Tampere University of Applied Sciences

REQUIREMENTS FOR CONTAINERISED EQUIPMENT

A study on product design and development

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ABSTRACT

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GLENN HOLMSTRÖM:
Requirements for Containerised Equipment
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This thesis was commissioned by Wärtsilä Finland Oy as product development for containerised equipment used by Energy Business sector. There was a need to collect design requirements and investigate the possibilities of shipping containerised equipment as standard containers since it would bring additional value in procurement. The results will be used to create a technical specification and logistics instructions for suppliers who manufacture the equipment. The scope of the study focused on three different products commonly provided as containerised equipment: The water treatment unit, the fire pump station, and the auxiliary container for heat recovery systems.

The study was conducted as a literature review and collection of preferences from key persons within the organisation. First the functions of the different systems were studied to address which modifications were needed to the container. This includes connections, control of ambient conditions, safety measures, and electrification. Requirements for the container to comply with standard shipping practices were studied from international maritime legislation and standards, Finnish legislation, and the company´s internal logistic instructions.

It was found that issues are mainly related to the modifications of the container´s outer structure which may cause invalidity of the container´s certification. Depending on the system, solutions to this problem could be implementing the equipment without modifications to the outer structure of a certified container or by having the container re-certified after implementing with modifications. There were also issues with applying the internal guidelines for logistics to containerised equipment. The current way of information handling considers containers as a load space for cargo and would need adjustment to present the true characteristics of the containerised equipment.

The results suggest that containerised equipment could be shipped as standard containers if the validity of the certification is cared for, and the document handling is appropriate. Carriers may have individual opinions about the realisation and the concept should be further developed in co-operation with a carrier commonly used by the company, preferably in a pilot project.

CONTENTS

ABBREVIATIONS AND TERMS

CSC	Convention for Safe Container
IMO	International Maritime Organization
RO	Reverse osmosis
LFO	Light fuel oil
CHP	Combined heat and power
OSHA	Occupational health and safety administration
EN	European Standard
NFPA13	Standard for sprinkler systems
COC	Carrier owned container
SOC	Shippers owned container
PES	Periodic examination scheme for containers
ACEP	Approved continuous examination programme
ISPS	International Ship and Port Facility Security Code
C-TPAT	Customs-Trade Partnership Against Terrorism
BIC	Bureau of International Containers
PS	Painting system
NDTF	Total nominal dry film thickness
TRAFICOM	Finnish Transport and Communication Agency
TUKES	Finnish Safety and Chemicals Agency
Bar(g)	Gauge pressure

1 INTRODUCTION

Wärtsilä is a Finnish company that manufactures power sources and other equipment for marine and energy markets. This thesis was done in cooperation with the Energy Business section of Wärtsilä Finland Oy as a product development task for their engineering team. Engineering team is responsible of engineering everything that goes into powering the plant and maintaining its operation. This includes delivery of fuel, cooling water, lubrication oil, and instrument air for the power unit, maintenance water and fire suppression water for the plant site as well as waste heat recovery systems. To save time and secure quality, some of the process related power plant equipment provided by the company will be pre-manufactured as units. These units are manufactured in workshops by the company, or their sub-suppliers and they are shipped to the site where they are connected using as little labour as possible.

Some units are manufactured as containerised solutions meaning the process equipment is installed inside a sea container. Sea containers in their original form offer great protection to outside factors and the dimensions and structural properties are standardized and familiar to involved parties which eases transportation and installation of the process equipment. The container will not only offer a load space for transportation but also accommodate the process equipment when installed on site. Once installed, the container will become a working area and the area should fulfil all the requirements of the operation taking place inside it. This while keeping its initial properties of a seaworthy container.

Despite the existing standardised program for transportation of sea containers, modified containers have traditionally required special transport arrangements. This fact reduces the value of using a sea container as accommodation for the containerised process equipment. The aim of this study was to collect general requirements that the process equipment have on the containers in terms of ambient conditions, health and safety and investigate the issues of transporting modified containers to later suggest solutions for overcoming the need of special transport arrangements when procuring containerised process equipment.

1.1 Background

Sea containers are easy to transport worldwide thanks to standardized shipping practises. Handling of the containers is a repeated and partly automated process and it is taken care of by a carrier. For smooth handling, all sea containers need to be of unified shape and have the correct markings. The container must also be seaworthy meaning it can withstand the forces they are facing on open sea. To save space, containers are stacked on top of each other during both transport and storage and it is crucial that the container fulfils the expected structural integrity.

Containerised process equipment is normally supplied as a complete solution by the supplier of the process equipment. Supplier is also responsible of the design which is done in accordance with the company´s preferences and requirements. Supplier will procure an empty container and install the process equipment and all other applications. Installation of the containerised process equipment on site will always depend on the projects scope of supply but will normally involve the company, the client, the supplier, or a contractor to any of these. A sequence diagram of different roles in the supply chain can be seen in Figure 1.

