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Design and Construction of Chemical Ageing Test Rig

Kim Norrgård

Bachelor´s thesis

Degree Programme in Electrical Engineering

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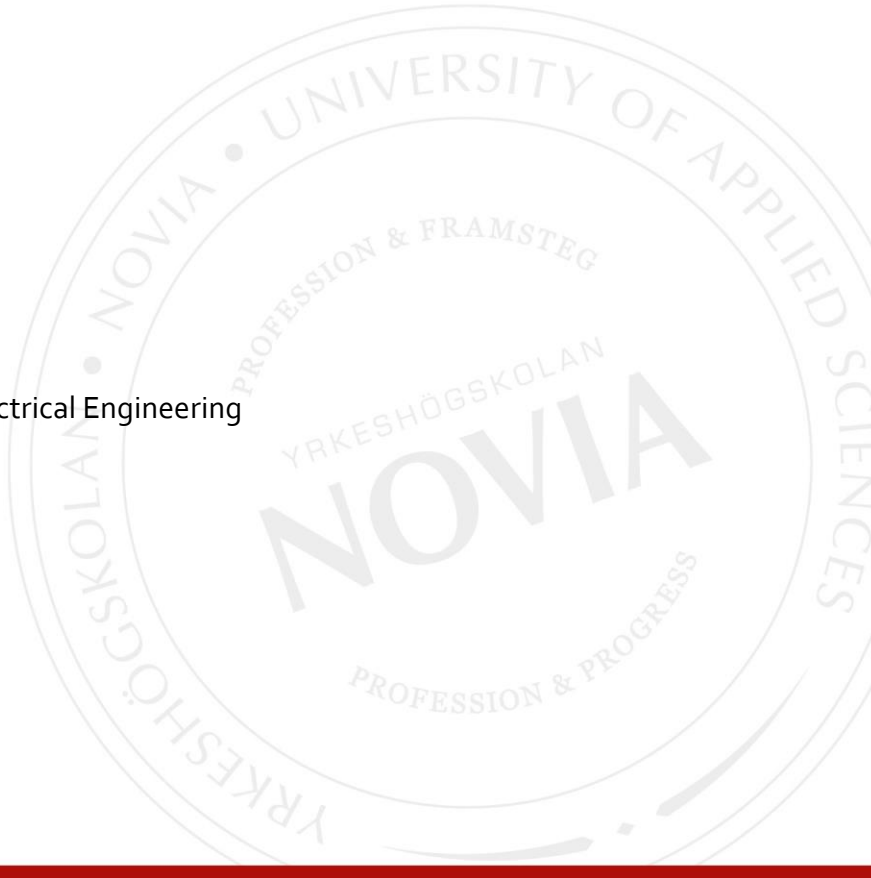

BACHELOR'S THESIS

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Title: Design and Construction of Chemical Ageing Test Rig

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Abstract

This thesis has been made for Engine automation testing at Wärtsilä in Vaasa. Engine automation testing has a chemical aging test rig at Wärtsilä in Vaskiluoto. The rig has to be updated because of the poor temperature stability of the fluid.

The purpose of this thesis is to find an oil bath for heating of the fluid and to redesign the fume chamber. Further the target is to find a good solution for remote monitoring of the rig via the Internet, to avoid unnecessary visits to Vaskiluoto. A pilot test will be run to make sure that the new rig can hold the fluid temperature stable better than the old rig.

The result of this Thesis is a chemical ageing test rig, that can hold a good and stable temperature of the chemical mixture. The existing fume chamber is modified so that the new oil bath can be installed inside the fume chamber and also to achieve a reliable remote monitoring of the rig. The oil bath controller can record temperatures into a file during the test.

Language: English Key words: Optimization, test rig, chemical

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EXAMENSARBETE

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Inriktningsalternativ:	Elkraftsteknik
Handledare:	Matts Nickull

Titel: Planering och konstruktion av kemikalisk föråldringstestrigg

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Datum 21.2.2019 Sidantal 25

Abstrakt

Det här examensarbetet gjordes åt Engine automation testing vid Wärtsilä i Vasa. Engine automation testing har en kemikalisk föråldringstestrigg vid Wärtsilä i Vasklot. Riggen måste uppdateras eftersom den gamla riggen inte kunde hålla en jämn temperatur på kemikalierna.

Målet med examensarbetet var att hitta ett nytt oljebad, som kan hålla jämn temperatur på vätskan och att göra nödvändiga ändringar på dragskåpets design, samt finna en lösning för fjärrövervakning av riggen över Internet. Genom fjärrövervakningen undviks onödiga resor till Vasklot från centrum. Ett pilottest gjordes för att få en uppfattning om den nya riggen kan hålla en tillräckligt jämn temperatur på vätskan.

Resultat av detta examensarbete blev en kemikalisk föråldringstestrigg. Den skall hålla en jämn temperatur på kemikalieblandningen, modifiera det befintliga dragskåpet så det nya oljebadet kan monteras inuti dragskåpet, samt få en fungerande fjärranslutning till riggen. Oljebadets styrutrustning sparar temperaturdata under testets gång till en datafil.

Språk: engelska Nyckelord: optimering, testrigg, kemikalisk

OPINNÄYTETYÖ

Tekijä:	Kim Norrgård
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Ohjaaja:	Matts Nickull

Nimike: Kemikaalisen ikääntymistestilaitteen suunnittelu ja kasaaminen

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Päivämäärä 21.2.2019 Sivumäärä 25

Tiivistelmä

Tämä opinnäytetyö on tehty Wärtsilän Engine Autiomation Testing -osastolle Vaasassa. Engine Automation Testing -osastolla on kemikaalinen ikääntymistestilaite Vaskiluodossa. Laitteeseen pitää tehdä päivitys, koska nestelämpötilan vakaus on ollut epätasainen.

Tämän opinnäytetyön tavoite oli löytää uusi öljyamme, joka pystyy pitämään nesteen tasaisessa lämpötilassa, ja tehdä tarvittavat muutokset vetokaapin muotoiluun sekä löytää ratkaisu internetin kautta tehtävään laitteen etävalvontaan. Etävalvonnan avulla vältytään turhilta ajomatkoilta Vaskiluotoon. Pilottitesti tehdään, jotta saadaan käsitys pystyykö uusi laite säilyttämään nesteen riittävän tasaisen lämpötilan.

