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TECHNO-ECONOMIC EVALUATION OF
STORAGE TANK OPTIONS FOR EPC PRO-
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Tämä opinnäytetyö käsittelee teknologisia innovaatioita ja jatkuvaa parantamista kansainvälisissä voimalaitosprojekteissa. Työn tarkoituksena on selvittää ja verrata hitsattujen ja pultattujen säiliöiden kustannustehokkuutta osana toimitettavaa voimalaitosprojektia.

Tutkimuksessa vertaillaan hitsattujen ja pultattavien säiliöiden kokonaiskustannusrakennetta. Kokonaiskustannusrakenteessa merkitykselliset muuttujat ovat materiaali-, kuljetus-, asennus- ja perustustöistä muodostuvat kustannukset. Työn tapaustudkimus käsittelee 700 m³ palovesisäiliöitä EPC-projektissa.

Työssä perehdyttiin tutkimusaiheen taustalla oleviin keskeisiin käsitteisiin ja teknisiin periaatteisiin. Näitä ovat EPC-sopimukset, ruuviliitosten suunnittelun näkökulmat voimalaitoksissa käytettävien säiliöiden toimivuuteen. Näitä aiheita tutkimalla saatiin luotua perusta kustannustehokkuus analyysille.

Tutkimus osoittaa, että pulttatut säiliöt tarjoavat kilpailukykyisen vaihtoehdon hitsatuille säiliöille erityisesti kustannusten ja joustavuuden kannalta. Tulokseen voivat vaikuttaa kuitenkin myös muut tekijät, kuten projektin vaatimukset tai poliittiset vaikutukset.

Avainsanat: pulttatut ja hitsatut säiliöt, kustannukset, kustannustehokas, projekti, standardi,

ABSTRACT

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This thesis discusses of the technological innovations and importance of continuous improvement in international power plant project deliveries. The aim of the thesis is to investigate and compare the cost-effectiveness of welded and bolted tanks as part of the energy power plant project supplies.

The research focuses on comparing the total costs of welded and bolted tanks. This considers materials, transportation, installation and foundation work. The case study of the work deals with 700 m³ fire water tanks in an EPC project.

The work examined the key concepts and technical principles underlying the research topic. These include EPC contracts, aspects of bolted joint design for the functionality of tanks used in power plants. By studying these topics, a basis was created for a cost-effectiveness analysis.

The study shows that bolted tanks offer a competitive alternative to welded tanks, especially in terms of cost and flexibility. However, the result could be influenced by other factors, such as project requirements or the political influences of the world.

Keywords: Bolted and Welded Tanks, Costs, Cost-effective, Project, Standard.

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ACRONYMS

AWWA American Water Works Association D 103 standard

API American Petroleum Institute 650 standard

NFPA National Fire Protection Association 22 standard

EPC Engineering Procurement Construction

1 INTRODUCTION

Technological innovations have a big role in the industrial solutions, like companies which operate in the energy industry, including different storage tank options in the power plant sector. Innovation means doing something which creates value. Implementation of new approaches to the existing technologies can result in efficiency, productivity and competitiveness. Through technological innovation it is possible for businesses to adapt more quickly to market changes, meet operational demands effectively, and stand out in competitive environment. In addition, technological innovations can be cost-effective, quality increasing products or services. Those innovations can open new business opportunities, that promote value creation and the longevity of the business.

1.1 Research Motivations

The purpose of the continuous improvement and innovation is to scout new solutions and improvements. The needs for cost-effective solutions in the energy industry and power plant business has led to an increased interest in exploring potential alternatives for storage tank options. Different approaches such as bolted tanks in storage options, could not only provide operational efficiency but also enable the development of new business opportunities. Welded tanks have been traditionally the preferred choice for large-scale storage because of good standards for design and construction. The case company has started investigating bolted tanks as a potential alternative due possible advantages in cost reduction and operational efficiency.

Companies should take advantages of new approaches and technologies to stay ahead in the competition. Keeping up with the development is important. When deciding between welded and bolted tanks, a cost comparison should be considered. With more up-to-date information in real time, deeper analysis of the available data is possible. Identifying patterns and fundamental trends is

important as it creates more convincing strategies that strengthen the company competitive position in the market with more cost-effective solutions.

1.2 Background of Research

The cost comparison of welded and bolted tanks has many factors. It is crucial to understand where the costs are generated from. The costs are generated from different fractions in idea to product delivery process for example, design, material, manufacturing, transportation, construction, commission and documentation cost.

The material costs depend on the price set by the manufacturer and the design requirements for each tank type. Welded tanks can require more raw material due to their structural design and wall thickness, which is necessary for strength and rigidity. These added material quantities can raise the cost of delivery. The modular nature of bolted tanks often involves the use of precisely engineered components that can be light. The total cost of the materials can be less on bolted than welded tanks, especially if lighter materials can serve effectively.

Large storage tank transportation has different aspects. Regulations determine road and shipping limits on sizes. For example, a wide delivery on roads requires special permits and use of big transportation vehicles which can be costly. Containers can be fully packed with parts and both tanks can be designed to be transported in parts. This can reduce transportation costs and logistical complications. In both tank types, the capability to ship components in containers reduces the restrictions of road width and oversized shipment costs, making it practical and economical.

Bolted and welded tanks have a different structural nature. This really can have effect on the foundation requirements. Welded tanks can be heavier than bolted tanks and therefore robust foundations could increase the costs. The lighter nature of bolted tanks can allow more flexible design of the foundation reducing

the costs. The final costs of the foundation can also include soil and environmental conditions of the construction site.

Installation costs depend on the labour level of cost and target country legislation. In the case of welded tanks, much of the work can be done by robots or skilled welders which can be expensive. Bolted tanks on the other hand, have a different on-site assembly. Tightening bolts could be more cost-effective because it requires less skilled labour.

