Identification of Mechanical Issues Related to Pressure Equipment Directive and Harmonised Standards

Wärtsilä Energy Business

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BACHELOR'S THESIS

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Abstract

This is the official version of the thesis that exclude execution chapter. The classified parts can only be studied within Wärtsilä.

This bachelor's thesis is made on behalf of Wärtsilä Energy Business. The purpose of this thesis is to aid and give an insight for every department that are involved with different kinds of powerplant projects on what kind of issues that have occurred due to Pressure Equipment Directive and standards in the European Economic Area and also how to cope with them.

The aim of this thesis is to identify and thoroughly present existing issues that have occurred, including lessons learned from them. This further avoids and prevents similar kinds of issues and problems that have occurred in power plant projects.

The methods used in this thesis are to interpret the Pressure Equipment Directive and the linkage and connection with the harmonised standards specified by this directive. The identification of occurred issues is executed by having several meetings with the stakeholders where discussions about the topic of this thesis have been thoroughly discussed.

Ultimately this thesis work will act as a knowledge base for future references when it comes to mechanical issues related to Pressure Equipment Directive and harmonised standards. The achieved result of this thesis can be related to the theory part which presents the connections between the directive, the occurred issues and the lessons learned.

Language: English	Key words: Mechanical issues, Pressure Equipment Directive, Standards

EXAMENSARBETE

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Titel:	Identifieringen av mekaniska problem relaterade till direktivet om tryckutrustning och harmoniserade standarder

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Abstrakt

Detta är den officiella versionen av examensarbetet som exkluderar utförande kapiteln. De sekretessbelagda delarna kan endast studeras inom Wärtsilä.

Detta examensarbete görs på uppdrag av Wärtsilä Energy Business. Syftet med detta arbete är att ge en inblick, åt involverade parter i olika slag av kraftverksprojekt, i existerande mekaniska problem som uppstått på grund av olika direktiv samt harmoniserade standarder.

Syftet med denna avhandling är att identifiera och noggrant presentera befintliga problem som har uppstått, inklusive lärdomar från dem. Detta bidrar till att liknande typer av problem och problem som har uppstått i kraftverksprojekt förhindras i framtida projekt.

De metoder som används i denna avhandling är att tolka direktivet om tryckbärande anordningar och sambandet med de harmoniserade standarder som är specifierade av detta direktiv. Identifieringen av de inträffade problemen utförs genom att ha flera möten med intressenter där diskussioner om ämnet för denna avhandling har diskuterats grundligt.

I slutändan kommer detta examensarbete att fungera som en kunskapsbas för framtida referenser när det gäller mekaniska frågor som berör olika direktivet om tryckbärande anordningar och harmoniserade standarder. Det uppnådda resultatet av denna avhandling kan relateras till teoridelen som presenterar sambandet mellan direktivet, befintliga problemen och de lärdomar som gjorts.

Språk: Engelska	Nyckelord: Mekaniska problem, Direktiv om tryckutrustning, Harmoniserade standarder

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TERMS AND ABBREVIATIONS

PM	Project Manager
CPE	Chief-Project Engineer
PE	Project Engineer
EEQ	Engineered equipment delivery
EPC	Engineering, Procurement and Construction
PED	Pressure Equipment Directive
WoW	Way of Working
WPS	Welding Procedure Specification
WPQR	Welding Procedure Quality Record
LNG	Liquified Natural Gas
ASME	American Society of Mechanical Engineers

1. Introduction

In the first chapter of this bachelor's thesis you will be informed about the background, purpose, scope, limitations and disposition of this thesis. This will create a broad starting point and hopefully will catch your interest so that you would stay focused throughout this bachelor's thesis.

1.1 Background

This thesis is made on behalf of Wärtsilä Energy Solutions, aimed particularly for Project Managers (PMs), Chief-Project Engineers (CPEs) and Project Engineers (PEs) working on the mechanical side with different kinds of power plant projects, mainly in the Europe area.

Every project is always different from the other, they may vary from size to location and from customer to different demands. Depending on the project delivery type, if it is an Engineering Equipment delivery (EEQ) or Engineering, Procurement and Construction delivery (EPC) some projects may be more difficult than others. What is mentioned in the contract and project scope should always be followed. An EEQ project is a bit simpler, so to speak, in an EEQ project, the customer is responsible for the piping. Later in this thesis work, cases will be presented which include issues that are related to Pressure Equipment Directive (PED) and lessons learned to these issues.

Yet, some projects have suffered of cost and time related issues. The source for these problems or issues may be due to knowledge in harmonised standards, and what standards are to be used in this particular country, is a bit scattered in the organization or department. Existing problems have been, for example; a total change of bolts and nuts that were incorrect and did not answer the requirement that was stated in the design code or standard. Another issue that has occurred is that the knowledge of which components or items require special kind of documents, for example the 3.1 material certificate, is a bit scattered as well.

Communication, information and knowledge of these occurred issues, including "lessons learned" to these issues is something that is not available at the moment. There is knowledge about PED and standards within the organisation, but it is still a bit unclear. Why these kinds of issues happen is the result of that something is missing or that something was missed, when reading the standards and directives or contract or even communication with the customer. The relationship and communication with the customer of the project must be of highest quality. Everyone should be aware of what is stated in the project scope and what has been decided in the design basis, what kind of requirements they have and according to which standards or design codes they refer to.

1.2 Purpose

The purpose of this thesis is to create a so called "knowledge base" for future references. With the result of this work, individuals within and outside the organization will have a clearer picture when working with different matters that are related to different standards or directives. Furthermore, cost and time related issues may be avoided at an early state – which results in projects being handed over in time and increase in revenue.

Throughout this work standards and directives in the EU will be taken into account, mainly PED. Different standards and directives that are related to the issues will be examined and studied. Standards are found internally within the organization, which in this case, when writing this work, has aided a lot. PED can be found from the official website of the European Union. Information will be gathered from multiple meetings with the stakeholders and employees that have been involved with projects were issues have occurred. The existing "Power Plants Mechanical Design Handbook", which is for internal use only, will be studied. "Lessons learned" and general knowledge from different project teams will also be gathered.

General Way of Working (WoW) may vary from team to team and project to project, this will also be taken into account and studied. Some teams may execute something differently – this could ultimately benefit other teams that have not worked with similar projects before.

This thesis will function as a knowledge base which includes links to standards and directives, all relevant information gathered from meetings with stakeholders, experience and "lessons learned", statements in standards and directives that refer to certain issues. It will not be a complete base which includes all issues that are known in every single system that belong into a Wärtsilä power plant. It will be a more of a shared folder or document which can be updated with more information and experience, it could also be a great opportunity for further development – with a potential research project.

These mechanical issues related to different standards could be brought up at an early state, for example already on the "kick-off" meetings. Material & technical specification documents are equally important for all projects. The third-party design company is the company that delivers these documents, so called product specific documents. It is important to know and that it is stated in the documents why some material is chosen in the material selection.