Opinnäytetyön tulos on vakaan kemikaalilämpötilan pitävä kemikaalinen ikääntymistestilaite ja nykyisen vetokaapin muokkaus siten, että uusi laite voidaan asentaa vetokaappiin sekä luotettava etävalvonta laitteeseen. Laitteella kyetään tallentaa lämpötiladataa testin aikana tiedostoon.

Kieli: englanti Avainsanat: optimointi, testauslaite, kemikaalinen

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Table of Content

Abbreviations

EUT	Equipment under test
HFO	Heavy fuel oil
LFO	Light fuel oil
DF	Dual fuel
SG	Spark-ignited gas
CCM	Cylinder control module
CAN	Controller area network
LDU	Local display unit
LCP	Local control panel
ESM	Engine safety module
IOM	Input/output module
PDM	Power distribution module
MCM	Main control module

1 Introduction

This bachelor's thesis is made for Wärtsilä Finland. The goal of this thesis was to update an existing test rig for chemical ageing test. Chemical ageing test is used to ensure that the high-quality parts, which are going to be installed on Wärtsilä engines, have a high standard. The testing also reduces service and downtime costs and ensures more reliable products.

1.1 Wärtsilä

Wärtsilä is a Finnish company established in 1834. Wärtsilä consists of three businesses; Marine Solutions, Energy Solutions and Services. Wärtsilä delivers complete lifecycle solutions for the marine and energy markets. In 2017, Wärtsilä's net sales totalled 4.9 billion euros with approximately 18,000 employees. Wärtsilä is listed on Nasdaq Helsinki. The company operates in over 200 locations in 70 countries around the world. Wärtsilä has a large portfolio offering engines, automation systems, gensets, ship designs, generating sets and lifecycle solutions. Energy solutions provide different and efficient energy solutions for the customers of modern energy infrastructure such as smart power generation, wind power and solar. Marine solutions provide different solutions for the marine industry; ship design, engines, electrical and automation systems and other systems. Services provide lifecycle solutions for the two other businesses in order to improve performance and efficiency and to provide a maximised life length for the products. (Wärtsilä Oyj, 2018).

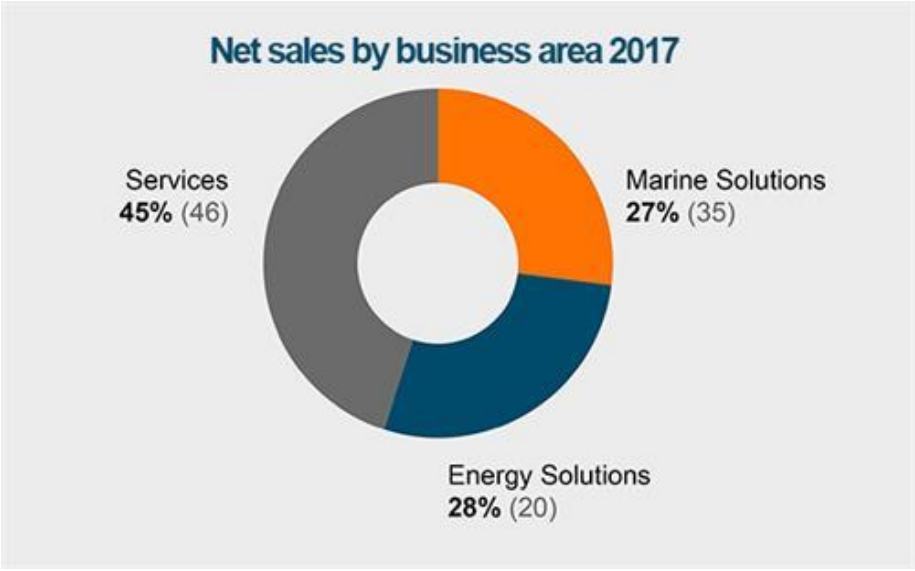

Figure 1. Net sales 2017 for Wärtsilä Oyj.

1.2 Engine

Wärtsilä manufactures different kinds of engines for power plants, various ships, and other purposes. Wärtsilä has different types of engines: Diesel engines, Dual fuel engines, and engines that can run on both diesel fuel and liquefied natural gas. There are six different diesel engines starting from the smallest: Wärtsilä 14, Wärtsilä 20, Wärtsilä 26, Wärtsilä 31, Wärtsilä 32 and Wärtsilä 46F. There are also five different dual fuel engines: Wärtsilä 20DF, Wärtsilä 31DF, Wärtsilä 34DF, Wärtsilä 46DF and Wärtsilä 50DF. Wärtsilä also makes some of these engines as pure gas versions (SG). The number in the model name Wärtsilä 31 means that the cylinder bore of the engine is 310 mm. DF in the model name stands for Dual Fuel. The engines are available in different configurations. For example, the 31DF is available from 8 to 16-cylinder models with different power output ranges. (Wärtsilä Oyj, 2018).

Figure 2. Wärtsilä 31DF Engine.

1.3 System construction

The main part of an engine is the engine block, which is the bottom end of an engine and is casted in one piece for all cylinders and supports for the crankshaft. Other parts are crankshaft, flywheel, bearings, cylinder liners which is the inner wall of a cylinder, piston, piston rings, cylinder head, turbo charger(s), camshaft, valves, fuel injection and engine automation system.

For genset application the generator is connected via a flexible coupling to the flywheel. The generator is a brushless synchronous type and usually of a medium voltage type (6-15 kV).

UNIC control system is an embedded engine management system. UNIC is used for all Wärtsilä engines. The functionality of the UNIC is: Engine control, Engine safety and Engine monitoring. The automation system enables centralized operation of the plant's control room. (Wärtsilä Oyj, 2018).

