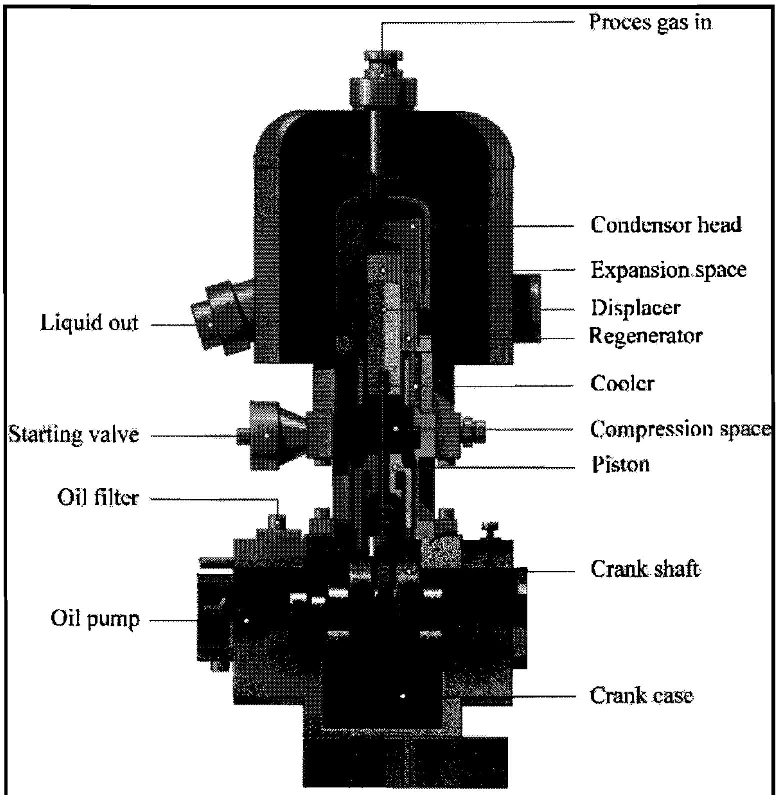

Figure II.1: Cut through of a one cylinder stage cryogenerator SPC-1

Based on this principle a whole range of products is offered by Stirling. These range from liquid nitrogen production plants and liquid air production plants to process cryogenerators used to cool specific processes. The newest addition to the range of products is an application for in laboratories called the StirLab which is basically a liquid nitrogen tap. Most of the product types are produced in a range with a different amount of compressors, the more compressors the higher the capacity of the product.

In the rest of this appendix a list will be given of the product range of Stirling from January 2005. The number in the name of a plant stands for the number of compressors present in the design. It should be noted that although there is a list of standard products Stirling needs to do modifications on almost every product they deliver. These modifications range from small, to rather large and sometimes even completely new.

Names Stirling plants

(January 2005)

Name	Previous name	Explanation
<u>Stirling Liquid Nitrogen Plants</u>		
StirLIN-1 Economy	--	5 Liter plant
StirLIN-1 Compact	MNP 10/1/300 Compact	
StirLIN-1	MNP 10/1/500	
StirLIN-1 Extendible	--	Extendible to StirLIN-2
StirLIN-1 Conversion	Conversion PLN106 or PLN108 → MNP	
StirLIN-2	MNP 20/2/1000	
StirLIN-4	MNP 40/4/2000	
StirLIN-4 Conversion	Conversion PLN 430→MNP	
StirLIN-4 Extendible	--	Extendible to StirLIN-8
StirLIN-8	MNP 80/8/2000	
<u>Stirling Liquid Air Plants</u>		
StirLAIR-1 Economy	--	5 Liter plant
StirLAIR-1 Compact	--	
StirLAIR-1	PLA 109	
StirLAIR-1 Extendible	--	Extendible to StirLAIR-2
StirLAIR-2	--	
StirLAIR-4	PLA 430	
StirLAIR-4 Extendible	--	Extendible to StirLAIR-8
StirLAIR-8	--	

Stirling Process Cryogenerator		
SPC-1	SPC01	
SPC-1*		* = tailormade version standard
SPC-1(500)	--	SPC of Economy (500W@77K)
SPC-4	SPC04	
SPC-1T	PGH107	T=Two stage
SPC-4T	(B20)	
Stirling Liquid Power Coolers		
LPC-1 FF	LPC01	FF = Forced flow
LPC-1 RL	LPC01	RL = Re-liquefaction
LPC-2 FF	LPC02	
LPC-2 RL	LPC02	
LPC-4 FF	LPC04	
LPC-4 RL	LPC04	
LPC-8 FF	LPC08	
LPC-8 RL	LPC08	
Stirling Gas Power Cooler		
GPC-1	GPC01	
GPC-4	GPC04	
Stirling Gas Liquefiers		
SGL-1	SGL01	
SGL-4	SGL04	
SGL-1T	PGH107	
SGL-4T	B20	

Stirling Liquid Oxygen Plants

StirLOX-1 Economy

StirLOX-1	MOS ../1/500
StirLOX-2	MOS ../2/1000
StirLOX-4	MOS ../4/1000
StirLOX-8	MOS ../8/2000

Stirling Nitrogen Gas Generators

StirliN2g 002
StirliN2g 004
StirliN2g 104
StirliN2g 106
StirliN2g 108
StirliN2g 110
StirliN2g 206
StirliN2g 208
StirliN2g 210
StirliN2g 310
StirliN2g 410

StirliN2g XYZ:
X = number of cilinder banks
(in which 0 = build in)
YZ= number of cilinders

IV. Company Description

Like mentioned in the introduction, his research will be conducted at Den Heijer Industries, a holding consisting of multiple companies as displayed in *figure IV.I.* Of the four companies displayed Combined Technologies B.V. is purely legal and only contains real estate. Since no knowledge work, or rather no work at all, is done within that company no further attention will be given to it. Stirling Cryogenics & Refrigeration B.V., Stirling from hereon, is the largest and will be the focus point of this research. CryoZone B.V., simply CryoZone from hereon, is a small company that has just started and is located in the same premises as Stirling. Finally Stirling Cryogenics India Pvt.ltd. is the service company for Stirling that is located in India due to the facts that wages are lower and a lot of clients are located in India. This part of the holding will receive less attention because of the physical location and because it is less innovation driven. The holding as a whole aims at growing, both through organic growth and extension of the practices, of which CryoZone is an example, but all within the field of cryotechnology. Each company will be discussed in more detail in the rest of this section.

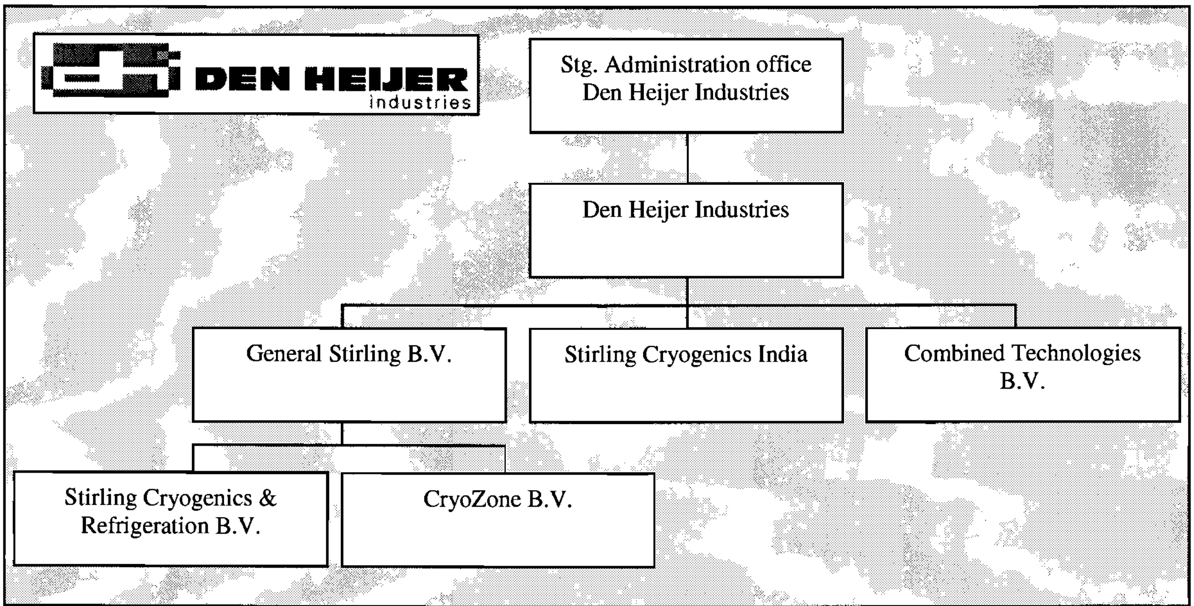

Figure IV.I: Legal Structure

Stirling Cryogenics & Refrigeration B.V.

Stirling is a company named after an Reverent Stirling born in 1816 (see Hargreaves 1996) on which its products are based; cooling facilities that can cool to minus 250 degrees Celsius. The principles behind this engine and the products based on this engine are displayed in *appendix II* and *appendix III* respectively. They have finished approximately 30 projects each year unto 2007. That year was very successful and an increase to almost 45 projects was seen. A not exhaustive sample of some of the recent finished projects and their characteristics is displayed in *appendix IX*. Expectations are that 2008 at least that many projects will be done, main constraints not being the demand but the capacity of Stirling. The organization structure is displayed in *figure IV.II*.

