VAASAN AMMATTIKORKEAKOULU
UNIVERSITY OF APPLIED SCIENCES

Samuel Uusitalo

PLANNING THE W20 TEST ENGINE CHANGE IN VEL

Wärtsilä Finland Oy

School of Technology
2019

VAASAN AMMATTIKORKEAKOULU
Konetekniikka

TIIVISTELMÄ

Tekijä	Samuel Uusitalo
Opinnäytetyön nimi	W20-moottorivaihdon suunnittelu Vaskiluodon moottorilaboratorioon
Vuosi	2019
Kieli	Englanti
Sivumäärä	48
Ohjaaja	Marko Rantasalo

Opinnäytetyö tehtiin Wärtsilä Vaskiluodon moottorilaboratorioon W20 Testing & Validation -osastolle. Tarkoituksena oli suunnitella uuden testimoottorin vaihto testiselliin ja selvittää kaikki tarvittavat resurssit vaihtotyöhön liittyen.

Työssä vertailtiin komponenttivaihtoehtoja ja valittiin niistä parhaimmat mahdolliset reunaehdot huomioiden. Moottorin vaihtotyö sisältää vanhan W9L20-moottorin poistamisen testisellistä ja uuden W8L20-moottorin asennuksen testiselliin. Projektin aikataulutus ja budjetissa pysyminen olivat keskeisiä tekijöitä opinnäytetyön tavoitteessa.

Projektista saatiin arvokasta tietoa moottorivaihtojen vaatimuksista, joita tullaan tulevaisuudessa tekemään Wärtsilän R&D-osastoilla. Moottorin vaihtoon liittyy paljon eri tekijöitä, jotka ovat huomioitava suunnitteluprosessissa. Tämän seurauksena generaattoripaketin lopullinen kokoonpano ei aina ole vastaava kuin ennalta arvioitu.

Avainsanat Moottorin vaihto, testiselli ja Wärtsilä

VAASAN AMMATTIKORKEAKOULU
UNIVERSITY OF APPLIED SCIENCES
Konetekniikka

ABSTRACT

Author	Samuel Uusitalo
Title	Planning the W20 Test Engine Change in Vaskiluoto Engine Laboratory
Year	2019
Language	English
Pages	48
Name of Supervisor	Marko Rantasalo

The thesis was done for Wärtsilä's Testing & Validation department in the Vaskiluoto Engine Laboratory. The main purpose was to plan the test engine change and find out all the necessary resources for generating set replacement.

The thesis included a component comparison and validation for the best possible components, taking into account boundary conditions. The engine change will include the planning for the old W9L20-engine removal from the test cell and the new W8L20-engine installation to the test cell. The main targets for the project was to stay in schedule and within the budget.

This project gave important knowledge about the requirements of an engine change for Wärtsilä R&D projects in future. There are many different variables involved in the engine replacement, which must be considered in the planning process. As a conclusion, the final configuration of the generating set is not always the same as planned.

Keywords Engine change, test cell and Wärtsilä

CONTENTS

LIST OF FIGURES AND TABLES

ABBREVIATIONS

CBF	Common base frame
DF	Dual Fuel (engine)
HFO	Heavy Fuel Oil
HV	High Voltage
Hz	Hertz, derived unit of frequency in the International System of Units (SI)
IMO	International Maritime Organization
ISO	International Organization for Standardization
kV	Kilovolt
kW	Kilowatt
kWe	Electrical output in kilowatts
kWm	Mechanical output in kilowatts
LFO	Light Fuel Oil
LV	Low Voltage
MDO	Marine Diesel Oil
MV	Medium Voltage
NOR	Nitrogen Oxide Reducer
NOx	Nitrogen Oxides

PF	Power Factor
R&D	Research and Development
rpm	Revolution per minute
SCR	Selective Catalytic Reduction
SFOC	Specific Fuel Oil Consumption
SI	International System of Units
SOx	Sulfur Oxides
VEL	Vaskiluoto Engine Laboratory
VIC	Variable Inlet Valve Closing System
W20	Wärtsilä 20 engine
D	Diesel

1 BACKGROUND AND INTRODUCTION

The starting point of the project was to get test results from a recently introduced W8L20E -engine, which is important from the point view of the final product and customers. Therefore, the W20 -engine management team had created a request for engine change project.

The testing of the old W9L20 -engine was almost finalized in the Vaskiluoto Engine Laboratory and planning for a new W8L20E –generating set was started four months earlier. The work began by finding out the main components for the genset and by specifying the requirements for common base frame (CBF) assembly.

After many discussions and meetings between different Wärtsilä's departments and employees, the final components were chosen and ordered for the W8L20 -genset.

Knowledge for the project has been gathered from Wärtsilä's employees, internet, Wärtsilä intranet, literature and courses taken during studies.

The thesis includes the theory behind the genset main components and it should help to understand the final component selections. Also, this should help decision making in other engine change projects.

2 WÄRTSILÄ COMPANY

Wärtsilä is a global leader in energy and marine solutions. In 2018, Wärtsilä's net sales totalled EUR 5.2 billion and it had approximately 19,000 employees. /1/

Wärtsilä has business in over 80 countries around the world and in total offices more than 200. The most of Wärtsilä's personnel working in Europe (Figure 1). /1/

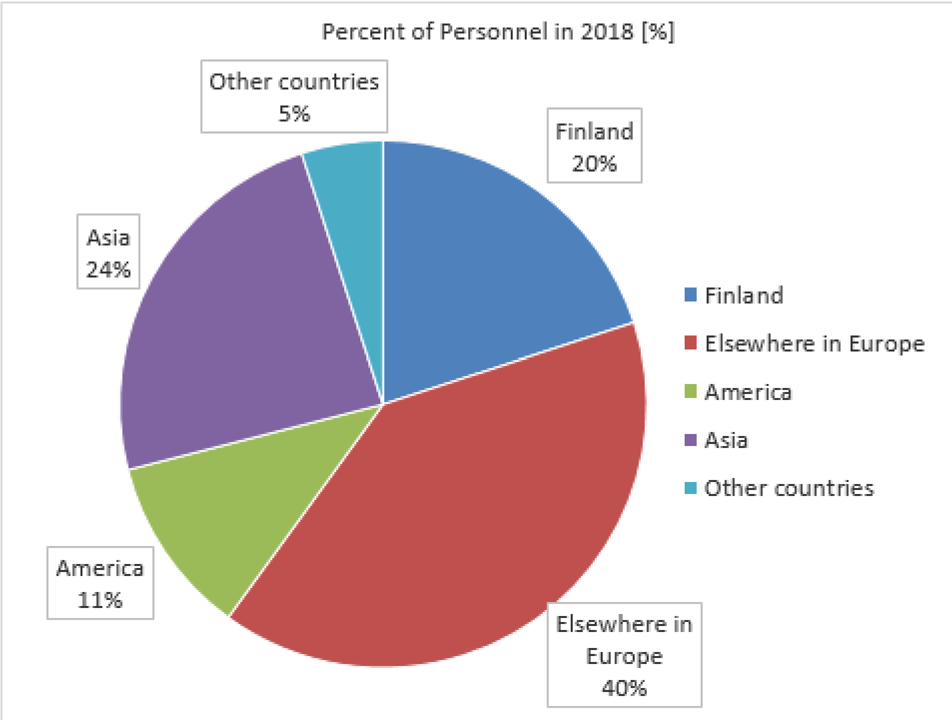


Figure 1. Pie chart of Wärtsilä's Personnel.

In 2018, Wärtsilä's operating result was 577 million euros, order intake was 6,307 million euros and order book in 31 Dec 2017 6,166 million euros. Wärtsilä is listed on Nasdaq Helsinki. /1/

Wärtsilä had three business segments; Marine Solutions, Energy Solutions and Services. From the beginning of the year 2019, Service operations were integrated into Energy and Marine Business.

2.1 Wärtsilä History

Wärtsilä was founded in 1834, when the construction of sawmill was approved in Tohmajärvi, in the province of Karelia. An important event for Wärtsilä's current business was an engine licence agreement with Friedrich Krupp Germania Werft AG in Germany in 1938. The first diesel engine was manufactured in Turku in November 1942. /2/

Wärtsilä has had many corporate acquisitions in their long history. Wärtsilä has had business in shipbuilding industry, paper machine industry, lock industry and ceramics industry. Nowadays Wärtsilä has focused more on innovative maritime and energy industry solutions.