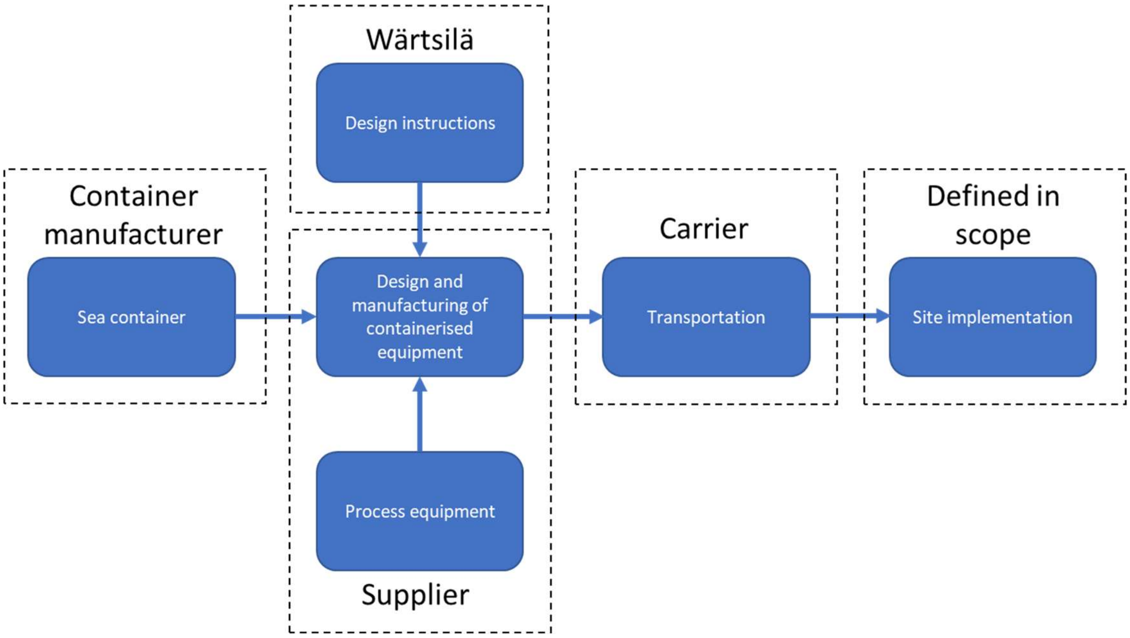

FIGURE 1. Roles of different stakeholders within the supply chain of the containerised process equipment. (Diagram: Glenn Holmström 2023)

Design requirements have normally been looked at case specifically and the ways of implementation have varied between different suppliers. As a result, modifications of the container might have led to the container losing its properties of a seaworthy container. This have caused the container to no longer comply with the requirements for handling as a standard container.

Despite attempts to preserve the initial properties of the container, common practise has been to ship the containerised equipment as break bulk cargo, rather than as a standard sea container. Modified containers haven't been shipped as standard containers due to precautions, since failure of the containers structural integrity could be devastating when handled with standard procedures. Shipping the container as a break bulk cargo instead of as a standard container normally involves latching the container individually on the flat deck of the ship without any other cargo stacked on top of it. Shipping the container as break bulk cargo is less efficient and more costly than as a standard sea container. To be able to ship the containerised equipment as standard sea containers instead of as break bulk cargo would bring economical value and provide more freedom for transportation. The possibility of applying standard container shipping for containerised equipment will be investigated in this study.

1.2 Scope

Each process system will require different modifications to the container so there was a need to study the different systems in detail. The study was limited to focus on the water treatment unit, firefighting pump station and heat recovery auxiliary system. The requirements for handling and modifications of standard sea containers will be determined according to international maritime legislation and conventions. The company is operating globally but the study will focus only on Finnish legislation on container shipping since the main part of its operation is based in Finland. The outcome of the study will be used to make a technical specification for containerised equipment for the company. The technical specification would be a specification of requirements which is aligned between engineering, supply chain management and supplier to ensure quality of the product.

Additional stakeholders such as suppliers were not involved in the study. Suppliers of the containerised who have an important role in realising the products and responsible of the final design were left out mainly to limit the number of resources but also to not favour a certain suppliers current design. Suppliers will instead be informed of findings of the study and have their opportunity to give comments on these.

2 METHODS

Data was collected using literature review as well as through interactions with several key persons within the organisation. The papers and their relevance to the study will be briefly explained in this chapter together with the process of setting up the study with the company and conducting interactions with key persons across the organization. Limitations in understanding the occupational risks of the containerised equipment were addressed and a risk assessment were conducted, the process is explained in its own sub-chapter.

2.1 Literature

Main part of the results will be based on available literature. Information about the different systems will be collected from the company´s internal documents such as process descriptions, process flow diagrams as well as the company´s internal product web pages will be used to set the requirements of the containers as accommodation for the process equipment. Descriptive documents of previous containerised solutions such as pictures and proposals will also be reviewed to gain information about previous implementations. Requirements already existing for one of the systems can in some cases be implemented as general requirements if relevant for others.

The company has its own logistics instructions for suppliers to ensure successful completion of their projects, this document was studied to get the company´s current practises and their view on transportation of containerised equipment. Container requirements will be studied from The Convention for Safe Containers (CSC) by the International Maritime Organization (IMO) that provides the core of standardization for shipping container the Hague-Visby Rules and the Hamburg Rules which are international set of rules that governs the shipment of goods by sea, and Finnish legislation including Konttilaki 762/1998 and Konttiasetus 1145/1998, and the company´s internal guidelines for logistics.

2.2 Meetings

The study will involve several stakeholders and it is a cooperation across more than one department of the organisation involving key persons from both engineering and supply chain management. Background of the study was presented to the writer during a meeting with the thesis supervisor from the company. The scope was proposed in a project charter by the writer and was later agreed upon in a kick of meeting. Thesis writer and the thesis supervisor from the company had reoccurring meetings to follow up on the process throughout the project. Several individual meetings were held with system responsible, experts and general managers to gain information and discuss the theoretical findings. Workshops including people from different departments were also held to specify matters where inputs from different directions of the company were needed. A list of the interactions is found in Appendix 1.

2.3 Risk assessment

A risk assessment was made according to ISO 12100:2010 for all the systems included in the study. ISO 12100 is a standard that aims to achieve safety in the design of machinery. A risk assessment according to ISO12100 involves identifying hazards, assessing risks, and implementing measures to eliminate or reduce risk as well as emphasizes the safety information to the user such as warnings and other clear instructions. The risk assessment covered life cycle phases: Installation, commissioning, use phase, and disposal. In this study the risk assessment was used as the main guidelines to address occupational safety risk and set requirements to increase safety of the containers.

The risk assessment was conducted using the software Safexpert (Certification experts). Process of the risk assessment begun with collection of background information related to the systems including material safety data sheets (MSDS) for all the chemicals used in the different processes. The risks were later identified and assessed using Safexpert during a workshop including the Product Safety Expert, system responsible and the thesis writer.

3 PROCESS EQUIPMENT

Process equipment provided as containerised equipment can belong to any process system of the power plant. They all serve very different purposes and operate with different mediums meaning the requirements of the container as accommodation for the equipment will be different. The study was limited to focus on the water treatment unit of the water treatment system, the fire pump station of the firefighting system and the auxiliary container of the heat recovery system. This chapter will provide an overview of each of these components, including their functions, operating principles, and operating mediums to understand the requirements they put on the container as space.