The ultimate goal is to prevent similar kinds of issues, that have occurred. Therefore, the issues are listed in this work, including the solution or lessons learned. The “Result” part will consist of summaries of each case, including general knowledge about design, ordering and understanding of the whole process – why it happened the way it happened and how one could avoid it from happening again.

1.3 Limitations

The subject of this thesis is very broad, therefore it will be narrowed into focus areas. In this thesis the work will be focused on systems that belong to engine powerplants, such as; compressed air system, district heating system etc. This thesis will also be narrowed to Europe and standards and directives that refer to that geographical area. In the next chapter a description of each chapter, including the context will be described.

1.4 Confidentiality

This is the official version of the thesis that can be studied freely by everyone. This thesis’ internal version covers a lot of sensitive data that cannot be shown outside the company. Execution chapter, which consist of different cases each covering an issue including lessons learned to it, is therefore classified and can only be studied freely within Wärtsilä. Appendices that are included in the internal version are also removed from this official version.

1.5 Disposition

The disposition in this thesis is built very simply, it consists of 7 chapters including “References” and “Appendices”.

The first chapter will describe the introduction and background of this thesis. It is followed by purpose, scope and limitations, which ties the whole thesis briefly into one.

The second chapter will consist briefly of the company which I am writing this thesis for, Wärtsilä. This chapter will describe each main business department which to date exist in Wärtsilä.

The third chapter will tell the whole theory part of this thesis. Which ways and from where the information and knowledge is gathered from.

The fourth chapter will tell about the whole process itself – how this thesis was created and where all the information is coming from.

The fifth chapter consists of case studies that have been analysed. These cases are actual cases that have happened in various projects in either Finland or Germany. The cases will tell an issue that has occurred due to standards or directives. A solution, a way of working or lessons learned will also be presented.

The sixth chapter presents the result that has been achieved with this thesis.

The seventh chapter will present the “discussion” part of this thesis where suggestions for future research or further studies could be inserted. In this chapter final conclusions, including thoughts, ideas and end words will also be presented.

2. Wärtsilä

Wärtsilä is a global leader in the smart technology and complete lifecycle solutions for the energy and marine markets, its motto and purpose is: Enabling sustainable societies with smart technologies. Wärtsilä has around 19,000 employees from all over the world, having operations in more than 80 countries. In 2019 Wärtsilä had total net sales of 5,2 billion Euros. Geographically, Americas consisted of 21%, Europe of 33%, Africa of 4% and Asia of 38% of the total net sales. (About Wärtsilä, 2020)

Terms such as sustainable innovation, total efficiency, data analytics, are close to Wärtsilä's heart. By emphasising the terms mentioned above, Wärtsilä maximises the economic and environmental performance of the vessels and power plants of its customers. (Wärtsilä, 2020)

Wärtsilä consists, as of January 2019, of two businesses; Energy Business and Marine Business. Service Business, which was before an own business, has now been incorporated into both Energy and Marine Businesses. (Wärtsilä, 2020)

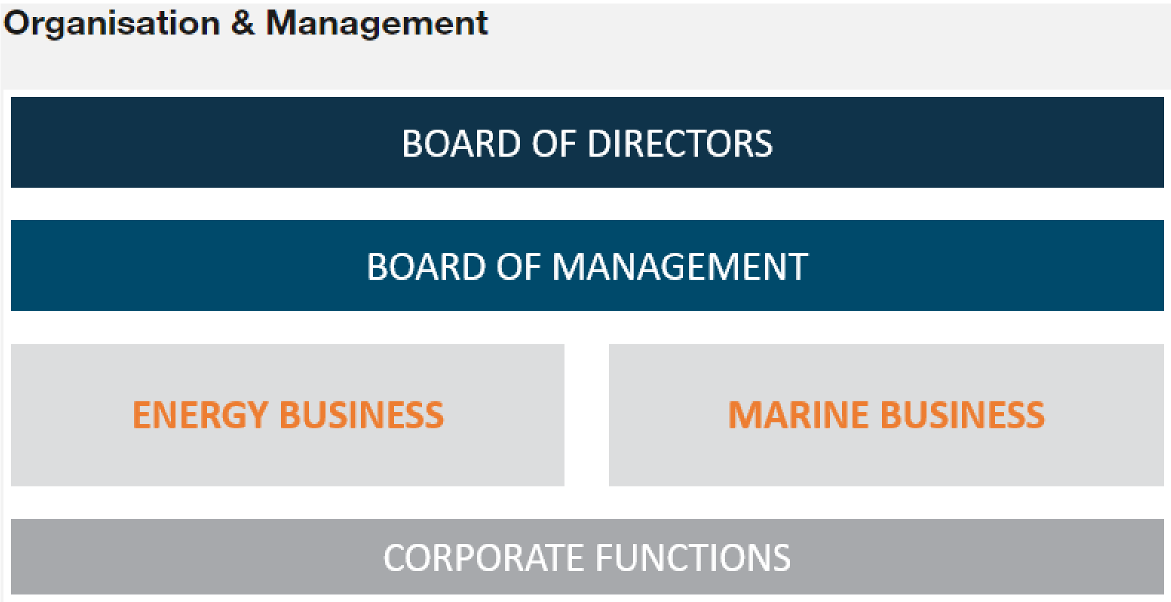


Figure 1 Organization & Management structure (source: https://www.wartsila.com/about/organisation-management)

One of Wärtsilä's many ambitions is to aim for 100% renewables, so with this mindset Wärtsilä is always striving to find the best solutions for every project or customer demand. The demand for clean and flexible energy, and the need for efficient and safe transportation are increasingly affecting the way that customers operate. This forms the basis for Wärtsilä's

Smart Marine and Smart Energy visions. With an integrated portfolio of services, systems, and products that covers customer needs across the full lifecycle, Wärtsilä is well positioned to respond to the demand for energy efficient and innovative solutions. (Wärtsilä, 2020)

2.1 Wärtsilä Energy Business

Wärtsilä Energy Business plays the leading role in the transition towards a 100% renewable energy future. They provide aid for their customers to unlock the value of the energy changeover by optimising their energy systems and ensuring their assets are fit for the future. (About Wärtsilä, 2020)

Energy Business offers flexible power plants, energy management systems, storage and also life cycle services that enable increased efficiency and guaranteed performance. Wärtsilä provides its customers with a comprehensive understanding of energy systems, including fully integrated assets and advanced software, complete with value adding lifecycle services. Wärtsilä has 72 GW of installed power plant capacity in 180 countries around the world. This number is increasing as projects are being handed over. (About Wärtsilä, 2020)

In 2019 Energy Business's key figures show small decreasing numbers, compared to last year. Net sales for Energy Business was at 1,840 million Euros and order intake at 1,810 million Euros. Wärtsilä and Energy Business always strive for continual improvement and increasing these key figures. Energy Business consist as of 2019 of 5,335 employees, whereas Marine Business consist of 13,460 employees. (About Wärtsilä, 2020)