Stirling offers cold solutions, which basically translates into liquid nitrogen or oxygen supply

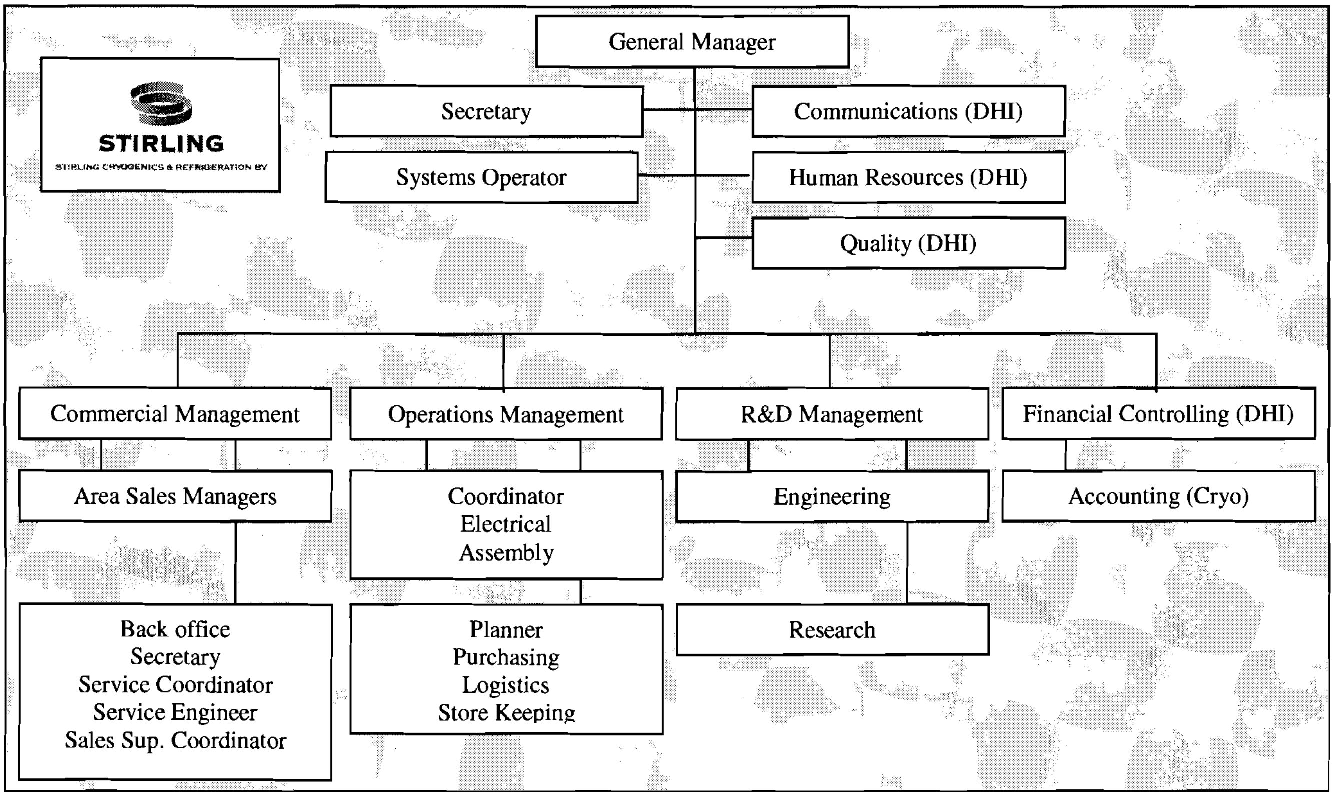

Figure IV.II:Stirling Cryogenics & Refrigeration B.V.

on-site most of the times. Machines delivered fall into a couple of categories, and subcategories are made on the basis of the number of cylinders and thus the production rate of the machines. The first category consists of machines that produce liquid nitrogen or oxygen. They form up the bulk of the projects being done. Of these the most popular are one-cylinder machines in either the compact or the economic variety. The second type of machines consists of machines that cool a part of a process without nitrogen or any other liquefied gas to transfer the cold. Finally a recent addition is the Stirlab, a laboratory friendly liquid nitrogen producer that is useful for small amounts and can be put in a quiet work space environment. This machine however is so recently developed that Stirling currently is in the phase of fieldtesting them in India.

CryoZone B.V.

CryoZone is the newest part of Den Heijer Industries and focuses on the creation of specific tailor-made cryostats, vessels to maintain cold temperatures. The company was started because Stirling was receiving requests for cryostats, requests that could not be met by other companies.

Also when Stirling needed a Cryostat their demands were not or rarely met by outside suppliers. Because of the high level of knowledge regarding cryogenics Den Heijer Industries decided to start a specialized company. This was not done within Stirling because now CryoZone is able to deliver solutions independent of the coolers produced by Stirling

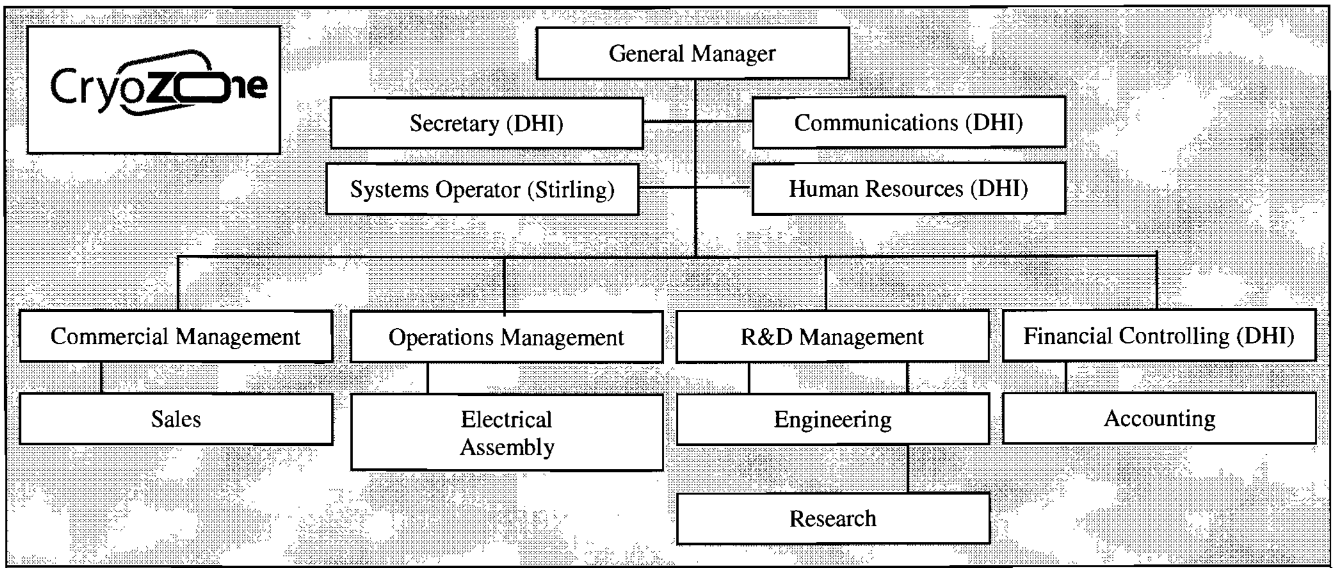

Figure IV.III: CryoZone B.V.

The approach is different from the one from Stirling, no predefined solutions that can be adapted for the customer exist but instead completely new products are developed. Examples can be found in *appendix X*. Because of this CryoZone delivers products for the really special cases and is economically inefficient for those problems that are "too simple". Another consequence of this way of doing business is the high level of interaction early on. Customers really need to define their wishes and needs and CryoZone already needs to do calculations and designing before the actual quote is offered. This in combination with the fact that the company is young, has a limited number of employees and at the moment only handles a small number of projects can cause financial trouble. In the beginning, before a quote is offered costs are already made, costs that are not covered if the customer decides not to take the quote. More elaborations on this can be found in *section 4* where the processes at Den Heijer Industries are discussed. Despite the number of functions displayed in *figure IV.III* there are only four people currently active within CryoZone. Of these four, Ronald den Heijer is also general manager of Stirling and thus only part-time active within CryoZone. The people currently working in CryoZone thus have multiple tasks, again for more information on how work is done see *appendix XI*.

Stirling Cryogenics India Pvt.ltd.

Stirling Cryogenics India Pvt.ltd., from hereon Stirling India, is the service organization and local sales organization within Den Heijer Industries. Like said in the introduction of this section this part of the holding will be studied less intensely during this research. The main form of knowledge interaction between Stirling and this service organization occurs when non-regular problems are found in the field and Stirling is called for additional support, often via telephone. Still while it may seem less feasible to conduct the actual studies in India it should be taken into account that the knowledge of the service engineers is located in another continent. At the moment it is not even known whether or not the service engineers from India possess idiosyncratic knowledge. Therefore, despite practical less feasible, it is still useful to look at Stirling India from a knowledge management perspective.