2.2 Wärtsilä in Future

Wärtsilä is strongly developing smart technologies. The best indication of that is the announcement of the construction of a brand new Smart Technology Hub in Vaskiluoto, Vaasa. By end of the year 2021, nearly all Wärtsilä's functions in Vaasa city and Runsor will transfer to the new hub. Part of Wärtsilä's functions in Runsor will still stay there. /3/

The new hub is not only a factory, the vision is to create a partners' campus between Wärtsilä's customers, suppliers, start-ups in the sector and universities. Overall the building of hub will cost 200 million euros and 83 million of that will be invested by Wärtsila in modern testing and production technology. /3/

2.3 Wärtsilä R&D

Wärtsilä has R&D activities in Vaasa city, Vaasa Vaskiluoto VEL and Bermeo in Spain. The main target of R&D is to strengthen the company's technology leadership position.

“The focus of Wärtsilä’s R&D activities is on digitalisation, smart technologies, new products, and solutions that are flexible, efficient, reliable, safe, cost-efficient to operate, and that have a minimal environmental footprint throughout their lifecycles.”. /4/

The tasks of the product development are securing environmental adaptability, enabling short- and long-term benefits for their customer’s. /4/

An important element of validation testing is field test experience in real conditions. The R&D assists a lot in solving problems from customer installations, together with technical services and other parties. That provides opportunity to find new solutions and learn about new technologies. At the same time, validation tests in Wärtsilä laboratories enable the best component specification for the final product. /4/

After the validation process, both in field and laboratory, and if the performance of the product meets Wärtsilä’s high standards, the product is ready to be delivered to the market. /4/

3 WÄRTSILÄ 20 ENGINE

The Wärtsilä 20 engine was introduced to the market in 1992. Until this day, more than 6000 engines have been delivered to the customers (Figure 2). /5/

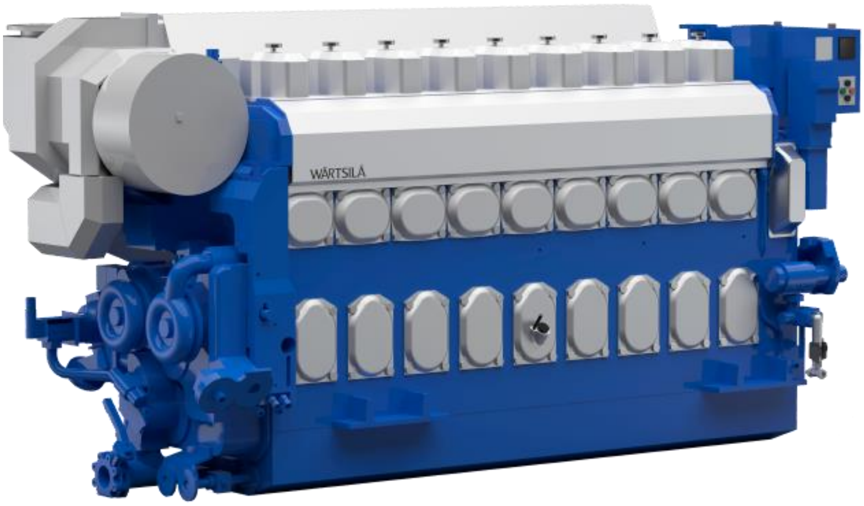


Figure 2. The Wärtsilä 20 -engine. /6/

As the model name W20 suggests, the engine has a 20 centimetre piston diameter and four different cylinder configurations are available for the auxiliary and main engine markets in the marine sector. The W20 engine can be used as a mechanical drive prime mover for smaller ships or generating set drive in both small and large vessels. In mechanical drive applications the engine runs at variable speed. Whereas generating sets which runs usually at constant speed.

Typical installation applications are cargo ferries, fishing vessels, dredgers, tug boats and small tankers. Available cylinder configurations are 4, 6, 8 and 9 (Table 1). /5-7/

Table 1. The W20 engine power range. Note that there is no 4L20 model of the 1200rpm version. /7/

Wärtsilä W20 power range (kW)			
Configuration/ rpm	900 rpm	1000 rpm	1200 rpm
4L20	740 kW	800 kW	N/A
6L20	1110 kW	1200 kW	1320 kW
8L20	1480 kW	1600 kW	1760 kW
9L20	1665 kW	1800 kW	1980 kW

Cylinder arrangement is always inline on the W20 engine (Figure 3).

Figure 3. Principle picture of the inline engine. /8/

In December 2017, Wärtsilä introduced an upgraded version of the W20 engine. The running speed was raised from 1000rpm to 1200rpm and the output power range increased from 200kW to 220kW per cylinder. This means that 50Hz frequency changed to 60Hz and fewer cylinders will be needed. Therefore, upgraded version enables greater payloads for vessels or achieve faster speeds. The fuel consumption will be at almost the same level than the previous 200kW version (Table 2). /5/

Table 2. The main technical data of the Wärtsilä 20. /7/

Wärtsilä 20	
Cylinder bore	200 mm
Piston stroke	280 mm
Cylinder output	185/200/220 kW/cyl
Speed	900/1000/1200 rpm
Mean effective pressure	28/27.3/25 bar
Piston speed	8.4/9.3/11.2 m/s
Fuel Specification	Fuel Oil
Viscosity at 50°C	700 cSt
Viscosity at 100°C	7200 sR1
Fuel consumption at ISO cond.	SFOC 190,0 g/kWh

A typical customer installation can save in both of capital and operational expenditures, because thanks to the increased output, the number of required cylinders reduces.

The W20 engine has two different fuel variations, one for pure diesel fuel and second one for Dual Fuel (DF). This means that the customer can run the diesel version engine with Light Fuel Oil (LFO), Marine Diesel Oil (MDO) or Heavy Fuel Oil (HFO). The Dual Fuel engine can be run with gas and diesel fuel.

The W20 engine meets the IMO Tier II exhaust emissions regulations. Also, the engine can be equipped with a SCR catalyst or Wärtsilä NOR. Then NOx emissions can be reduced up to 95%, which means the engine can be compliant with the strictest emission limit, IMO Tier III. /7/

The W20 engine has low lifecycle costs thanks to the engine's maintenance friendly design. This enables a long recondition interval which is up to 24,000 running hours. At low engine loads, the standard VIC system provides low fuel consumption and therefore lower emissions. /7/

4 GENERATING SET AND AUXILIARY SYSTEM

The generating set (genset for short) is a product assembly which can generate electricity by using fuel. The genset can be installed to the ship or power plant. The Wärtsilä gensets consist of four-stroke medium speed engine, flywheel, coupling and generator. The components are mounted to the common base frame (Figure 4). /9-10/

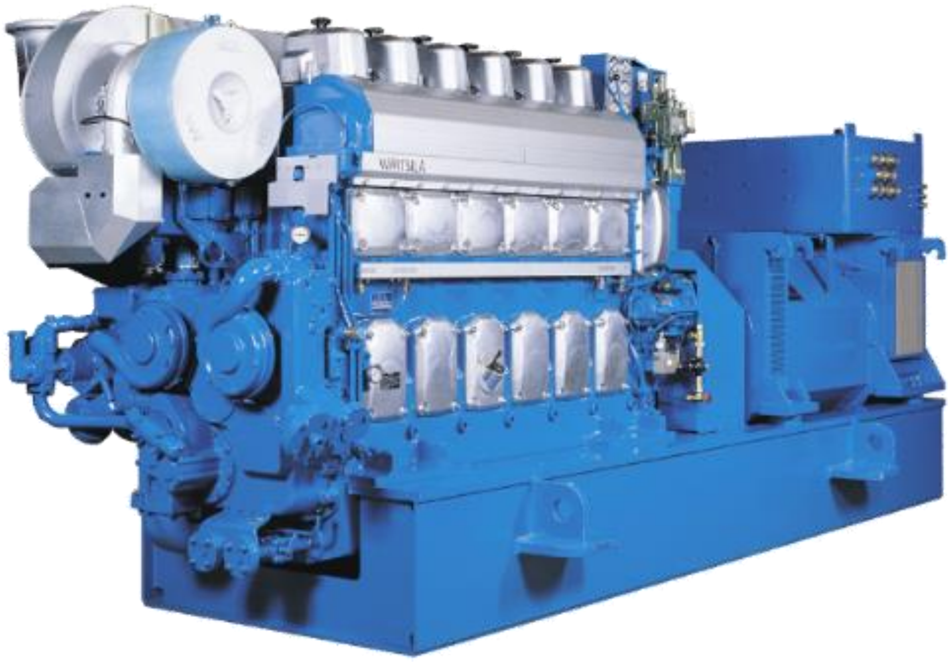


Figure 4. The Wärtsilä 20 -genset. /9/

To operation, the genset needs an auxiliary system which typically consist of cooling system unit, fuel equipment system unit and starting air system unit. The auxiliary system is always dependent on the type of application. The most of the equipment are delivered as separate units or grouped in modules. Some equipment, such as oil pumps, coolers and filters can be assembled straight on the engine (Figure 5). /11/