Solid and active growth in the world economy increases the need for electricity. Tightening environmental norms and high oil prices favour high efficiency products and work in favour for Wärtsilä and its products and solutions. Developing countries have a big demand for Wärtsilä's heavy fuel oil and gas power plants, due to their electricity consumption growth, these rates are fairly high. Wärtsilä's demand in the industrialised world is mainly driven by the need for stable, reliable and flexible energy that Wärtsilä power plants provide. (Wärtsilä's markets, 2020)

2.2 Wärtsilä Marine Business

The other half of Wärtsilä's businesses, equally important, is Marine Business. This business drives to improve its customers in the marine, oil and gas industries by providing innovative products and integrated solutions that are environmentally friendly, safe, efficient, flexible and also economically sound. As a leader of the marine technology and through experience, knowledge and serious commitment, Wärtsilä is able to tailor solutions that provide customers with the best value around the world. (Wärtsilä, 2020)

3. Theory

This chapter will be the whole backbone of this thesis. It will include information regarding PED and harmonised standards specified by this directive. Discussions about CE-marking, how to get it approved and what kind of documents are needed will also be included in this chapter. The information and facts are gathered from EU regulations, websites, books, standards and directives.

3.1 Directives

An EU-directive sets out what goals the member states should achieve, the next step is for the member states to decide for themselves on how to do it. An example on this would be, the waste water directive, which sets out the required minimum standards for the treatment of water and sewerage, the member states have to follow this but they often apply higher standards instead of the minimum required stated in the directive. (What is an EU Directive?, 2020)

The directives' function is to mainly help promote the free movement, free trade and competition rules across the EU. The directives can also be used to formulate common social policies and thus affect employment issues, labour law, working conditions and health and safety. Considering this, they can have significant impact on businesses. (What is an EU Directive?, 2020)

Directives in general deal with product safety requirements and are incorporated into national law. For the CE-marking there are 20 different product directives. These product groups include machinery, personal protective, toys, pressure equipment, construction products and measuring equipment. (SFS, 2020)

Directives are easily accessible for the general public from the official website of the European Union. There are a lot of different sectors consisting each area, such as automotive industry, chemicals, cosmetics and so on.

3.1.1 PED 2014/68/EU

In this chapter, the biggest source of information and knowledge in finding the cause to why issues have occurred, will be presented. This directive should be known by everyone, mainly engineers, who deal with pressure equipment, but also all manufactures who manufacture pressure equipment.

The pressure equipment directive entered into force in 1997 and was then titled 97/23/EC, it was fully suspended and replaced by directive 2014/68/EU on 20 July 2016. This directive is applicable to the manufacture, design and also conformity assessment of stationary pressure equipment with a maximum allowable pressure greater than 0,5 bar. As has been mentioned earlier, this directive aims to guarantee free movement of products in its scope while also focusing and assuring high level of safety. With the free movement, it is meant that PED acts as a legal structure and then pressure equipment can be manufactured and sold throughout the European Union without having to go through a local regime in every member state. (Pressure Equipment Directive, 2020)

The correct approach to this directive would be, when dealing with pressure equipment one would search and relate to the directive and act according to it, when in need for knowledge about the minimum requirements for a product or system or actions that are required to be taken in order to get in approve or certified. There is a document called “Pressure equipment directive: guidelines” which is very useful. In this document there are properly written answers and guidelines to the most common questions that may rise when interpreting PED.

This directive classifies the pressure equipment into categories, there are 5 existing categories: SEP (Sound Engineering Practice), I, II, III and IV. Each category represents a level of hazard, meaning the higher level of hazard (SEP being the lowest level), the more extensive the quality assurance. These categories further decide the conformity assessment procedure to be applied to the item of pressure equipment. The pressure equipment is described in Article 4 (1) in PED, in short, the equipment types consists of piping, vessels and steam generator. What decides into which category the equipment falls to is: the maximum allowable pressure then either vessel volume or pipe diameter, one must also mention the fluid state, is it liquid or gas, and the fluid group. Fluids are divided into two groups, 1 and 2. Group 1 include different hazardous fluids, and group 2 consists of substances and mixtures not referred in group 1. This can be read for further explanations in Article 13(1) in PED. (EU Pressure Equipment Directive (PED), 2020)

The categories include different modules, so called Conformity Assessment Modules, which define what kind of documentation is needed for the pressure equipment and also to what extent a notified body should be involved. For example, module G is one of the demanding for piping equipment, it requires, including all the documents, that a notified body goes through the design and approves it. These documents are important to have in possession, one must always inform the manufacturer to include documents in an early state, who is required to have the correct documents in possession, when procuring i.e. for a powerplant project.