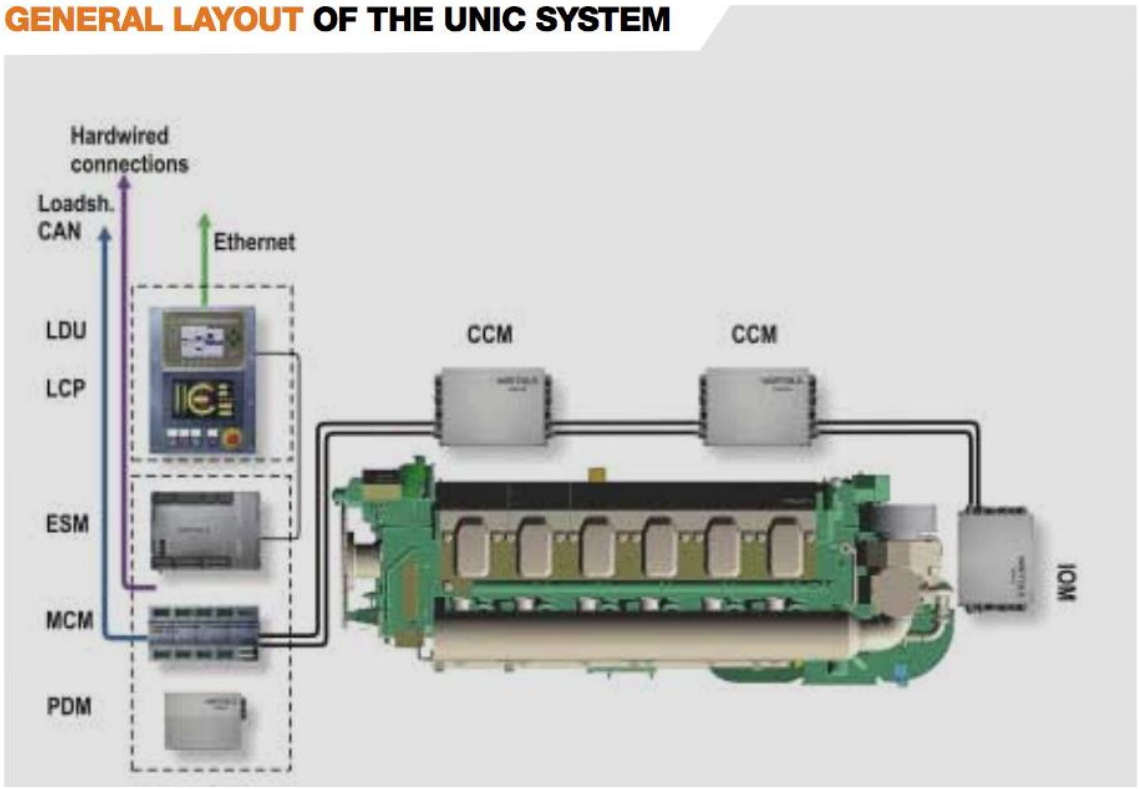

Figure 3. Layout of the UNIC system.

The automation system for a power plant application is designed for safe, reliable, efficient and easy operation of the generating sets, their associated auxiliaries and electric systems. The automation system handles:

- Local interface for the operator, including a local display, which indicates all important engine measurements and a local control panel.

- Engine start/engine start management, including start block handling and slow turning, load redaction, waste gate control and the LT/HT thermostatic valve control.

- Engine safety (alarms, shout-downs, emergency stops, load reductions) including hard-wired safety for engine over speed, lube oil pressure, cooling water temperature and external shutdowns.

- Electronic speed/load control with various operation modes.

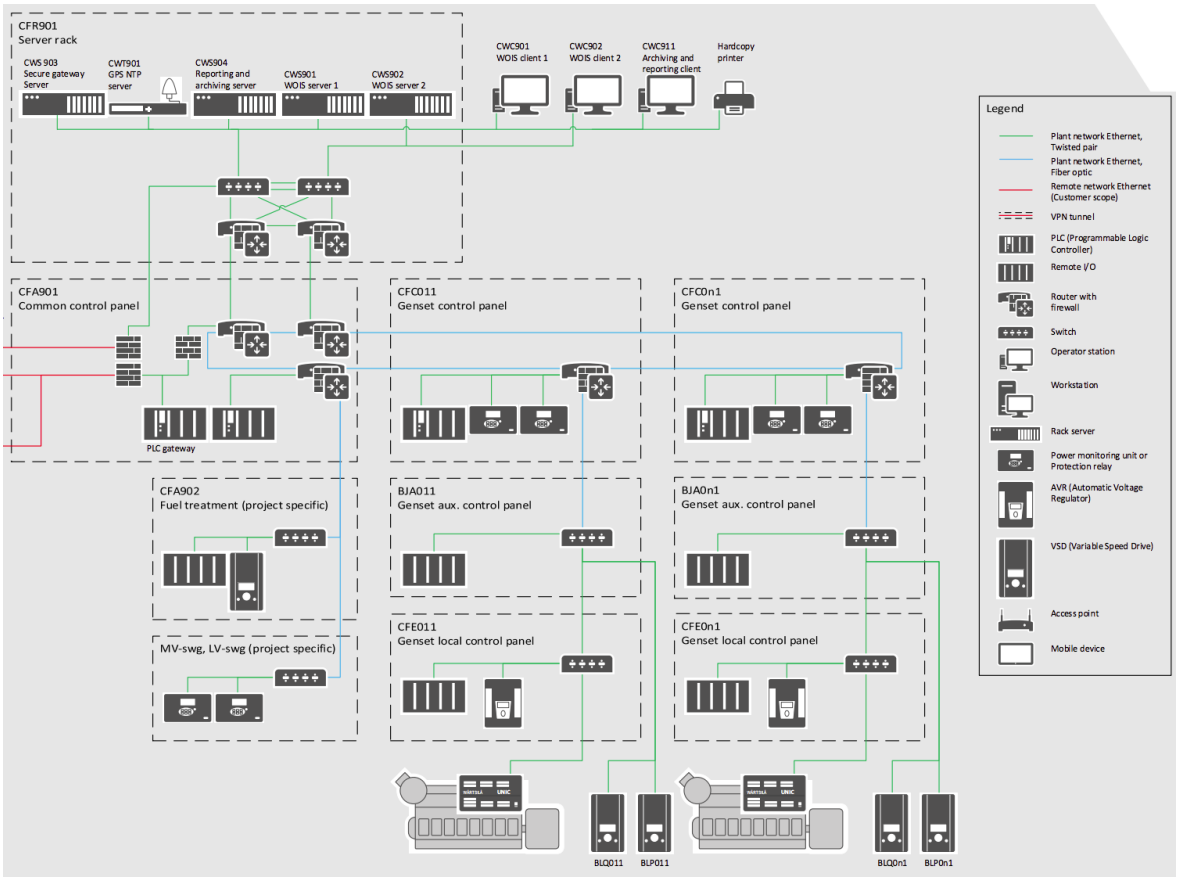

Figure 4. Power plant automation layout.