The connection to corporate strategies lies in the drive for efficiency, cost reduction, and optimization in the projects. By evaluating bolted tanks as an alternative to welded tanks, the thesis aims to identify potential saving and increasing of quality. This study will help determine the cost-efficient option for specific storage application, aligning with strategic goals to enhance operational efficiency.

The background research for the thesis involved interviews with stakeholders and gathering relevant data. The agendas of the background interviews were formed preparing questions and searching data from documents in advance for the interviews. Discussions during the interviews often evolved around the topic. Rather than asking the list of question from the expert, it was better to have an open conversation, which allowed to the interviewees to share their insights more. While not all details were important for the research, this kind of interaction gave a clearer understanding of the topic, helping to determine suitable options for the topic.

Interviews were done remotely both in Finnish and English. One of the interviewed stakeholders working in the case company as a civil engineer provided information about tank foundation types. Vital information was gathered from an interviewee that works as a strategic purchaser in the case company. He could provide data of the tank costs from previous projects. Interviews with all the stakeholders were valuable. They provided information and approaches on the research that would

have not been known otherwise. Ideas of the topic were developed considering pros and cons with the stakeholders for building reasonable test case.

1.3 Research Questions and Scope

This thesis is done to benefit a project team of the case company. The primary objective of this research is to analyse the total costs of bolted tanks compared to welded tanks across various factors. The main reason for this is to find out which tank type is more cost-effective option to procure for the project. Specifically, a test case for a 700 m³ Fire Water Tank in EPC project will be used.

This thesis will answer the following two research questions:

- RQ1: What are technical requirements for bolted tanks?
- RQ2: What is cost effective between bolted and welded tanks?

The research method of this thesis is quantitative. The test case breaks down cost factors for bolted and welded tanks and a comparison is performed. A comparison is made between two similar tanks API 650 (welded) and AWWA D103 (bolted) to assess their feasibility.

The theory will include EPC contract, bolted connections and elements relevant to them as well as standards relevant to bolted tanks. In the theory review, only bolted tanks standards AWWA D 103 and NFPA 22 are explained.

This thesis is limited to cylindrical firewater tanks, and it does not include any other tank types. The API-650 standard relevant to welded tanks is not included. Additionally, some sources in the theory review could only be found on web sites. This research does not include a technical difference analysis between welded and bolted tanks.

2 THEORETICAL FRAMEWORK

This theoretical framework chapter will present the foundations to better understand the key concepts and technical principles behind this research topics. The essential topics presented here will be Engineering, Procurement and Construction (EPC) contracts. The technical aspects of designing bolted joints towards functionality of tanks used in power plant applications. These topics will further help create a basis for the cost-effectiveness analysis.

2.1 Understanding EPC contracts

There are several project management methods such as EPC contracting. The EPC stands for Engineering, Procurement and Construction. Such a contract is an agreement between the project owner and the contractor where are clarified and stated e.g., the requirements, scope and responsibilities of the delivery. The EPC contract can be used, for example, in the construction industry. The structure of the EPC contract allows the project owner to transfer the design, procurement process and construction to the contractor (Blackridge Research & Consulting, 2024). (Cova & Hoskins, 1997) presents the EPC contract as an agreement involving a complex combination of products, services, and construction activities, specifically suited to deliver a complete asset for the client within a defined timeframe. This could include structures such as buildings, turnkey facilities, power plants, weapon systems, or similar projects. The EPC contractor is fully responsible for the completion of the entire project life cycle. Delays, additional costs, site preparation, construction and delivery to the customer in a fully functional turnkey state. This is why EPC contracts are sometimes called turnkey solutions, as the contractor does everything from start to finish (Blackridge Research & Consulting, 2024).

2.1.1 Overview of the EPC Contract in Power Plant Projects

When executing projects with the EPC method, usually the target of the project is clearly stated. Most of the cases it is some sort of plant built for the operating company. The plant can either be a petrochemical plant, a refinery, a power plant or an offshore platform (Choi, 2008). The EPC contracts are particularly suitable for projects based primarily on technical engineering plans rather than architectural design. (Forbes & Ahmed, 2011). The EPC contracts are suitable for situations when there is a large project with several activities that require good coordination. This approach ensures integrated project delivery. The EPC contract can also provide a turnkey solution that can help when an organization lacks internal expertise. It reduces the need for large internal capabilities. The EPC contract is ideal for tight project schedules. The EPC contract can make the project more efficient and possibly speed up the completion time (Blackridge Research & Consulting, 2024).

The EPC contract includes the establishment of a project company that will take the project from start to finish. Typically, the scope of works must be clearly defined in the contract that the work is done (Rentschler & Shahani, 2019). The EPC contractors are responsible of whole project life cycle including to carry out for example, design, procurement, construction, commissioning and handover. Generally, the full EPC contract places design, procurement and construction on overall control for project delivery. The contractor is responsible of each stages of the project's life cycle, including design, procurement, construction, and final commissioning (Projectometric, 2023). Figure 1 shows the scope of the EPC contract.