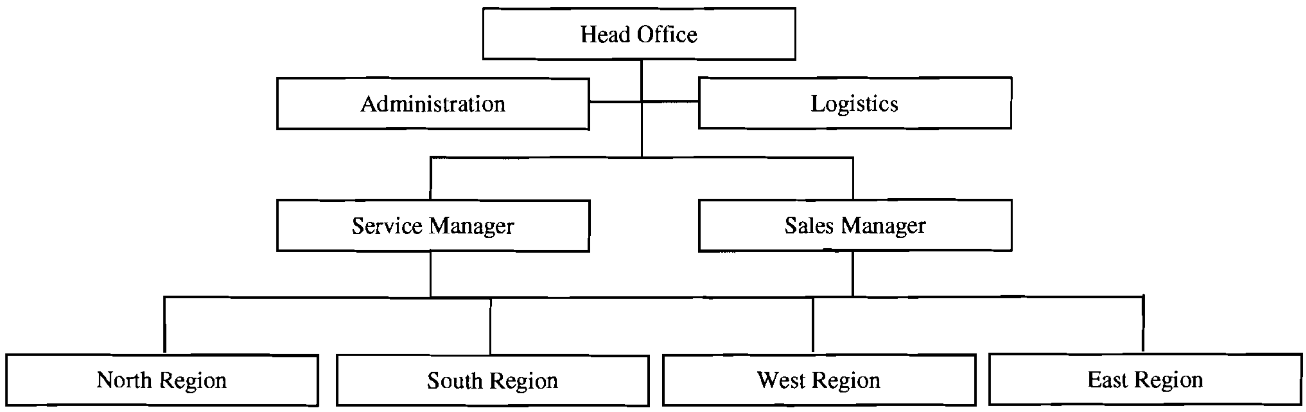

Figure IV.IV:Stirling India Pvt.ltd.

V. Interview protocol

All of the appointments for the interviews were made in advance. The space to conduct the interviews was also reserved at the same time. Every one of the interviews was conducted at the premises of Stirling. All interviews were conducted in Dutch which was the native language for all but one of the interviewees and the interviewee. One person was a native Chinese speaker however the interview was conducted in Dutch, when misunderstanding arose English was occasionally used. The interviewer did not use a tape recorder but made notations during each interview. Whenever necessary, in case of uncertainty of lack of completeness, follow-up interviews were conducted.

When it was the first time a person was interviewed a short introduction of the research and the background of the researcher were given. The interviewee also had the opportunity to ask additional questions and inform about the research project.

After each interview the interviewee was presented with a summary of the interview and asked to comment. This gave the interviewer the opportunity to correct mistakes or misunderstandings and some case receive additional information. After that the interviewee was asked if he or she could be contacted again regarding the topic and thanked for his or her time.

Process

Goal of these interviews was to discover how people reused knowledge and if they did how it worked. For each person interviewed the job description was read by the interviewer before the interview. The persons interviewed were all the employees of CryoZone and the people working at Stirling research and Stirling engineering. Appointments were made in advance for a time period of one hour. In practice most of them took longer and none of them shorter. While a room was reserved for the interviews every interview ended at the workspace of the interviewee. There he or she showed examples.

1. How do you start a project?
2. Where do you get your input for projects?
3. Do you consult others when working on a project?
4. Do you reuse your work or that of others in projects? If that is the case could you provide examples?

Knowledge needed

These interviews were conducted to establish what kind of knowledge was present within the organization. The persons interviewed were all of the employees of CryoZone and everyone working at Stirling research and Stirling engineering. Interviews were conducted in approximately fifteen minutes. Appointments however were made for half an hour with the comment that probably less time was needed.

1. What is your own personal background in terms of education and work experience?
2. How long have you worked at [Stirling/CryoZone]
3. What kind of knowledge does one need to your work?
4. What kind of knowledge does the [Stirling engineering/Stirling research/CryoZone] as a whole need to possess to function effectively?
5. What kind of personality does one need to work at [Stirling engineering/Stirling research/CryoZone]? When the question was unclear examples were given by the interviewer; precise, patient or creative.

Problems

These interviews were conducted in order to locate problems that were the direct result of a lack of knowledge reuse. When examples hereof were encountered during other interviews the interviewer pursued these lines of enquiry during that interview. The persons interviewed were all the people working at Stirling research and Stirling engineering. Furthermore people with a long history at Stirling (The CEO and the manager of the sales and the service department) were interviewed regarding this topic. Interviews were conducted in approximately half an hour minutes.

1. Can you recall recent problems within Stirling?
2. What caused these problems?
3. How were these problems solved?
4. Could these problems have been prevented by using knowledge already present in the organization?

New Employee

Goal of these interviews was to see which knowledge related problems a new project manager encountered when he started at Stirling engineering. These interviews where conducted during the course of approximately one and a half month. They were conducted each week when possible (the interviewee needed to be in Italy for a project in certain weeks.) and took about half an hour. A predefined day of the week and hour was chosen but this time was often changed. The first interview took about an hour and additionally was used for introductions and providing the interviewee with information regarding the research. Because the interviewee new what to expect later interviews were more in the form of him reporting his experiences. The interviewer only needed to ask questions to direct the conversation and to inform about details.

1. What projects have you been working on since the last interview?
2. Have you encountered any problems since the last interview?
3. Have you encountered any knowledge related problems since the last interview?

VI. Benchmarking

<table>
<tr><th>Name</th><th>People interviewed</th><th>Business</th><th>Size compared to Stirling</th></tr>
<tr><td>Philips Lighting Automotive</td><td>Group leader basis development burner</td><td>Research, creating lighting for automotive industry</td><td>Very large</td></tr>
<tr><td colspan="4">• Personalization methods where used organization wide, spreading knowledge throughout Philips using seminars. These topics of these seminars are the result of bottom-up process and are supported by management.
• Philips Lighting Automotive uses technology owners. These persons become responsible for one of the predefined core technologies. Responsibilities entail keeping up-to-date, reviewing related patents and acting as a hub for people looking for information regarding that technology.
• Technology rules were created. These rules consisted of a limited number of sheets. The first described the rule as effectively as possible in one line. The remaining one or two sheets provided the result and links to more detailed documents.
• Codification methods are seen as something potentially valuable but hard to actually get working</td></tr>
<tr><td>Bosch Rexroth</td><td>Product quality manager cylinders
Quality support engineer cylinders</td><td>Hydraulics</td><td>Very Large</td></tr>
<tr><td colspan="4">• Knowledge needs to be codified in order to be valuable. Codified knowledge is considered a “higher order” knowledge.
• Due to the nature of the business a lot already needs to be codified in order to guarantee the quality.
• Other methods as codification are regarded less valuable due to the uncertainties it brings with them.</td></tr>
<tr><td>OTB Solar</td><td>COO</td><td>Solar</td><td>Slightly larger</td></tr>
<tr><td colspan="4">• In order to successful manage knowledge only two things were considered vital; knowing what one needs to know and knowing who knows what.
• The interviewee’s point of view was that knowledge did not just vanish, by making phone calls someone who possess the knowledge needed will always be found.
• Codification methods where deemed not necessary but still valuable. By using them correctly efficiency can be gained.</td></tr>
<tr><td>Singulus</td><td>Manager research & development
Manager operations</td><td>Optical disc mastering</td><td>Slightly larger</td></tr>
<tr><td colspan="4">• When Singulus faced the problem that they had only one experienced service engineer remaining they took action. They made him technical director. By doing so other service engineers were faced with more complex problems and the formerly experienced service engineer had more time to assist the remaining service engineers. This way he was forced to transfer his knowledge and the others were forced to learn.
• Rather than codifying their knowledge general issues were transformed into lessons given to service engineers. These lessons were held when as many of them were in the Netherlands to attend.
• Codification methods were used but are now rather old and not kept up-to-date.
• Codification methods are still deemed useful but very hard to use effectively. This is because of their time consuming nature and their lack of value when they are not kept up-to-date.</td></tr>
<tr><td>VDH Beheer</td><td>Director</td><td>Knowledge management tools</td><td>Smaller</td></tr>
<tr><td colspan="4">• States that codifying knowledge is possible but has to be done smarter.
• Aims mainly at knowledge sharing between companies.
• You need to create a data structure that fits with the way of working and thinking of people, not the other way around.</td></tr>
<tr><td>Pernosco
(used to be part of VDH Beheer)</td><td>Owner</td><td>Knowledge management tools</td><td>smaller</td></tr>
<tr><td colspan="4">• States that codifying knowledge is possible but has to be done smarter.
• Aims mainly at knowledge sharing between companies.
• You need to create a data structure that fits with the way of working and thinking of people, not the other way around.</td></tr>
</table>

VII. Problem Summary

Main Problem	Related causes	Explanation
Capturing the "why"	Underlying reason not captured or lost	At the moment the reasons behind certain designs are not recorded, not at engineering, not at research and not at CryoZone.
	No reviewing of the project	At the end mistakes made and paths taken to solution are not analyzed so people might not even realize they made or took them.
	Large history + Size of archive + Relevance of old solutions	Throughout the history of the Philips Stirling engine a lot of research was done. The results of all this time, money and other resources is for a large part stored in the archives of Den Heijer Industries. However why these solutions were chosen and why others were not is difficult to find.
	Archiving has low priority	Not so much the archiving itself but rather the descriptions that explains why things have been designed in a certain way.
Over reliance on people, codification needed in order to preserve the knowledge for the organization in the long run		
Traceability	No adequate search system	At the start of the research there was no other way of looking for project than by project number or memory (or the memory of experienced employees).
	Size of archive + Large history	Search systems are relevant because the size of the archive makes it impossible to search otherwise. At the moment this is not the case for CryoZone.
	Relevance of old solutions	Because the old archive is not only large but also span of possible documents that could be relevant becomes larger.
	Archiving has low priority	Not so much the archiving itself but rather the descriptions and tags that could make it traceable
	One person per field of expertise	When only one person is concerned with a certain field he or she is less inclined to increase the traceability since he or she already knows enough about the subject stored.
Lack of attention to codification methods, needs to be structured in order to achieve higher effectiveness.		
No structured knowledge sharing	No knowledge sharing structure + Ad hoc sharing of knowledge	People share knowledge on an ad hoc basis. If someone is not included a meetings while he has relevant knowledge he or she will only be able to share that knowledge if he or she randomly finds out about the project. So while people have a general impression who to go to when faced with certain issues there is no structured way of doing so.
	People know each other	People do not feel the need to structure or formalize the way they deal with each other in order to share knowledge. This way the illusion is created that everything is shared while some things might slip through.
	Knowledge at engineering	The sharing of knowledge across departments becomes more relevant because of the large amount of historical know-how located in the engineering department. This results in the engineering department having more in-dept fundamental knowledge of the older machine types
	One person per field of expertise	Since each person has his or her own expertise it is hard for an individual to judge what others know or do not know. This does no motivate someone to go and look for information with others
	Skewed division of	Due to the organic growth of the company expertise has ended up with a limited group of people. Furthermore this knowledge may not always be of use to that group but rather valuable to other parts of the organizations. Aside

	knowledge + Research dependent on engineering	from this strange division of knowledge there is also the issue with the recently created CryoZone. Because this part of the company is young and has relatively few employee's knowledge needs to be imported from the rest of the organization
More personalization activities in a structured fashion are required, might even be supported by the use of codification methods.		

