Updating automation system and making user manual

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Valkeakoski

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ABSTRACT

Automation Engineering
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ABSTRACT

The purpose of this project was to update an automation system (thermal cycling testing chamber) and to make a user manual. The main purpose of this thermal cycling testing machine was to test building materials quality through dramatic changes of temperature of Finland.

The project was divided into two parts, which were: updating the thermal cycling testing machine and making the user manual. The first part of this project was to successfully update the thermal cycling testing chamber, to be easy and safe to use and maintain. Related topics are also mentioned in this thesis to provide readers with an in-depth knowledge of the concept. The second part in this thesis introduces the user manual of the thermal cycling testing chamber, which provides the needed knowledge for users to be able to use this thermal cycling testing chamber with ease.

The starting point for the design work was proposing ideas on how to update this thermal cycling testing chamber during several discussions between the author and the original co-creator of this thermal cycling testing chamber. Background information was also collected from the creator of this machine. Practical work was required to gain an actual understanding as well as specific information about the machine, how it works, how to maintain it and to make a user manual about how to operate it.

Keywords thermal testing, automation testing, temperature, user manual, maintenance

Pages 36 pages including appendices 2 pages

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1 INTRODUCTION

1.1 Thermal cycling testing

According to the Associated Environmental Systems, there are two kinds of thermal / environmental testing: thermal cycling testing and thermal shock testing. Although the names are quite similar, there are significant differences in the procedures. While thermal shock testing is very quick in terms of bringing the product / material to the other state of temperature, which is why it normally has two zones of different temperatures inside the chamber; the thermal cycling testing method is much slower in which the soak time is longer, meaning a certain level of temperature stabilizes in a specific period before changing into the other state of temperature.

In this project, the thermal cycling testing method was used to create an environmental change in the chamber to test the quality and reliability of the product / material.

According to the testing target, two states of temperature must be created sequentially, and a suitable solution must be found using air and liquid to decrease and increase the temperature of the product / material inside the chamber to reach the target. To decrease the temperature, a refrigeration system was taken into use to remove the heat inside the tank by using compressor, condenser, oil and radiator to make the product / material reach the given lowest temperature. To increase the temperature, an amount of warm water from a water supply flowed inside the chamber until the temperature of the product reached a certain level of temperature.

1.2 Automated testing methods

Nowadays, automated testing has become popular and the term "automated testing" becomes the common word used in a wide range of industries. Almost every large-scale organization has its own testing department to ensure the quality of the final products.

Many kinds of testing methods exist and each one has its own advantages and disadvantages. However, when time and labour cost are a significant aspect in the field, an automated testing method will be adopted. For example, with normal testing methods, at least one person must be present the whole time when testing take places to ensure there will be no errors during the test, which may usually last for days. In that case, not only labour and time consumption become an issue, but also the energy consumption will become a significant problem.

By acknowledging the importance of applying automated testing method in the long term, in this project, the thermal cycling testing chamber has also made based on automated testing method to save time, energy and labour costs and still ensure the outcome quality.

1.3 Importance of user manual

With the massive development of technology, a lot of machines and products have been invented. Following that is the amount of new information and packages of brand new features that users must comprehend quickly to update and be ready to apply to the field in which they are working. Therefore, every brand-new machine should have a user manual which is thorough and easy to scan.

Which aspect should be considered to make user manual a complete and reliable documentation that users can rely to in every situation?

Based on the author’s research, an effective user manual should have these main sections:

- Clear navigation
- Basic outlook of the machine
- Operation of the machine
- Guide with steps to show how to use main functions of the machine
- Common issues with easy-to-follow solutions
- Maintenance.

2 INTRODUCTION TO THERMAL CYCLING TESTING CHAMBER

2.1 Purpose

The main purpose of thermal cycling testing is to determine the endurance of materials after many cycles of high and low temperatures.

In this project, the specimen was a piece of concrete for house building. Thermal cycling testing has been taken into use to test the ability of the specimen to endure the rapid changes of temperature in Finland. This would give a specific perspective on how to improve the quality of concrete by using data, which would be provided after the testing period was over.

2.2 Main idea

Firstly, consideration was drawn to the set-up of the test. The main feature in this project was to perform testing 50 times. The initial state was cooling, the second state was warming, and then back to the cooling state. Therefore, the test was referred to as a cycle.

Secondly, in order to get the current temperature of the specimen, a temperature sensor with two ends was used for this purpose. One end of that temperature sensor had to be drilled into the specimen, the other connected to the PLC controller. The temperature signal was sent to a PLC controller and it was taken as one of the inputs of the program to perform the logic part.

Thirdly, inside the PLC controller, comparator operations were used to compare the current temperature of the specimen with the set-points, which were the highest and lowest temperatures. These two set-points were set depending on user needs by using an HMI panel.

When all the components were connected, once the start button was hit, the cooling state was activated. The relay was closed and let cool air flow inside the testing chamber by using both radiator panels and motor fans which were placed inside the door of the testing chamber.

In the cooling state, if the current temperature was equal to the lowest temperature (eq. -20 degrees), meaning it was reached its first set-point, the relay was opened, and cool air stopped flowing inside the chamber, while the filling valve was opened to let warm water from the water supply flow inside the testing chamber through a filling pipe.

During the warming state, if the water level was overflowed, it was a hindrance to the process and could lead to damage. Acknowledging this fact, an overflow pipe was installed next to the filling pipe, and this pipe connected with the draining pipe which would let water flow out of the chamber to the environment.

If the current temperature was equal to the highest temperature (second set-point), the filling valve was closed and water from the water supply stopped flowing in the chamber, while the draining pipe was opened to let all the water out of the chamber.

At this point, the author faced another challenge; if the chamber was not fully dry before starting the cooling state again, the specimen would be broken and not only the specimen, even the chamber would be broken. Hence, to solve this issue, a safety valve had to be installed to make sure the water was fully out of the testing chamber, and the chamber completely dry. However, in this project, only a delay timer was used in the programming part to make sure the chamber was out of water, and the equation to calculate the amount of time that should be delayed is available in chapter 3.4 Operations.

2.2.1 Basic outline

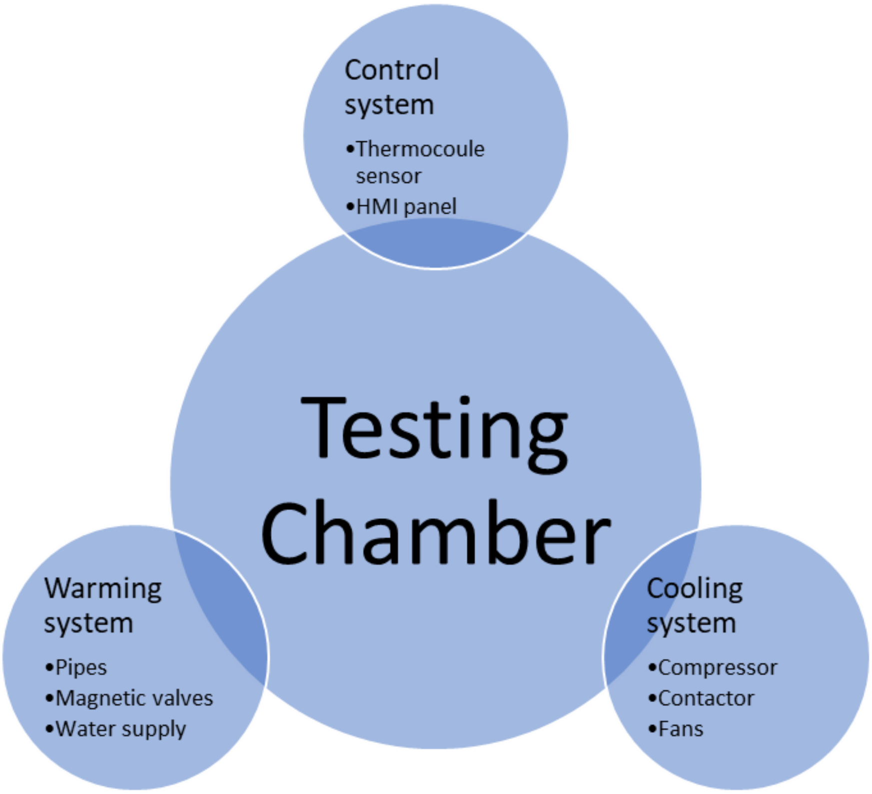


Figure 1. Basic outline of thermal cycling testing chamber (chart created by the author)

Figure 1 illustrates the rudimentary idea of the thermal cycling testing machine. There was a thermal chamber / tank put in the middle of the system which would contain the testing piece (specimen) surrounded by three other main systems, they were warming system, cooling system and control system as observing from counter clock-wise direction.