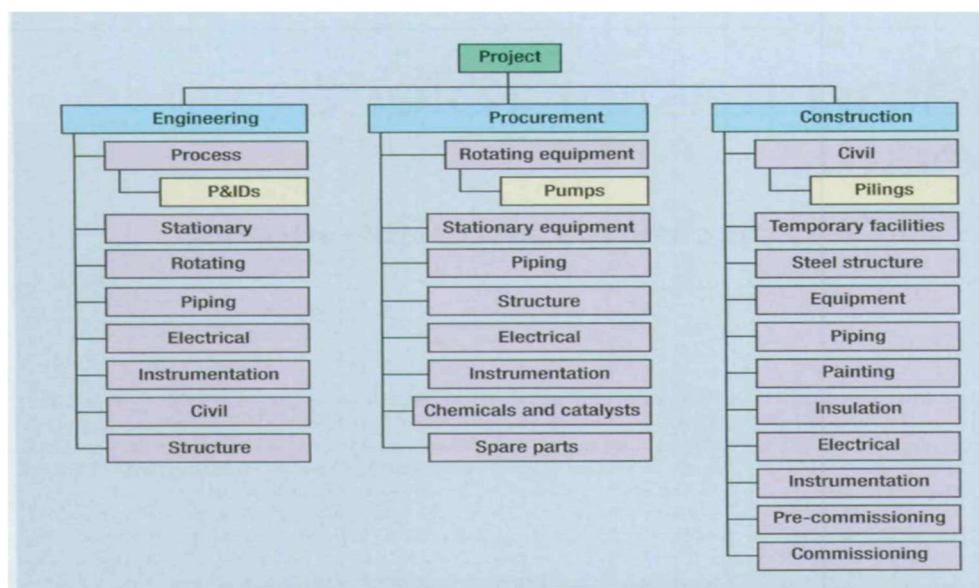


Figure 1. Scope of the EPC contract (Choi, 2008)

Essentially, engineering part covers the entire technical side of the power plant project. It should cover the basic and detailed design and engineering, and the construction drawings of the entire project, taking care of structural, mechanical and electrical components. The specification drawing and preparation of the project's technical documents must also be taken care of. Procurement refers to gathering materials, equipment and services needed for the project. Ensuring quality assurance and timely availability. During the construction phase, the contractor must maintain and coordinate on-site construction, including safety and quality. Complete physical assembly, installation and construction of the product. In addition, the commissioning phase includes testing and handing over the finished product to the customer. (Projectometric, 2023).

The EPC delivery method offers significant advantages, including innovative design and construction approaches, upfront cost and schedule certainty, assured performance, and minimized administrative workload associated with asset development (Forbes & Ahmed, 2011). A fixed completion date, where the contractor commits to completing the project by a certain deadline is a key aspect

for the EPC projects. It ensures delivery on time and allows the owner to plan operations efficiently. The EPC contracts may also include different payment plans for example, with a fixed price which is agreed upon at the beginning. This brings financial clarity to the owner and transfers the risk of cost overruns to the contractor and promotes efficient project management. The turnkey delivery is also vital aspect and makes the contractor to handle all aspects from design, procurement, construction and commissioning to deliver a fully functional facility. In this way, the owner can start operations immediately without additional tasks. Performance guarantees are also important in EPC contracts, as the contractor ensures that the facility meets the specified performance criteria. This protects the owner and ensures that the project works as planned (Wambetilegal, 2024).

2.2 Understanding Bolted Joints

The design of the bolted connection is a very important design aspect in bolted tank constructions. Good quality connections will ensure the safety and reliability of the joint over longer period of operation. Proper bolt design will depend on the application and force loading of the bolt joint. For example, choosing high strength bolts for high loads will prove to be effective design strategy, although may not be necessarily cost-effective. Another crucial factor is the corrosion resistance of joints, and proper coated or treated bolts should be used in respective environments based on type of environmental corrosion factors such as moisture, salty environment, indoors or outdoors use or contact with other corrosive substances. It is therefore essential to select the correct bolt size and quality to ensure that the joint can withstand the expected loads and environmental stresses (Ischuk, 2024).

Safety and reliability of the bolted joint depends on correct installation of bolts. This involves applying the appropriate torque lubricating to the bolts and tightening them to the specified tension. External forces like wind or seismic activity should be taken into account. They can increase stress on the joint and can demand extra bolts or reinforcements. Regular inspections are also essential to

make sure that the bolts remain in good condition and can handle different loads. These inspections should involve checking for corrosion or damage and verifying that the bolts remain properly tightened over time (Ischuk, 2024).

The Bolted Joint Analysis calculator (Figure 2) shows illustrations of stress analysis of a typical bolted joint, accounting for preload, applied axial load, and applied shear load (MechaniCalc, 2025). The diagram shows the two plates (shown by the pale green blocks) being pulled in opposite directions, putting the bolt (shown in blue colour) in a shear stress situation.

Bolt Inputs:

Joint Type:	<input type="text" value="Bolt With Nut"/>	
Tensile Force:	<input type="text" value="1000 lbf"/>	<input type="button" value="Calculate"/>
Shear Force:	<input type="text" value="0 lbf"/>	<input type="button" value="Calculate"/>
Bolt Material:	<input type="text" value="Example Material 2, Fictitious"/>	<input type="button" value="Create New"/>
Thread Size:	<input checked="" type="radio"/> Inch <input type="radio"/> Metric	<input type="text" value="#10-32"/> <input type="button" value="Size Chart"/>
Preload, % _{yield} :	<input type="text" value="67%"/>	<input type="button" value="Calculate"/>

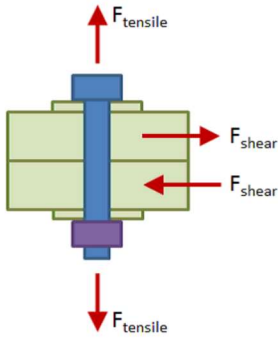


Figure 2. Bolted joint calculator (MechaniCalc, 2025).

2.2.1 Design Factors of Threaded Fasteners

The dimensions of the threads and the accuracy of the profile are decisive when determining the hardness of the threads. It is important that the mounting surface can be machined, the parts joined together, and the threads can transfer the forces for which the components are designed. Threads main dimensions are nominal diameter, pitch and minor diameter, as shown in Figure 3. The stress which can break the screws is tensile strength. Fracture may occur in the shank or thread of the screw, but not under the head. If testing is done with full size screws, the result is reliable. Tensile strength can be determined accurately; this requires that the machined test rod is pulled, excluding stainless steel screws (Ferrometal, 2024).