(Wärtsilä Oyj, 2018).

1.4 Engine room environment

There are more different types of components in the engine room than in the engine and generator. These are for example pumps for fuel and cooling water, heaters, fuel modules and separators. In the case of a gas engine, there is also a gas valve unit. The environment in the engine room is very hot even though there are ventilation fans for cooling the engine hall air. There are inlet ventilation fans in front of the generators and in the auxiliary area. Outlet ventilation is on the top of the engine room's roof. During engine maintenance, there can be fluid leaks, such as fuel, oil, cooling fluids and washing fluids.

This is the reason why different parts such as cables, rubber and other parts need to be tested so that they can withstand these rough conditions.

2 Chemical ageing test

The chemical ageing test is an accelerated ageing test that uses aggravated conditions of heat and chemicals. It is used to help determine the long-term effects of expected levels of stress by controlled standard test methods in a laboratory within a shorter time. Examples of EUTs that are tested:

- Rubber parts for example gaskets.
- Different plastics like zip-ties and cable markings.
- Different types of labels.
- Cables.
- Different types of sensors, like temperature and pressure.
- Label text and paint on metal.

The EUTs are to be installed on or near an engine, so they need to be resistant to heat and different liquids. The EUT (equipment under test) are immersed into the chemical mixture that contains two fuels, two oils and a mixture of water and detergent. After the immersion, the chemical mixture is heated up and temperature is held in 90 °C. The test is continued for 100 hours. After the test, the components are inspected for possible damages and photographed. The result will be documented in a report. The report will be added to the database.

The chemical ageing test is done in order to prevent bad products, which are used in the engines. This cuts down warranty costs of faulty products.

The old chemical ageing test rig was composed of a fume chamber and inside the chamber there was a Metos Multi-Line hotplate that is designed to be used in a restaurant kitchen and cooking pot. The hotplate was unstable when the temperature was set to 90 °C. The temperature was fluctuating between 86 °C and 98 °C and it never stabilized at 90 °C. The old system did not have a remote control/monitoring. Because of this one had to drive to Vaskiluoto's engine laboratory to check the chemical ageing test when it was running.

2.1 Memmert

When searching for a suitable solution for the chemical ageing test, available on the market was baths and heaters but only two solutions was suitable for this. For example, the Memmert bath's container did not have the right measurements for this application and it did not have a USB connection that was required.

Memmert bath Specifications:

- Maximum temperature 5 - 95 °C.
- Digital LED display.
- Timer from 1 min to 999 hours.
- Temperature control with two pt100 sensors.
- Automatic switch off in case of over temperature.
- Audible and visual alarm in case of low liquid level heater is switched off.

(Memmert GmbH, 2018).

2.2 Grant

The manufacturer Grant, however, had different kinds of models that were suitable. There were some other systems but none of them was as good as the Grant. All the other systems were missing some of the important details required. Grant TX150 was the most suitable for this application. Specs of the new heater:

- Maximum temperature of 150 °C.
- Heating circulator incorporates Intelligent Control Optimization for adaptive intelligent PID temperature control and includes a powerful integral pump with maximum flow 18 l/min, making TX150 systems suitable both for immersing samples.
- PC communication and data collection, memory capacity of 30 segments.
- Full Color QVGA TFT screen.
- Adjustable over temperature cut-out.
- Variable high and low temperature alarm settings - configurable to switch a relay.

(Grant Instruments Ltd, 2018).

2.3 Pros and cons with Memmert and Grant

Memmert:

+ Timer.
+ Automatic switch off in case of over temperature.
+ Led display.
+ Audible alarm in case of low liquid level.
− No data connection for remote control or remote monitoring.

Grant:

+ Maximum temperature of 150 ℃.
+ Internal pump for liquid mixing.
+ PC communication for both remote control and monitoring.
+ Over temperature switch off.
+ Low liquid alarm.
+ Timer that automatically switches off the heater after the time runs out.
− No backlight screen.

2.4 Grant 150 TX150-ST26

Grant 150 TX150-ST26 was chosen. Grant TX150 is a digitally controlled heated with a circulation pump. The integrated pump is powerful with a maximum flow of 18 l/min. The unit has an intelligent accurate PID temperature controller for various applications. The maximum temperature of the TX150 unit is 150 ℃.

The TX150 control unit has an RS232 and USB data connection for programming and recording of various temperatures. The TX150 can be programmed directly from the unit push buttons. The unit has also a color screen for displaying actual and set temperatures, pump speed and clear status icons.

The bath is made of stainless steel and has a volume of 26 liters. The bath is equipped with an outlet drain valve to empty the bath. The bath has an outer metal enclosure and between the bath and the enclosure air will circulate in order to cool the outside of the bath enclosure.

Other features:

- High and low alarms.
- Timer 1 minute to 99 hours and 59 minutes.
- Low liquid detection.
- Over temperature with adjustable cutout.
- Stability (DIN12876) @70/℃ ± 0,01/℃.
- Can store one program with 30 segments and therefore Labwise was chosen to easy to upload different programs.
- Power requirement one phase 230 VAC, 2000 W.

(Grant Instruments Ltd, 2018).

Figure 5. Grant TX-150 controller for the bath.

Figure 6. Grant TX-150 controller and ST26 bath. The bath has a volume of 26 liter.

2.5 Labwise Software

Labwise is an option that can be selected from Grant.

Labwise is a Windows PC software for the oil bath for program set-up, data logging and real-time graphing and this can also be done remotely.

Set-up features:

- Set temperature.
- Set high and low alarms; can be used to control output relay.
- Set reaction timer.
- Set delayed start and stop time.
- Control output relays for refrigeration on/off control and operation ancillary equipment.

Programming features:

- Set cool and heat time to target.
- Program values may be set graphically or numerically.
- Set number of loops, 1 to 254 or infinite looping between selected way points.
- Program control of output relays for each segment, for operating ancillary equipment.

Display and logging features:

- Display of temperature/time profile screen in real time.
- Real time zoom and scaling of graphical display.
- Logging of temperature profiles to disk for storage and subsequent analysis.
- Store programs to disk.