Figure 5. The auxiliary system module. /11/

5 ALTERNATING CURRENT GENERATOR

The generator (also called alternator) provides electrical output by using mechanical power. Electrical output has usually a fixed voltage and frequency. The main material of the generator is copper wire which is built into metal frame. This part of the generator is usually static mounted and is also called a stator and the second part of generator called rotor, is driven by the prime mover. /12/

The generator operates with the same principle as electromagnetic induction. A simplified AC generator has a wire loop, which is rotated in the magnetic field. As the loop rotates, the magnetic flux is constantly changing and the voltage is generated in the loop. The ends of the loop are fixed to slip rings and connected to an external circuit with brushes (Figure 6). /13/

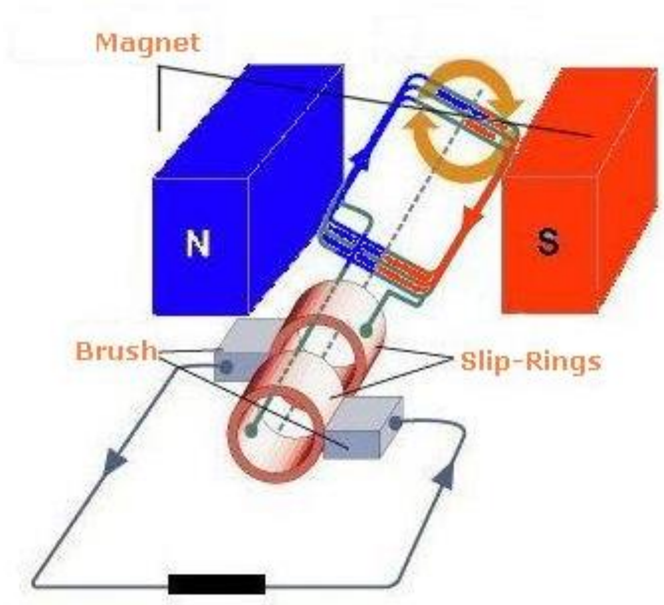


Figure 6. Principle of simplified generator. /14/

5.1 Consept for AC Generators

The following sections define the most important concepts for AC generators. The terminology is valid for range of from 600 to 12 000 kVA generators.

5.1.1 Voltage Levels for AvK Generators

Note that voltage levels may vary between generator manufacturers. The following voltage levels are defined by Cummins Generator Technologies.

The voltage levels are classified as low, medium and high. The low voltage generator provides voltage below 1000V. The medium level is between 1000 - 6000V and the high voltage over 6000V. /15/

5.1.2 Power Factor

The power factor is a measure of wasted current which occurs in inductive load systems, such as generators, transformers and some forms of lightning. With inductive loads the power factor is typically 0,6-0,9. When the genset is driven with fully resistive load to load bank, the power factor is 1,0. /16/

The formula for calculating the power factor:

$$PF = \cos\theta = \frac{P}{|S|} = \frac{kW}{kVA}, \text{ where} \quad PF = \text{Power Factor} \qquad (1)$$

P= real power, [*kW]*

S= apparent power, *[kVA]*

Q= reactive power, [kVAr]

The power factor is the same as the ratio of real power (kW) and apparent power (kVA) (Figure 7). /17/

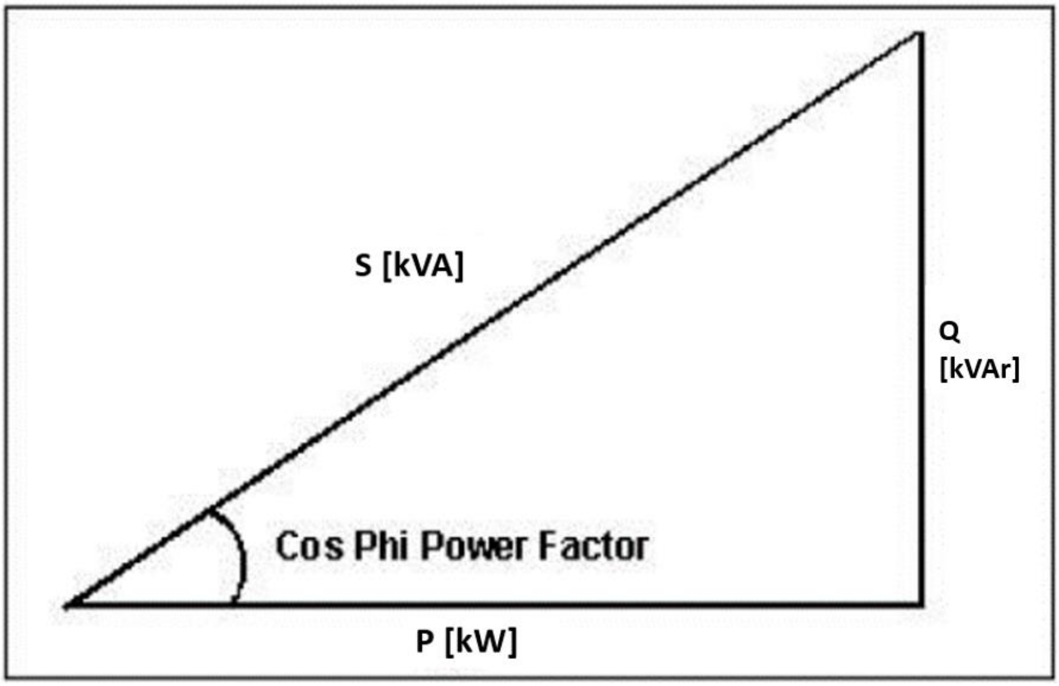


Figure 7. Power triangle. /18/

5.1.3 Frequency

Frequency is the number of occurrences of a recurring event per unit of time. Typical applications of frequency are cyclical processes, such as vibration measurements in the engines and sinusoidal waves in electrical engineering (Figure 8). The unit of frequency is Hertz (Hz) in the SI. /17/

$$f = \frac{1}{s}, \text{ where } \quad f = \text{frequency} \quad (2)$$

s = second.

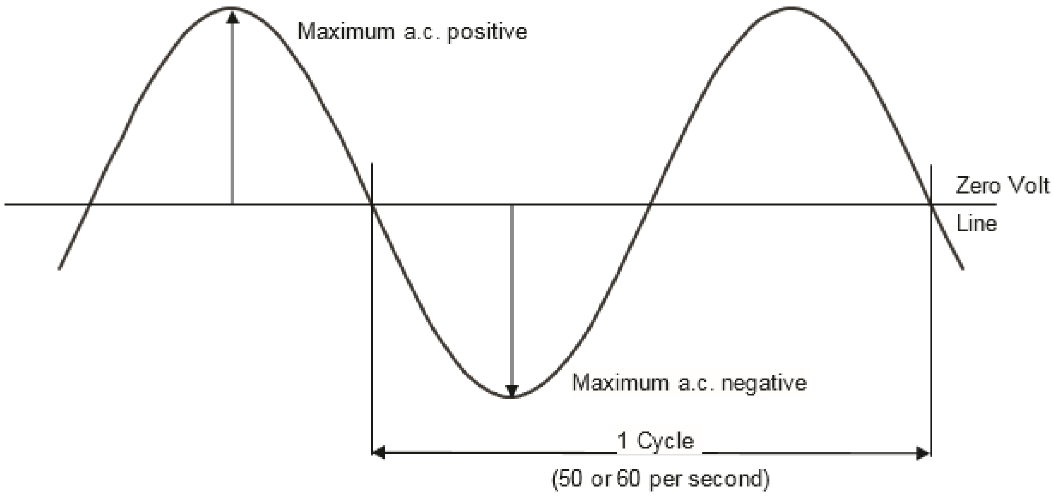


Figure 8. The A.C (one phase) supply is shown as sine wave. /17/

5.1.4 Frequency Determination of the AC Generator

The frequency is dependent on rotor speed and number of poles in AC generator. The number of poles are 2, 4 or 6. Those numbers are only technically realizable. /18/

$$f_g = \frac{N\ x\ P}{120}, \text{ where} \qquad f_g = \text{frequency (Hz)} \qquad (3)$$

N = rotor speed (rpm)

P = number of poles in rotor

5.1.5 kVA

The kVA (kilovolt-amperes) is the power in kW, when the theoretical efficiency is 100%. In electrical systems the efficiency is never 100% (see 6.2 efficiency). Therefore, the kVA is called apparent power. /17/

The formula of kVA in *one* phase systems is calculated as follows:

$$kVA = \frac{V\ x\ A}{1000}, \text{ where} \qquad V = \text{Volt} \qquad (4)$$

A = Amperes

The formula of kVA in *three* phase systems is calculated as follows:

$$kVA = \frac{\sqrt{3}(V\ x\ A)}{1000}, \text{ where } V = \text{Volt} \qquad (5)$$

A = Amperes

5.1.6 kWe

kWe is electrical output in kilowatts.