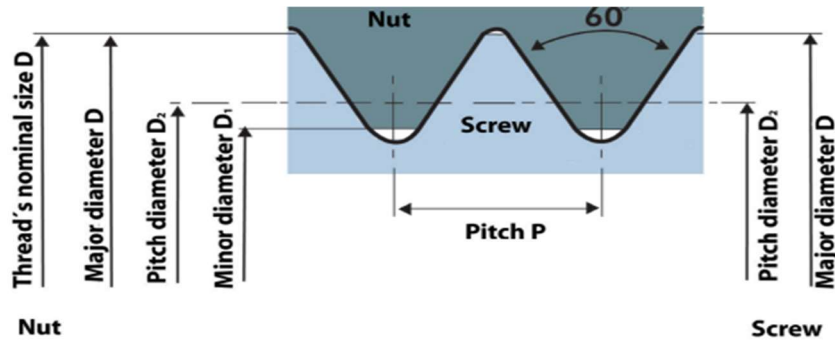


Figure 3. Threads dimensions (Ferrometal, 2024).

One of the most used types of threaded fasteners in machinery and construction are hexagon bolts or hexagon head screws. These bolts or screws can be tightened with a nut or screwed into a threaded hole. Wood screws have large threads and a smooth section near the head. Those characteristics helps pull two pieces of material together. They are mainly used for wood and other soft materials. Sheet metal screws have sharp points and threads, allowing them to be screwed directly into sheet metal, plastic, fiberglass, or wood. Machine screws are fully threaded and designed to be used with a nut or a tapped hole. Socket screws are a type of machine screw with a hexagon shaped hole in the head for tightening with an Allen wrench. Longer ones may have a smooth section near the head. Lag bolts, also called lag screws, are large wood screws with hexagon heads. They are mainly used for building with wood and landscaping. (Boltdepot, 2019).

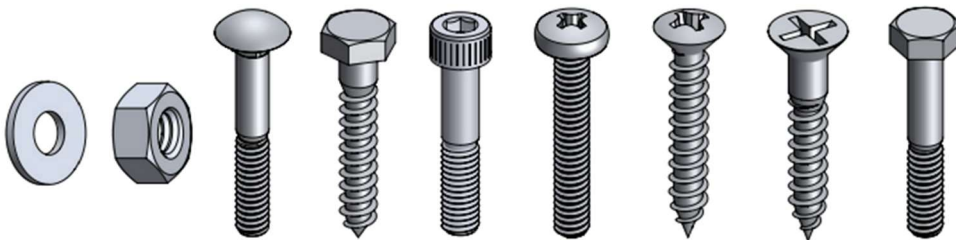


Figure 4. Common fastener types (Boltdepot, 2019).

Nuts are used to secure machine-threaded fasteners that pass-through holes. Lock nuts help keep them from loosening over time. Washers spread the load over a larger surface when tightening a bolt, screw, or nut. Locking washers add extra grip to prevent nuts from coming loose (Boltdepot, 2019).

2.2.2 Advantages and Disadvantages of Threaded Fasteners

The screw joints are one of the most common removable joints. They are easy to install and uninstall, reliable when used correctly and can be used in many environments. Standard fasteners are relatively inexpensive products and are available in several strength classes (Boltdepot, 2019).

One disadvantage of screw connections is their reliability. Ensuring the correct tightening torque can be challenging. Choosing the right tool for fastening the screws such as torque wrench is essential for proper fastening. Also, the screws have points of discontinuity where stress concentrations occur. Most screw connections are subject to two main forces: a tensile force along the screw axis and a shear force perpendicular to the screw axis. Corrosion can also be problematic. It can often be caused by exposure to the weather or the interaction of different metals. To prevent corrosion, a suitable protective coating is recommended to have. Over time, vibration can loosen the joint, which can be mitigated by using an appropriate lock nut or lock washer (Ferrometal, 2024)

2.2.3 Corrosion of Fasteners

With fasteners, quality is defined by durability and flexibility. Since fasteners connect or combine elements, it is essential for the integrity of the structure that the correct type is used. Correspondingly suitable coatings guarantee the longest service life of fasteners by providing protection for the metal underneath (Global Certified Fasteners, 2024).

Being exposed to extreme conditions or chemicals can significantly reduce the lifespan of a fastener, especially if it lacks proper coating. Fasteners that are

damaged or rusted, faces risks and can be expensive to replace. That is why selecting the appropriate coating is crucial. Manufacturers rely on salt spray testing to assess the corrosion resistance of coatings. Basically, the longer the coating can withstand salt spray exposure before showing signs of oxidation or rust, the more effective it is (Global Certified Fasteners, 2024).

There are many types of corrosion inhibitors for fasteners. For example, stainless steel and zinc. While stainless steel is not coated, it is popular choice for rust prevention because of natural corrosion resistance in various environments. This makes stainless steel a popular material for marine, food, and medical applications, as well as products intended for outdoor use. Zinc is one of the most used adhesive coatings, as it is relatively inexpensive to apply and effectively protects against rust, making galvanized fasteners ideal for moist environments. Yellow zinc, named for its electroplating process, often has a more golden hue than clear zinc coatings. Yellow galvanized fasteners are particularly suitable for applications where water or other liquids may be in contact the product (Global Certified Fasteners, 2024).

2.2.4 Application of Bolted Joints

Bolted joints are commonly used to connect two or more components together in mechanical applications. To transfer force from one part of the structure to another or for stability, different steel parts of steel structures must be connected to each other, and this is known as connection. Bolted joints have proven to be effective and safe joints, and several design change options ensure the best fit for overall structural stability. The elements needed for connection are called connectors or fasteners (Ischuk, 2024).