Before hitting the start button, there are several aspects which need to be concerned based on the research of the author, they are:

- The space inside the chamber must be cleaned
- All pipes and connections must be dust-free and dry for safety and quality purposes

Thereafter, the specimen could be placed inside the chamber and closing the door would be the last step.

The initial temperature would be the environment temperature; therefore, a certain amount of time must be spent for the temperature inside the chamber to reach a certain point for the very first state to be activated.

2.2.2 Working process

- Set two set-points of desire temperature range
- Connect thermocouple sensor to the specimen
- Put the specimen inside the chamber and close chamber’s door
- Start the machine using controller’s interface screen
- After starting, warming system would take place to heat up the thermal chamber to desire temperature (20 degrees) by pumping warm water inside the chamber
- When at 20 degrees, valves would be activated and open the gate for water to go out the chamber and compressor will be started to cool up the chamber
- Compressor uses oil to make cool air and fans to flow cool air into chamber until specimen’s temperature reaches 20 degrees
- When at -20 degrees, stop the compressor and pump warm water in until specimen’s temperature reaches 20 degrees, and it was the end of the first cycle
- The process would repeat 50 times

To be more specific, there were two phases per testing cycle: cooling and warming. Each cycle of the test started from +20 degrees to -20 degrees, and from -20 degrees back to +20 degrees, that is why it is called a cycle.

The main purpose of this project was to test the endurance of building material such as concrete / cement in the severe impact of weather: very low to high temperatures.

To ensure the accuracy of the conclusions made after the test, the testing cycle must be repeated at least 50 times. This led to the first concern of the durability of the machine (energy, safety, quality of each test).

Figure 2. Working process by flowchart (chart created by the author)

2.3 Preparation and list of components

Table 1. Components

Component	Quantity
PLC controller (Siemens 7 1200)	1
HMI panel	1
Cooling system (compressor)	1
Filling pipe	1
Draining pipe	1
Overflow pipe	1
Solenoid valve / magnetic valve	2
Motor fans	2
Radiator	2
Thermocouple sensor	1
Relay	2

a) PLC controller

In this project, PLC Siemens 7 1200 programmable controller was used to control the thermal cycling testing chamber as can be seen in Table 1.

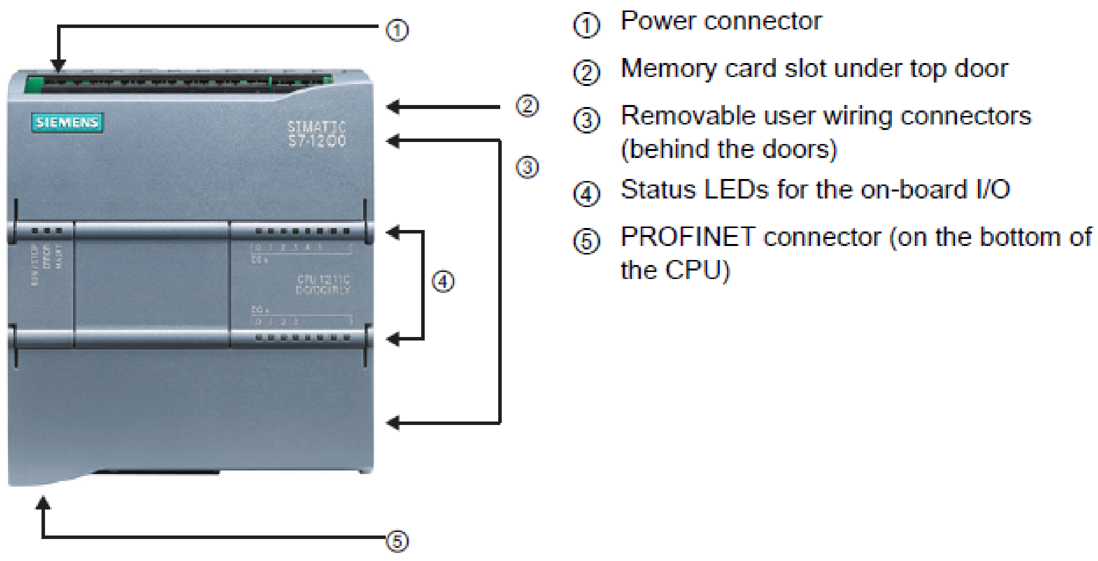


Figure 3. Outline of PLC Siemens 7 1200 (picture taken from page 19 S7-1200 System Manual)

Each PLC has its own input and output model. For the thermal cycling testing chamber, input signals were collected mostly from HMI panel (temperature range and amount of cycles) and from thermocouple sensor (to get current temperature of specimen).

If inputs were used to collect the data to help the PLC to analysis which state it should be in, outputs were used to execute the orders PLC controller has been made to reach another step and continue the whole process.

The system has totally four inputs and several outputs, which are:

- hot water filling valve
- another solenoid valve to ensure the tank out of water between stage 1 (20 degrees) and stage 2 (-20 degrees)
- draining valve
- safety valve
- relays to activate / inactivate the compressor (cooling system)
- motor fans

Moreover, to secure output wires, this project used two terminal blocks.

Terminal block type using here is single feed through which can connect wire to wire. One input has one output, they are connected to each other and connect with their housing.

Output signals were transmitted from PLC through terminal block 1 and then go directly to instruments or to terminal block 2.

In this case, only output signals used to control the compressor went directly from terminal block 1. The other output signals went to terminal block 2 and from terminal block 2 to each instrument which was used to control the warming system.

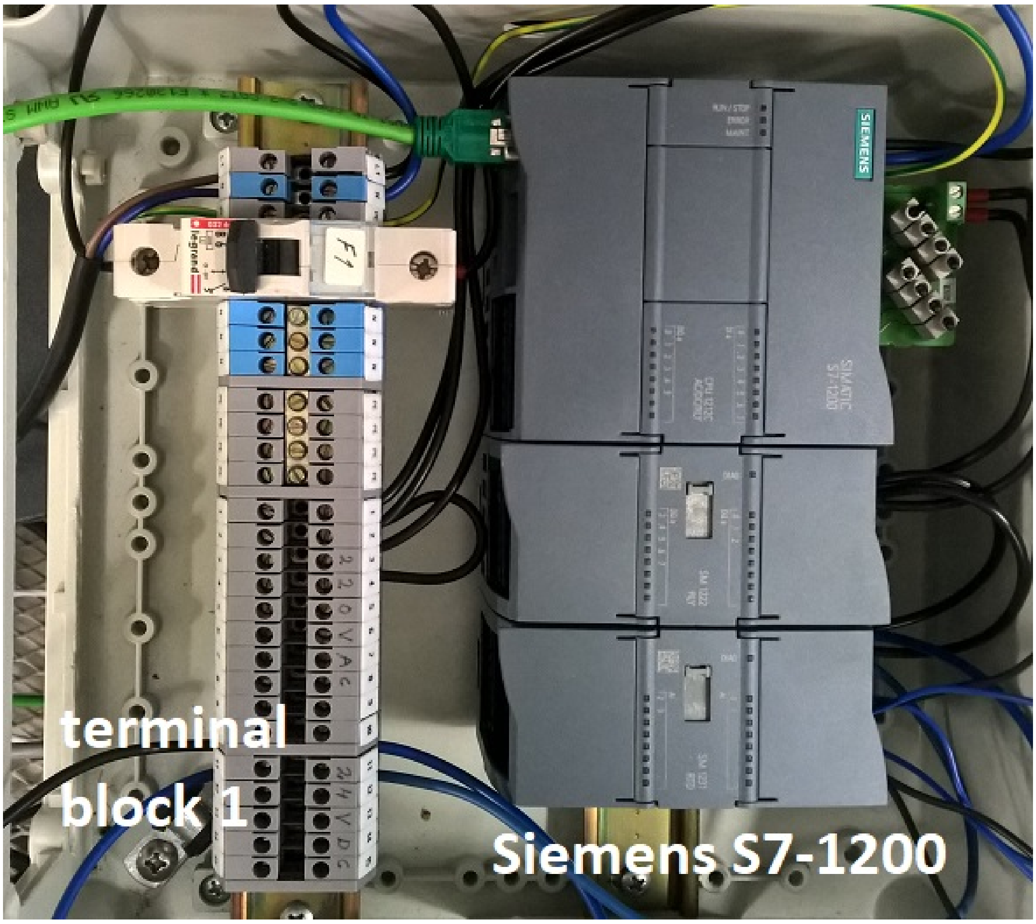


Figure 4. Terminal block 1 and PLC controller (photograph taken by the author)