VIII. Projects Stirling

Structure

Design Preview: What is meant by design reviews are certain points in the process where people are forced to consult, or consider consulting, other sources not directly related to the project. That can also be sources outside the organization but since that falls outside the scope of the research it will not be taken into consideration. This personalization strategy focuses on bringing together people at the right time and thus facilitating the reuse of knowledge early on in the project when it still has the most value. Goal is to identify and locate knowledge before it is needed and acquire it in time. This strategy is aimed at all the different departments and should also transcend the boundaries between those departments.

Design previewing is by no means an expensive undertaking since it can be incorporated into already existing steps within the process. At the start-up meeting for example, one can simply add a step where the project members need to define problems and who might be of use regarding those problems. This same consideration goes for how big the chances of success are for this method. Because it is only a minor change into current procedures and consulting each other already happened, albeit in a less structured fashion, only a limited amount of discipline is required and chances of success are thus high. The potential profit to be gained however is quite large. This is because potential problems and solutions can be defined early on leading in an increase in efficiency through knowledge reuse. The final aspect of potential benefits is that knowledge will spread throughout the organization as project teams more actively try to tap into it. And even if knowledge is not dispersed every time a design review takes place, at least the awareness will increase.

Exchange Sessions: In order to improve the relation, or the mutual awareness, between research and engineering mutual exchange sessions are proposed. On a regular basis, for example three or four times a year, research and engineering employees gather and discuss their projects and problems. These sessions should be organized from a research perspective because it is more apparent when the engineering department needs the research department than visa versa. Short presentations should be prepared about the most important research projects discussing goals, problems and solutions considered to deal with these problems. After that there will be the opportunity for discussion in which engineers can shed their light on the issues encountered by research. Depending on the subjects that will be discussed people from CryoZone should also be invited.

The costs of such an exchange session would be rather large. A lot of people will need to invest time in the preparation from the research department and during the actual session even more people will be involved. Furthermore success will not be guaranteed. The exchange sessions are nothing more than a safety catch for when other formal and informal methods fail to transfer required knowledge from engineering to research. With an increasing efficiency of these other methods exchange sessions will become more and more redundant. Finally the potential benefit is also related to the amount of knowledge not transferred using those other methods. Furthermore it might be argued that the majority of the issues that fail to be transferred are minor ones. This however will not always be the case and it is very well possible that certain practices deemed obvious by engineering are overlooked by research.

Modularity: The implementation of modules is a strategy that has the characteristics of both a project approach and a codification approach. Furthermore it has far more uses than purely knowledge related issues (Baldwin & Clark 1997, Robertson & Ulrich 1998) and thus cannot be treated solely as a tool for improving the knowledge sharing structure. These other potential benefits were also the reason that the decision to implement modularity was already taken during the course of this study. Therefore modularity is not actually proposed as a knowledge management tool but rather adding a knowledge management perspective to an already chosen strategy. Main difference with the already used platform method is the ability to use parts as knowledge carriers and the ability to transfer knowledge over platforms. Platforms and modularity are not redundant but rather reinforce each other (e.g. Robertson & Ulrich 1998, Yang & Yiang 2006).

Since the choice to implement modules has already been taken, only the extra costs for adding the knowledge management perspective have to be taken into account. These extra costs will not be very large, especially not when comparing them to the process of implementing modules as a whole. The risk of failure on the other hand is much larger. Because modules already inherently posses a degree of knowledge in the same way that a product does, it will require discipline or other measures to make sure the accompanying documentation is updated in such a manner that it will remain its knowledge related value. This updating of module specific information and linking it to projects represents a change from the normal way of working and introduces an extra step. Finally the potential benefits are mainly related to smoothening the everyday process. Modularity is not of any real use when encountering specific situations. Thus while in regular situations a higher efficiency can be reached for more idiosyncratic events other methods need to be used.

"Why"

Compendium of Knowledge: While "compendium of knowledge" might sound a bit ominous or even pretentious this is not at all true. Den Heijer Industries is an organization that possesses a wealth of knowledge regarding cryotechnology and the principles behind the Stirling engine. This wealth of information needs to be preserved as the competitiveness of Den Heijer Industries depends on it. This database may take the form of a handbook, something like wikipedia or anything that is feasible with the technology that is available to Den Heijer Industries.

Spending time on codifying knowledge in a precise manner requires time from specialists and this is valuable time. On the other hand researchers already have to write reports and might adjust those or at least derive from them. Still, keeping such a compendium up to date will not be cheap. What might even be more problematic is that simply implementing an IT-structure in order to achieve the codification of knowledge is extremely unlikely to succeed. People need to invest time in it but get no direct payoff. It does not contribute to their everyday activities and thus will be the first activity many will choose to drop when work pressure increases (Huber 1991). In the long run however the payoffs for these investments are substantial. By creating a repository the relevant knowledge is made independent from people and is secured for the organization. Aside from that the process of codifying in itself may lead to learning (Prencipe & Tell 2001)

Technology Owners: While knowledge needs to be codified it is imminent that duties regarding this codification are clearly assigned. Assigning responsibility for different technologies is a way of doing this. When somebody is assigned this responsibility he or she becomes a technology owner. As a technology owner one must try to keep up to date in his or her field of expertise. Therefore they need to invest time in studies but also keep track of projects in which their field is involved. By identifying valuable knowledge in these projects and leveling them over to the archive or the previously described compendium knowledge will be preserved for the organization and easier to access.

The chance of failure and the costs are equally low if one assigns ownership in a responsible manner. In that case the majority of the activities already were part of the tasks of that person. The only difference is that reports now need to be formatted in such a manner that they are accessible for others. The unfortunate downside is that the added value is limited unless it is combined with the before mentioned knowledge repository or a good storage structure.

Traceability

Search System: As long as a search system is adequate the amount of data does not really matter anymore. It is advised Den Heijer Industries invests in a search system that can locate the required documents out of the archive. Attention should for example be given to issues regarding the different names the same object might have and locating solutions by naming a problem. This could results in some google-like function not only filtering out spelling mistakes but also resulting in synonyms and related terms. Input and output variables have to be defined carefully so that input is guided and alternative suggestions are given. Output should be specific and not too broad otherwise it will lose its value by forcing the searcher to still look through large amounts of data.

The chances of success of an adequate search system are very good. Since the database is already being used, a more proficient way of navigating through it will most likely be used. The costs and effort into designing it and implementing it however can be quite steep. Finally the benefits to be gained are quite large. Usage of the archive will no longer be person dependent and new people will be able to draw knowledge from it without help of others. Furthermore the memory of men might not be perfect and a good search system might bring to attention documents otherwise forgotten.

Storage Structure: While a search system that is adequate helps to find the correct knowledge from a large repository it does help when this repository itself is structured. By linking documents and formatting those in certain ways traceability can be increased even without a search system. And when working in unison it becomes even more feasible to locate knowledge in a timely fashion. Important hereby is that the storage structure is simple and intuitive so that people do not spend too much time archiving the documents they produce. Special attention should be given to the linking of documents and projects. If documents are only assigned to projects this limits the ease with which they are traced. If a document, aside from the project it belongs to, is also related to for example a general problem, a module and a technical field multiple starting points in a search will lead to it.

Creating an adequate storage structure needs a high amount of discipline from the persons entering information in the database. Not only do they have to codify their knowledge but they also have to do that in certain formats and follow storing procedures. This requires time and attention and the effort is something which comes with little satisfaction and without an immediate payoff. The costs however are less of a problem since not too much time should be invested in placing the codified knowledge in the structure. The benefit of all this tedious work is that one can start browsing through the archive and finding related material increasing the value of everything one can find through the search system and acting as a failsafe when the located documents are not exactly what one was looking for.

After-Project Review: The after-project review has two distinct different goals. First of all it is meant to have people learn from there mistakes as they review them. Secondly the document created will serve as an anchoring point for locating the project and making it more traceable. Important is that, when specific solutions have been used, the theory behind them but also solutions tried and not taken should be mentioned and linked to the subjects they belong to. In the case of research such an after-project review may serve as a starting point for adding upon the before mentioned compendium.