There are various kinds of bolted joints, such as the lap joint, formed by bolting two overlapping plates together. This type is commonly used in sheet metal fabrication. Figure 5 shows how a lap joint is structured. Another type is the flange joint, which is made by bolting two flanges together. Figure 6 shows an example

of flanged joint. Flange joints are often used in piping and other industrial settings. (Ischuk, 2024). Flange joints and lapped joints are generally used in bolted tanks. (American Water Works Association, 2020)

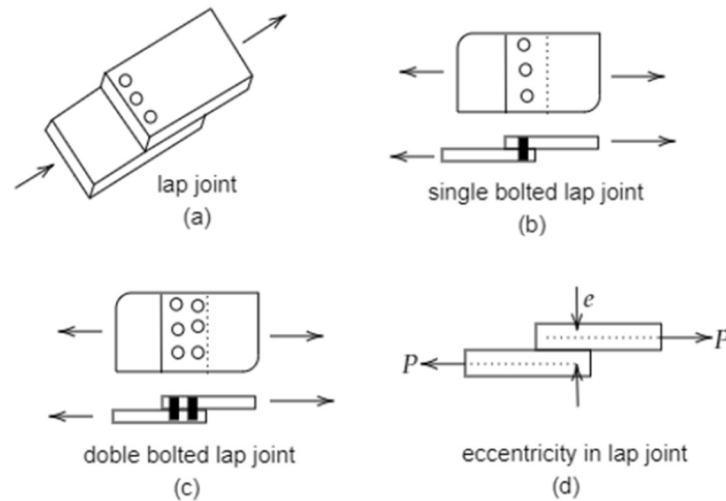


Figure 5. Lap joints (Apsed, 2022)

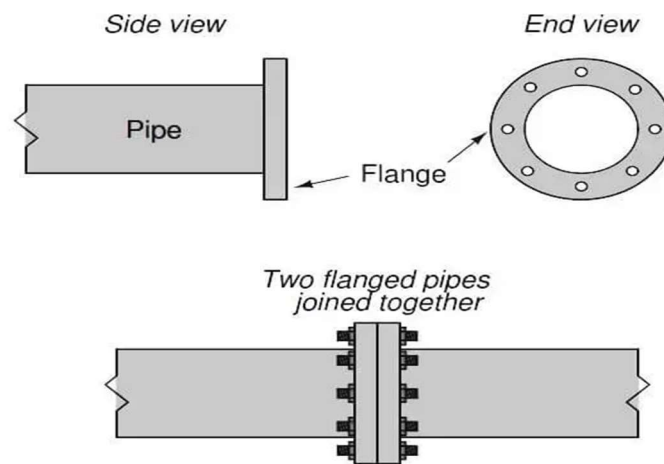


Figure 6. Flange joint (Firdaus, 2024)

Flanged joints have several advantages, such as external bolts that reduce the need for special corrosion protection on the inside, easy inspections and quick installation thanks to small and large bolts. The additional stiffness of the flanges

also facilitates handling and improves structural integrity, while some manufacturing tolerances allow for easy adjustment when installed without scrapping entire panels. The lap joints have their own advantages. They require less material making them more cost-effective and generally provide a better sealing than flange-type joints if manufactured with high precision (Buys, 2024). Figures 7 and 8 below illustrate the installation method with both joint types.



Figure 7. Installation of Lap joints (Buys, 2024)



Figure 8. Installation of flange joints (Buys, 2024)

2.3 Tank Design Standards and Requirements in North American Projects

A technical standard is described as a document that provides requirements, specifications, guidelines or characteristics. It can be used to ensure materials, products, processes and services are fit to their purpose. Standards are used in industries and such, that produce, use, or rely on information and communications technologies. (International organization of standardization, 2025) Technical standards in this chapter described are AWWA D103 and NFPA 22. Both American water works association (American Water Works Association, 2020) and National fire protection standards (National Fire Protection Association, 2023) provides technical standards.

2.3.1 Standard Based Design of Bolted Tank

The bolted tank is one of the atmospheric storage tanks, which is alternative to the welded tank. Bolted tanks are made from factory made panels which are also called sections. These panels are manufactured in a factory line with precise quality. The panels of bolted tanks are connected to bolted joints. These tanks are found in industrial, commercial and domestic variations in various sizes. Bolted tanks can be used for many purposes, for example as water storage tank (Lusi, 2021). Figure 10 shows an example of bolted tank.



Figure 9. Bolted tank (Steven Brown & Associates Inc, 2025)

AWWA D103 provides the minimum requirements for the design, construction, inspection, and testing of new cylindrical, factory-coated, bolted carbon steel tanks for water storage. It is only applicable to tanks whose base elevation is substantially at ground level.

The AWWA standard specifies the types of steel used for the tank and gives specifications for the materials. Requirements for coatings and specification of bolts and gaskets with emphasis on strength and corrosion resistance are also

presented. The standard further provides requirements for both interior and exterior coating systems against corrosion protection. In that way the standard ensures long lasting service.

The standard provides the tank capacity and dimensions calculations. Loads like wind, seismic, and snow loads are included. Calculations ensure that the stresses within the tank walls and roof remain in the safe limits. Bolted connection requirements are mentioned, including spacing, sizes, and watertight seals. Additionally, the specifications for the panels to be used, as well as specifications for sealants used between panels and around bolted connections.

Foundations suitable for AWWA bolted tanks include embedded or concrete ring walls and slab foundations, ensuring good bearing capacity to support the tank. When wind or seismic loads go beyond the threshold for self-anchored tanks, anchor bolts should be provided. The acceptable types of roofs are fixed, dome, or open-top roofs, which are also specified along with structural requirements. Those meant for safe access and maintenance include specifications concerning manholes, accessways, ladders, platforms, railings, overflow outlets, and drainage systems (American Water Works Association, 2020)

2.3.2 Requirements for Firefighting Tank Design

Firewater tanks are essential for industrial safety systems, designed to store and supply water for firefighting purposes. These tanks can be found for example in power plants and large commercial facilities. Fire water tanks can be constructed by bolting (Mahoney, 2024).

The NFPA 22 standard provides minimum requirements for the design, construction, installation, and maintenance of tanks and accessory equipment that supply water for private fire protection. NFPA adds additional significant requirements for fire protection including water capacity, water level indicators, heating systems to prevent freezing in cold climates and piping configurations.

When designing a tank for fire protection, it needs to meet both AWWA D103 for its structural integrity and coating and NFPA 22 for features related to fire protection.