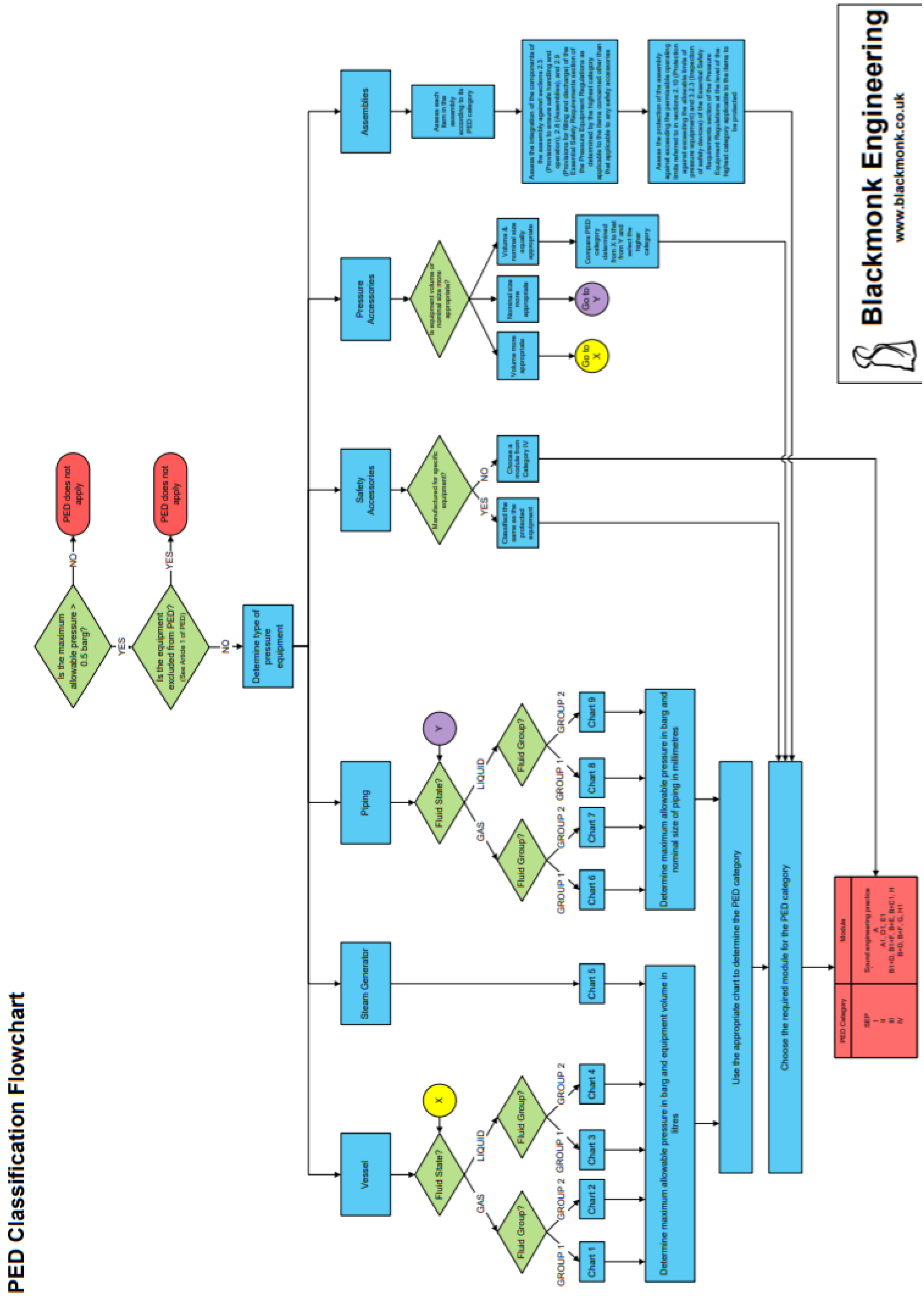


Figure 2 PED Classification Flowchart (source:http://www.blackmonk.co.uk/downloads/ped_guide.pdf)

Figure 2 illustrates each step to be made in order to determine the PED category and the required module, that belongs to the PED category, for the pressure equipment itself. It decides which chart is required to be followed in order to choose the correct category for the pressure equipment. Wärtsilä has also a PED category calculator, which can be found internally. Appendix 4 shows Lloyd's PED category selection flowchart, including the modules.

Appendix 1 gives a view of the PED category calculator intended for piping. The calculator has the charts built in, charts that can be found from PED as well. The tool is simple and easy to use, one must only know what kind of gas or liquid it flows in the piping and then insert the pressure [bar] and the size of the piping [DN]. The tool then calculates and tells what category the piping falls into.

Appendix 2 gives a view of the PED category calculator intended for vessels.

One issue with this calculator that can be found within the organization is that it does not include, in the calculations, hot water with temperature over 110 degrees Celsius. Therefore, it is not fully complete, and Lloyd's PED software should be the one to go for, for assurance of the correct choice of PED category and module.

Lloyd's PED software

This is a free software which can be used for calculating the category and module of the pressure equipment. It gives the opportunity to specify all the necessary information that are required for the decision making, it will automatically suggest and show available modules that could be applied. It also includes the different charts that exist and can be found from PED as well. This software is easily accessible online and can be found from link in Appendix 3.

3.1.2 Machinery Directive 2006/42/EC

The machinery directive is part of the mechanical engineering sector, which is one of the largest industrial sectors in the EU economy in terms of number of enterprises, production, employment and the generation of added value. (Mechanical Engineering, 2020)

This directive plays an important part of the whole engineering industry. Furthermore, this directive includes of an assembly of components, at least one of which moves, joined together for a specific application. The source which powers the drive system of the machinery is energy other than human or animal effort. (Machinery, 2020)

The main aims that this directive strives to achieve is promotion of the free movement of machinery within the single market, it also guarantees a high level of protection for EU workers and citizens. (Machinery, 2020)

The combination of this directive and the Pressure Equipment Directive is essential when working with projects in Europe. It provides aid and guidelines when dealing with for example, power plant projects.

3.2 Standards

Standards and similar standardisation publications are voluntary guidelines that provide technical specifications for service, products and processes. These standards are drawn up by private standardization bodies or organizations, usually at the initiative of stakeholders who need to apply a standard. (Standards in Europe, 2020)

When European Standards are created, all interested parties are brought together, including manufacturers, users, consumers and regulators of a particular material, product, process or services. There are essential factors with standardization that everyone benefits of, through increased product safety, quality and also lower transaction costs and prices. (CEN, 2020)

Every European Standard is known and identified by a unique reference code which contains of the letters 'EN'. It continues with a set of numbers which further makes the standard more unique and easier to refer to. Each member state has their unique reference codes as well, in Finland they apply to the original 'EN' a reference code containing letters 'SFS'. Lastly, each European Standard has been approved by one of the three European Standards Organizations (ESOs), which are European Committee for Standardisation (CEN), European Committee for Electrotechnical Standardisation (CENELEC) and European Telecommunications Standards Institute (ETSI). (CEN, 2020)

Standards are not available for the general public for free. From "SFS Standard webstore", which is the web shop of the "Finnish Standards Association", one can search for information on standards and SFS handbooks, order products and download most SFS, ISO, IEC and ASTM standards electronically. (Detailed instructions on using the SFS webshop, 2020)

Access to the standards are available for all employees within the organization.

Harmonised standards

A harmonised standard is a European Standard which is developed by one of the ESOs on request, called a ‘mandate’ from the European Commission. These harmonised standards are a specific category of European Standards. Harmonised standards have the opportunity to prove one’s products, processes or services comply with the technical requirements of the relevant EU legislation. (Standards in Europe, 2020)

Harmonised standards are published and must be published in the Official Journal of the European Union (OJEU). In this journal there are listed different directives and manuals such as, PED, ATEX (Atmosphéres Explosibles, Explosive Atmospheres) and Machinery Directive. (Harmonised Standards, 2020)

Harmonised standards that are specified by PED can be viewed in a list format from the European Commission website, following link can be found in Appendix 3.

AD 2000

This code is mentioned many times when working with projects across Europe, especially in Germany. In the “Execution” chapter of this thesis work AD 2000 will be mentioned alongside with EN 13480, which is a European standard for Metallic Industrial Piping.

The AD 2000 Code sets out in detail the safety specifications required for compliance with the European Pressure Equipment Directive (PED). It meets the conformity specifications of the Directive while upholding the high standard of quality that is the mark of the AD collection. (AD 2000 Code in English, 2020)

Alongside its focus on quality, safety and conformity with the essential requirements of the Pressure Equipment Directive, it is the clear and unambiguous nature of the specifications, on design, assessment, testing and documentation. (AD 2000 Code in English, 2020)

Local Standards

Local standards may also cause trouble when working with different power plant delivery projects. It may happen, depending on quite a lot of factors, for example if the project is a EPC or and EEQ, that a project stumbles upon several conflicts between European Standards, directives, local standards and demands or requirements from the customer that are stated in the contract or project scope. This may result in vagueness in which should be followed.