The chance of success in implementing an after-project review is rather great since it becomes a part of the process that people cannot be allowed not to do. It is verifiable and as soon as people are reviewing their project it is only a small step to creating a standardized review that can be linked to the project and relevant other documents. As work pressure increases project leaders must be careful not to neglect these meetings (Zedwitz 2003). However once it solidly has become a part of the workflow the after-project review will be hard to skip. The costs will also be rather low since an after project review includes only a limited number of people of the project team. The benefits of these reviews however is potentially huge as people are confronted with their own actions and learning from their own mistakes (Zedwitz 2003). Furthermore the documentation created at the after-project review can serve as an anchor point for the project in the database facilitating the traceability of related documents.

IX. Projects Stirling

Only completely finished projects were included in this sample. Furthermore some project dossiers were not reviewed because they were being used by various members of the organization at the time the sample was taken. All information was taken literally from the project dossiers.

Project Number	Project Name	Year	Location
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Project Number	Plant type	Quantity	Production	Purity (%)	Pressure (bar)
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Project Number	Intended use	Prize	Project leader
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Prize	
Total prize	[redacted]
Average prize	[redacted]
Minimum prize	[redacted]
Maximum prize	[redacted]

Year	
2007	[redacted]
2006	[redacted]

Number of projects	[redacted]
Number of products	[redacted]
Type of Product	
StirLIN-1 economy	[redacted]
StirLIN-1 compact	[redacted]
StirLIN-2	[redacted]
StirLIN-2 conversion	[redacted]
StirLIN-4	[redacted]
StirLIN-8	[redacted]
SPC-1	[redacted]
SPC-1T	[redacted]
SPC-4	[redacted]
Other	[redacted]

General product type	
StirLIN	[redacted]
StirLIN %	[redacted]
SPC	[redacted]
SPC %	[redacted]
Conversion	[redacted]
Conversion %	[redacted]
Other	[redacted]
Other %	[redacted]

Project leaders	
HS	[redacted]
HS%	[redacted]
MI	[redacted]
MI%	[redacted]
TOB	[redacted]
TOB%	[redacted]

Average prize per product	
StirLIN-1 economy	[redacted]
StirLIN-1 compact	[redacted]
StirLIN-2	[redacted]
StirLIN-2 conversion	[redacted]
StirLIN-4	[redacted]
StirLIN-8	[redacted]
SPC-1	[redacted]
SPC-1T	[redacted]
SPC-4	[redacted]
Other	[redacted]

Total prize per product	
StirLIN-1 economy	[redacted]
StirLIN-1 compact	[redacted]
StirLIN-2	[redacted]
StirLIN-2 conversion	[redacted]
StirLIN-4	[redacted]
StirLIN-8	[redacted]
SPC-1	[redacted]
SPC-1T	[redacted]
SPC-4	[redacted]
Other	[redacted]

Price per Product Type	
StirLIN average prize	[redacted]
SPC average prize	[redacted]
Conversion average prize	[redacted]
Other average prize	[redacted]
StirLIN total prize	[redacted]
SPC total prize	[redacted]
Conversion total prize	[redacted]
Other total prize	[redacted]

Price per Project Leader	
HS average prize	[redacted]
MI average prize	[redacted]
TOB average prize	[redacted]
HS total prize	[redacted]
MI total prize	[redacted]
TOB total prize	[redacted]

Figure V.I: Product type

Figure V.II: Product type Generic

Figure V.II: Product revenue generic

Figure V.V: Projects per Project Leader

Figure V.VI: Revenue per Project Leader

Figure V.VII: Prices of the projects

X. Projects CryoZone

Billet heater

CryoZone has designed and delivered an application tailored cryostat for a High Temperature Superconducting DC-coil for a billet heater. Given the required set-up of the superconductive coil, the demands on the cryostat are high. Four goals had to be accomplished;

- sustain a very high temperature difference with a very small 'air gap'
- holding the coil in position under very high forces
- adapt to the very limited space which is available within the billet heater system.
- keep a small temperature difference over the full length of the coil with the cryocoolers situated at one side.

To maximise the Eddy currents to be induced, the temperature difference is to be maintained over an as small as possible distance. After careful design this has become 20 mm 'air gap' between the cold coil and the cryostat outside. This cryogenic insulation space contains 5 mm cryostat wall, 40 layers of mylar insulation and, in some spots, down to 1 mm of vacuum gap.

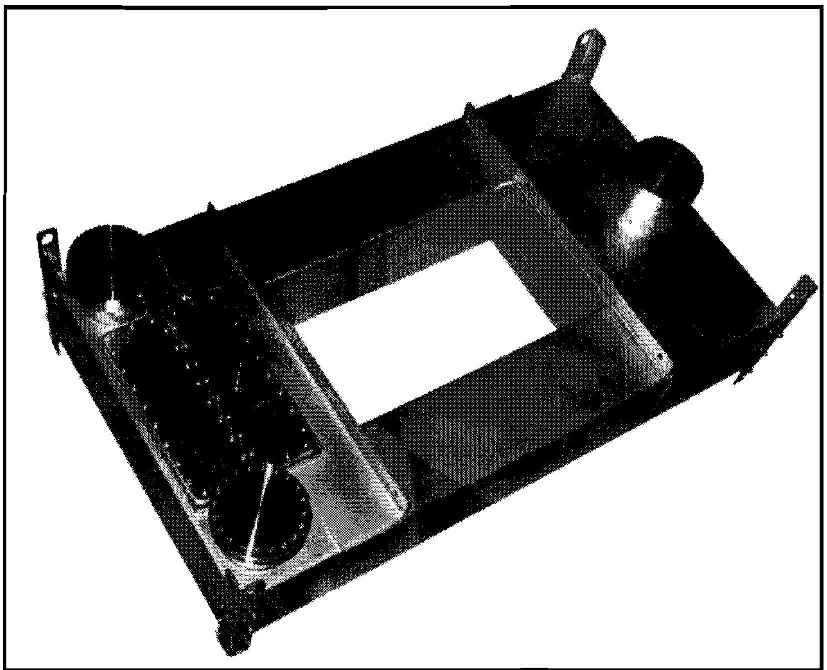


Figure VIII.1: Cryostat for billet heater (1800x1200x300 mm)

Since the superconducting coil creates a high magnetic field, it tries to move with a force of 15 tons. This force has to be supported through the vacuum insulation, while at the same time limiting the heat flux into the cold coil to a minimum.

To match the available space, the cryostat has been build rectangular, a quite uncommon shape in the cryogenic industry since not suited for vacuum forces.

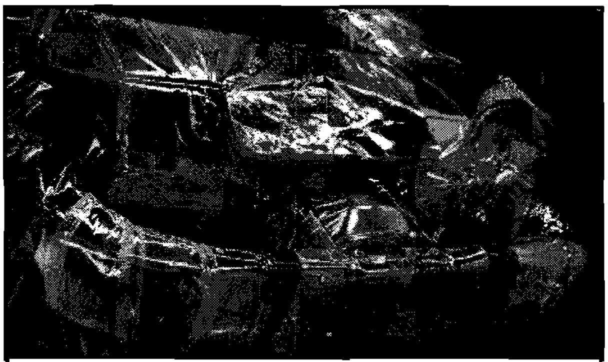


Figure X.II: Cryostat inside

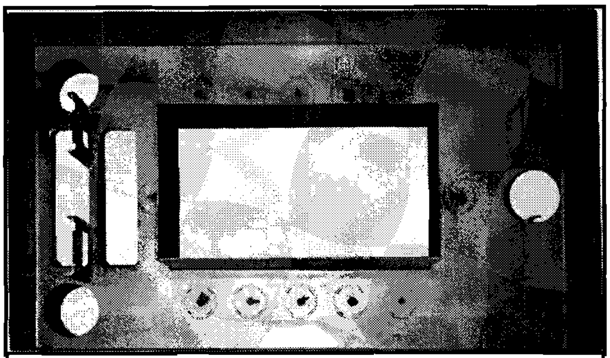


Figure X.III: Thermal and electrical coil insulation

The superconducting coil is cooled by two Leybold 140T cryocoolers. Because of space restrictions, these are positioned at one side of the cryostat, cooling the entire length of the coil by a conduction system. FEM simulations have been done during the design to prove this system would indeed keep the temperature variation over the coil length within a few K.

Since the assembly of the total billet heater system in May 2007, it has been showing excellent results. The cryostat performs very well with no vacuum loss or deformation despite it rectangular shape. The temperature variation over the coil is 3K, with operational cryostat heat losses of <25 W @ 21K.

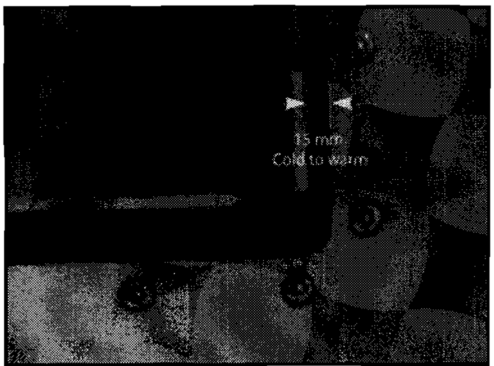


Figure X.IV: Coil conner detail

Example taken of www.cryozone.nl

Liquid neon closed loop cooling

CryoZone has designed and produced a CryoFlow system based on a liquid neon convection loop for an HTS motor.