(Grant Instruments Ltd, 2018).

3 Assembly and test of the new rig

The old rig was a heater plate and a pot. The old heater plate was removed and the hole in the bottom of the fume chamber had to be modified by widening the hole. The stainless-steel shelf under the fume chamber had to be modified so that the bath could be installed at the top of the shell. The old shelf was too small, and it was modified by welding a new stainless-steel plate on top of the old one. Then the bath was installed inside the fume chamber. The electrical connection from the bath is going through the chamber wall to a safety switch that is located on the wall close to the chamber. The chamber is equipped with an EX ventilation fan for extracting the fumes from the chamber to the process ventilation system.

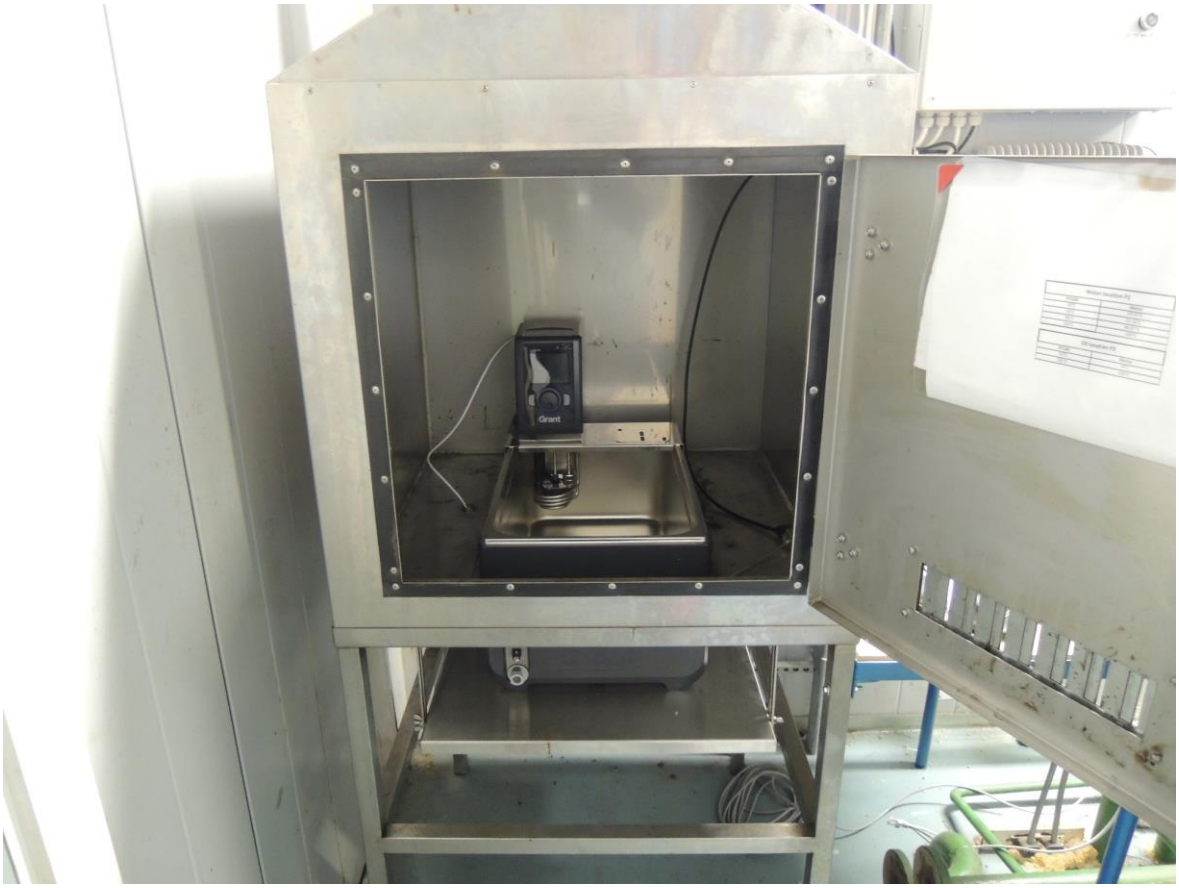

Figure 7. The new bath fitted inside fume chamber.

3.1 Pilot test with water as a liquid

Before the bath was installed in the fume chamber, a pilot test was run with water to make sure that the temperature stability was good. The test with water had to be stopped after a short time due to evaporation of the water. The result of the test was good. The stability of the water temperature was excellent.