These local standards vary or may vary from country to country and city to city, for example in the US there are ‘local standards’ for every state, one does not apply in the other state. Other goals and requirements issued by the country plays a significant role as well, these may be the foundation to why some local standards tell what they tell. Local standards are always on top of the EN, ISO or any other design standard. Meaning that these local standards must always be followed in addition to the design standards.

3.3 CE-marking

The letters ‘CE’ are abbreviation of a French phrase “Conformité Européene” which literally means “European Conformity”. (What is CE Marking (CE Mark)?, 2020) The CE marking is the manufacturer’s declaration that their products or processes meets the correct requirements of the relevant directives, for example PED. (CE marking and labelling, 2020)

The marking indicates that products have been assessed to meet high safety, health and environmental protection requirements, when being sold in the European Economic Area (EEA). Products that bear the CE mark can be traded within the EEA without any restrictions. For affixing the CE marking to one’s product one must undergo six steps, that may differ by product as the conformity assessment procedure varies. These six steps are intended for the manufacturer of the product. (CE marking, 2020)

1. Identify all the applicable directive and harmonised standards
2. Verify the product specific requirements
3. Identify whether an independent conformity assessment is necessary (here a notified body is to be included)
4. Test the product and check its conformity
5. Draw up and store for availability the required technical documents
6. Lastly, affix the CE marking and draw up the EU Declaration of Conformity.

In step three, with conformity assessment it is explained that it includes testing, inspection and certification of the product, it also needs to demonstrate that all legislative requirements are met. Depending on the applicable legislation, which is required in the assessment procedure and carried out by the manufacture, a conformity assessment body is involved, these are named as notified bodies. (Conformity assessment, 2020)

In chapter 5.4 Case 4: Third party / notified body inspections, a further explanation of these notified procedures will be presented. For more information regarding the conformity assessment procedure can be read in the Pressure Equipment Directive in Annex III.

3.4 Certifications

There are certain certifications that are important, that one should put extra focus on. These certificates are in compliance with the declaration of conformity and also required for the CE-marking.

In Guideline G-05 in Pressure Equipment Directive 2014/68/EU Guidelines it is mentioned that: *"According to the 1st paragraph of Annex I, section 4.3, the material manufacturer shall certify, that the delivery complies with the requirement of the specification and the order he has received. This affirmation of compliance shall be stated on or appended to the certificate, whichever type is issued."*. It further continues explaining the second paragraph: *"According to the 2nd paragraph of Annex I, section 4.3 a certificate of specific product control is required for the main pressure-bearing parts of pressure equipment in categories II, III and IV. Account shall be taken of the requirements in 4.1 and 4.2 (a) of Annex I."*. (G-05 in Guidelines related to the Pressure Equipment Directive 2014/68/EU (PED), 2020)

Next, certificates 2.1, 2.2, 3.1 and 3.2 according to EN 10204 will be presented and also the differences between them. EN 10204 is a European standard for the inspection documents and it applies for metallic products, such as pipes for example.

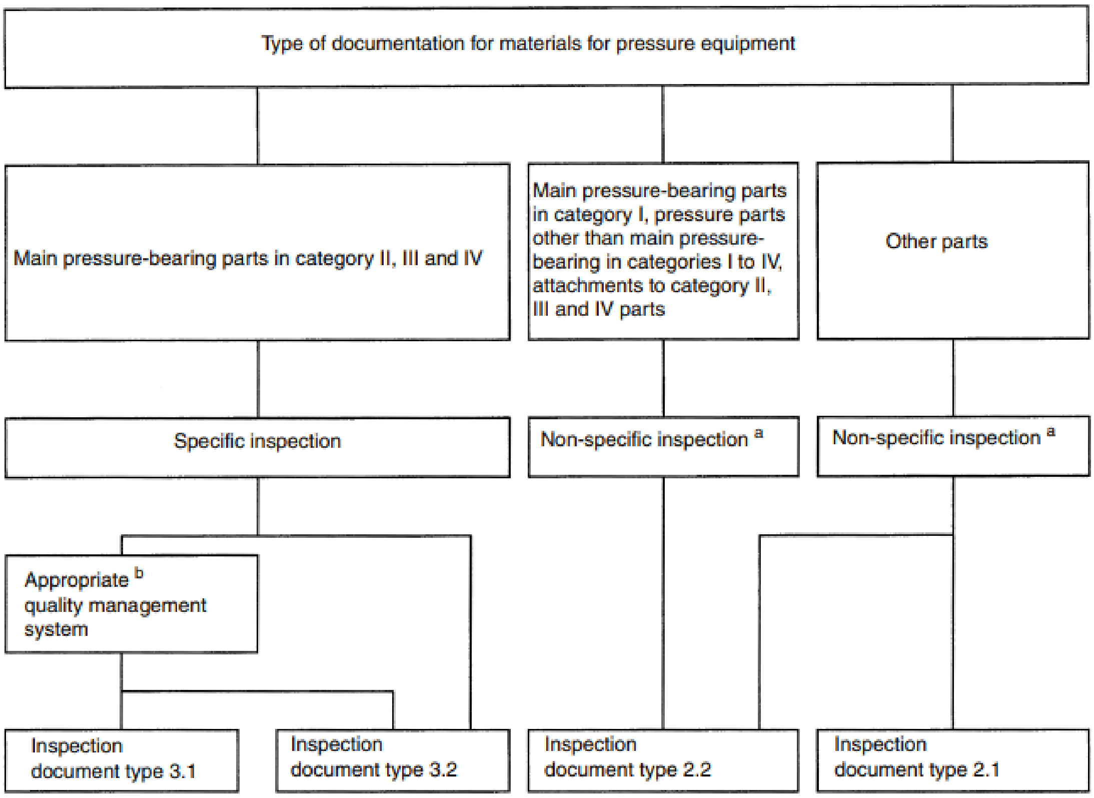
In SFS-EN-10204 it is described that the 2.1 certificates consist of a declaration of compliance with the order, this declaration needs to be validated by the manufacturer. The 2.2 certificate on the other hand further requires an indication of results of non-specific inspection. (SFS-EN 10204-2004, 2004)

The 3.1 certificate is a bit advanced, compared to the earlier ones. The 3.1 certificates for metallic products consist, in addition to the statement of compliance with the order, a "Inspection certificate 3.1" which indicates the results of a specific inspection. This inspection is to be done, by an inspection representative independent of the manufacturing department, authorized by the manufacturer. The inspection certificates consist of documents issued by the manufacture of the product in which the manufacture declares that the products follow the requirements of the order and in which the manufacture supplies test results. The test unit and the tests to be carried out are defined by the product specification, the official regulation and corresponding rules and/or the order. (SFS-EN 10204-2004, 2004)

The 3.2 certificates are even more demanding compared to 3.1 certificates. In addition to what the 3.1 certificates require – the 3.2 certificates require also either the purchaser's authorized inspection representative or the inspector designated by the official regulations to provide inspection documents as has been mentioned in the presentation of the 3.1 certification documents. (SFS-EN 10204-2004, 2004)

What then decides if a system, module or item is required 2.2 certificates or 3.2 certificates is, for example, into which category a system falls to under PED. Figure 3 illustrates briefly which documents are intended and required for materials for pressure equipment. The higher type of material certificate – the higher the costs for them.