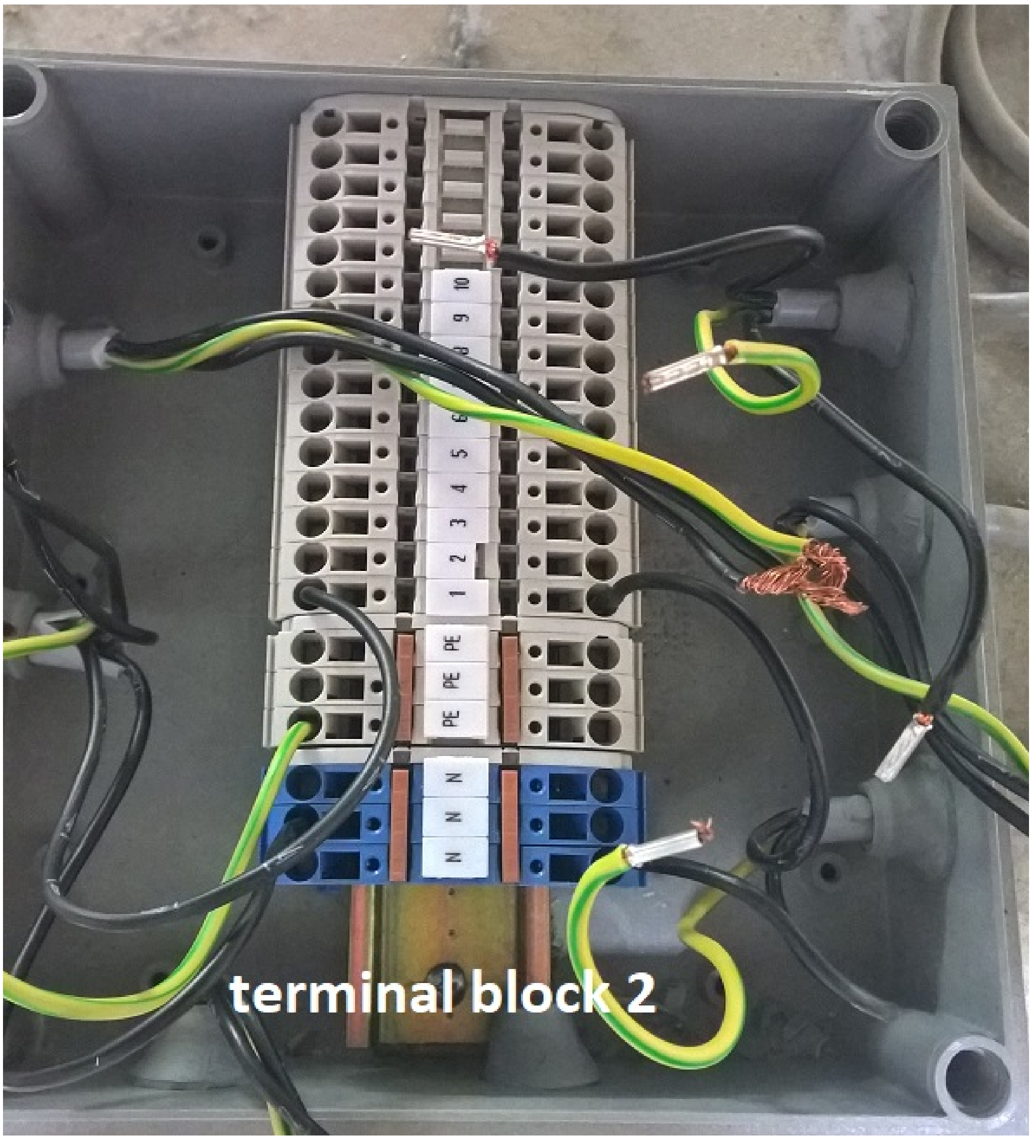


Figure 5. Terminal block 2 (photograph taken by the author)

On Figure 5, the terminal block 2 can be seen which carried an output signal from the PLC control system to the instruments which were using to control the warming system. They are filling valve, draining valve and safety valves.

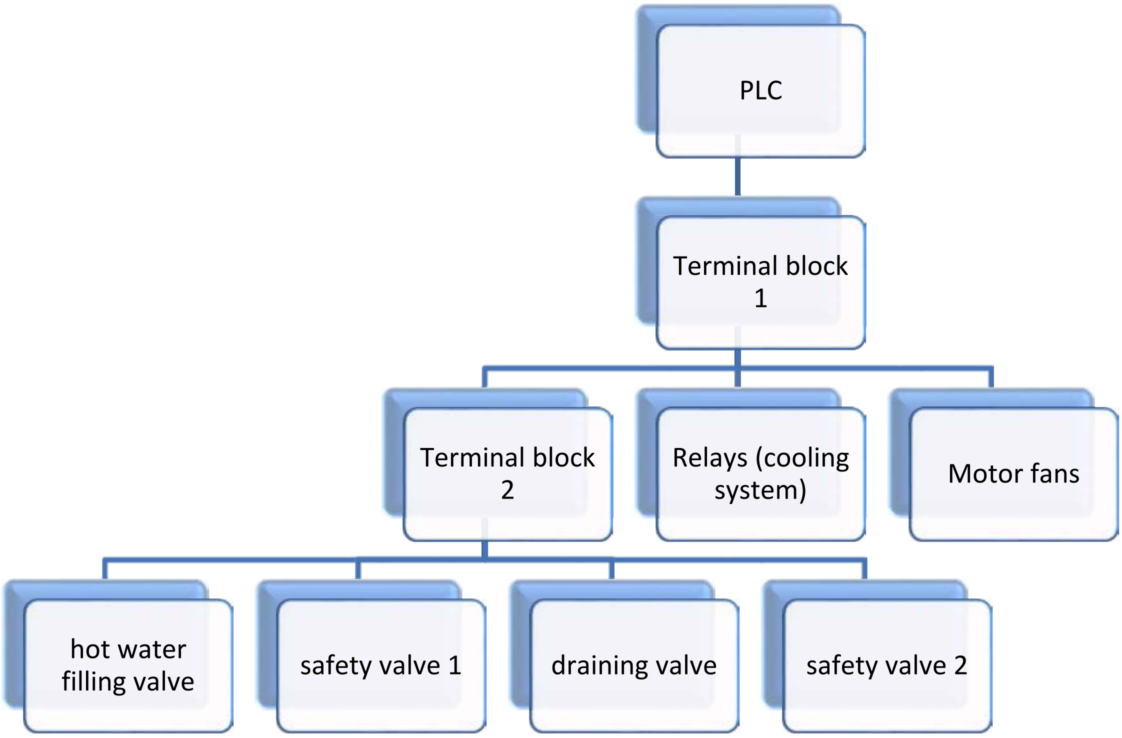


Figure 6. Connection between PLC and instruments

b) HMI panel

The HMI panel is a human machine interface which will let users to adjust the number of cycles and set the temperature set-points for the testing.

The HMI panel was directly connected to the PLC; therefore, users can easily control the testing operation using this HMI panel. For example, the next step after connecting the machine to power supply was to start the test. Basically, all the steps could be handled using this HMI panel such as START, RUN, STOP and choose the desire testing patterns (number of cycles, lowest temperature, highest temperature).

During the test, the HMI panel showed the current state with the current temperature and the real-time chart of current temperature for users to observe the testing process. If there was something wrong with the system, a message appeared with the information about the issue and a guide on how to resolve it.