3.1 Water treatment unit

Power plants needs a continuous water supply for various operations. The quality of the supplied water must meet the quality requirements and be delivered at sufficient pressure. If the water that is available is not sufficient, a water treatment plant is implemented. The company has water treatment plants in their portfolio that are offered to the client to address the issue. All water treatment plants within the portfolio uses similar treatment technology but vary in capacity. The standard water treatment plant relies on reverse osmosis (RO) as their main treatment method with some additional treatment steps to intensify the process and extend the lifetime of the reverse osmosis membranes. (Wärtsilä Finland Oy 2021d.)

Raw water is first pumped into an external raw water storage tank located close to the water treatment plant. First step of water treatment process is raw water chlorination. Raw water is pumped from the raw water supply through the water treatment plant container where hypochlorite (NaOCl) is added to the raw water filling line before entering the raw water tank. NaOCl deactivates microorganisms in the water and prevents bacterial growth in the storage tank. (Wärtsilä Finland Oy 2021d.)

A booster pump takes the chlorinated water from the raw water tank and feed it into the water treatment unit with sufficient pressure. Following step in the treatment process is pre filtration through sand filters, sand filters remove solid particles from the water. An additional filter with activated carbon follows the prefiltration. The main task of the activated carbon filter is to remove residual active chlorine from the raw water disinfection, this since chlorine would harm the RO membranes later in the process. (Wärtsilä Finland Oy 2021d.)

Once passed through the filtration process, hardness is removed from the water. Water flows through a softening vessel and calcium and magnesium is removed through an ion exchange process. Ion exchange resin beads are regenerated with sodium chloride (NaCl). After softening, an optional chemical dosing stage can be applied If needed that adds antiscalant to the water to prevent scaling on the RO membranes. (Wärtsilä Finland Oy 2021d.)

The RO feed pump increases the water pressure and pushes the water through the RO membranes. RO membranes separate salts and impurities from the water. Water that makes it through the membrane called permeate is led into an external pure water tank. From the pure water tank, it can be distributed to consumers. The rejected water is lead to effluent drain. The RO unit needs to be frequently manually washed by circulating a cleaning solution through the system, how often depends on the total drift time of the unit (Meeting 10.3.2023) Process values and chemicals used in process are collected in Table 1. (Wärtsilä Finland Oy 2021d.)

TABLE 1. Process values of water treatment unit and chemicals used in the process and for maintenance (Wärtsilä Finland Oy 2021d).

<table>
<tr><th rowspan="2">Medium</th><th colspan="3">Process</th><th colspan="2">Ambient</th></tr>
<tr><th>Max pressure (bar (g))</th><th>Max temp. (°C)</th><th>Min temp. (°C)</th><th>Max temp. (°C)</th><th>Min temp. (°C)</th></tr>
<tr><td>Water</td><td>10</td><td>50</td><td>0</td><td>50</td><td>0</td></tr>
<tr><th colspan="6">Chemicals used in process</th></tr>
<tr><th colspan="2">Name</th><th colspan="4">Application</th></tr>
<tr><td colspan="2">NaOCl</td><td colspan="4">Disinfectant</td></tr>
<tr><td colspan="2">NaCl</td><td colspan="4">Softening</td></tr>
<tr><td colspan="2">ULTRASIL 110</td><td colspan="4">Alkaline RO cleaning agent</td></tr>
<tr><td colspan="2">ULTRACIL 75</td><td colspan="4">Acidic RO cleaning agent</td></tr>
</table>

3.2 Fire water pump

A firefighting system is in place to put out flames and to cool down adjacent structures in a fire situation. The firefighting system consists of a water distribution system connected to different extinguishing equipment. The extinguishing equipment needs to be always supplied with a constant water pressure and in case of fire, the whole system needs to be fed sufficiently with water. To ensure water availability a tank located close to the plant and dedicated only for firefighting purpose is always kept full. The fire pump station draws water from the tank and supplies the firefighting system with water. (Wärtislä Energy Business 2021c)

The fire pump station has two main pumps using different energy sources. One is an electrical pump and to ensure performance during black out the other pump is LFO driven. The fire pump station has its own external LFO tank which can be located outside or inside of the container for powering the diesel pump. Pumps are dimensioned so that each pump is alone capable of supplying the whole system with water in case one of them fails. In addition, there is a smaller so-called jockey pump. The jockey pump is always active and keeps the system pressurized when there is no fire consumption. (Wärtislä Energy Business 2021c.)

In a fire fighting situation the jockey pump will not be able to maintain the system pressurized due to the large consumption. The main pumps will then start automatically on at a time. If there is not a blackout, the electric pump will start first and only after will the LFO-driven pump start. The main pumps will not shut of automatically, but they need to be turned off manually once the firefighting situation is recognized to be over. Process values and chemicals used in process are collected in Table 2. (Wärtislä Energy Business 2021c.)

TABLE 2. Process values of fire pump station (Wärtsilä Finland Oy 2021c).

Medium	Process			Ambient	
	Max pressure (bar(g))	**Max temp. (°C)**	**Min temp. (°C)**	**Max temp. (°C)**	**Min temp. (°C)**
Water	16	40	0	40	0
LFO	-	-	-	-	-

Normally no additives are used in the process and only general cleaning agents are used for cleaning purposes. Process values for the fuel supply of the LFO-driven pump will depend on the type of engine setup used for the application. The process values of the fuel supply are also not considered to be significant in this study.

3.3 Heat recovery auxiliary container

Waste heat from the engine can be utilized as steam to produce electricity using a turbine, used in industrial processes, or used for own consumptions in the power plant. A typical steam generating system consists of at least a feed water setup including feed water tank with chemical dosing unit and feed water pumps, main boiler with a blow down tank, and a steam header for distributing the steam to consumers. An auxiliary boiler is needed as a back-up and for pre-heating of the plant. (Wärtsilä Energy Business. N.d.)

For smaller systems such as own consumption steam systems, the feed water setup and the auxiliary boiler can be prefabricated as a containerised solution. The heat recovery container would typically include a feedwater tank, chemical dosing unit, feed water unit, oil detector, auxiliary boiler, and a fuel tank for the auxiliary boiler. The feed water tank is not fitted into the container but shipped separately and mounted to the roof of the container. Feed water tank works as buffer for the boilers and for deaeration of the system. The temperature in the tank is kept at 95 °C by feeding steam back to the feed water tank through a temperature control valve. (Wärtsilä Energy Business 2021a.)