The formula of kWe in *one* phase systems is calculated as follows:

$$kWe = \frac{V\ x\ A\ x\ PF}{1000}, \text{ where V = Volt} \quad (6)$$

A = Amperes

PF = Power Factor

The formula of kWe in *three* phase systems is calculated as follows:

$$kWe = \frac{V\ x\ A\ x\ PF\ x\ \sqrt{3}}{1000}, \text{ where V = Volt} \quad (7)$$

A = Amperes

PF = Power Factor

5.1.7 kWm

kWm is mechanical output in kilowatts.

The formula of kWm is calculated as follows:

$$kWm = \frac{kVA\ x\ PF}{\eta}, \text{ where kVA = Kilovolt-amperes} \quad (8)$$

PF = Power Factor

η = Generator efficiency

5.1.8 Inertia

Inertia is the resistance which affects the velocity of any physical object. The object velocity change can be the motion of direction, speed or acceleration.

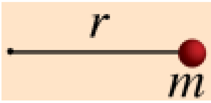
5.1.9 Moment of Inertia

Moment of inertia is defined with respect to a specific rotation axis. The unit of moment of inertia is kilogram per square meter (kgm^2) in SI. A point mass unit is kilogram (kg) and radius unit is meter (m).

The moment of inertia for point mass is calculated with the following formula. /18/

$I = mr^2$, where I = Moment of inertia (9)

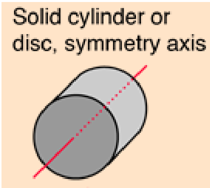
m = A point mass



r = Radius between a point mass and rotation axel.

The moment of inertia for central axis is calculated as follows: /18/

$I = \frac{1}{2}mr^2$, where I = Moment of inertia (10)



m = A cylinder mass

r = A cylinder radius

M = a point mass

5.1.10 Current Ampere

The ampere in generator systems can be determined in the following ways:

The formula of ampere in *one* phase systems is calculated as:

$A = \frac{kVA \; x \; 1000}{V}$, where kVA = kilovolt-amperes (11)

V = volts

The formula of ampere in *three* phase systems is calculated as:

$A = \frac{kVA \; x \; 1000}{V \; x \; \sqrt{3}}$, where kVA = kilovolt-amperes (12)

V = volts

5.2 Generator Efficiency

Generally, the efficiency describes the ratio of produced energy to used energy. The efficiency is expressed as a percentage.

There are several causes of power loss in machines that also affect the efficiency. Typical losses for generators are:

- typical losses for materials, (copper and iron)
- stray loss
- excitation loss
- windage and friction loss. /18/

The formula of efficiency is calculated as follows:

$$\eta = \frac{P_2}{P_1} \text{ , where } \quad P_1 = \text{Useful power output [W]} \quad (13)$$

P_2 = Total power input [W]

5.3 Comparison between Generators

The main requirements for generator selection were compatibility with Wärtsilä 8L20 -engine power class, 11 kV output voltage and 60 Hz output frequency. Switchgears, cables, transformers and load banks are built for the above-mentioned electrical system. The option was to choose the current electrical system, or the second option was to build a new electrical system for low voltage generator.

Typically, the highest load in laboratory tests is 110%. The calculated crankshaft maximum output for the W8L20 engine is:

$$1{,}1 * 220kW * 8 = 1936kW$$

At the laboratory conditions, the power factor is usually 1,0. For example the theoretical kVA -class for AVK DIG k/6 generator is calculated as:

$$1{,}0 * \sqrt{3} * 11\ 000V * 101A = 1924{,}3kVA$$

The generator alternatives were ABB AMG 0560BM06, AVK DIG 130 i/6, AVK DIG 130 L/6 and current AVK DIG 130 k/6 models. The quotations were taken for three first models. KVA -class was from 1924kVA to 2200kVA.

The turning point in the generator choice was the price of a new electrical system. The total costs for the new electrical system would have been up to 30% of the project budget. Therefore, it was sensible to choose a generator for the current electrical system.

From the point of view of the laboratory test results, it would be better if the moment of inertia was as small as possible. Therefore, a smaller generator rotor is not capable to smooth out mechanical motion as well as bigger ones, due to its smaller moment of inertia.

When comparing the generator choices, there were differences in total weight, kWe, kWm and moment of inertia. The correlation found with i/6 and k/6 models in kVA class (1924kVA) and current A class (101A) (Table 3).

The final choice was made between the current AVK DIG 130 k/6 and DIG 130 i/6 generators. Eventually the current DIG 130 k/6 generator was selected for cost and delivery time reasons. The DIG 130 i/6 generator was left as an option for the future. The main drawback of DIG 130 k/6 was a slightly larger moment of inertia.

Table 3. Generator alternatives with technical main data.

Model	kVA	kWe	kWm	Weight [kg]	Moment of inertia [kgm²]	Rated current
ABB AMG 0560BM06 DAP 11kV/60Hz	2108	1686	1760	8500	161	110,6A
AVK DIG 130 i/6 11kV/60Hz	1924	1539	1612	6900	126	101A
AVK DIG 130 L/6 11kV/60Hz	2200	1760	1843	8200	158	115,5A
AVK DIG 130 k/6 11kV/60Hz	1924	1539	1608	7500	144	101A

6 COUPLING AND DAMPER

The main function of coupling is to connect two shafts together without disconnecting during the operation. The coupling transmits the mechanical power to another axis and absorbs misalignments between the prime mover and the secondary axis (Figure 9).

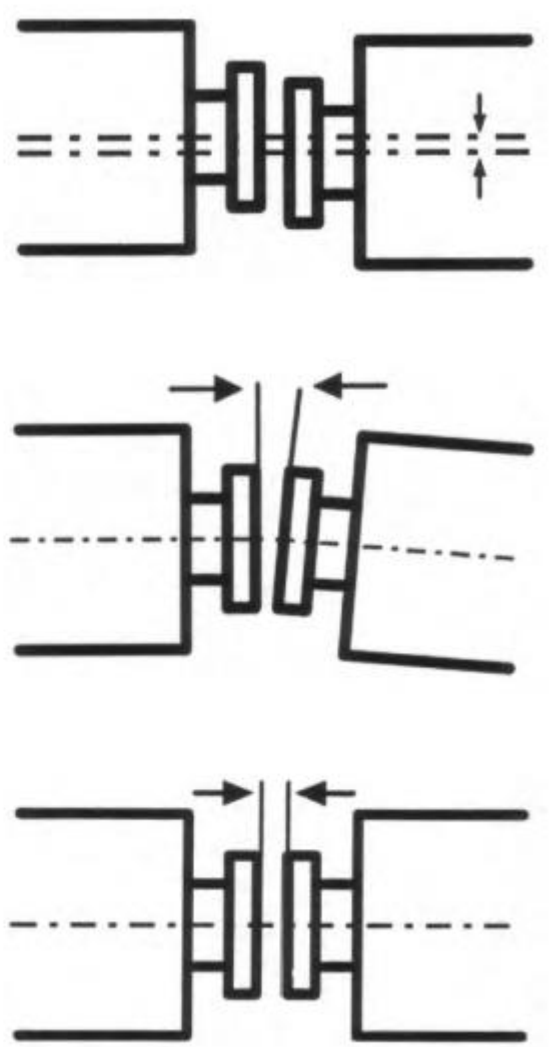


Figure 9. Types of misalignments. From top to down: Radial offset, angular offset and axial offset. /19/

6.1 Flexible Coupling

The flexible coupling consists of flanges, vibration damper and fixing equipment. The main target of flexible coupling is to mount the slightly misaligned shaft to another shaft. The flexible coupling with damper absorbs torsional vibration which is directly proportional to the lifetime of moving parts in the system. /20/

Torsional vibration is the consequence of axis imbalance which is emphasized in large rotational forces. This is noticeable noise and variation deviations in the speed in both ends of shaft. Torsional vibration is an oscillation of angular motions which occur along rotating parts (Figure 10). /21/

Figure 10. Principle of twisting. /21/

6.2 Shore Hardness

The flexible coupling includes the damper, which is made of rubber. The shore hardness class has been defined for the different types of rubber. The shore hardness is named by an inventor, Albert Shore. There are up to 12 different scales for measuring the hardness of material, but the best-known scales are Shore A and Shore D. Shore A hardness scale is used for soft elastomers such as flexible mould rubbers and shore D for hard plastics, hard rubbers, semi-rigid plastics, other hard elastomers and polymer materials (Figure 11).