Once the test was done, there was a save button to save the result document to be used as references for the future.

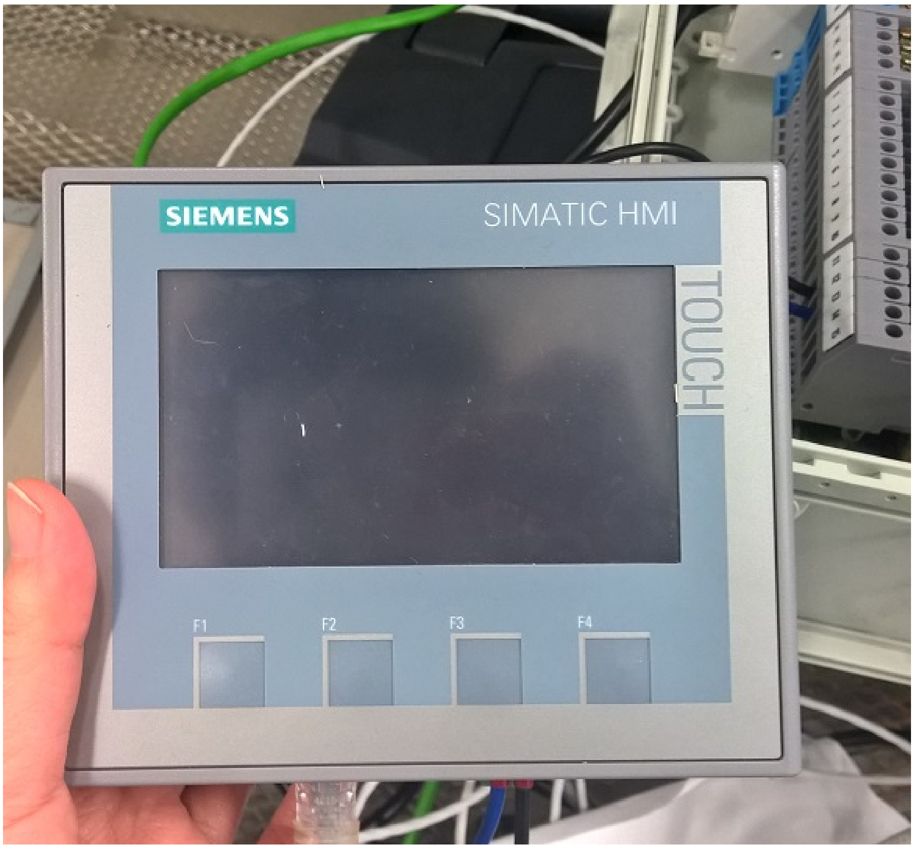


Figure 7. HMI Panel used in this project (photograph taken by the author)

The HMI panel used in this project was the KTP 400 Basic PN included in PLC Siemens 7 1200 product package as illustrated in Figure 7, the specifications of this human machine interface are as follows:

- 4" touch screen with 4 tactile keys
- Mono (STN, gray scale)
- 76.79 mm x 57.59 mm (3.8") Portrait or landscape
- Resolution: 320 x 240
- 250 tags
- 50 process screens
- 200 alarms
- 25 curves
- 40 KB recipe memory
- 5 recipes, 20 data records, 20 entries

c) Cooling system

A refrigeration system was used to cool or reduce the temperature inside the chamber as the cooling system. Basically, the main component of this cooling system was the compressor, which produced cool air and let it flow to the chamber using radiators and motor fans.

Cool air flowed constantly to the chamber until the specimen reached its desired temperature. In this case, it was -20 degrees for the lowest temperature set point.

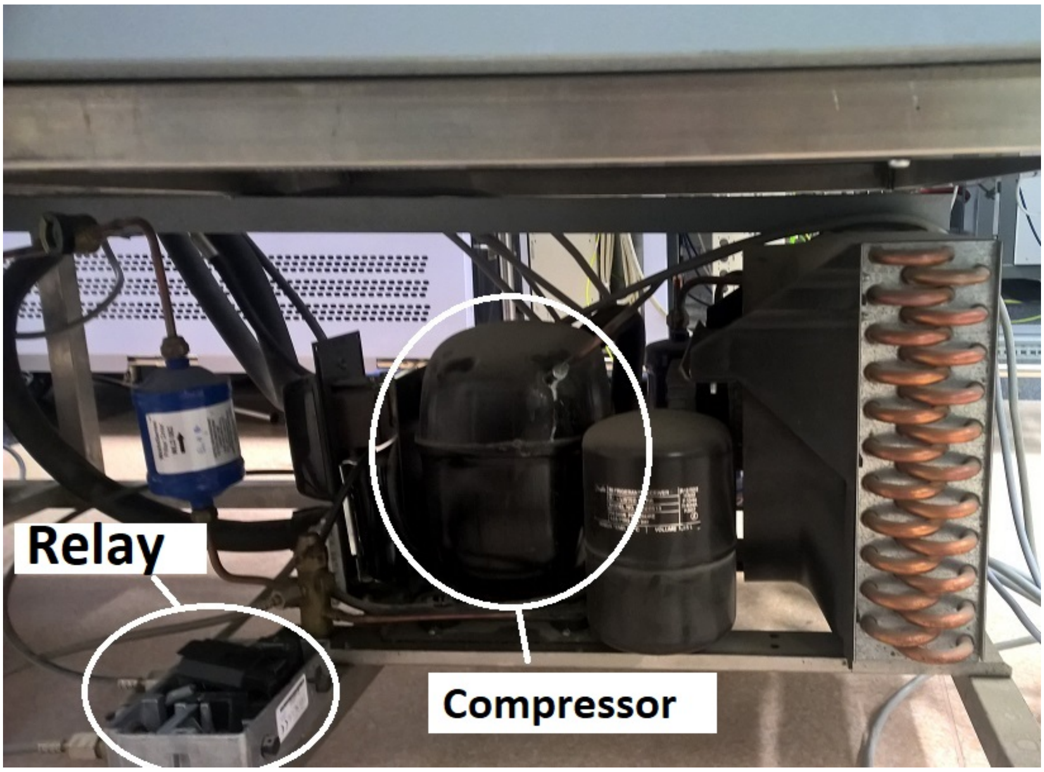


Figure 8. Cooling system (photograph taken by the author)

On Figure 8, we can see the relay on the left which was used to control the compressor. When testing state changed into the cooling stage, relay was closed, cool air generated by compressor permeated and speeded into the chamber by using motor fans and radiators.

Respectively, the relay was opened, the radiators and fans stopped running, and the operation turned to warming stage.

d) Filling pipe

The filling pipe was connected to the water supply and controlled by a hot water filling valve. When the valve was opened, and hot water from the water supply flowed into the chamber.

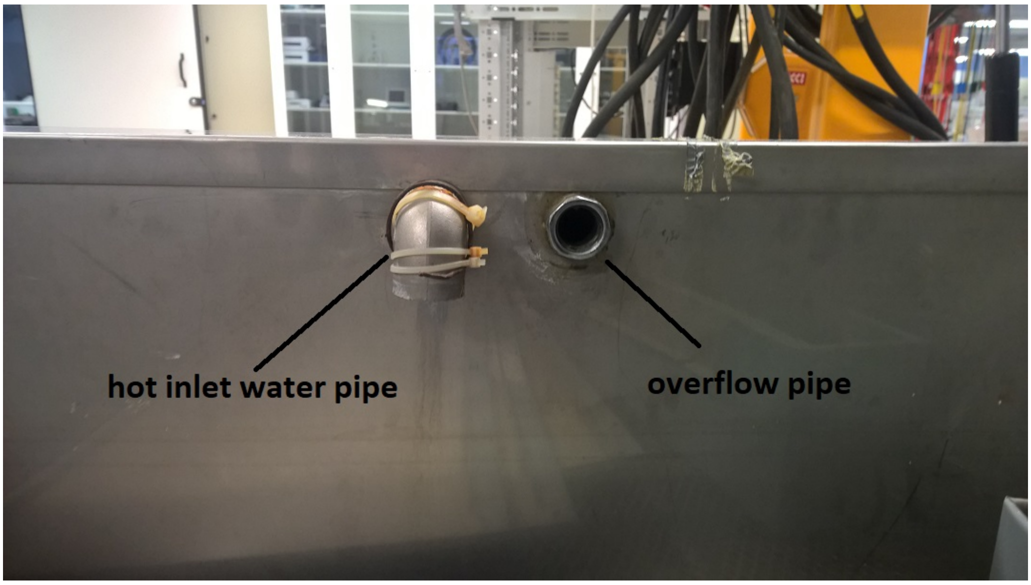


Figure 9. Hot inlet water pipe and overflow pipe (photograph taken by the author)

e) Draining pipe

Basic draining pipe controlled by draining valve. When valve was closed, water would drain out of the chamber.