Chemicals are added to the feedwater tank to bind oxygen and increase pH of the water. Typical chemicals are mentioned in the Table 3. There are two chemical dosing units in the container. Each unit consists of a tank, a dosing pump and valves for circulation and drainage. A feed water pump unit consisting of two feed water pumps supply the boilers with water from the feed water tank. The feed water pump unit consists of two electrically driven pumps; one in operation and one in stand-by. The feed water pump unit is equipped with a minimum circulation loop, where a small amount of water is continuously led back to the feed water tank. This circulation loop guarantees a sufficient flow through the pump even if all boiler control valves are closed. Each pump can be run individually, and they can be separately isolated with valves for maintenance. Oil contaminants in the steam would harm the equipment and therefore part of the returning condensate from steam consumers passes through an oil detector which is fitted inside the container. (Wärtsilä Energy Business 2021a.)

An auxiliary boiler is needed for pre-heating the plant at cold start-up. An oil-fired burner operates during pre-heating and as back up for the main boiler. The oil-fired boiler operates with fuel oil and has its own day tank located outside the container. The oil-fired boiler receives water from the same feed water pump as the main boiler. Flue gas from the boiler is led out to the atmosphere through its own stack, mounted to the side of the container. The boiler is protected from over pressure by two safety valves which opens if pressure exceeds the allowed limit of 10 bar(g). The boiler is also protected from under pressure by a non-return valve, which opens in case the pressure falls below atmospheric pressure. Process values and chemicals used in process are collected in Table 3. (Wärtsilä Energy Business 2021a.)

TABLE 3. Process values auxiliary boiler and chemicals used in the process (Wärtsilä Energy Business 2023b).

Medium	Process			Ambient	
	Max pressure (bar(g))	Max temp. (°C)	Min temp. (°C)	Max temp. (°C)	Min temp. (°C)
Water	10	184	0	50	0
Fuel oil	-	-	-	-	-
Chemicals used in process					
Name		Application			
Ammonia		pH Control			
Carbohydrazide		Oxygen scavengers			
Trisodium phosphite		Hardness Control			

Process values of the fuel supply of the oil powered boiler will depend on the boiler type. The process values of the fuel supply are not considered to be significant in this study.

4 CONTAINER EQUIPMENT

The process equipment installed in the containers will put certain requirements on the container as accommodation. Requirements will mainly be related to ambient conditions, operation of the system, execution of maintenance, and health and safety of the workers. These requirements and the need for additional container equipment and possible modifications of the container related to each system were collected using existing documentation such as system describing documents, quality assurance guidelines, risk assessments and preferences from system responsible. The need for applications and their modifications to the container will be very specific for each module and project specific. This chapter will however briefly cover the most general applications and their modifications that can be expected for the containers.

4.1 Access

The initial doors of a CSC container are not sufficient as an entrance once accommodating the process equipment. The original doors are bulky, and they can only be latched from the outside. Access to the containers must be arranged with standard doors with industrialized finish, preferably made from steel. The doors shall have push bar handles to enable easy exit of the containers in emergency (Wärtsilä Energy Business 2023c, Wärtsilä Energy Business 2022a). The fire pump station requires similar emergency exits on both ends of the container (Wärtsilä Energy Business 2022a). There are generally no requirements on locking mechanisms of the entrance doors since they are located inside the plant area and access should normally be allowed by all employees. The containers are not expected to have any windows.

4.2 Climate

The outdoor conditions that the containerised solutions will phase at the power plant site can vary from very warm to sub- zero conditions. The process equipment that is installed has requirements on ambient temperature that are likely to be exceeded in normal outdoor conditions (Chapter 3.). Inside temperature of the container will have to be controlled by either heating, by cooling or in some cases using both methods depending on the season.

4.2.1 Temperature control

Heating devices must be installed whenever the containers are experiencing sub-zero ambient conditions and are considered a standard procedure. The water treatment unit are sensitive to higher temperatures and will need to also have a cooling device to ensure the right inside temperature (Chapter 3.1).

Insulation should be applied in almost all cases. Insulation of the container helps to maintain temperature inside the container and makes control measures more effective. Insulation also protects from disturbing sound if such are occurring from inside the container. The amount of insulation needed will depend on the outdoor ambient conditions and the heat loss of the equipment. Due to the small size and the characteristics of the container, they are generally not classified as a building. This means that a certain level of insulation will not be covered by legislation such as the Energy performance of building directive 2010/31/EU by the European Union (2010/31/EU). Too little insulation will however result in large energy consumption by the temperature controlling devices and too much will occupy additional space.

Insulation should be made with fireproof material. A proven concept is using 100mm steel-wool-steel sandwich panels made with mineral wool. Other insulation material such as polyurethane could be considered if supplier finds it more convenient. Insulation material should however have similar fire resistance to those of mineral wool. In cases where temperature is controlled only by cooling, floor will not necessarily need to be insulated. (Meeting 23.3.2023.)

4.2.2 Ventilation

To ensure a convenient working environment, containers need to be ventilated. Different ventilation requirements will apply for different applications. In first-hand the requirements on air quality of the installed equipment needs to be considered since this might be related to the warranty of the equipment. Requirements can be related to humidity, particle content, or air flow and the solutions might be very product specific. For example, the diesel pump of the fire pump station will need a large ventilation opening to allow for cooling the engine (Wärtsilä Energy Business 2022a). In many cases harmful fumes are generated by chemicals used in the processes and active ventilation are required by occupational health reasons (Wärtsilä Energy Business 2023c). Since temperature control measures are applied, ventilation capacity should not be excessive to minimise energy consumption and possible energy saving measures could be applied if possible (Meeting 22.3.2023).

4.3 Surfaces

Inside container walls and roof shall have an even surface finish with bright colour. Initial corrugated steel can be kept as outside wall. Floors shall at least be coated with anti-slip material to prevent slipping (Wärtsilä Energy Business 2023c). In the case of fire pump station, aluminium tread plate is required as floor surface to ensure good grip and durability (Wärtsilä Energy Business 2022a). Container shall be equipped with floor drains for water resulting from leakage and maintenance operations to escape. The floor drains shall be separated from process drain (Wärtsilä Energy Business 2022a).