Figure 11. Shore hardness chart. /22/

The shore hardness is measured by a durometer instrument. "Durometer utilizes an indenter loaded by a calibrated spring. The measured hardness is determined by the penetration depth of the indenter under the load". /23/

Measuring depth results may vary from 0 to 2,5mm and correspondingly shore hardness varies from 0 to 100. The result value 2,5mm corresponds to the shore number 0 and the measurement result 0mm corresponds to the shore number 100 (Figure 12). /23/

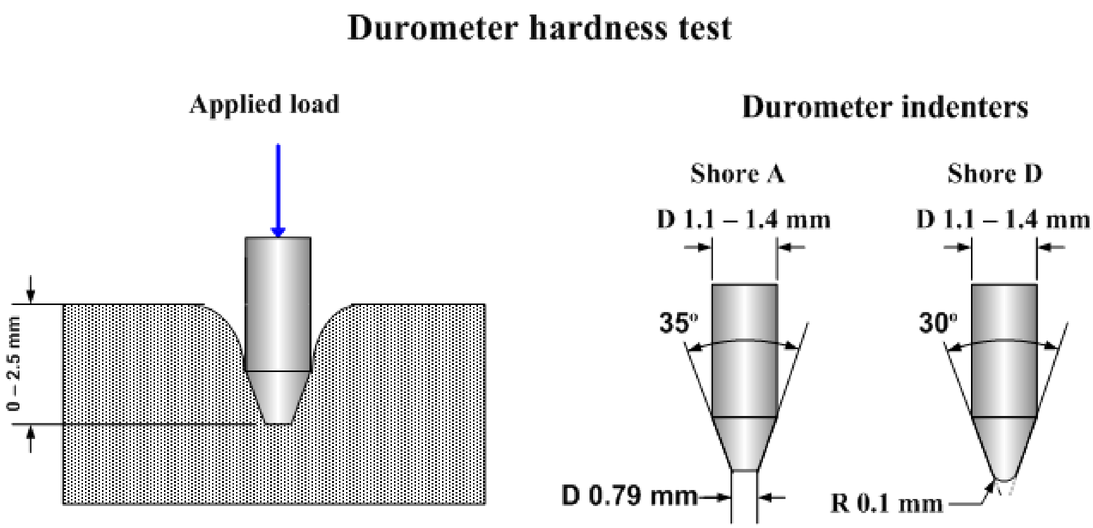


Figure 12. Durometer hardness measuring. /23/

6.3 Calculations for Flexible Coupling

The calculations were made by Wärtsilä's Vibration Engineer department, which is specialized for vibration calculations and vibration reduction components.

The following values were used in the calculations. The typical running range at the laboratory:

- Constant speed 1200 rpm / 220kW per cylinder
- Constant speed 1000 rpm / 200kW per cylinder
- Variable speed 400-1320 rpm
- Loads 0-110 %
- Speeds 0-110 % /24/

When the calculation results were completed, some restrictions were found. These speed ranges are not recommended in the case of misfiring (Table 4.). Also, the crankshaft stress might be over 40MPa at 110% loading point with normal firing. Those values exceed only slightly the recommended limits. This will not have too much impact on this test engine. /25/

Table 4. Restrictions for the laboratory W8L20 – engine.

Restrictions				
Gen: DIG 130-k/6		Coupling: Centa CX 75-60		
nominal speed	load	rpm (min)	rpm (max)	restriction
200kw/cyl	100%	600	850	misfiring
1000 rpm	110%	600	850	misfiring
220kW/cyl	100%	630	760	misfiring
1200 rpm	110%	630	760	misfiring
Crankshaft stress >40MPa				
220kW/cyl	110%	1310	1320	normal firing
1200 rpm	110%	1300	1320	misfiring

6.4 Torsional Vibration Damper

The torsional vibration damper eliminates most of the critical resonance and noise, which is typical in all kind of reciprocating systems. The damper protects cam- or crankshaft from possible damages. There are several types of dampers available for marine and energy solution engines. The most common dampers are viscous or steel spring damper.

In large diesel and gas applications, the damper is mounted to the free end of the crankshaft (Figure 13). The damper is also fixable to the camshaft end if necessary.

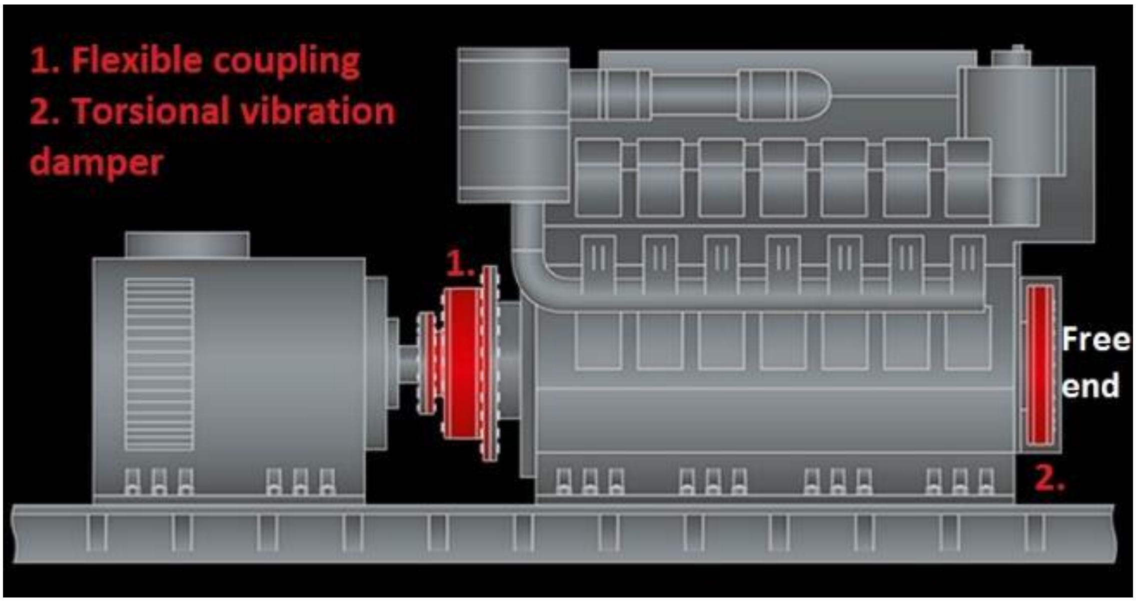


Figure 13. Flexible coupling and torsional vibration damper. /26/

6.5 Geislinger Steel Spring Type Damper

The Geislinger type damper consists of two sections; a primary section and a secondary section. Between the sections, there are groups of steel leaf spring packs. These spring packs, together with intermediate pieces and the secondary section, create chambers which are filled with pressurized engine oil. /26/

The damper is tuned to optimize natural frequency by specified steel leaf springs and the engine oil reduce the torsional vibrations. The number and shape of steel leaf springs define the damper's elasticity. /26/

As the damper rotates and the exterior section vibrates in relation to the inner one, leaf springs (B) and (C) bend and forces oil from one chamber (A) and (D) to the next (Figure 14). This reduces the proportional motion of the two parts and thus dampens the residual torsional vibrations. /26-27/