The NFPA standard determines several tank types for firefighting purposes. The standard includes ground supported tanks such as steel and concrete tanks, elevated tanks like steel elevated tanks mounted on towers. It also includes pressure tanks which store water under pressure for immediate firefighting. Materials for firefighting tanks should be suitable for their use and location. The standard defines that tanks can be made of steel, concrete, fiberglass, or other approved materials. The materials of firefighting tanks should be durable, corrosion resistant, and appropriate for the long-term use.

According to the standard the tank must hold enough water to meet the fire protection demands of the facility it serves. This capacity is typically determined by local fire codes, and the design of the fire protection system in the facility. The location of the tank is critical for effective firefighting. The location should ensure that water delivery effective for firefighting but also safe from fire exposure.

A reliable water supply and good refill rate are essential for the tank. The refill system should be capable of refilling minimum firefighting volume in 8 hours. Proper hydraulic design ensures that the water is delivered at the required flow rates and pressures. The tank must have properly sized piping and valves to deliver water at the necessary flow rates and pressures for firefighting. Tanks must be equipped with heating systems or other methods to prevent freezing in areas with freezing temperatures. This ensures the water always remains available for firefighting. Tanks must have water level indicators to monitor the water level continuously. Manholes or other access points should be provided for maintenance and inspection purposes. Proper ventilation must be installed to prevent vacuum formation or excessive pressure buildup, ensuring the tank operates in a correct way (National Fire Protection Association, 2023).

3 RESEARCH METHOD

The quantitative research method used in this research is a methodological trend in scientific research based on describing and interpreting an object using statistics and numbers. Quantitative research is often interested in different classifications, cause and effect relationships, comparisons and explaining phenomena based on numerical results (Jyväskylän Yliopisto, 2025).

The data relating to this research was collected by studying internal documents, including technical drawings, quotations and cost information from significant stakeholders. The stakeholders are from the case company and its suppliers.

3.1 Data Collected and its Analysis

The data was collected under following themes: material, transportation, installation, and foundation work costs. Sources are from different tank manufacturers and project-related documents from the case company. After examining the data, an analysis could be formed for better understanding of the themes.

The purpose of the thesis was to clarify which tank type bolted or welded would have a lower overall cost, based on the costs after manufacturing through to construction. The primary cost factors that were included in this study are material costs, transportation costs, installation costs and foundation work. Together these factors make total costs of the tank for the project.

The data collected and its detailed analysis were sensitive information to the case company and therefore classified. An analysis of the non-sensitive part is presented in chapter 4. The detailed data and its analysis cannot be publicly presented, however, a sample of the data collected is presented in Appendix 1 of this document.

4 ANALYSIS OF THE COSTS

This chapter provides a comparison of the various factors influencing tank costs. Evaluation and comparison of the cost are done. Also, the result of the analysis is presented. A test case was established to estimate those cost factors. It was decided that the test case would be based on an EPC project, and it would include total of three 700m³, steel firewater tank types instead of just two, to improve the quality of comparison and reliability of the cost analysis.

4.1 Comparison of Design Factors

The comparison includes one welded tank with a standard foundation typically used for the case company projects and two bolted tanks, one with an embedded foundation and the other a bolted enamel floor type foundation. The tanks comply with API 650 standard (welded) and AWWA D103 standard (Bolted). Figures 10, 11 and 12 give an idea of what the tanks look like with their respective foundations.

Since both standards are relevant in the USA, the chosen location of the tanks was set in Florida, as the case company has some available construction data from there. For the reliable transportation data, it was chosen to transport the materials of the tanks from Finland to the destination in USA.

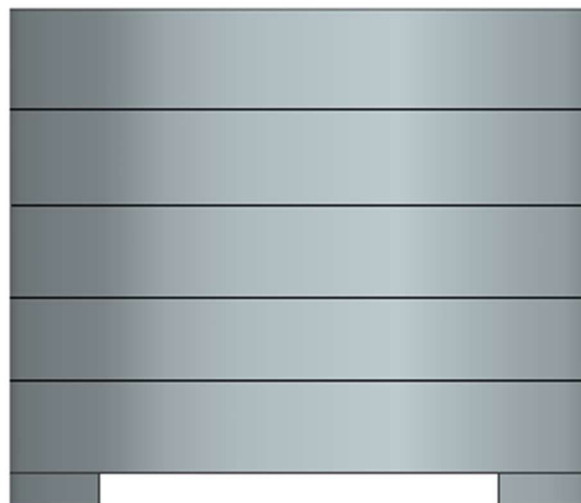


Figure 10. Welded tank including the standard foundation.

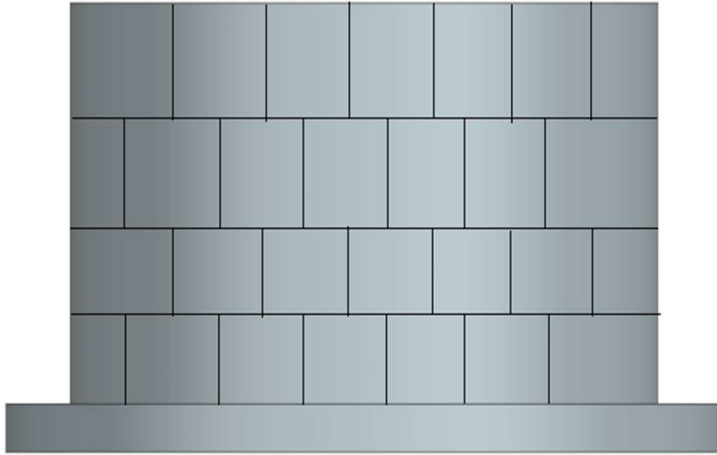


Figure 11. Bolted tank including the embedded foundation.