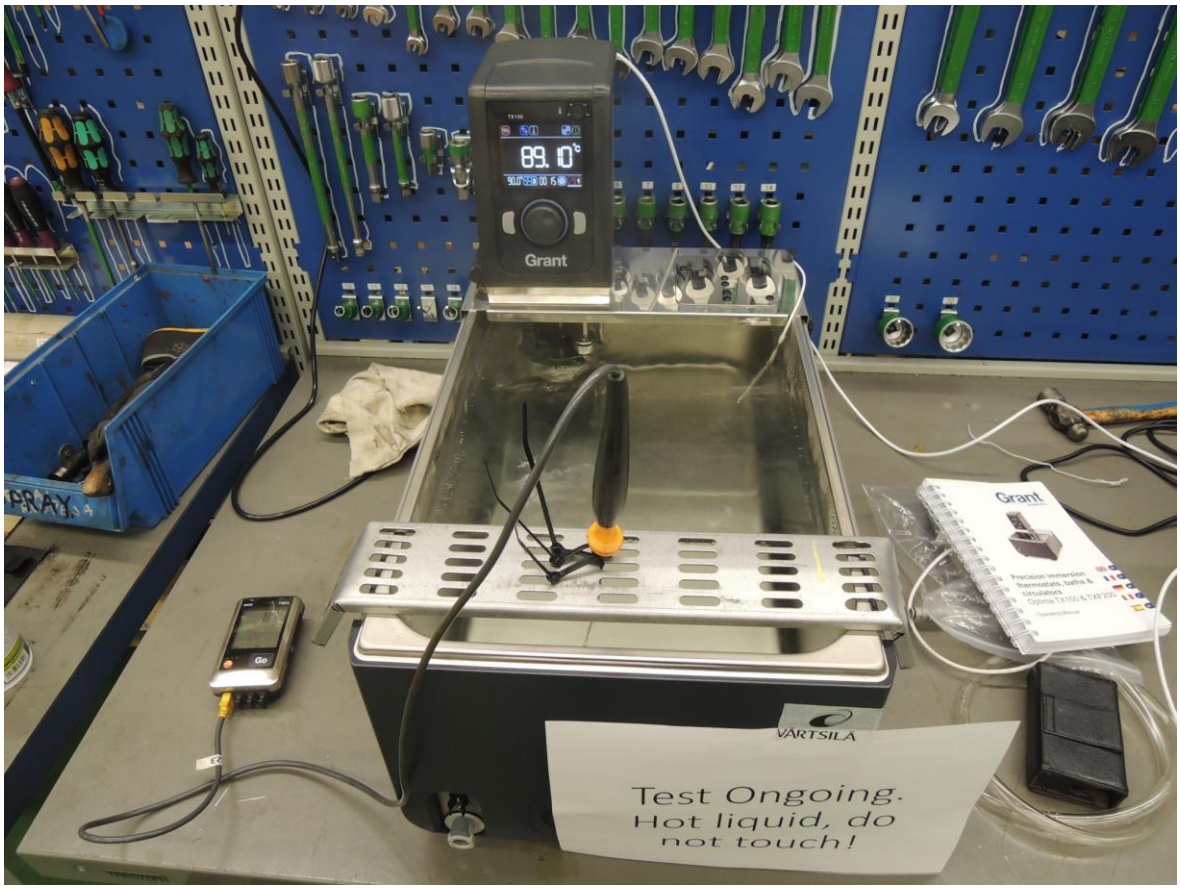

Figure 8. Bath with water test. The test was run in the workshop.

4 Pilot test with chemical mixture as a liquid

The test run was a proper chemical aging test. All chemicals were added to the bath, the computer was connected to the controller and the EUT was emerged in to the chemicals. The temperature and ramping parameters where set on the computer.

- Test length 99 hours 59 minutes with automatic shutoff of the heater.
- Temperature ramp 1 ℃/minute.
- Liquid low level alarm.
- The test computer was remotely controlled from another computer.

For safety the following functions where selected:

- Low liquid alarm.
- High/low liquid temperature.

- Automatic shutdown of the heater after selected time.

4.1 Chemical mixture

This chemical mixture is used in all tests and consists of 5 different chemicals. The chemicals have different viscosities. Due to different viscosities, it is challenging to mix the fluids. If there is no mixing of the mixture under the test the chemicals will sit in layers.

- 20 % of Teboil Motor KL, LFO (Light fuel oil).
- 20 % of Teboil HFO 180 LS Mix, HFO (Heavy fuel oil).
- 20 % of Mobilgard M 440, Lubrication oil (Diesel engines).
- 20 % of Mobil Pegasus 805, Lubrication oil (Gas engines).
- 20 % of Pineline Degreaser (dilution factor 1/5).

4.2 Result of the pilot run

The test was stopped after 100 hours. The EUT was removed and the chemicals where left to cool down. After the chemicals had cooled down, the bath was drained to a container and then emptied in to a separator. After the test was completed, the bath was drained and cleaned with a rug. The heater pump was rinsed with hot water.

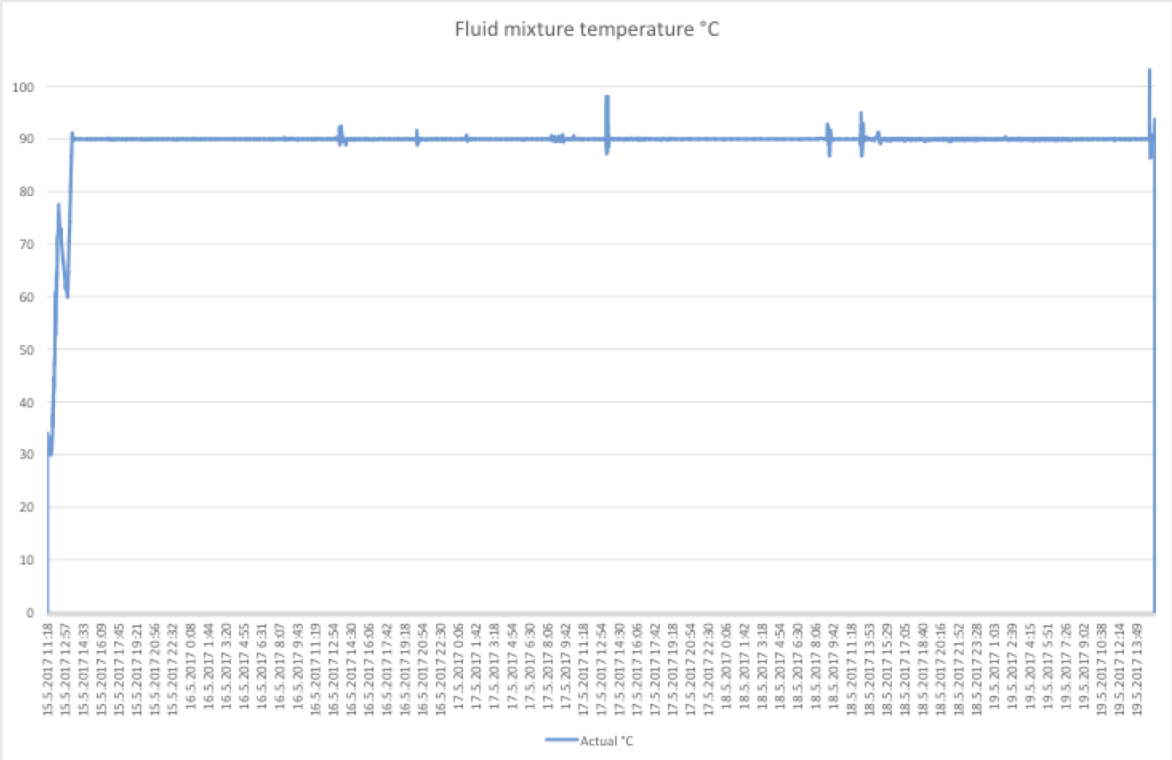

Figure 9. Fluid mixture temperature under test process.

The graph shows that the temperature of the liquid has stayed stable with some temperature spikes. A hotspot could have caused the temperature spikes might have caused. The HFO is much thicker liquid than the other chemicals, so it might be that the HFO was not mixed as well as the other chemicals.