All metal surfaces must receive anti-corrosive treatment according to ISO 12944 standard. The colours will be system specific and can be project specific. The containerised equipment is classified with corrosivity category C3, which according to ISO 12944 is used for industrial areas and coastal areas with moderate salinity (ISO 12944:2018). Following painting systems (PS) should be used for containerised equipment in C3 environment with high durability expectation:

- Unit frame, wall elements external surfaces PS-3A
- Unit roof element external surfaces PS-4A
- Internal surfaces, equipment, and units PS-1A

Painting systems are explained in Table 4. In case supplier prefers to use other ISO 12944 compliant painting system, that shall be separately agreed on with the company. (Wärtsilä Energy business 2021b).

TABLE 4. Explanation of painting systems for C3 corrosive category. EP = Epoxy, PUR=Polyurethane, Zn(R)=Zinc rich primer, NDFT=Total nominal dry film thickness (Wärtsilä Energy business 2021b).

Painting system	Corrosivity category C3 High durability expectations			
	Primer	Final inc. intermediate	Number of layers	Total NDFT
PS-1A	EP (indoor)	EP	1-2	20 µm
PS-3A	EPZn(R)	PUR	2-3	200 µm
PS-4A	EPZn(R)	PUR	3-4	240 µm

4.4 Electricity

Containers will need an electrical connection to power the process equipment, for lighting, and for performing different tasks inside the container. Lighting illumination level should exceed the Occupational health and safety administration (OSHA) and European Standard (EN) requirement for average industrial work area, expected value between 300 to 500 lux. Electrical sockets shall be installed in all the compartments of the container. All electrical equipment needs to be water and dust protected, typically IP54 or higher (SFS-EN 60529) to suit the environment they are installed in. The electrical cabinet powering lighting and sockets shall be separate from the cabinet powering the process related equipment. Both direct cable connection as well as plug connection can be considered for the containers. (Wärtsilä Energy Business 2022a.)

4.5 Fire protection

Requirements of fire classification is normally decided in local legislation and the containerised equipment needs to comply with the active legislation of the destination country and it needs to be considered project specific. The containerised equipment will however normally avoid any requirements of passive fire protection classification due to several reasons: The container is not big enough to be considered a building, no people are working inside container, container is detached from other building and separated with large enough distance for fire not to spread (Meeting 20.3.2023). As earlier mentioned, Wärtsilä will however not allow fibre glass for wall insulation but the walls must contain mineral wool or other fireproof insulation (Meeting 23.3.2023).

When it comes to active fire protection, the company will have their own requirements on the containers. All containers shall have point smoke detectors causing a common fire alarm when activated (Wärtsilä Energy Business 2023a). Additional requirements are existing for the fire pump station for which wet pipe sprinkler protection according to NFPA13 standard is required.

5 CSC-CONTAINERS

Sea containers are available in many different types for different applications including flat racks, open-top, dry-freight, insulated, refrigerating containers, and tank containers. In addition, each type can have different properties such as being ventilated, insulated, different opening arrangements etc. ISO 668:2020 standard defines the required dimensions of each container type and must be followed by container manufacturers. The size and type of the container must be defined, and it should receive a classification code according to ISO 6346:2022 standards. The classification code is included in the container's identification number so that the properties of the container can be easily identified. (ISO 6346:2022.)

Every container must have its identification number registered to the global container prefix registry which is managed by the Bureau of International Containers (BIC). In addition to the classification code, the identification number includes an owner code so that the container and the owner of it can be identified at any time, serial number, check digit, and equipment category. The identification number must be visible on the container and for example in in the case of a dry-freight container, the owner code should be marked to the container door if the door is located at the end of the container.

Normally a general-purpose dry-freight container of 20' (6,1 m) or 40' (12,2 m) length would be used for the purpose of accommodating the process equipment. General-purpose container is a fully sealed container with openings in one or both ends intended for transporting dry cargo such as pallets and boxes. (ISO 6346:2022.)

Transportation of the containerised equipment from manufacturing facility to site usually involves transportation with truck and with ship. Majority of the transportation done with containers are happening in carrier owned containers (COC), meaning that the carrier owns the container and offer the container space for costumers to ship their goods in. It is also possible to own your own container and have it shipped by carriers for you, it is then referred to as shipping with shippers owned container (SOC). (S, Callarman 2020.) The case of transporting containerised equipment for the company, will be considered as SOC.

5.1 CSC-certification

Sea containers used for international shipping must be manufactured according to Convention for Safe Containers (CSC) which is a standard governed by the International Maritime Organization (IMO). Containers needs to be certified and equipped with an approved CSC-plate before being shipped as a standard sea container. A container that is manufactured in accordance with the convention and have been successfully certified is referred to as a CSC-container. The CSC certification program is implemented to guarantee safe handling of the containers for all involved parties. The CSC plate must show following information:

"CSC SAFETY APPROVAL"
Country of approval and approval reference
Date (month and year) of manufacture
Manufacturer's identification number of the container
Maximum operating gross mass (kg and lbs)
Allowable stacking load for 1.8g (kg and lbs)
Transverse racking test force (newtons)"
(CSC 1972.)

Part of the information visible on the CSC-plate is also displayed on the container door with large visible font as operational markings to make handling of the container easier, see Figure 2. This includes the information of Gross weight, tare weight, net weight, and the total volume of the cargo space (ISO 6346:2022). The responsibility of maintaining the containers in safe condition is at the owner of the container. To keep the certification valid the owner needs to be under a periodic examination scheme (PES) or under an approved continuous examination programme (ACEP) where the containers are inspected of weather the container still is in such shape that it complies with what is stated on its CSC-plate. (CSC 1972.)

Containers are usually equipped with a valid CSC-certification when purchased by the contractor before modification. If doing modifications to the container that could compromise the structure, the CSC-plate will become obsolete, and the container can no longer be treated as a standard shipping container. Also, any modifications extruding past the exterior walls or blocking the lifting attachments would make the container impossible to handle equal to other containers during transportation. All modifications might however not affect the structural strength and modifications in the important structure can be compensated by additional support to ensure the same structural strength as before modification. (CSC 1972.)

The CSC standard states that structurally sensitive components are: Top rail, Bottom rail, header, sill, corner posts, corner- and intermediate fittings, under structure, and locking rods. Sensitive components described in Figure 2. Serious structural deficiency is listed in the convention, and it is stated that the deficiency should only be used for immediately determining a container unusable and considered as a safety standard and not to be used as repair and in-service criteria. (CSC 1972.)