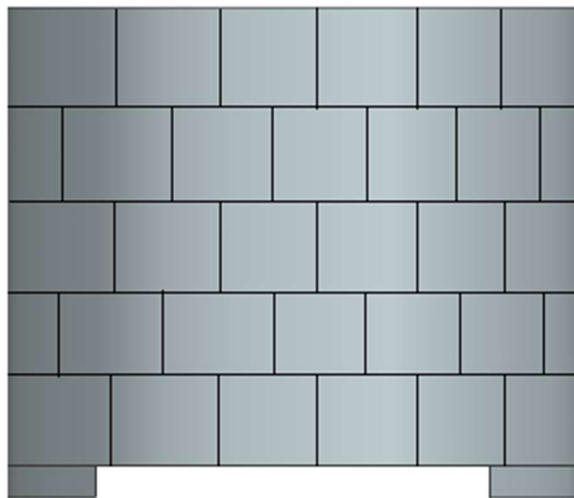


Figure 12. Bolted tank including the enamel floor foundation.

4.2 Comparison of Cost Factors

In the test case of steel firewater tanks, the costs of the tank materials were based on estimations. The estimations were acquired from various sources, including different tank manufacturers and case company data such as old quotations and past project costs. The tank prices were set at the price per kilo. For all calculations which were formed by using cost estimation tool, inflation rates were included, expect for transportation costs. The estimation tool used in this study is property of the case company for cost estimations. The cost estimations were calculated for an EPC project.

For welded tanks the cost estimation of tank materials was gathered from a project quotation that has been completed few years ago. In contrast, the cost estimation of bolted tanks material costs was acquired directly from a bolted tanks manufacturer. The material costs of both tanks include necessary equipment for fire water tanks.

Transportation costs estimations were calculated by using a calculator tool. The transportation calculator tool is affected by two factors: the price of the shipment per one container and the weight limit per one container. The weight limit of the shipping container is specific. Since the welded tank weigh over this limit its parts must be packed into two containers. Both bolted tanks weigh less than the specific limit so ideally, those can be packed only in single container.

The installation costs for both welded and bolted tanks were based on the references from the past projects in the case company. These costs were estimated using a cost estimation tool considering local labour rates.

Civil work costs for foundation works costs were also from past delivered projects as a reference information. The cost estimation tool includes prices both for material and installation costs for all foundation types. Also, subcontractor indirect costs were considered for in the cost estimation of different tank types.

4.3 Comparison of the Tank Costs

The decision which tank will be used is very much related to a detailed analysis of transportation, foundation works, installation, and material costs. Gaining insight into these cost will help to determine the decisions that meet economic priorities.

In the collected data there are visible cost-based and construction type themes. These themes can be formed into clusters, making it easier to understand the data. Figure 13 highlights the themes of the different tank types. The cost theme is clear by examining the numbers. The construction type theme is revealed through different tank types and foundations used. These are labelled below the or beside the bars, such as “Welded, standard” or “Bolted, embedded”.

Additionally, detailed cost analysis is presented in Appendix 1. This data gives an understanding of the costs. The data is hidden in Figures 13, 14 and Appendix 1 in the public publication of this thesis, due to company specific reasons.

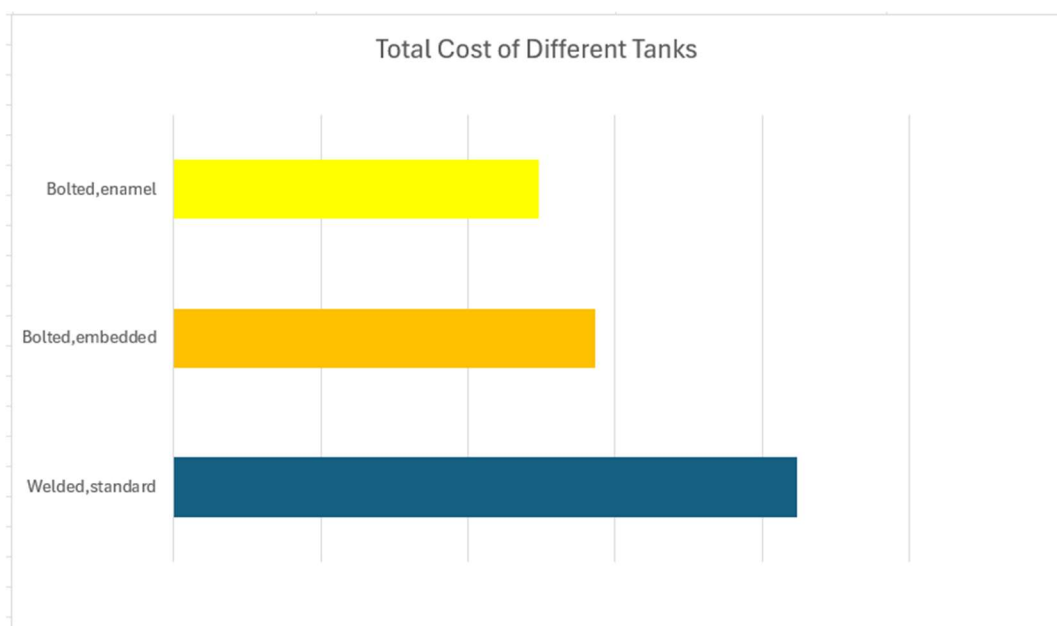


Figure 13. Total Costs of Different Tanks.

Figure 13 shows the overall costs of the different tanks. The welded tank is the most expensive tank, whereas the bolted, enamel tank has the lowest costs. The difference between welded and bolted tank costs is notable, highlighting the lower costs of bolted tanks.