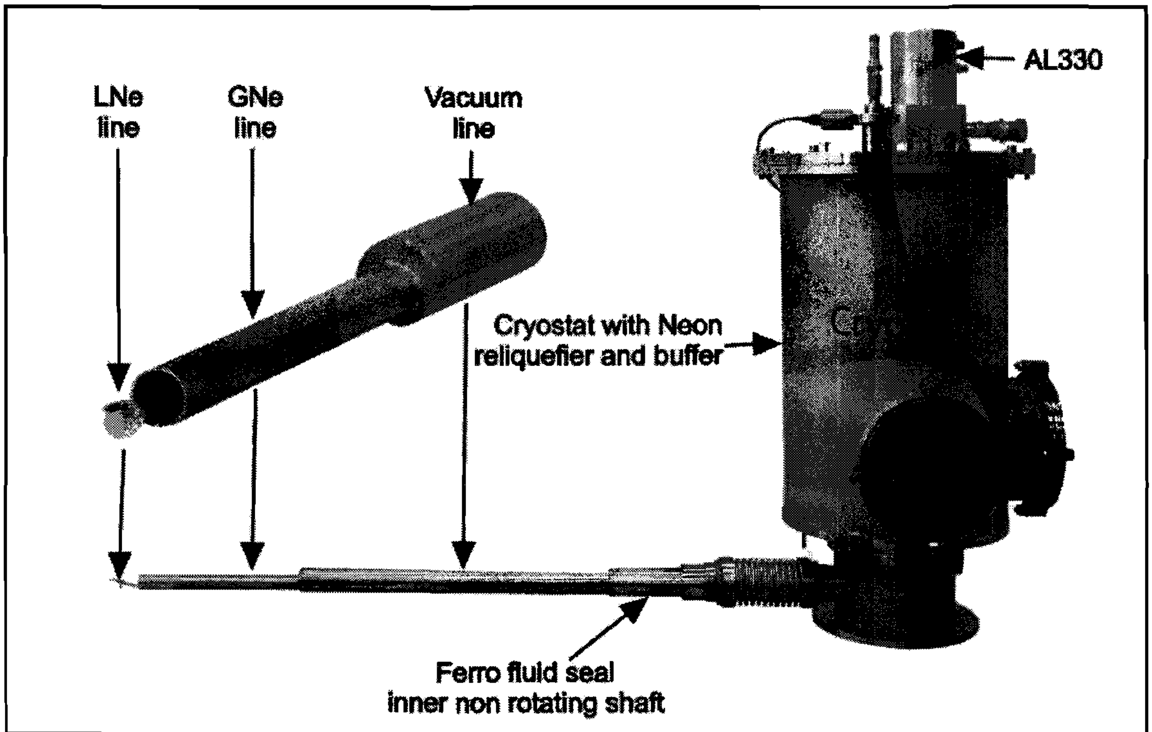


Figure X.V: Liquid neon closed loop cooling

The system consist of three main elements. The cryocooler, a neon re-liquefaction and collection buffer, and a triple transfer pipe.

The transfer pipe is vacuum insulated and sticks into the cryogenic HTS rotor through a rotating ferrofluid seal. The liquid neon flows through a thin pipe into the inner vessel of the rotor. Here it divided over the cylindrical wall and cools the HTS coils mounted at the outside. The resulting vapor is transferred back to the cryocooler through the second tube. The insulating vacuum tube starts within the rotor and acts as the thermal resistance to the warm ferrofluid seal.

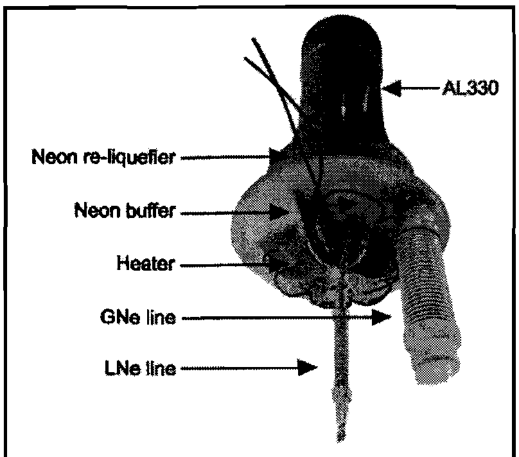


Figure X.VI

Cooling power is provided by a Cryomec AL330, to which a CryoZone design neon re-liquefier is mounted. This is placed in a small neon buffer, collecting the re-liquefied gas. From the buffer, liquid flows to the rotor and gas flows back.

Since the cooling power of the cryocooler is fixed, regulation is done by evaporating LNe in the buffer using small heaters. These are regulated with a PID control, measuring the neon system pressure. This is set at e.g. 1316 mbara to keep the liquid and hence the rotor at 28K.

The *picture XI.VI* shows the part of the system to be placed in the vacuum cryostat before being thermally insulated.

Below a FEM model of the copper neon re-liquefier situated between the cryocooler and the neon buffer. Shown is the temperature variation, which was proven to be very small. This is necessary because copper parts being relatively warm will not participate in the liquefaction process.

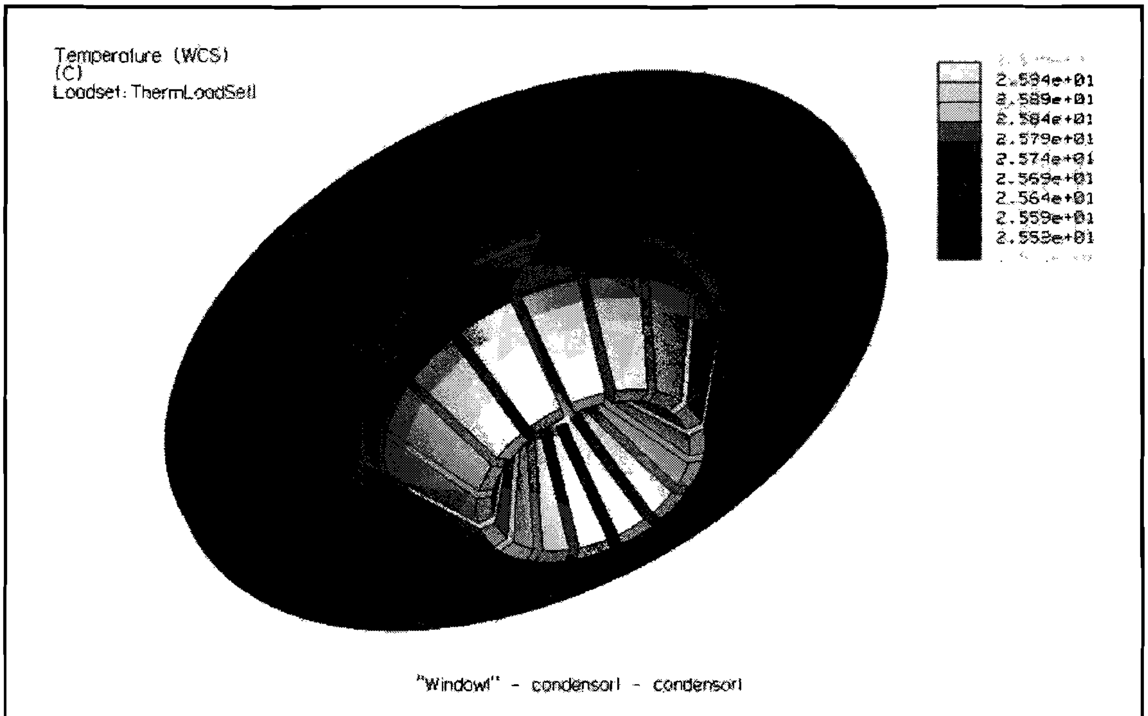


Figure X.VII: FEM model of the re-liquifierl

Example taken of www.cryozone.nl

XI. Process Description

This section will elaborate on different processes of interest taking place within Den Heijer Industries. The processes described here are not the actual knowledge related processes but the activities that benefit from or need these knowledge sharing activities. The actual processes of interest will be uncovered while answering both research questions 1 and 2.

The first process that will be discussed is order procurement, design and assembly within Stirling and CryoZone. Basically what happens and how things happen from the moment a sale is made to the moment the delivery is done. Delivery is the not the actual delivery at the customer but the point where the finished project is ready to be picked up by the transporter. The second will be services, or maybe more service support since Stirling India will not be the focus point of this research. Finally the research department and the way they work will be described.