Figure 3 illustrates the steps to be taken in order to understand which type of document is required. More information regarding documentation can be found in EN 10204:2004 which is the standard for: Metallic products. Types of inspection documents.



[a] Non-specific inspection may be replaced by specific inspection if specified in the material standard or the order.

[b] Quality management system of the material manufacturer certified by a competent body established within the Community and having undergone a specific assessment for materials.

Figure 3 Conformity with Annex I section 4.3 of Directive 97/23/EC (source: SFS-EN 10204:2004)

4. Methodology

The methodology in this thesis work is performed with relating every issue in each case presented in the next chapter to corresponding standard and directive. The cases in the next chapter have been looked into as in Figure 4, taking into account different factors that are crucial. Cases presents explanations of the mechanical issues, including lessons learned, that have occurred due to PED.

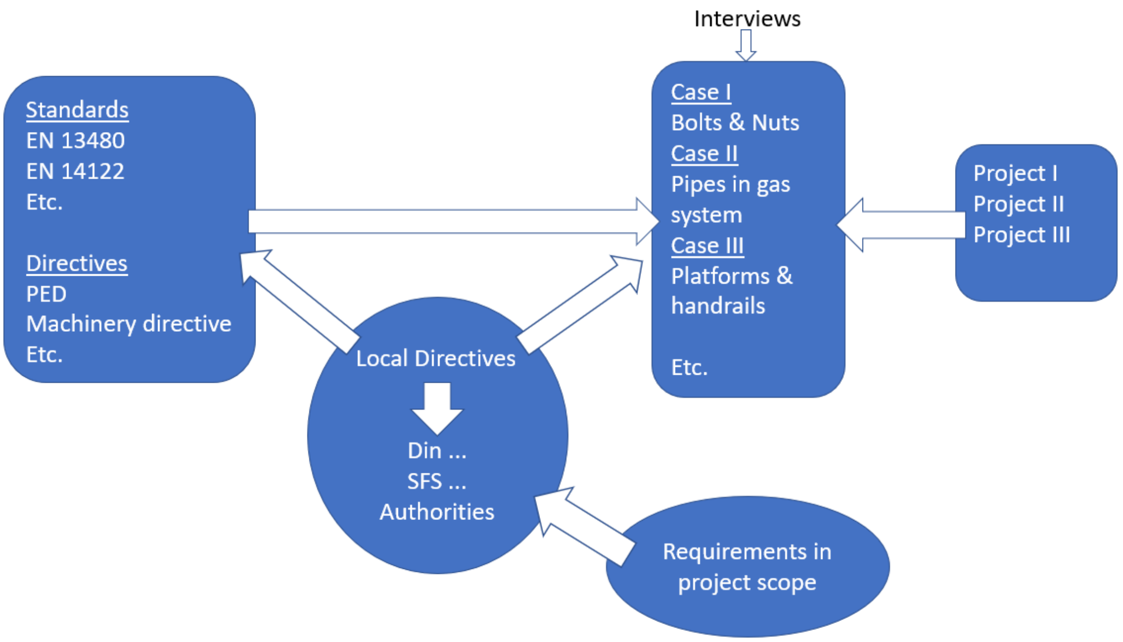


Figure 4 Illustration of how the cases are viewed

For easier understanding each case and issue – the relatable standards have been thoroughly read and analysed. This enables one to actually understand the whole picture and maybe find traits to what, where and why some issues actually are issues.

Meetings with at least 6 CPEs have been held to further understand the bigger picture. CPEs have been responsible for different projects, both in Finland and in Germany. In Finland the projects have been Liquified Natural Gas (LNG) projects, meaning the operating medium is natural gas. Topics that were discussed in the meetings with stakeholders were:

- What kind issues related to PED and/or other directives and also standards have you faced, when working with different power plant projects?
- How did you solve the issues you faced and how did you get it approved?

Two meetings were arranged together with the third-party design company. Both the meetings were really interesting. The design company has much knowledge about design related issues, regarding material and dimension of different types of items. This communication between the project team and the design company is utterly important and should be up to date. It is the project team's responsibility to be aware of the importance of properly executed material and technical specification documents. Project teams must also take appropriate measures to ensure compliance with the design code. These documents will ultimately make the whole WoW much smoother and easier in terms of getting the CE-mark and so on.

All meetings were recorded so that any important information would not be missed. A total of 8 meetings with at least one stakeholder was held. Apart from what has already been mentioned regarding the topics in the meetings, topics such as general information and discussions about the whole thesis and its progress, PED and also standards and design codes that are relevant, were included.

More meetings could have been held, for gathering even more information and knowledge. Even though the existing current situation with the COVID-19, meetings could have been held through teams or skype. Nevertheless, time and commitment has decided the amount of meetings held.

Stakeholders referred to directives and standards regularly in the meetings, this shows and tells that people within the organisation are aware of them. Listening to the meeting-recordings afterwards has aided a lot when one could relate to the corresponding directive or design code.

The cases were not so easy to create, since quite a few of the meetings that were held with the stakeholders did not actually have any concrete issues, that they had stumbled upon. This was of course great news for the project team and the organisation's part, but not for me. Furthermore, most of the issues that have occurred have been issues that have not occurred before, meaning they are new. Some of the issues may have occurred due to a new solution deliverable, i.e. design temperature in gas system that is below -10 degrees Celsius.

Reading and understanding PED is very time consuming and quite complex to understand, it contains of around one hundred pages with information and charts, of which some then refer to some other points or paragraphs in the directive. Having read the PED and the document including guidelines to PED, has facilitated the whole writing process of this work.

5. Execution (confidential)

This chapter consists of confidential information and data that can not be shown outside the organization. Therefore, this chapter is removed from the official version

In this chapter the issues are presented in case format. Explanations of the issues that have occurred are presented including lessons learned and solutions to them. Summaries of related harmonised standards to the issues are also included. All information in this chapter is gathered from meetings with stakeholders and discussions with both CPEs and PEs. An estimation of time and money is also necessary and equally important to take into account – it creates a picture of what kind of impact these issues have created.