Figure 10. Draining pipe (photograph taken by the author)

This draining pipe should be connected to the wasting pipe or placed near the floor drain.

f) Overflow pipe

When water inside the chamber overflowed, water would go through this pipe to the outside environment. This pipe relates to the draining pipe, but the junction was placed at the point which is after the draining valve, so it was free flow which is not controlled by any valve.

Figure 11. Hot inlet water pipe and overflow pipe looks from the outside (photograph taken by the author)

g) Solenoid valve / Magnetic valve

These magnetic valves are two ways valves which were controlled by the PLC controller. They were in normally close state. If there was a signal from PLC controller, valve would change its state to open to let water flow in or out of the chamber.

Figure 12. Old valve which needs to replace (photograph taken by the author)

Figure 13. New magnetic valve (photograph taken by the author)

h) Motor fans

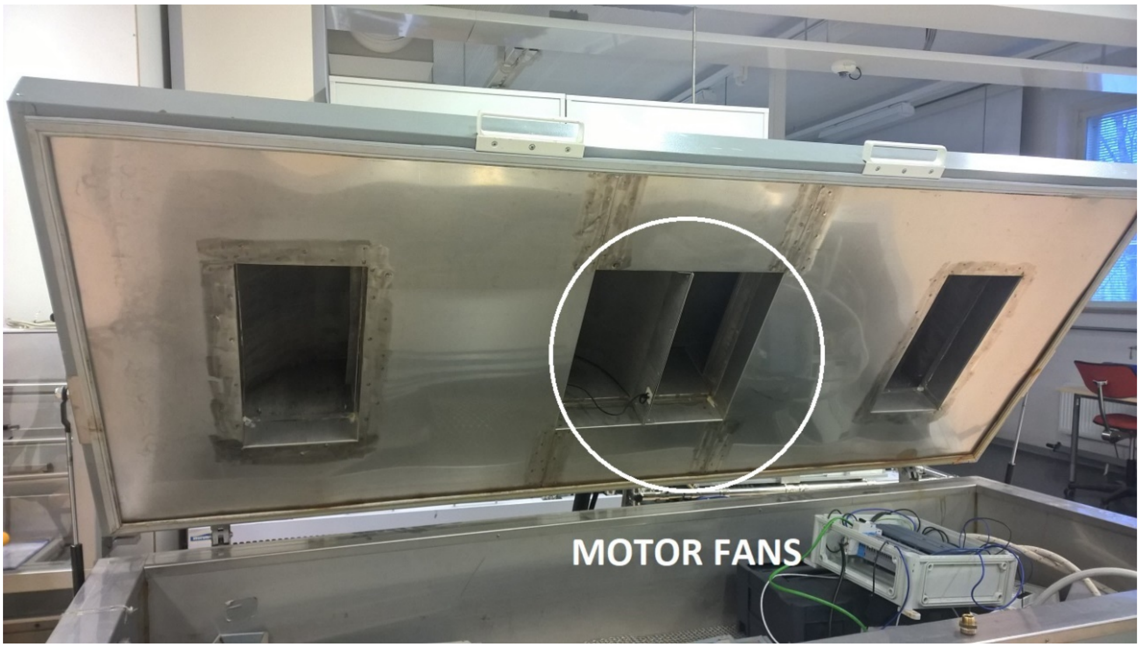


Figure 14. Motor fans (photograph taken by the author)

Fans are placed inside the chamber’s door, which is controlled by the relays. When contact was closed, cool air flown into the chamber by using these motor fans and the radiator.

i) Radiator

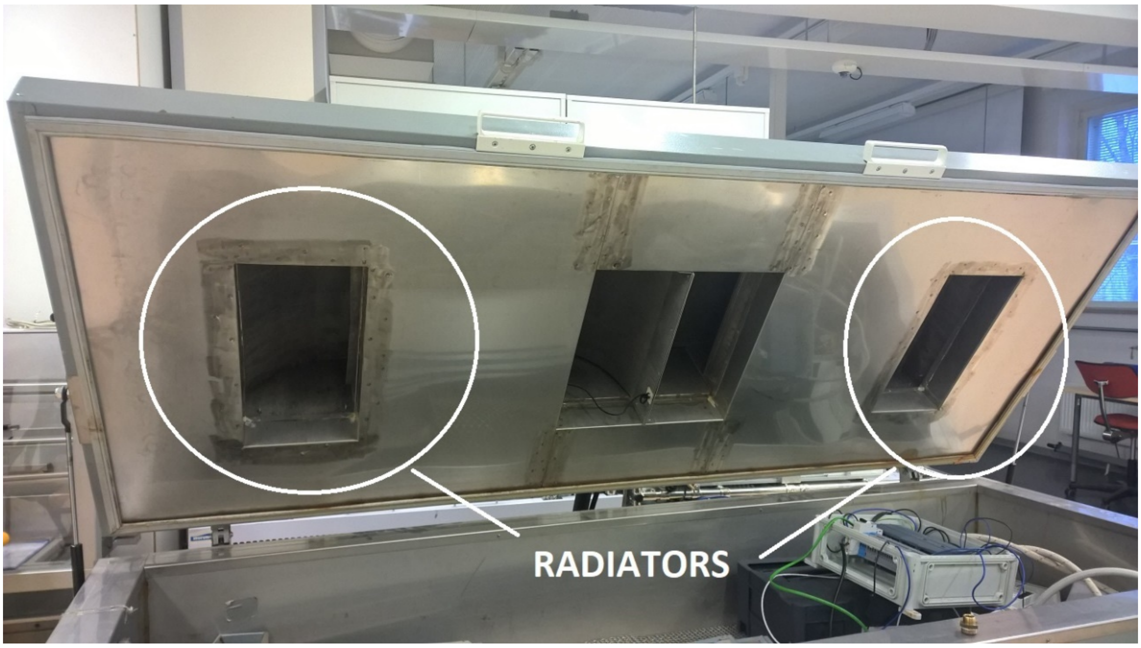


Figure 15. Radiators (photograph taken by the author)

There are two radiators were also placed inside the chamber’s door, one was on the left and one was on the right of the motor fans. Radiator is the heat exchange panel used to transfer thermal energy.

j) Thermocouple sensor

Thermocouple sensor is used to measure the temperature of the specimen. It is a two dissimilar metal wires with 100 metres length. One end of this thermocouple sensor would be drilled into the specimen and the other end connect to SM 1231 Thermocouple module within PLC controller.