FIGURE 2. Picture of modified container with descriptions of sensitive structure. Container in picture have no relation to the company and was never intended for transportation as standard container (Picture: Glenn Holmström 2023, edited).

The convention of safe containers states that it is at the owner's responsibility to ensure that any modifications to an approved container does not adversely affect the information stated on the CSC-plate. Modifications resulting in structural changes shall be notified to the Administration or an approved organization. The administration or the authorised organisation may determine whether the results of the original tests conducted for the initial approval remain valid for the modified container. The original structural safety requirements and tests relates to lifting from corner fittings, lifting by any other additional method, stacking, concentrated loads, transverse racking, static longitudinal restraint, end-walls, and side walls. (CSC 1972.)

When applying for re-approval of a modified container, the applicant might be required to certify that, to the best of their knowledge, any modifications made to the container do not affect safety or relevance of the container. If due to the modifications, the results of the original structural tests can no longer be considered valid, the container will need to undergo new structural tests. Testing methods are specified in ISO 1496 standard, and they include at least stacking test, floor load test, water tightness test, corner-post test, and twist lock test (ISO 1496-1:2013). The tests can only be conducted by an approved instance. (CSC 1972.)

5.2 Finnish container legislation

Depending on country, administration of the CSC may be arranged a bit differently. In Finland there is legislation in place that supports the International Convention of Safe Container. The legislation applies to container owners who is registered or has the main part of its operations in Finland. The use of containers is supervised by Customs, Border control, police, occupational health authorities as well as the Finnish Transport and Communication Agency (TRAFICOM), all in their respective area of authority. The organisations authorised for inspection of containers are approved and supervised by the Finnish Safety and Chemicals Agency (TUKES). (Konttilaki 762/1998.)

About approval of modified containers, it is stated that if owner modifies the container from its initial design, changes should be informed to the inspection body. The inspection body can then re-approve the container. Depending on the modifications, the inspection body might require the container to undergo tests to prove its structural integrity. Containers already approved in other member state of the Convention of Safe containers does not need new approval in Finland. (Konttiasetus 1145/1998)

5.3 Carrier

Carriers have a range of responsibilities when it comes to the goods they transport. The responsibilities are significant and can have important legal and financial implications. These responsibilities are typically governed by international conventions and national laws such as the Hague-Visby Rules or the Hamburg Rules. One of the main responsibilities of the carrier is ensure the goods are loaded, carried, and delivered safely and without damage. They are also responsible for preventing loss or damage of the goods during transport and they may take necessary measures to prevent such. Maritime carriers are also responsible for providing accurate documentation related to the goods, such as bills of lading and other shipping documents. They must ensure that these documents are properly completed and that they accurately reflect the nature and condition of the goods being transported. Carriers are also responsible for damage caused by their operation, including damage caused from goods they transport such as spills and pollution. (Hague-Visby Rules 1968; Hamburg Rules 1978)

It is in other words important for the carrier to know the exact content and the characteristics of the content. First, for safety reasons the carrier must be informed of any hazardous or in other ways harmful material that can potentially cause harm to any surrounding elements. The carrier is also responsible for complying with various regulations and laws related to goods such as custom regulations, trade sanctions, and environmental laws. It is also important when it comes to liability, in the case of damage or loss of goods the value of compensation needs be specified according to what have been informed by the shipper. Carrier might also want to know the content to increase its efficiency and be able to offer a better service by providing special handling of some container or prioritize containers containing perishable goods. (Hague-Visby Rules 1968; Hamburg Rules 1978)

6 RESULTS

From the gathered material we can find that fitting equipment to a container can cause certain issues with the validity of the CSC-certification. CSC-certification is directly related to the possibility of standard transportation arrangements and to safe handling of the container when moving the container during manufacturing and installation. Having a valid CSC-certification on the containerised equipment will ease the arrangement of lifting instructions and guarantee its seaworthiness with regards to being watertight. Depending on the description of container content, the characteristics of the containerised equipment as a product might also cause some initial issues when it comes to liability during shipping. This chapter will explain the issues found related to transportation more in detail and possible implementations that could work as a solution to the issues.

6.1 Issues

The containerised equipment will need to have several pipe connections to allow connection to the systems in which they are working, the connections will require penetration of the outer structure (Chapter 3.). Penetrations in outer structure will also be required for doors to access the container, ventilation arrangements, electrical cables etc. (Chapter 4.). The CSC states that modified containers needs to have their certification reconsidered if tests conducted for the initial approval no longer are sufficient, it will need to undergo the same tests again (Chapter 5.1.2). Same is stated in Finnish legislation (Chapter 5.2). Penetrations would most naturally be placed on the long side of the container through the corrugated steel wall. The container wall is not mentioned as serious structural sensitive components in the CSC (Chapter 5.1). The corrugated steel wall will however naturally contribute to the structural integrity of the container and there are no certainties that it was not playing a part in the initial structural tests. In other words, containers that have had any modification would need to renew its certification, and most likely containers with their outer structure penetrated would need to be undergo structural tests. For example, original CSC-certification of the container visible in Figure 2 would no longer be valid after the modifications of the walls and it would need to be re-certified if certification ever were to be relevant for its operation.

The company have implemented seal policy that complies with requirements set up by the International Ship and Port Facility Security Code (ISPS) and the Customs-Trade Partnership Against Terrorism (C-TPAT) program. This involves that all containers must have a high-security bolt seal always affixed to it during transport to restrict unauthorised access. (Wärtsilä Energy Business 2022b). If the container doors, or the door locking mechanisms are removed or modified, protection of unauthorized access can no longer be implemented in a standardised manner. Painting of the container might cover important markings related to CSC-certification and identification of the container. Issues might also occur if leaving marking that have lost its relevance after the modification (Chapter 5.1). For example, identification number for container in Figure 1 (G1) suggest that container is a “General purpose container without ventilation”, when in reality it is both insulated and ventilated which would result in a different classification. The containers and their content will face very heavy loads during loading and seafaring. Both the company internal logistics instructions as well as the international conventions such as the Hamburg Rules underlines the importance of proper strapping of goods transported inside containers (Wärtsilä Energy Business 2022b; Hamburg Rules 1978). This of course also applies to mounting of the equipment inside the container. Normal installation for process and other equipment might not be sufficient in containerised equipment. On the same time, installation of the equipment must not compromise the structural integrity of the container.