5.1 Case 1: Bolts & Nuts

5.1.1 Summary of related directives & standards

5.1.2 Lessons learned

5.2 Case 2: Pipes in gas system

5.2.1 Summary of related directives & standards

5.2.2 Lessons learned

5.3 Case 3: Platforms and its handrails – health & safety environment

5.3.1 Summary of related directives & standards

5.3.2 Lessons learned

5.4 Case 4: Third party / notified body inspections

5.4.1 Summary of related directives & standards

5.4.2 Lessons learned

5.5 Case 5: Welding in pressurised systems

5.5.1 Summary of related directives & standards

5.5.2 Lessons learned

6. Results

In the European Economic Area and basically all around the world, there exists a lot of standards and directives, guidelines and minimum requirements that need to be followed and obeyed, in order to ensure top quality, safety and environmental aspects, for the products or solutions. It is a struggle to constantly be aware of rules and regulations that apply in one place but not in the other, so called local standards.

The result that the issues in the cases have caused is additional time in terms of work, that had to be done in order to solve the issues.

Placing an order to the supplier

When ordering components from the supplier, one must remember to mention according to which design code the material needs to be. The moment when there are different design codes in play, for example AD 2000 and EN 13480, in a system the whole process of receiving the CE marking and getting it approved becomes a lot harder. One small component may change the requirements for the whole system if it is according to a different design code, compared to the rest of the system. Before it sufficed with 3.1 material certificates, but now it requires 3.2 material certificates.

Therefore, standards and design codes should not be mixed.

Bolt material for design temperatures of -20 degrees Celsius

The material to be chosen here should be: 25CrMo4. This material will suffice in temperature between -40 degrees to +400 degrees Celsius and will fulfil the EN design code.

The standard and the table that one should focus on is EN 13480 part 2, Annex D, table D.

Documentation and certificates

Referring to chapter 3.4 in this thesis work, one must always specify what kind of material certification is needed when ordering. In the theory part of this thesis, the approach to when what kind of documents are needed and why, is explained.

Regarding calibration certification i.e. safety valves, planning and timing with the whole installation of the system can be quite crucial and important. Calibration tests should be timed in a later stage so that they are still active and alive when notified body executes the inspections for the CE marking. Two weeks of extra or avoidable work had to be planned in order for the calibration certificates of the safety valves.

When working with systems or equipment that fall under PED, it can be really time consuming to digest the relevant information from the directive that applies to the particular system or equipment. There exists a “guidelines of PED” document which can be found from the European Commission website, and also from Appendix 3. This guideline document is referring to PED and it includes very good information, with answers and explanations to the most common paragraphs and questions from the PED.

How to interpret the knowledge or information in the articles, paragraphs, annexes in both the EN design codes and PED may vary from person to person. This is something that was noted in some of the meetings with the project members. There are “gray lines” so called areas, where one could choose one or the other PED class and for that there can be practicalities that determine the correct way of working. Here a certified third-party can be used for the correct choice of statement, to choose either PED I or PED II for example. Best practices should be communicated in order to avoid major mistakes or issues of uncertainties in the future.

Figure 5 illustrates how project related work should be viewed. The most important specifications and requirements must be stated in the project scope.

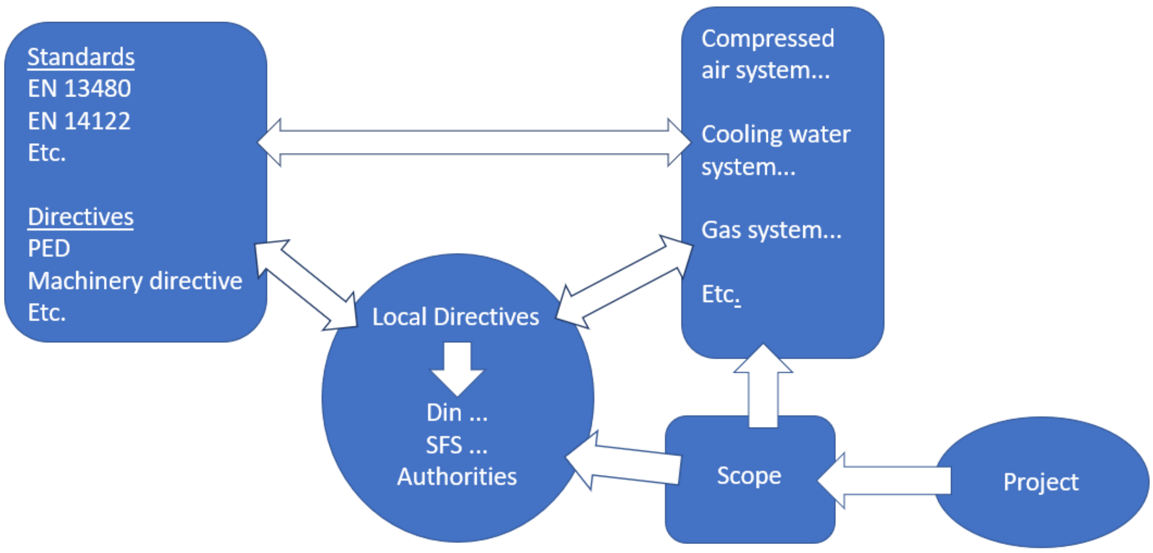


Figure 5 The way of working view when viewing project scope

7. Conclusions

The purpose of this thesis was to identify mechanical issues that are related to PED and harmonised standards specified by that directive. This thesis was limited to mechanical issues that exist pressurised systems, for example gas piping. First and foremost, the whole understanding of the directive is utterly important, general knowledge of it and how to interpret is the whole backbone to why these issues have occurred. Ultimately this thesis work has identified and listed some cases that include issues that have occurred in projects in Europe. With the presentation of PED and identification of these issues related to the directive, it has been an eye-opener for me and could be as well for the reader of this thesis work to think differently, when next time working with PED related work. The whole purpose of this work is to make project members more aware of PED and that similar kind of issues, that have occurred, will not occur a second time.

Everyone should be aware of the importance of the PED and what material certificates are required for the approval from the notified body. Already in the project's kick-off meeting or design basis a separate device list or list that would include all items that would require 3.1 certificates, this could be very useful if presented to the project team in an early state. This would ease the whole way of working with projects when everyone, mainly PEs and CPEs are aware of which and what require further inspection and documents or certifications.

The cases in this thesis have resulted in delays and extra work, which in the end has led to costly and timewise issues that could perhaps have been avoided. Some projects may have really tight schedules and deadlines, therefore if similar kinds of issues would occur in new projects, it can cause significant costs, delays and deadlines can be harder to achieve.

In the end it is the requirements in the scope and the country or state, in which the project is being built, that has the final say in everything, these requirements must of course reflect the standards and directives. In the project scope it must be clearly stated according to what directive and standard the work should be executed. This should correspond and be realistic in order for the approval and CE marking.

Even though this thesis has only touched the tip of the iceberg when tackling PED and harmonised standards that are specified by that directive, including issues and lessons learned related to the earlier mentioned, I feel like I have learned a lot and made something useful that would at least open some eyes when working with PED.