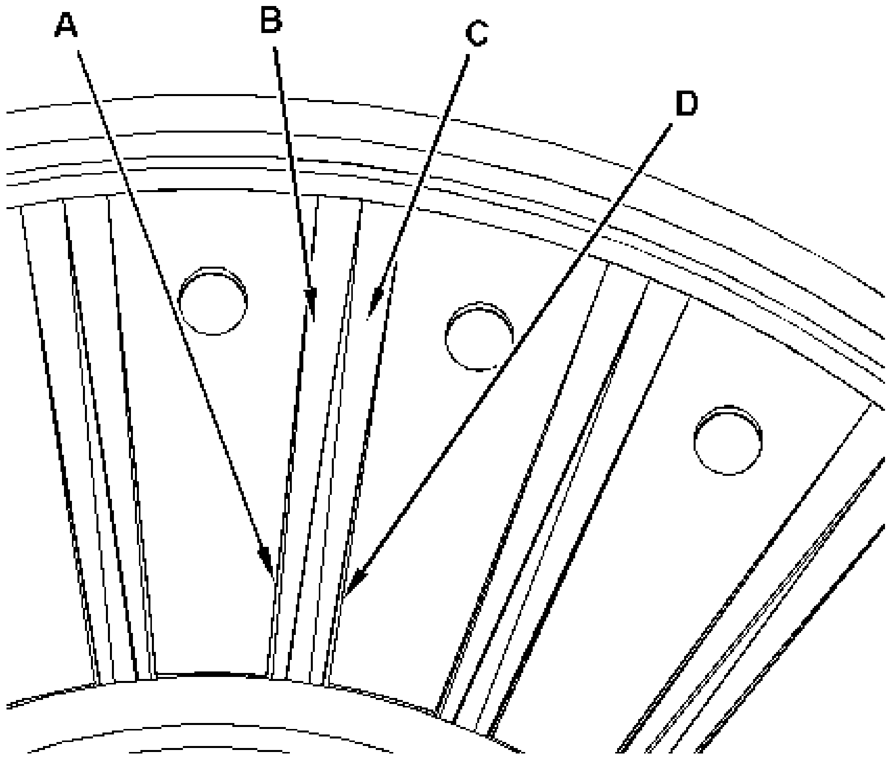


Figure 14. Steel spring type damper. A) & D) Oil Chambers B) & C) Leaf springs. /27/

The steel leaf spring type damper was pre-installed at DCV to the new W8L20 engine. Therefore, the current damper was selected to the final assembly. The current leaf spring type damper was taken into consideration in all vibration calculations. The trade name of the installed damper is Geislinger D63/69 (See Figure 15).

Figure 15. The Geislinger damper. /26/

7 COMMON BASE FRAME

The common base frame (CBF) is a welded steel frame on which the engine and generator are mounted. The CBF is mounted to the spring packs on the bottom of the vessel or power plant floor. At the laboratory conditions the CBF is also fixed to the spring packs on the test cell floor. The common base frame is optimized for the selected engine and generator, usually CBFs are designed to be modular which decreases production and designing costs (Figure 16).

Figure 16. The common base frame.

7.1 CBF Designing Process

The new design for W8L20 was made by Wärtsilä’s Mechanical Engineering Design Department. The starting point of the new CBF design was the old W9L20 base frame design. The old design required some modifications to be compatible with the laser welded deep oil sump, the new coupling and the shorter W8L20 engine. Therefore, the new CBF is 122mm higher and 660mm shorter than old W9L20 CBF (Figure 17).

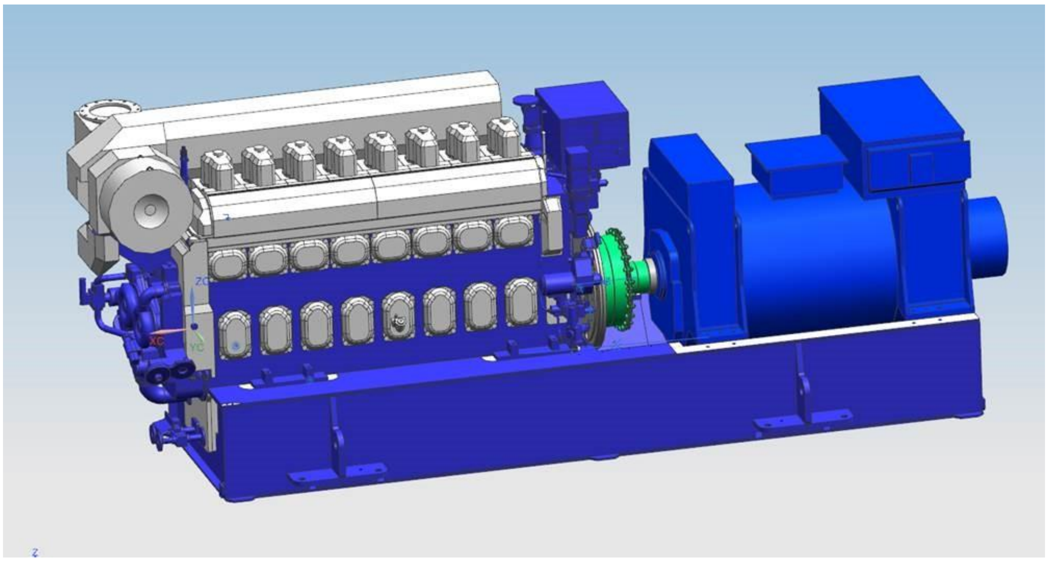


Figure 17. 3D- model of the W8L20 genset. /28/

The old support for piping was removed from the W9L20 CBF’s free-end (Figure 18). The pipe support is implemented with separate components.

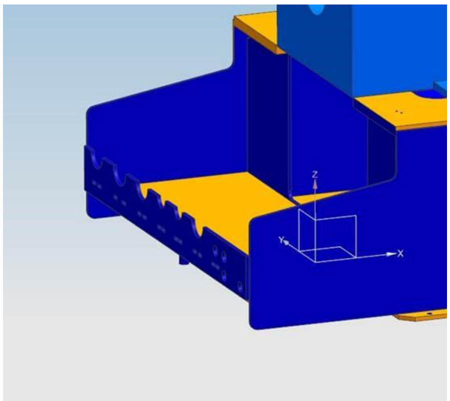


Figure 18. The removed pipe support. /28/

The CBF was designed according to Wärtsilä's design guide for common base frames. Allowed distances between components, welding instructions, thicknesses of materials and type of materials have all been defined in the guide.

7.2 Spring Packs

The main purpose of spring packs is to attenuate the generating sets vibrations which could move the genset in an undesirable way. Less vibrations will also travel to the rest of the building or vessel. One spring pack can be loaded with 3500- 7000 kilograms (Figure 19).

The total mass of generating set defines the number and type of spring packs to be used. In this case the total mass of the generating set is 22804 kg. According to the resilient mounting calculation with 4 spring packs there is a rolling frequency at ~540rpm. With six spring packs the rolling frequency would be at ~660rpm. /23/

In laboratory variable speed tests, a smaller rolling frequency is favourable, because the lowest running speed for this engine is 400rpm. Therefore, four spring packs were chosen for cost reason, which means 5701kg load per spring pack.

However, the speed around 540rpm should be avoided, but the real results are obtained in a test run.

Figure 19. The spring pack.

8 ENGINE SITUATION IN TEST CELL

There were not any significant differences between the old and the new common base frame dimensions. The main dimensions of the new CBF design are smaller than the old ones and from this perspective there are no major limitations on the location of the engine in the test cell.

The greatest impact on the location of the engine is the medium voltage cables of the generator. The extension of the medium voltage cables is not recommended. Therefore, the new generator should be positioned so that the generator connection remains as close as possible to the old position. In any case, the genset situation will change, also due to a different height of the CBF. The engine pipe and PLC connections are modified according to the new location of the engine (Figure 20).

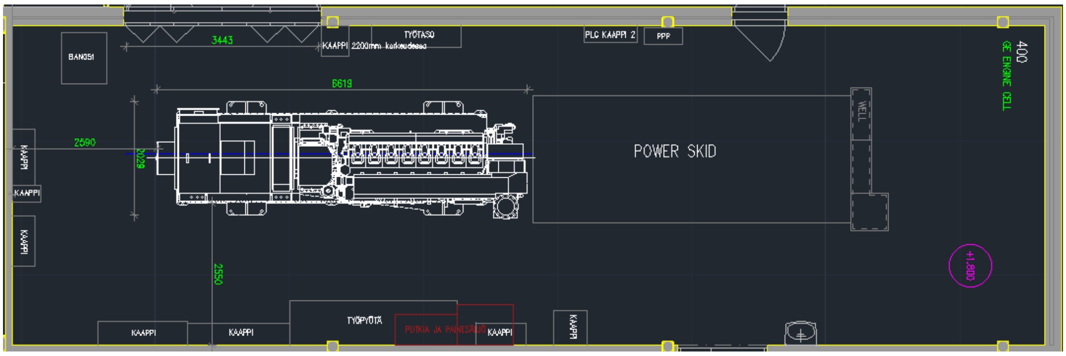


Figure 20. The new genset situation in the test cell.