The importance to inform carriers about the container content in detail is mentioned in chapter 5.3 and also in the company´s internal logistic instruction. To comply with these requirements, the company have careful procedures how the material that is sent with container shall be listed and marked before shipment so that carriers and possibly other parties can evaluate and identify each item. There are also separate instructions for pre-made modular solutions which shall have all their components labelled and manufacturing drawings available. The internal logistics instructions do not however take containers into account as individual products nor as transport packaging, but containers are only considered as a load space used for transporting cargo. (Wärtsilä Energy Business 2022b.)

Technically if following existing procedures, all the material installed to the container including doors, temperature control devices and even insulation needs to be marked and included in the packing list. This might be an inefficient way of handling the issue. Leaving out any details about characteristics of the container or its content might raise suspicion among the carrier and make them take extra unnecessary measures. To be able to ship the containerised solutions in standardized manner, the container must also be registered by the company to BIC and equipped with an identification number which includes the owner code. Who is set as owner of the container is unclear. The registration to BIC could however be cancelled after its one and only voyage since after installation the container is no longer owned by the same company, and it will most likely not do another voyage.

6.2 Implementations

The largest issue with modifying the containers comes down to the validity of the container CSC-certification after the modification. As mentioned in chapter 5.1.1 and 5.2, there are procedures established to perform re-certifications of modified containers. The price of going through such a procedure seems to vary significantly depending on location. According to partners of the company, in Finland for example there are no structural testing equipment for containers available and the price is too high to make it beneficial since it must be done abroad (General Manager, Logistics 4.4.2023). If the supplier however can arrange re-certification at a reasonable cost this is an option for dealing with the issue of CSC-certification. It is also not clearly mentioned if tests can be done to one individual container and later have containers with same modifications re-approved based on the same tests.

In some cases, the implementation of the applications could be done without modifications to the outer structure of the container. The container door opening provides an approximately 5,6 m^2 opening when wide open or removed (ISO 668:2020/Amd 1:2022). The initial doors of the container are not to be used as entrance once the container is installed to its final location. It is possible to install an additional wall behind the initial doors of the container which can then host location for the entrance door and pipe connections. Openings for ventilation could also be placed in the additional wall or the existing ventilation openings of a ventilated container could be used. The initial doors would then be removed completely once installed to its final location (Figure 3). CSC-containers are available in many different configurations and a container with openings in both ends or an open side container could be chosen if all penetrations cannot be fitted to one end of the container.

FIGURE 3. Illustration of modified sea container where access door, pipe connections, and AC unit is fitted in additional wall behind original doors. Published with permission from initial author (3D model: Jakob Adora 2019, derivative work Glenn Holmström 2023)

Another option is to have CSC-certified containers custom made with openings for the wall penetrations. Manufacturing of CSC-certified containers is possible by various workshops and to order custom made containers from larger manufacturers is possible, even in smaller quantities. According to a partner of the company, this is the more viable option compared to having a modified container re-certified in most cases (General Manager, Logistics 4.4.2023).
Ideally the custom-made container would be insulated and have all the necessary penetrations for piping, ventilation, and access. It would also be classified with suitable type coding when leaving the factory.

Regarding the benefits that was addressed by the company before the study plus the additional benefits addressed in this study it would be relevant to ad valid CSC-certification as a requirement or as a recommendation for containerised equipment. Design process of the products should prioritise the CSC-certification and only as a last option, the containerised equipment would be manufactured without valid CSC-certification. If it is decided to manufacture the containerised equipment without valid CSC-certification, CSC-plate and any other original markings should be removed from the container to not show misleading information. If the CSC-certification for the container is valid, but the characteristics of the container have changed, the container should be registered with identification number that represents the current characteristics of the container and the markings should be changed accordingly.

Whether the aim is to keep the CSC-certification valid or not, the correct information needs to be exchanged so that each party can complete their tasks successfully. This includes correct instructions from the company to the supplier about how to prioritise CSC-certification of the containerised equipment. The supplier shall inform in offer stage if they are able to deliver the containerised solution with CSC-certification or not and how it is implemented. The company should also provide the correct logistics instructions, so that the supplier in turn can provide the carrier with correct information. Design process where CSC-certification is prioritised, and typical information flow is shown in Figure 4.