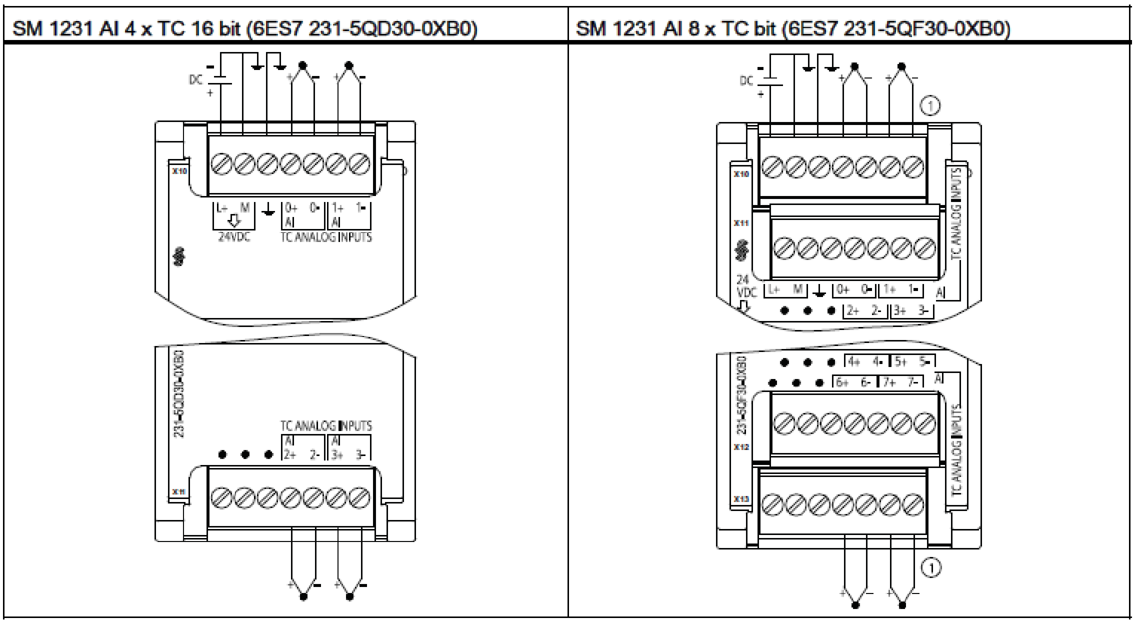


Figure 16. Wiring diagrams for the thermocouple SMs (picture taken from S7-1200 System Manual)

k) Relay

Relay is a built-in element of the Siemens 7 1200, which is used to control the flow of cool air with ON and OFF state.

When cooling state is activated, a signal would be sent to relay and the relay is closed to turn the motor fans and radiators on and let cool air from compressor flow into testing chamber.

There are still some other components to make this thermal cycling testing chamber, but they are not considered main components. Mostly they were integrated into the machine for safety purpose, for example, to check pump pressure. Therefore, to save reader from inconsistency, those components have been ignored.

2.4 Connection diagram

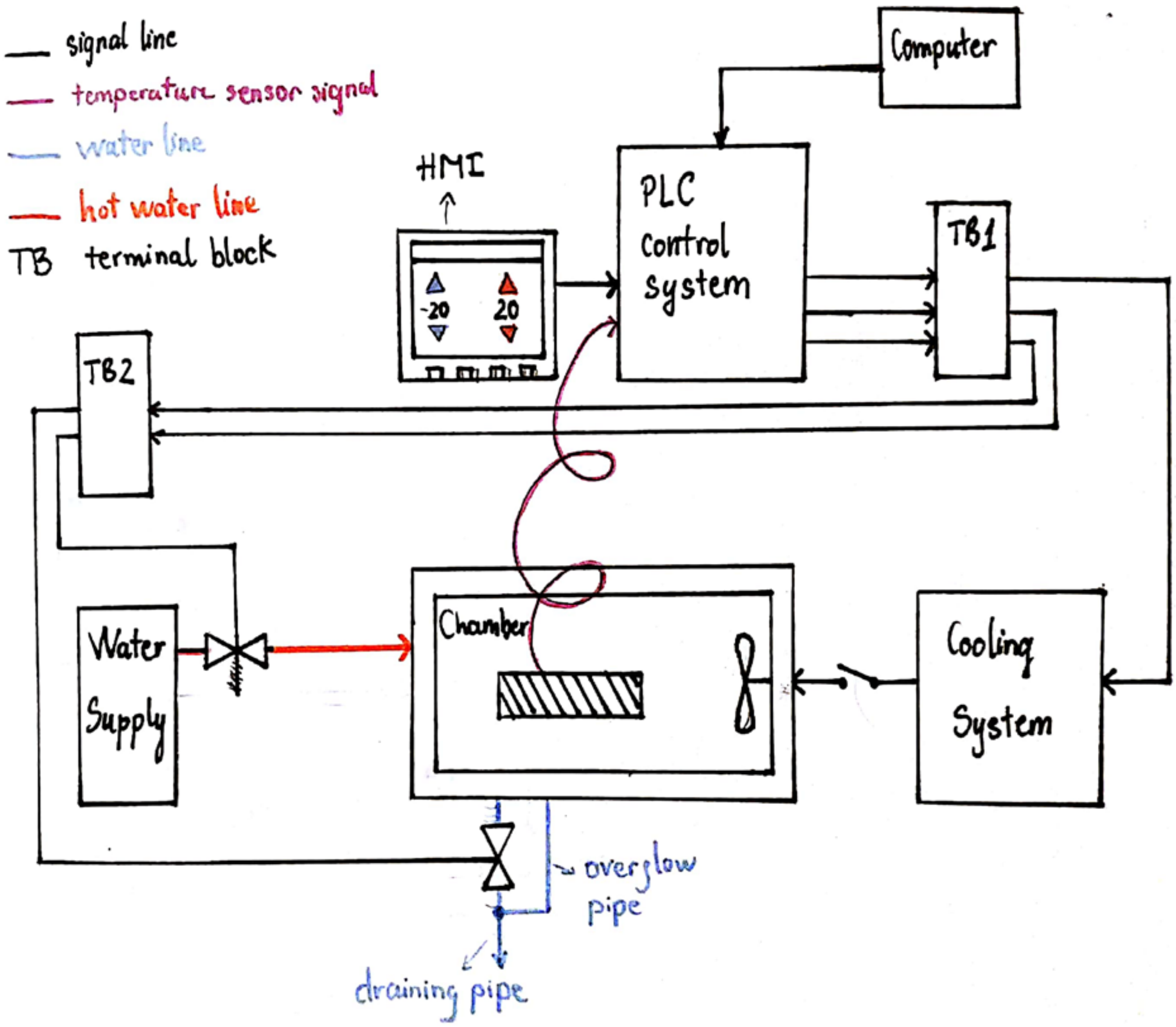


Figure 17. Thermal cycling testing machine connection diagram (diagram drawn by the author)

3 THERMAL CYCLING TESTING USER MANUAL

After completing this manual, readers will be able to:

- Familiarize with thermal cycling testing chamber
- Use the machine independently and confidently with error free
- Know how to maintain the machine and keep it in good condition
- Solve problem if something happens

3.1 Exterior Design

This thermal cycling testing chamber has a rectangular form built with four standard wheels for it easy to mobilize and the control system was placed under the chamber. It has the specifications as follow:

Dimensions: 215 cm W × 85 cm H × 30 cm D
Insulation: 15 cm thick
Material: stainless steel sheet

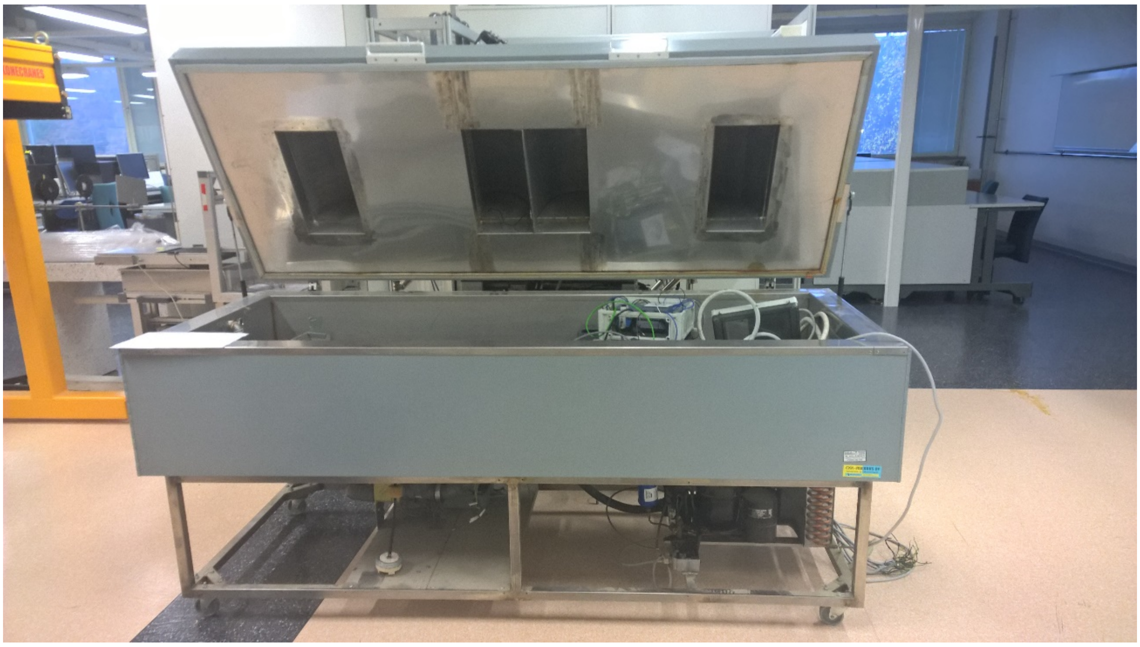


Figure 18. Exterior design of thermal cycling testing chamber (photograph taken by the author)

3.2 Installation

3.2.1 Control system installation

Control system contains a PLC Siemens S7-1200, a HMI panel and two terminal blocks. Functional program has been stored in PLC memory and it has been programmed to test the endurance of specimen by changing the state of temperature from lowest point to highest point and then to lowest point again, until it reaches the desire number of cycles depend upon the need of users.