Requirements for service spaces and overhead crane must be considered. However, the new W8L20 engine is lower than old W9L20. The whole genset is ~100mm lower than old one and thus no problem occurs. There will be more lifting space available in the vertical direction.

The distance between the crane at the maximum height and the top of the W9L20 -genset is 881mm. With the new W8L20 -genset the distance increases to 998mm (Figure 21).

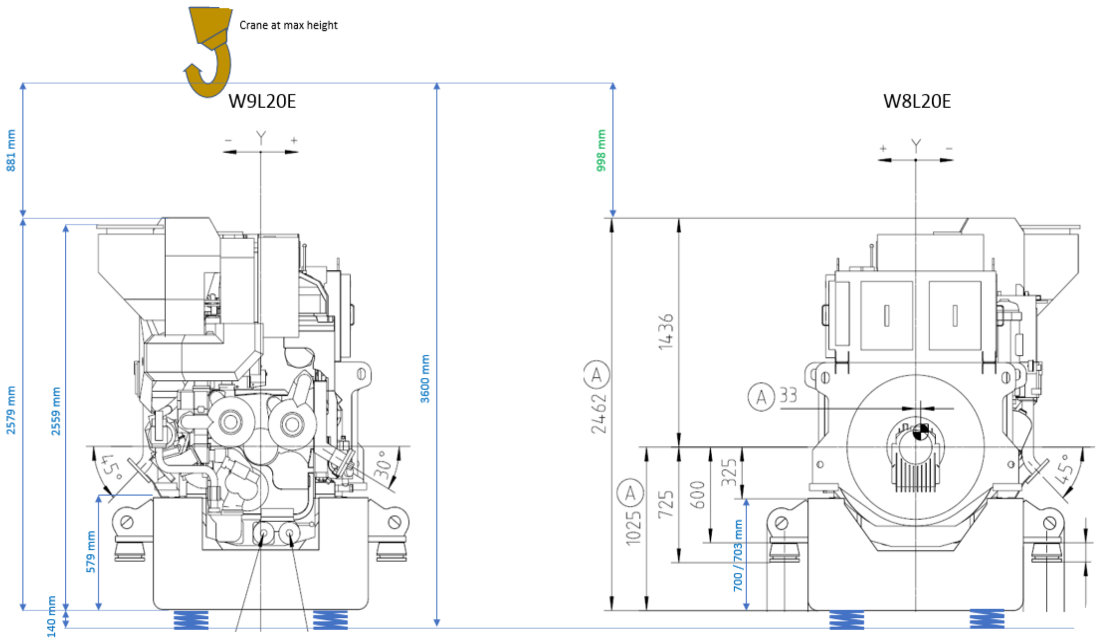


Figure 21. Lifting space in the test cell.

8.1 Exhaust System

According the Installation manual for the W20E -engines the minimum diameter of exhaust gas pipe has been determined to be 450 millimetres. The minimum bending radius of the exhaust pipe is 1,5 times the pipe diameter. The calculated minimum radius for the W8L20E exhaust pipe /29/:

1,5* 450mm = 675mm

Each exhaust pipe must be provided with a connection for the measurement of the back pressure. The connection must be accessible outside the insulation and the recommended location of the connection is as close to the engine as possible. /29/

The exhaust pipe must be insulated all the way from the turbocharger and the insulation protected by metal sheeting or corresponding material. The thickness of insulation is 10cm per side. /29/

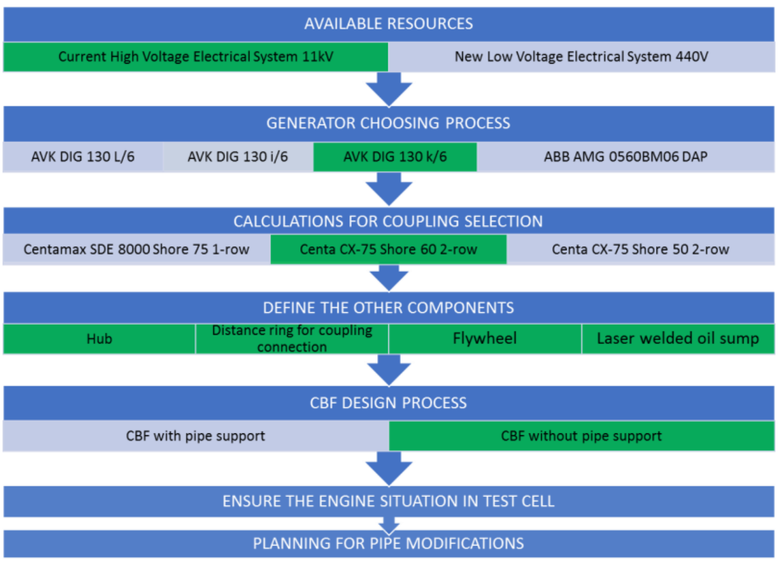
9 SUMMARY OF PLANNING AND COMPONENT SELECTION PROCESS

The whole project started by defining available demands and boundary conditions. The engine and laser welded oil sump had already been ordered before the thesis was started. A test request had been created for the laser welded oil sump by the component expertise team. This request had to be considered in the CBF design step. Also, the laser welded oil sump had to be changed to the engine before the genset assembling started. The steps of planning process are shown in Table 5.

The current 11kV electrical system was chosen by cost reasons. The process of choosing the generator was started after the list of requirements had been done. The AVK DIG 130 k/6 was a sensible choice. The electrical system had already been built for this generator specifications and the generator was already available.

After the generator had been selected, the calculations were started by N&V Engineering department. The most favourable calculation results were obtained for the Centa CX-75 Shore 60 2-row coupling.

Table 5. Process table of planning the engine change. Green columns show the selected components into the final assembly.



The other components were selected and ordered according to the engine, the generator and the coupling specifications.

The CBF design process started after the all critical components had been chosen. The old CBF was used as a starting point for the designing, but the pipe support was not considered necessary. In the final configuration, the height of the new CBF increased because of the new laser welded deep oil sump needed more space in width, length and vertical directions.

At the end of planning process, the location of the engine was ensured in the test cell and the planning for pipe modifications was started. It must be noted that the rest of the work will not be covered in this thesis work.

10 PROJECT BUDGET

The budget of the project will be discussed next.

10.1 Budgeting

The capital expenditure had been assigned and approved for the W8L20 engine change project in June 2018. Significant resources for the project had been determined.

The entire project budget covers material, transport and installation costs. The material costs consist of the W8L20 engine, generator, common base frame, coupling, flywheel, fixing screws and elements. The installation costs include piping work (subcontractor), lifting (subcontractor), installation and contingency. The salary costs of the lab staff have not been considered.

The most of project budget (63,4%) was planned to the new W8L20 engine. Other costs were estimated as shown in Figure 22.

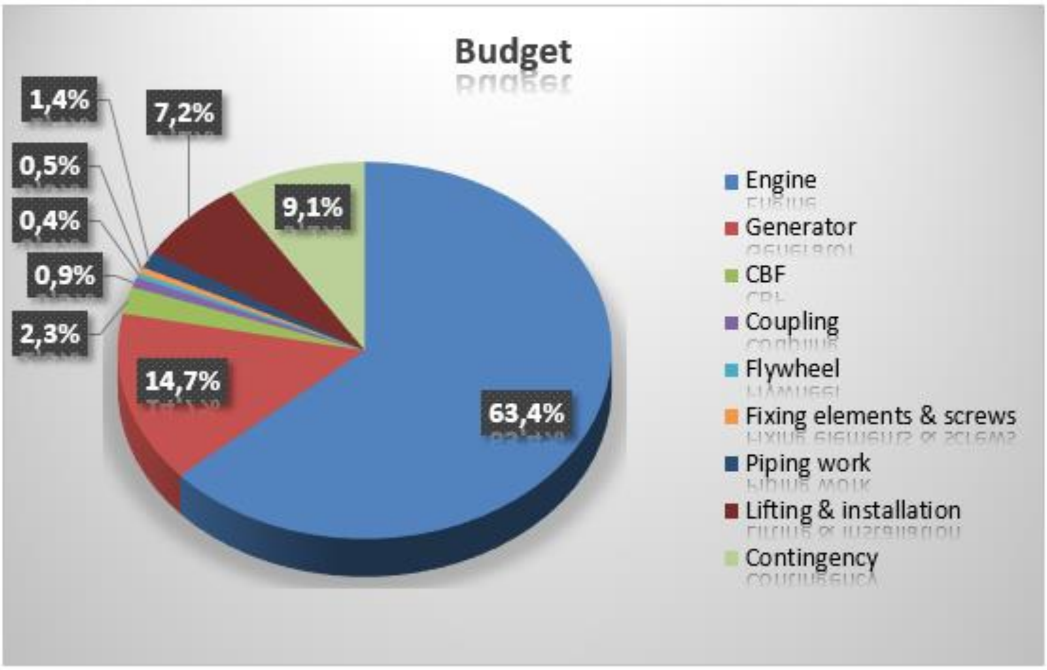


Figure 22. Pie chart of budget.