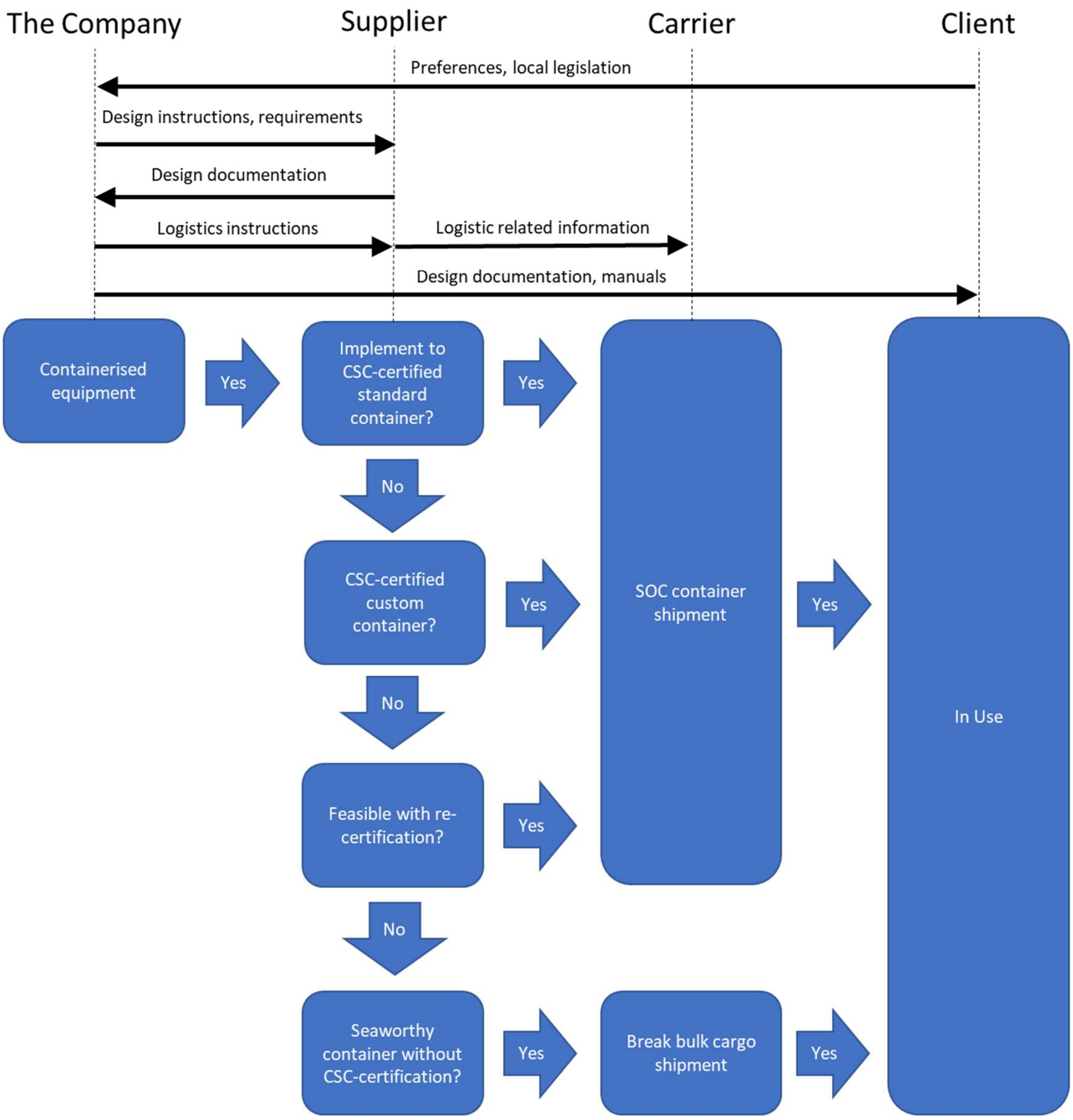

FIGURE 4. Sequence diagram of design and communication process where CSC-certification is prioritised. Design process shown in blue, information flow shown in Black (Sequence diagram: Glenn Holmström 2023).

7 DISCUSSION

This study gave knowledge to the process of developing a concept for procurement of containerised equipment where the containers can be shipped in a standardized matter. Largest findings were related to the CSC-certification of the containers and importance of transportation documentation. According to the study there are no obvious reasons why the containerised equipment could not be shipped as standard container if validity of the container certification is considered in the design and the transportation related paperwork is handled properly.

A tricky part of developing this concept is that the last saying of how the container should be treated during sea transport is at the carrier and even at the captain of the ship. This since they in the end have full responsibility and governance of the cargo during the voyage. This means that even if the design is based on paragraphs such as the maritime legislation and standards, the carrier can deny accepting the container if they see there is a reason for preventing damage. To have a fully assured concept, it could be developed in co-operation with and include agreements with carriers repeatedly used by the company.

The study was done to create guidelines for designing the containerised equipment and design is normally done by the supplier, this means that there was little documentation of a product to refer to when investigating logistic arrangements. Next step in refining the concept could be a real case study involving an actual product which are sold to a customer, the drawings of the containerised solution could then be discussed with logistics department and partners of the company already in design stage and the project could proceed with manufacturing and shipping the container. This is a process that involves resources from many different stakeholders, and it could be easier to get commitment from involved parties if it was a real case bringing immediate value to all the parties.

The idea of generalised requirements for the containerised solutions were challenging due to different characteristics of the systems. Requirements of equipment might also depend on the climate and local legislation of the destination country, and this might have to be considered case specifically. Advantages of shipping the containerised equipment as standard container was mentioned in the study and briefly studied. Any advantages except for being safer option was not investigated for shipping the containers as break bulk cargo. Naturally the containerised equipment could benefit from receiving special treatment during transportation. This includes less cosmetic damage to the containers during transportation which can be quite sever and not acceptable for containers that will work as a building for tens of years.

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APPENDICES

Appendix 1. List of meetings

Date	**Matter**	**Designation of participant**
12.1.2023	Presentation of thesis background	Manager, Technical Expertise, Mech & process, Thesis supervisor
30.1.2023	Kick off meeting (TAMK)	Senior lecturer, thesis supervisor
3.2.2023	Kick off meeting	Manager, Technical Expertise, Mech & process, Thesis supervisor
21.2.2023	Safety aspects of containerized equipment	Product Safety Expert Process Engineering And Safety
24.2.2023	Follow up meeting	Manager, Technical Expertise, Mech & process, Thesis supervisor
27.2.2023	EN12100 background	Product Safety Expert Process Engineering And Safety
3.3.2023	Follow up meeting	Manager, Technical Expertise, Mech & process, Thesis supervisor
8.3.2023	Follow up meeting (TAMK)	Senior lecturer, thesis supervisor
9.3.2023	Containers from supply chain management point of view	General Manager, Supply Planning & Development
10.3.2023	Water treatment container	Senior Expert, Water Treatment Balance Of Plant
15.3.2023	Logistic arrangements	General Manager, Logistics
16.3.2023	Risk assessment	Product Safety Expert; Senior Expert, Water Treatment
17.3.2023	Follow up meeting	Manager, Technical Expertise, Mech & process, Thesis supervisor
20.3.2023	Fire protection requirements	Senior Expert, Fire Protection Balance Of Plant
22.3.2023	Inside air requirements	Senior Expert, Process Balance Of Plant
23.3.2023	Insulation requirements	Senior Development Manager, Civil Engineering
23.3.2023	Follow up meeting	Manager, Technical Expertise, Mech & process, Thesis supervisor
31.3.2023	Follow up meeting	Manager, Technical Expertise, Mech & process, Thesis supervisor
14.4.2023	Follow up meeting	Manager, Technical Expertise, Mech & process, Thesis supervisor
21.4.2023	Follow up meeting	Manager, Technical Expertise, Mech & process, Thesis supervisor

28.4.2023	Follow up meeting	Manager, Technical Expertise, Mech & process, Thesis supervisor
2.5.2023	Follow up meeting (TAMK)	Senior lecturer, thesis supervisor