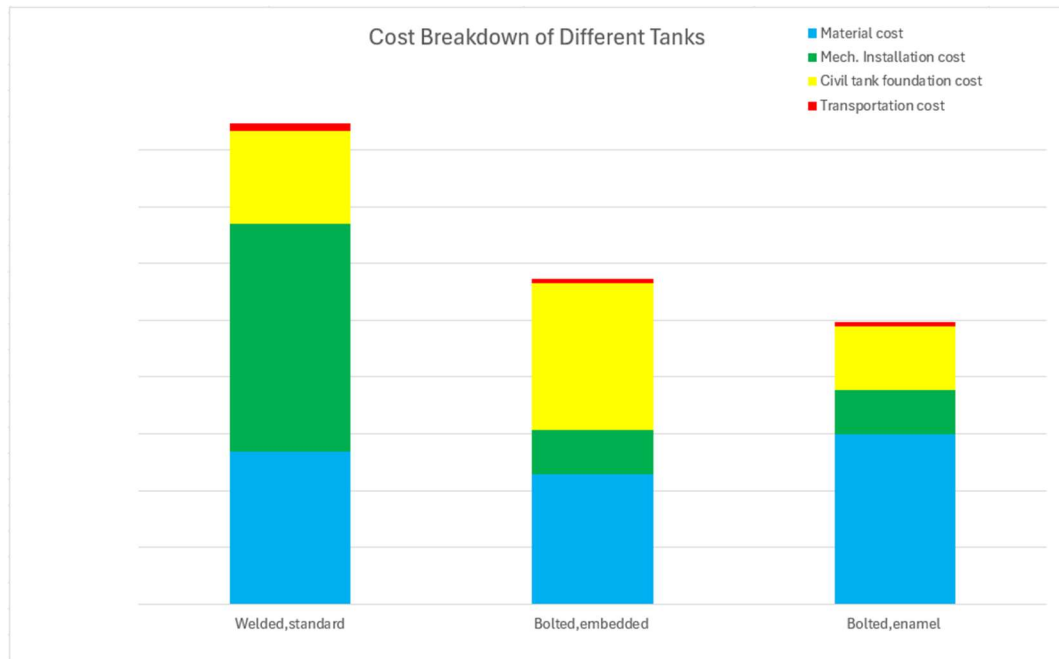


Figure 14. Cost Breakdown of Different Tanks.

By examining Figure 14 all the factors that influences the costs of the tank types can be seen. In terms of total costs, the welded tank is the most expensive while the bolted, enamel tank type has the lowest costs. The difference between the costs of the welded and bolted tanks is notable as it is clearly supported by Figure 13.

For material costs, the welded tank has the second highest costs. Among bolted tanks, the tank with embedded foundation has the lowest material costs. The bolted tank with an enamel foundation has the highest material costs.

The installation costs for the welded tank is significantly higher than for bolted tanks. Among the bolted tanks, the bolted tank with an embedded foundation has the lowest installation costs. The bolted tank with an enamel foundation type is the most expensive to install.

The civil work foundation costs for the welded tank are the second highest. The bolted tank with an embedded foundation has the highest foundation work costs overall, whereas the bolted tank with an enamel foundation has the lowest foundation work costs.

The transportation costs for the welded tank are the highest, two times higher than Bolted tanks. Both bolted tanks have the same transportation costs.

4.4 Results of the Analysis

Overall, the welded tank has a significantly higher total costs, primarily due installation costs and transportation costs. In contrast, bolted tanks have generally lower costs. However, foundation costs changes between embedded and enamel foundation types. The bolted tank with an embedded foundation is the most expensive foundation type among all types. The bolted tank with an enamel foundation has the lowest costs. Based on this analysis bolted tanks are the more cost-effective than welded tanks

It can be said that bolted tanks are more cost-effective option than welded tanks. However, there are undisclosed or unknown factors to consider. The different cost factors are seen but there are factors that are not considered for sure in the calculation of the tank costs, such as indirect costs from political factors, environmental and transparency factors or material certificates. There is not full certainty that these are considered when calculations are done. If these factors are not included, it could result in the underestimation of initial costs.

5 CONCLUSION AND DISCUSSION

Today's business environment requires companies to constantly change and adapt. The case company is also actively looking for new approaches for doing the business. The first research question is "What are the requirements for a bolted tank?" To be able to do the research, it was necessary to find out the characteristics of the bolted connections and tanks, their essential elements and relevant standards as described in Sections 2.2 and 2.3. These provided enough information about bolted tanks, their characteristics and their requirements. With those, it was possible to move towards the test case and cost analysis.

The second research question is "What is cost effective between bolted and welded tanks?" The results of the study with the given scope limits, indicates that bolted tanks are overall more cost effective than welded tanks. The detailed results of this analysis can be found in Chapter 4.

As the title of this thesis is: "Techno-Economic Evaluation of Storage Tank Options for EPC Projects in North America," it was mandatory to study how EPC projects are defined. Since the case company already possessed data about welded tanks it was decided that the focus of the theory review is towards bolted tanks and their technical data. The Cost data for the analysis was gathered from relevant project data and quotations from manufacturers. These findings were useful for the case study. The study of the EPC projects gave understanding how the matters of the project are managed. In the case study the costs are generated for an EPC project and structuring calculations accordingly. Studying the technical requirements of the bolted tanks gave understanding if the case could be possible and what kind of cost comparison specifications could be made. When the tank requirements were made, calculating the cost variations became more straightforward.

From the company's point of view, the goal of the research was to determine whether bolted tanks are more cost-effective option than welded tanks for the

projects. Based on the given scope for the research and the calculations the question was answered. Considering a larger view of the thesis, I gained insights into various subjects, including key factors affecting rough cost estimations for the tanks. Overall, everything went quite well, and activities were completed on time. The case company got valuable data for the future projects and according to this research, it would be a more cost-effective option to procure bolted tanks for the different power plant projects. These findings will be beneficial to the project team.

For the future research, it would be valuable to consider the pros and cons of the different variations of the tanks. Then it would be possible to see if that data would align with the costs. Also, expanding the comparison of the costs in different countries or states rather than just in the one selected state in the USA to show if the findings of this study are supported or not. Exploring different kind of tank types, such as cubic water tanks could also be interesting to study for further examination.

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APPENDICES

APPENDIX 1: Cost Comparison Analysis (Confidential)