A connection has been made between CPU and HMI panel and the S7-1200 has made this an easy task with several communications between CPU and HMI offer. Communication can be made via three ways, which are PROFINET, PROFINET RT IO Controller and PROFIBUS. Each way of communication has its own purpose and it all depends upon user's need.

Required steps to connect CPU to HMI:

- Configure the PROFINET port of the CPU
- Setup and configure HMI
- Use Ethernet cable to connect CPU with HMI via PROFINET port
- Test the network

3.2.2 Cooling system installation

Since the thermal cycling testing chamber needed cool air (heat removal) to achieve state two of the testing process, in this project, cooling system was used the refrigeration system to bring down the temperature inside the chamber.

The most important part of the cooling system was the compressor, it helped to turn oil to cool air using various procedures. Air circulation would be provided by fans driven by motor which draws air from the working space, blows it over the radiators to maintain uniform temperature throughout the chamber. To keep the flow of cool air inside the chamber, two radiators placed in two sides of the chamber's door and two motor fans placed in the middle of the chamber's door were used to achieve that purpose. Those radiators and motor fans were already installed to the cooling system.

This system controlled by built-in relay outputs of Siemens 7 1200 which is ON and OFF type. When the system is ON, relays are closed, radiators and fans would be activated to flow cool air inside the chamber.

3.2.3 Warming system installation

When cooling system had only ON and OFF state to control the motor fans and radiators, warming system had more to handle with.

Firstly, connection must be made between water supply to filling valve.

Secondly, connection must be made between PLC output module to filling valve as well. Filling valve would receive signal from PLC to control the water flow, meaning, to open and close to let water from water supply flow inside the chamber through filling pipe.

Thirdly, connection must be made between PLC output module to draining valve. Draining valve would receive signal from PLC to control the water flow to go out of the chamber. Draining valve should be also connected to the water waste pipe or placed near the draining floor to prevent flooding.

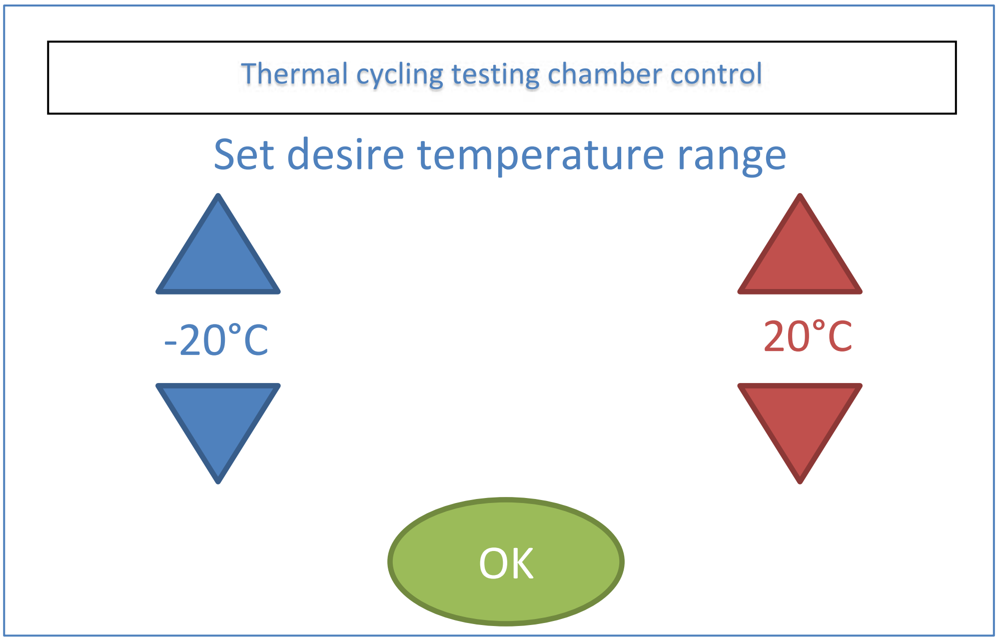
Fourthly, connection must be made to connect overflow pipe with draining pipe for it to implement its duty.

3.3 **Setup**

3.3.1 Setpoints setup

Using HMI panel, users can adjust the desire temperature range to meet the testing purpose by pressing action buttons on the screen. On each interface screen, there was a headline of text to guide and show which step was currently in charge.

On the initial screen:



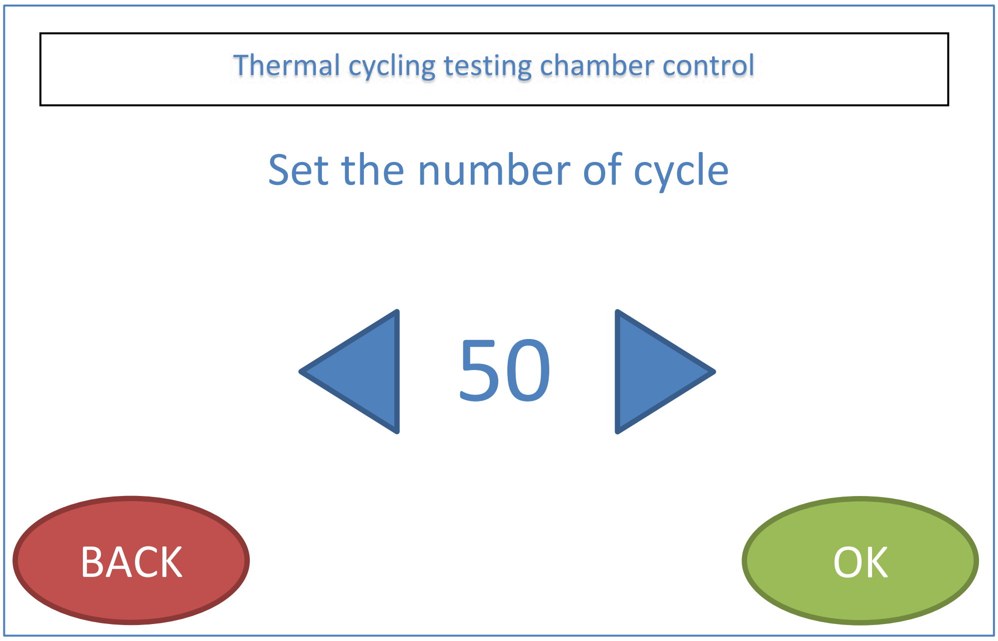
The headline text is "Set desire temperature range"

The default temperature range is from -20 degrees to +20 degrees. To change the temperature range, press upward arrow or downward arrow until reaches the desire range.

The arrow button will add one or minus one for each pressing time.

Press "OK" to turn to the next screen.