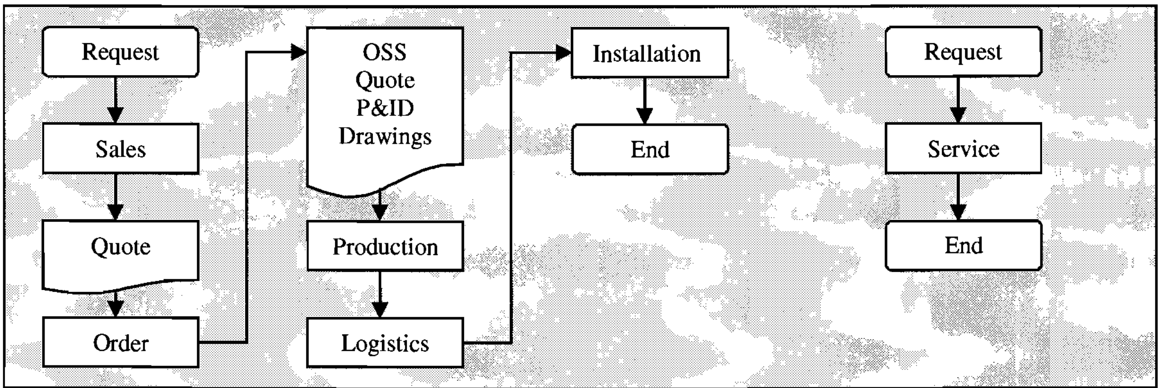


Figure XI.I: Process at Stirling

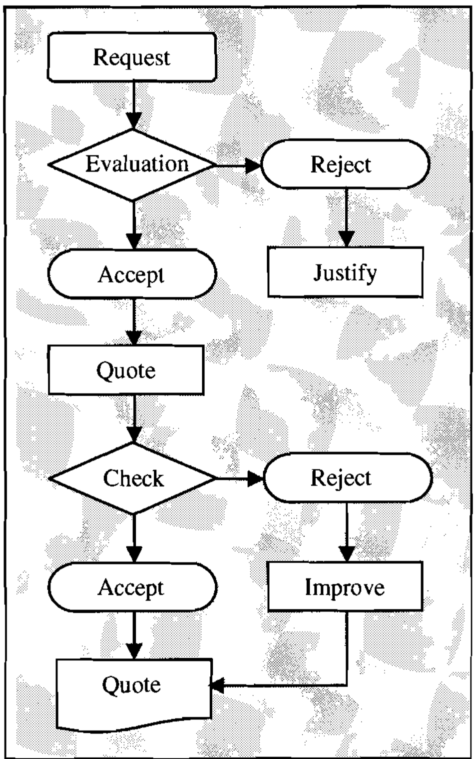
For Stirling flowcharts were created, *figure XI.I* shows the overview of what these flowcharts will describe. In *appendix IX* more elaborate flowcharts describing each process can be found. For CryoZone this was not done, this is because the unstructured way CryoZone operates. This in combination with the relative low number of employees makes it not only unfeasible to create flowcharts but also unnecessary. Research is the exception to this, there will be no flowcharts for neither of the companies. Goal of this part of the research proposal is partly to inform the uninformed reader and partly to define the work processes that will be examined during the research. It should be noted that the described processes are not the boundaries of the research. Much of the knowledge transfers in any company do not fall neatly into definable actions but are nonetheless relevant for knowledge work.

Regular

The core business of Stirling and CryoZone is creating and selling cold solutions for clients all over the globe. First the sales process of Stirling will be discussed. After that the complete production process will be described. Following that the same descriptions will be supplied for CryoZone.

Sales Stirling

A flowchart for the sales process at Stirling is depicted in *figure XI.II* in the corresponding appendix. While the process may seem rather straightforward in practice this may not be the case. The evaluation phase in which the decision is to be made whether or not installation of a Stirling plant is technically feasible and economically sound for both Stirling and the customer, another type of problem may occur. Since a large part of customers consists of research facilities and universities money needs to be reserved. This can result in decision trajectories that may last many years. During this a lot of unregistered costs are made and projects may even be abandoned without any actual sales being made.



Picture XI.II: Sales at Stirling

After this part of the process the decision is made and the quote is being offered. This is not a final quote so the same delays regarding academic partners may be present during this phase of the sales process. After the quote is created and issued it needs to be checked if it goes with the customers request or if they have changed their specifications. When there is no discrepancy the quote is accepted by both customer and Stirling and presented to the engineering department. If there is still discrepancy improvements or adjustments will be made until a match is found.

During this sales process technical knowledge is not only useful but even necessary. What can Stirling deliver under what circumstances? This is furthermore complicated by the sometimes long time span between initiation and final order.

Production Stirling

The process of production is depicted in *figure XI.III*, a flowchart that depicts the ideal situation of how the engineering department at Stirling should work. It should be noted that the implementation of this process started only a few months before the start of this research. In other words, theory and practice may still deviate at the moment although what *figure XI.III* depicts is the goal Stirling is working towards.

As can be seen the process starts with the result of the sales process, a set of documents consisting of an order summary sheet, the quote, a provisional piping and instrument diagram (P&ID from hereon) and provisional drawings. The drawings and the order summary sheet (an empty form to be found in *appendix X*) form the reference point at the beginning of the production process. The process ends when the final product is packed and ready for transport and does not include the shipment and on-site installation.

A kick-off meeting in which the order summary sheet is discussed is followed by a basic design phase. This phase will have several deliverables as can be seen in the flowchart and include a P&ID, a system description and the specifications. If it is decided that the basic design complies with the desires of the customer and the capabilities of Stirling five parallel processes are started. These processes are; purchasing primary components, mechanical design, electro technical design, software design and the detailed system design. The first is a very important process for the lead time of a project since the delivery of for example the compressor can be up to three months. The third, electro technical design more often consists of ordering components instead of actually designing and manufacturing them internally because of the higher work pressure. Finally the fourth, the (re)designing of the software, is something Stirling is capable of but what in practice rarely is needed. If all processes are completed to satisfaction the process continuous with the production, which mainly consists of assembling the different components, and the testing of the product before shipment. Finally the design is validated and if everything is found to be in order the production process is at an end.

During this process there are of course feedback loops present to deal with mistakes and to create an opportunity for corrections. These are not necessary for smooth projects and Stirling naturally rather has that these loops do not need to be used most of the time.

time is less then when a service engineer needs to be scheduled and flown in. An example of an extended manual that was sent to a customer is to be found in *appendix XIII*. In order to enable this kind of service provision Stirling also provides maintenance trainings. In a week a delegate of the customer will be schooled in the correct maintenance of the machine. Furthermore the general workings and the principles behind the machines are explained. As a result of this the customer should be able to, at the very least, locate the source when a problem does occur.

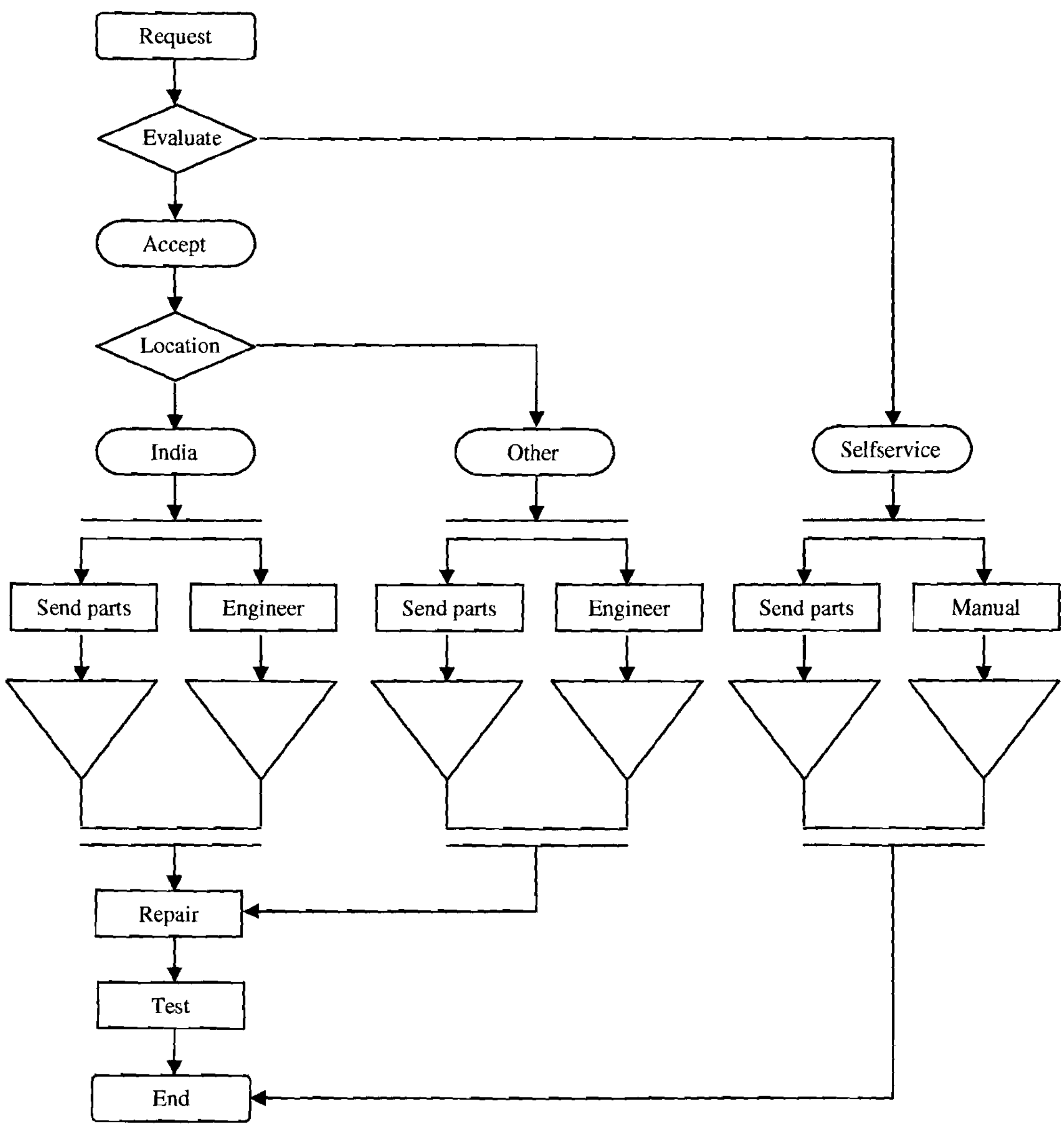


Figure XI.IIII: Flowchart Service Stirling

Service CryoZone

Installation of the products of CryoZone is straightforward and products created by CryoZone require no service at all. Basically what the customers receive are boxes. Therefore they need to be put in the right place and the cold source needs to be connected. Upon installation they will withstand the pressure put on them by the installations or they will not. If they will withstand the pressure there is almost no wear or tear and if they do not they will collapse and be so damaged repair is not even possible anymore.