The cables are fastened to a piece of steel so that the height of the sample can be adjusted. (see Figure 10.) The sample is lowered down in the chemicals. Fluid level has decreased due to evaporated liquid. The liquid is probably water (see Figure 11.)

Figure 12 illustrates how the cable looks like after it has been taken out of the chemical ageing test. The result of the test is OK. The cable sheet is intact. In Figure 13 a bit of the cable sheet has been removed to be able to see what the AB-tape looks like after the chemical ageing test.

In Figure 14 is a brand new cable for comparison (compare with Figure 13). In Figure 15 the cable, that was in the chemical ageing test, has been striped and the chemicals has not gone through the cable sheet and AB-tape.

Figure 10. EUT to be tested.

Figure 11. Chemical mixture.

Figure 12. EUT after completed test.

Figure 13. Peeled cable.

Figure 14. New cable.

Figure 15. Striped cable.

Conclusion of the pilot test:

- The result from this chemical ageing test of the cable is questionable.
- Before the testing was started it, was noticed that the cable is sticky. This could affect the installation of the cable.
- After testing it was noticed that the AB-tape barrier layer turned from white to yellow.
- The AB-tape barrier layer was also very hard compared to original sample that was soft.
- Otherwise the cable seemed okay.
- Another sample of this cable was also in a temperature-ageing test earlier, where the colour of the cable changed from black to brown.
- The cable was also much less sticky after the temperature-ageing test.

4.3 Summary of the new rig

The new chemical ageing test rig works well and it is easy to use. The pump in the controller enables the chemicals to have a more even temperature and prevents layering, although the HFO is much more difficult to move around than the other chemicals. The power of the pump was enough to pump the chemical mixture.

This solution for the chemical ageing test works very well.

4.4 Short instruction of how to use the rig

- Prepare the EUT.
- Check that all cables are connected.
- Start the fan to the fume chamber.
- Fill the bath with chemical mixture.
- Turn on the bath heater.
- Immerse the EUT in the chemicals.

- On the computer, select the program you want to run in the test and start the program.
- Check on the temperatures regularly as the test is running.
- End the test and empty the bath.

4.5 Remote desktop manual

1. To be able to remote control the test Rigg computer, you have to add your computer to the list of allowed computers for remote control.
2. Start by opening the control panel and search remote.

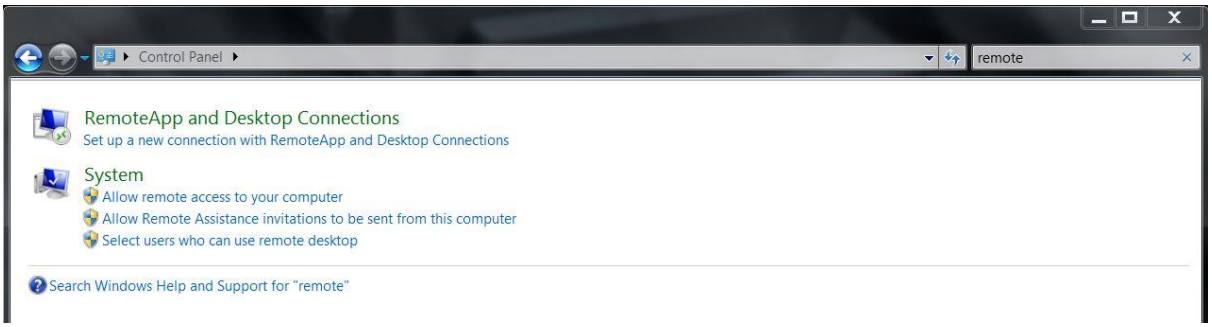

Figure 16. Control panel window in windows.

3. Allow remote access to your computer.
4. Log in as administrator.

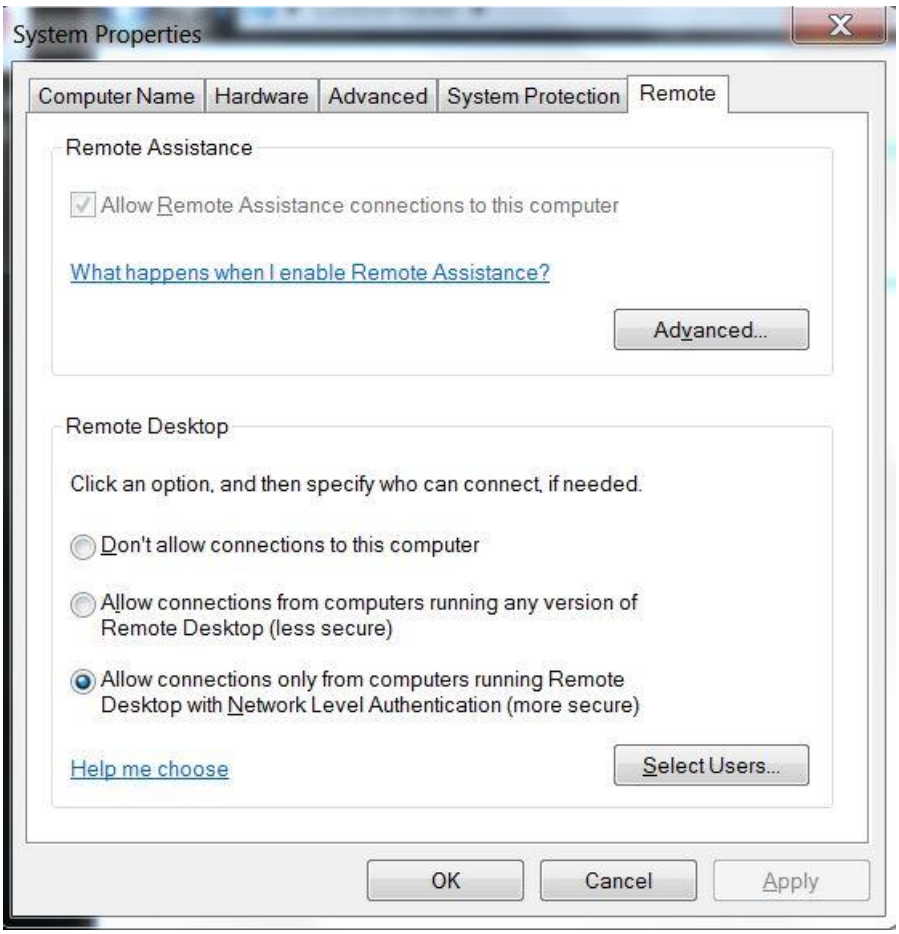

Figure 17. System properties window.