7.1 Challenges faced in this thesis work

Obstacles in this thesis work have been to actually interpret and completely understand the PED and the design codes, mainly EN 13480. Reading these is not something one does overnight. It has been time consuming and quite tough, in sense of that it is quite “dry reading”. Another thing that needs to be pointed out is the information that I have gathered for the cases – it was not quite what I expected, in terms of issues occurred due to PED. Some meetings that were held had not experienced any kind of issues, which is totally a great thing. Here one factor that could have aided, would have been adjustment of “methodology”. What could have been added to the existing methodology process is a “survey” kind of e-mail that would have been sent out to every PE and CPE working with mechanical related matters in power plants in Europe. This way more people would have been involved, which would only have been a good thing, since this kind of information has to come out and experiences of mistakes need to be gathered.

7.2 Proposal to further research

As has been mentioned earlier, this thesis touches the tip of the iceberg when it comes to issues that may occur or have occurred due to PED and harmonised standards specified by it. In terms of potential future research, this thesis could be a very good starting point to continue the expansion into more systems or to tackle other issues regarding PED.

The result of this thesis has been the identification of some of the issues that have occurred including lessons learned. A more detailed guide or handbook could be created as well, where even more issues are listed that have occurred due to PED throughout Europe and most importantly how to tackle and avoid the issues.

Another potential future research would be to look into the American Society of Mechanical Engineers (ASME) world, which is a standards organization. In America there exist different approaches when it comes to directives and standards and so on. Issues have occurred there as well; the identification of these issues would be necessary so that they would not occur once again.

7.3 Closing words

I would like to show my deepest gratitude to everyone who has been involved with this thesis work, everyone who has sacrificed a couple of hours of their workday to attend my meetings, where we have discussed issues that are related to PED and general WoW in their projects, it has given me a deep and broad insight in different approaches towards successful execution of project related work.

Special thank you to my supervisors Prasad Kharche and Peter Bergqvist from Wärtsilä with their invaluable expertise, who has shown great interest and pushed me for achieving the best possible result. I would also like to show my deepest gratitude to Mikael Ehrs, from Novia UAS, who has kept me up to date with feedback related to this thesis work and who has given me well-structured instructions for achieving the best possible result.

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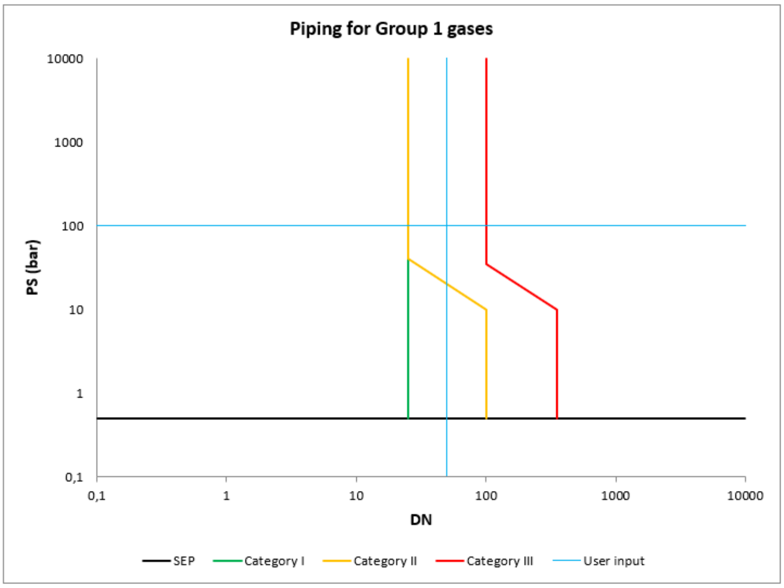
Appendix 1. PED Category Calculation Tool for Piping

This is a quick PED guide for piping system categories. For more information see Pressure Equipment Directive or WDAAA325535



HAZARDOUS GASES
OTHER GASES
HAZARDOUS LIQUIDS
OTHER LIQUIDS
v1.26

PS (bar) 100,00
DN 50,00

PS*DN = 5000
Category II

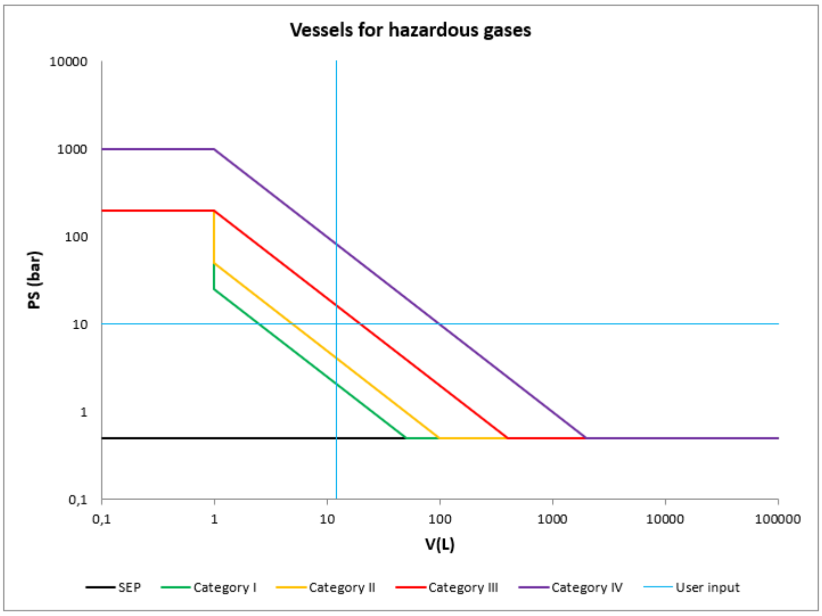
1. Select the correct chart

2. Enter the pressure and pipe size above to see which Category your case belongs to.

Note!
Exceptionally, piping intended for unstable gases and falling within categories I and II, must be classiifed in category III.

Appendix 2. PED Category Calculation Tool for Vessels

This is a quick PED guide for vessel categories. For more information see Pressure Equipment Directive



HAZARDOUS GASES
OTHER GASES
HAZARDOUS LIQUIDS
OTHER LIQUIDS
STEAM GENERATORS
v1.10

PS (bar) 10,00
V(L) 12,00

PS*V = 120
Category II

1. Select the correct chart

2. Enter the pressure and vessel size above to see which Category your case belongs to.

3. Use common sense.

Notes:
Exceptionally, vessels intended to contain an unstable gas an falling within categories I or II must be classified in category III.

Appendix 3. Useful links

- Link to PED and guidelines in PED: https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/pressure-equipment_en

- Link to list of harmonised standards specified by PED: https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/pressure-equipment_en

- Link to Lloyd’s PED category selector tool: https://www.lr.org/en/pressure-equipment-directive/ped-software-tools/

Appendix 4. Lloyd's PED category and Module Decision flowchart (source: https://www.lr.org/en/pressure-equipment-directive/ped-flowchart-poster/)