Research

This section will describe how the research departments of Stirling and CryoZone work. Whereas Stirling has a research department where four men are fully dedicated, CryoZone has only a limited amount of time for research. Therefore the second part of this section will be rather short, because there is not much to describe.

Research Stirling

Research at Stirling is rather unstructured and the relationship between research and engineering is complicated. This is partly because the research department is only five years old while the organization and the products are much older. Therefore most of the knowledge of the original products and their derivatives are better understood at the engineering department than the research department. However for the new developed products, the cryosphere and the stirlab are unfamiliar to engineering and created by research. Combine this with the fact that research has to rely on engineering for electrical know-how and one can see that research is dependent and interwoven into the organization.

Research CryoZone

The research at CryoZone is momentarily done by one person, this same person also does the majority of the calculations needed to check if future projects are possible. The remaining time is spent on the creation of computer simulation models for example for the simulation of fans in cold environments.

XII. Order Summary Sheet

STIRLING
STIRLING CRYOGENICS & REFRIGERATION BV

PROJECTSPECIFICATIE

Type installatie:	
Hoofdcomponenten:	

MANUALS — 1 x CD en 1 x papieren manual

Anders:

OMSCHRIJVING / GEBRUIK

- Medical
- Research
- Nuclear
- Defence
- A.I.
- Miscellaneous

FUNCTIONELE SPECIFICATIE		TEST
Productie:		
Zuiverheid:		
Druk:		
		Zie ook aangehechte afnamelijst

Standard Order Summary Sheet	Order Summary Sheet refers to Job Number:			60.3027
Rev: 12	Date: 11-10-2007	Rev:	Date:	Proj.leader:	Pagina 3 van 6

STIRLING
STIRLING CRYOGENICS & REFRIGERATION BV

VOORZIENINGEN

Spanning:	V	+	%	-	%	Norm: ± 5%	
Frequentie:	Hz	+	%	-	%	Norm: ± 2%	
Aantal fasen:	Ph	Aarde: ja / nee				Neutraal	ja / nee
Opmerkingen:							

OMGEVINGSCONDITIES

Temperatuur, omgeving:	min	°C	max	°C	Norm: +5°C - + 45°C	
Temperatuur, ruimte:	min	°C	max	°C		
Relatieve vochtigheid:	min	%	max	%	Norm: 20% - 95%	
Opstellingshoogte:	m				Norm: =< 1000 m	
Woestijncondities (stof):	Buiten opstellingsruimte:	ja	nee			
	In opstellingsruimte:	ja	nee			
Opmerkingen:						

ALGEMENE OPMERKINGEN

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STIRLING

STIRLING CRYOGENICS & REFRIGERATION BV

FINANCIELE GEGEVENS

LC:		
Vervaldatum LC verscheping:		
Vervaldatum LC negotiatie:		
30 dagen na factuur		
CAD. Documenten inleveren bij:		
% vooruitbetaling:		
% resterend gedeelte:		Moment:
Eventuele vooruitbetaling garantie geldig tot (datum):		
Anders:		
Bankgarantie / performance bond	ja nee	
Bedrag:		
Geldig vanaf (datum):		tot (datum):
Voorwaarde vrijvallen:		

ORDERVOORCALCULATIE

	Munt:	Bedrag:	Koers		
Verkoopprijs:		*		=	
Kostprijs: zie toegevoegde ordervoorcalculatie					-
Bijdrage = verkoopprijs – kostprijs				=	
Commissie:	%	van	*	=	
Uit te keren aan:					
Garantie:	%		Who		
Vrachtkosten / verzekering:	ja nee				
Installatie / commissioning:	ja nee		Cno		
Post-commissioning:	ja nee				
Training bij Stirling:	ja nee		Tno		
LC / bankkosten:	ja nee				
Maintenance contract:	ja nee				

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STIRLING

STIRLING CRYOGENICS & REFRIGERATION BV

LEVERGEGEVENS

Gevraagde leverdatum*:		Bevestigde leverdatum*:	
Leveringsconditie:	EXW FCA FOB FOP C+F CIF		
(Lucht)haven:			
Vervoerswijze:	truck boot vliegtuig		
Verpakking:	standaard afwijkend:		
Deellevering toegestaan:	ja nee		
Opmerkingen:			

* Dit is de datum dat de levering gereed en verpakt klaar staat. Deze datum ligt 10 dagen voor de verschepingsdatum.

DOCUMENTEN

Importlicentie:	ja nee	Verzorgd door:	
Exportlicentie:	ja nee	Verzorgd door:	
Certificaten:	CVO: ja nee	EUR: ja nee	
Normen:	geen CE anders te weten:		
Opmerkingen:			

AFNAME

Afname/inspectie bij Stirling:	ja nee	Datum:
Uitvoering door:	klant keuringsinstantie:	
Opmerkingen:		

INSTALLATIE / COMMISSIONING

Installatie / commissioning:	ja nee	door: Stirling anders te weten
Post-commissioning:	ja nee	door: Stirling anders te weten
Maintenance contract:	ja nee	door: Stirling anders te weten
Opmerkingen:		

Standard Order Summary Sheet	Order Summary Sheet refers to Job Number:			60.3027
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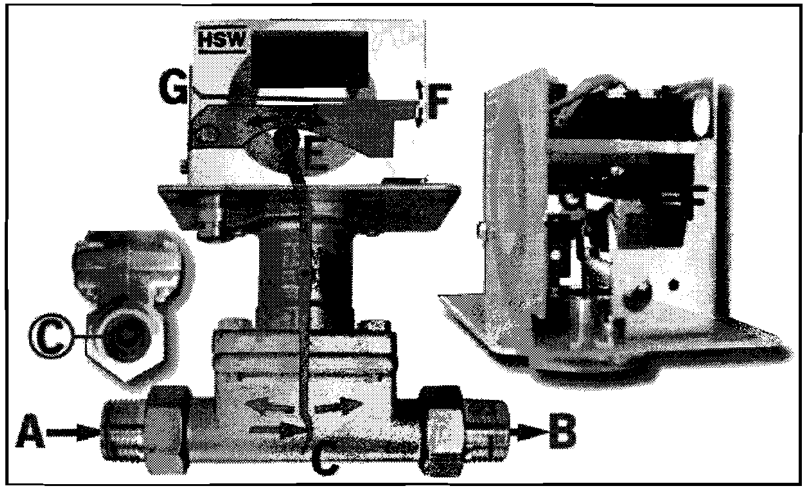
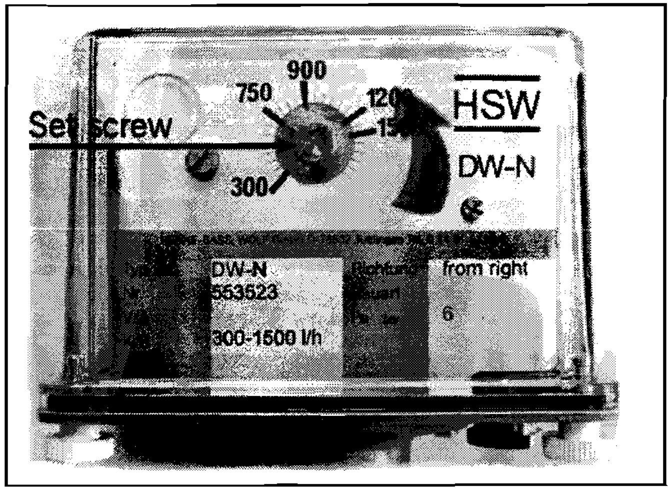
XIII. Example service document

WATER FLOW SWITCH 1-CYLINDER CRYOGENERATOR



FUNCTIONING OF THE FLOW SWITCH
- Cooling water enters at A and exits at B
- Cooling water flow presses the spoon C to the right pivotting around point D.
- Spoon actuates moving part E upwards
- Moving part E moves plate G upwards at point F thus actuating microwitch H signalling there is sufficient cooling water coming through the cooling circuit.
- If there is not sufficient cooling water the cryogenerator will not start or it will be stopped (when running) to prevent damage to the installation

HOW TO CHECK THE WATER FLOW SWITCH
In case where the cryogenerator is repeatedly switched off by the flow switch the following should be checked as follows:
- Check water filter which is mounted in the cooling water circuit. Clean if necessary.
- Disconnect water flow switch and take out of the cooling circuit.
- Check for particles or dirt stuck at the spoon (C) thus obstructing free movement of the spoon. Clean if necessary.
- With a pencil delicately push spoon C from side A. Check whether at point E part moves to actuate the switch H (switching can be heard by clear clicking sound when actuated on and off).
- If switch H works correctly (check with ohmmeter) check whether cable connection to the electrical cabinet is fixed correctly (no loose contacts).



Hello Charlie,

It seems that the flow is sensed but that the electric switch may not be working frankly from "On" to "Off" positions (0 Ohms to Infinity).

Please do following:
- On the flow meter check that the real water flow is 1100 liters/hr as you indicated
- On the side of the flowmeter is a set csrew that should be turned carefully in a counterclockwise direction till a clear klick is heard from the switch indicating there is enough flow).

This should solve the problem.
Please remember that the scale on the side is only for indication purposes and that no precise quantities should be read out. The flow meter is normally far superior in precision.

Have you checked whether the circuit has air in the cooling water? I do not understand why there is turbulence. How did you determine this?

Please let me know the results

Kind regards,

Norman Quast - Service Department
Stirling Cryogenics & Refrigeration BV
Science Park Eindhoven 5003
5692 EB SON - The Netherlands
Tel: +31 (0)40 26 77 331 - Fax: +31 (0)40 26 77 339