5. Press select users.
6. Log in with the user who wishes to remote control the chemical ageing test computer.

7. To start the remote connection from your computer, open start menu and search for remote desktop connection.

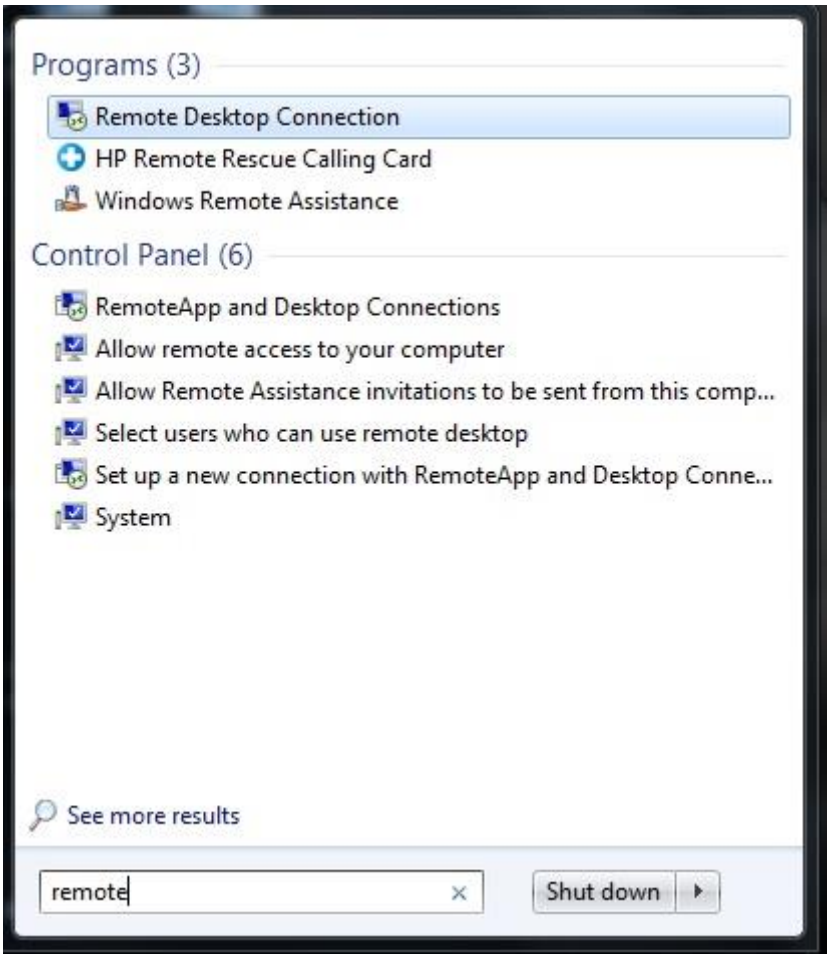

Figure 18. Windows start menu.

8. Choose Connect

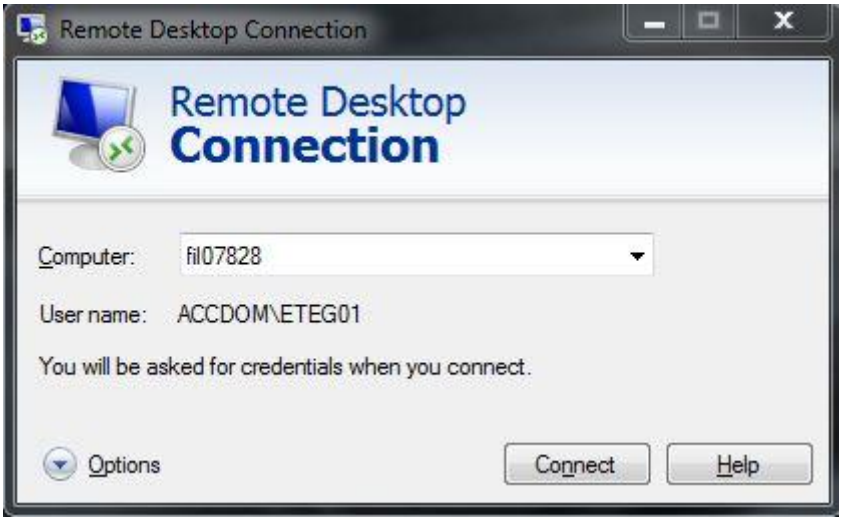

Figure 19. Remote desktop window. Make sure that the computer name is correct.

Figure 20. Log in window for remote control of a PC.

9. Log in and press ok.
10. To end the remote connection, log on to the remote computer or press the cross in the upper corner.

5 Result

There were some requirements for the new rig: one requirement is data connection for remote control and monitoring of the heater. It was also needed to keep a stable temperature under the test and automatically switch the heater off in case of overheat or low liquid level. One heater was chosen between two different manufacturers. The Grant was chosen because it has more features for this rig. Labwise software was chosen for monitoring and programming of the rig. Windows remote control was chosen for remote controlling the lab computer that was connected to the heater. A pilot test was run with water, with the new heater. The new heater was assembled inside the fume chamber. A chemical ageing test was run with chemicals and cables where immersed in the chemicals. The chemical ageing test was considered as a success.

6 Discussion

The company we ordered the equipment from had a problem with delivery of the Grants equipment. The delivery was delayed by several weeks. Other than that, I did not encounter any other problems.

The conclusion of this thesis work is a complete working chemical ageing test rig. The temperature is stable, and the remote connection works well. The new bath and the software that it comes with is easy to use and makes the chemical ageing test easier and less problematic. The bath works with remote control so that you can monitor the liquid temperature and do not have to make trips to Vaskiluoto’s lab to check on the chemical ageing test. The bath is made of aluminium which makes it easy to clean up. The bath also has a drain, so it is easy to empty. The heater has a backlight colour display which makes it easy to read in dark environments such as a fume chamber. The buttons on the heater unit are big, so it is easy to press them.

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