The second largest part was the generator (14,7%), the third largest was generator (9,1%), the fourth largest Lifting & installation (7,2%). The remaining budget was divided evenly with other components (0,4%-2,3%).

10.2 Actual Costs

The project budget was not exceeded. The old generator was utilized and therefore money was released into other use. The released money, 15,8% of budget will be used to the extra contingency, PLC upgrade and to the test cell environment improvements later (Table 6). The project schedule did not allow all changes at the same time, therefore only the most critical updates were made during the engine change.

Table 6. Cost follow up in percentage.

Material	Projected % of budget	Actual cost % of budget	Difference %
8L20 Engine	63,43	59,5	3,92
Generator	14,70	0,00	14,70
Common base frame	2,31	3,00	-0,69
Coupling	0,86	1,17	-0,30
Fixing screws & elements	0,43	0,12	0,32
Flywheel	0,52	0,49	0,03
Installation costs			
Piping work	1,44	1,73	-0,29
Lifting & installation	7,21	8,07	-0,86
Contingency	9,10	10,09	-1,00
For later use, extra contingency and PLC upgrade %			15,83

11 DISCUSSION AND CONCLUSIONS

This project gave important knowledge about project management and planning of the engine change. Many things can only be learned on the basis of work experience.

The main requirements for engine change projects in future are listed below:

- Clarify the demands for the engine:
    1. The physical size and ventilation of the test cell– ensure that the auxiliary system is suitable for the engine.
    2. Requirements for the MV/HV electrical system – the distribution of electricity to the electrical grid or to the load banks.
    3. Requirements for the LV electrical system – possible changes in the PLC.
    4. Modifying of pipe connections – PED -standards for chemical pipes.
    5. Vibration and noise factors – take into account in design and component validation process.

There is available literature on the detailed requirements of the test engine cell environment, for example A.J. Martyr's Engine Testing. Inflows and outflows to and from the test cell are determined in more detail in it. This book gives an extensive idea of the theory of the test cell structure. Also, there is important information about project management tools.

The second important part of project is management.

- Make sure that the following things are done:
    1. Make a preliminary project schedule
    2. Estimate the risk factors
    3. Make a cost follow up

4. Keep yourself and your contacts up to date
5. Make the necessary changes to the project schedule and be prepared for them
6. Organize the required number of meetings with contact persons

In conclusion, working in a large company brings its owns challenges in communication and delay times. On the other hand most of the knowledge is already available in house. It is important for the project management to remind people of the agreed issues often enough. However, usually the project schedule will be change as the project progresses and all component suppliers will not stay on delivery times. The risks can be estimated beforehand, but they cannot be completely avoided. This must be considered in all projects by reserving enough time.

REFERENCES

/1/ Wärtsilä. About Wärtsilä. Accessed 13.3.2019 https://www.wartsila.com/about

/2/ Wärtsilä. The history of Wärtsilä 1834-1990. Accessed 3.10.2018 https://www.wartsila.com/about/history

/3/ Wärtsilä. Wärtsilä's Smart Technology Hub. Accessed 18.10.2018 https://www.wartsila.com/sth

/4/ Wärtsilä. About Research & Development. Accessed 9.10.2018 https://www.wartsila.com/about/research-development

/5/ Wärtsilä. More powerful version of Wärtsilä 20 engine introduced. Accessed 19.10.2018 https://www.wartsila.com/media/news/04-12-2017-more-powerful-version-of-wartsila-20-engine-introduced

/6/ Wärtsilä. Products: Wärtsilä 20. Accessed 8.11.2018 https://www.wartsila.com/products/marine-oil-gas/engines-generating-sets/diesel-engines/wartsila-20

/7/ Wärtsilä. Brochure of Wärtsilä 20. Accessed 2.11.2018 https://cdn.wartsila.com/docs/default-source/product-files/engines/ms-engine/brochure-o-e-w20.pdf?utm_source=engines&utm_medium=dieselengines&utm_term=w20&utm_content=brochure&utm_campaign=msleadscoring

/8/ How stuff works. Types of engines. Accessed 4.2.2019 https://auto.howstuffworks.com/question366.htm

/9/ Wärtsilä. Products: Power Plant Gensets. Accessed 8.11.2018 https://www.wartsila.com/products/power-plants/power-plant-genset-overview

/10/ Wärtsilä. Wärtsilä Encyclopedia of Marine Technology. Accessed 15.11.2018 https://www.wartsila.com/encyclopedia/term/medium-speed-engine

11/ Wärtsilä. Products: Wärtsilä Engines Auxiliary Systems. Accessed 16.11.2018 https://www.wartsila.com/products/marine-oil-gas/engines-generating-sets/wartsila-engines-auxiliary-systems

/12/ Electrical Engineering Community. What is an Electric generator?. Accessed 22.11.2018 http://engineering.electrical-equipment.org/electrical-distribution/what-is-an-electric-generator.html

/13/ Inkinen, P., Manninen, R., Tuohi, J. 2009. Momentti 2. Keuruu. Otava.

https://stamford-avk.com/tdfaultmangbjuly2009gb

/14/ National Council of Educational Research and Training. Principle of AC generator. Accessed 1.2.2019 http://www.ncert.nic.in/html/learning_basket/electricity/electricity/machine/ac_generator.htm

/15/ Stamford AvK. Power portfolio. Accessed 3.12.2018 https://stamford-avk.com/alternator-products-selector

/16/ Wärtsilä. Widdas.J, Manager, Plant Operation, VEL. Discussions. 11.2.2019

/17/ Stamford AvK. Technical information, Terminology. Accessed 14.1.2019 https://stamford-avk.com/terminology-view

/18/ Fault Finding Manual for Stamford AC Generators. Accessed 20.12.2018

https://stamford-avk.com/sites/default/files/literature/fault-finding-manuals/TD_FAULT_MAN_GB_JULY_2009_GB.pdf

/19/ Stamford AvK. Product manuals. Accessed 3.12.2018 https://stamford-avk.com/sites/default/files/literature/manuals/A046V044_DSG_DIG_EN.pdf

/20/ Geislinger. Products, Coupling. Accessed 13.12.2018

https://www.geislinger.com/en/products/product/coupling

21/ Dewesoft. Rotational and Torsional Vibrations Manual. Accessed 27.1.2019 https://dewesoft.com/applications/rotating-machinery/rotational-and-torsional-vibration

/22/ Environ molds. Shore Hardness Explained. Accessed 10.12.2018 https://www.artmolds.com/shore-hardness

/23/ SubsTech. Shore (Durometer) hardness test. Accessed 10.12.2018 http://www.substech.com/dokuwiki/doku.php?id=shore_durometer_hardness_test

/24/ Wärtsilä. Birell.T, Chief Test Engineer, Small & Medium Bore Testing. Conversations. 3.12.2018-10.1.2019.

/25/ Wärtsilä. Hynönen.P, Vibration Engineer, Noise, Vibration & Calculation, Email messages. 25.10.2018 – 10.1.2019.

/26/ Geislinger. Products, damper. Accessed 13.12.2018 https://www.geislinger.com/en/products/product/damper

/27/ Avspare. Inspection and cleaning procedures for Geislinger Dampers. Accessed 27.12.2018 https://avspare.com/catalog/cat/content/i04193951/

/28/ Wärtsilä. Törnqvist.A, Design Engineer, Mechanical Engineer. Email messages. 20.12.2018 – 11.1.2019.

/29/ Wärtsilä intranet. Exhaust gas system, General Description. Accessed 14.1.2019