On second screen:

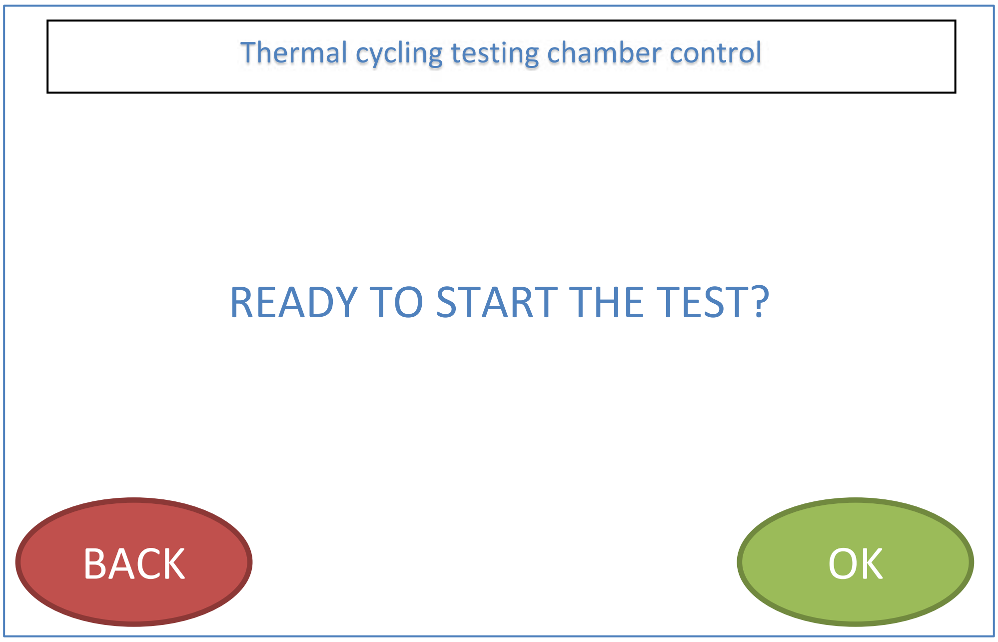


This screen's headline text is "Set the number of cycle". To change the number of cycle, press left or right arrow to minus or add 5 times for each press.

When everything looks ok, press "OK" to continue to the next screen. If still want to change the desire temperature range, press "BACK" to go back to the previous screen.

The default number of cycle is 50.

On third screen:



Headline text: “Ready to start the test?”

Press “OK” if ready and the test will be run automatically, the screen will also change to the next phrase. If want to adjust any value, press “BACK” until land the desire screen and adjust the value then press “OK” to continue.

3.3.2 Wiring specimen

Specimen connected with thermocouple sensor by the metal end of that wire. In some cases, thermocouple sensor must be embedded (cast or drilled) into the specimen to ensure the accuracy of the outputs.

3.4 **Operations**

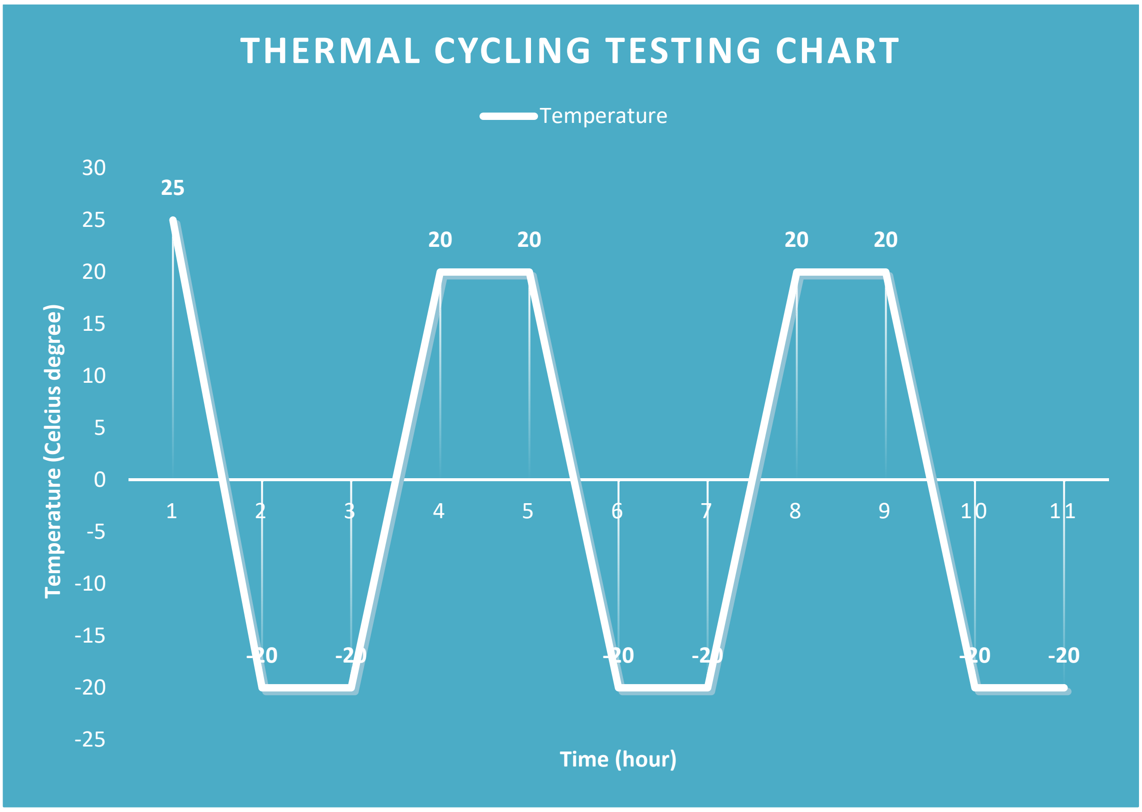


Figure 20. Thermal cycling testing chart (chart created by the author using Microsoft Excel)

Figure 20 illustrates the expected outcome of the test with two full cycles.

Started from room temperature (normally +25 degrees), first setpoint is the lowest temperature (-20 degrees), when -20 degrees has been reached, the cooling system has been stopped and it changed to warming part which will open filling valve to let warm water flowing into the chamber. When 20 degrees has been reached, close filling valve, open draining valve to let water out of the chamber. Before turn straight to cooling part, an extra step has taken into use to ensure the chamber is completely dry before cool air flowing in.

From the dimension of the chamber and radius of the draining valve, the flow rate could be calculated and the time it might take to let water completely out of the chamber by this single equation:

$$Q = \frac{V}{t}$$

In which:

Q is the flow rate
V is the volume of the tank
t is the total time it takes for all liquid flow out of tank

From that equation, the total time which will take for liquid flow out of the chamber would be easily to calculate by $t = \frac{V}{Q}$

There left two unknown elements which are V and Q. From the dimensions of the chamber, we can calculate V by

$$V = W\ x\ H\ x\ D = 2{,}15\ x\ 0{,}85\ x\ 0{,}3 = 0{,}54825\ m^3$$

And the flow rate can be calculated by another formula using the cross-sectional area of the pipe which we can also calculate by using the radius of the cross-sectional area of the pipe.

Here we have: $A = \pi r^2 = \pi\ x\ 0{,}03^2 = 0{,}0009\pi\ m^2$

Then $Q = A\sqrt{2gh} = 0{,}0009\pi\ x\ \sqrt{2\ x\ 9.8\ x\ 0{,}3} = 0{,}0068\ m^2/s$

Hence, $t = \frac{V}{Q} = \frac{0{,}54825\ m^3}{0{,}0068\ m^2/s} \approx 80{,}625\ s$

The answer is approximately 80 seconds to achieve this step and for the safety reason, in programming part, author used 100 seconds in the delay timer for this period.

Next, when reaches -20 degrees again, stop the cooling system and this is the end of first cycle. The test will repeat 50 times corresponding to 50 cycles.

3.4.1 Warm-up

For safety reason, if the chosen testing pattern set for cooling state the first state, it takes two hours before starting the test. Because similarly to refrigeration system, two hours is the reasonable amount of time.

3.4.2 Test operation

During the test, on HMI panel, there is a real-time chart which is showing the current state of the test, and it keep updating every five minutes. There is also the current temperature.

3.4.3 End of test automation

A notification would be appearing on HMI panel and there were also two options which user can take benefit from.

Option 1: to save all the testing data (document)
Option 2: run the test again, and the system will keep all the testing pattern which user doesn’t need to set up again for the second time.

3.5 **Maintenance**

Since this thermal cycling testing chamber has been made to test the endurance of house building materials through the changes of environment, the endurance of the machine itself also be considered significant.

Testing would be made by at least 50 times of temperature cycle, with water and air come in and out constantly, which will lead to chamber damages. Moreover, the testing duration might last for a long time, which can lead to components damages as well, that is the reason why maintenance is one of the most crucial part of the machine.

For this thermal cycling testing chamber, maintenance should only be done by qualified engineers or technicians. Rapid changes of temperature, long period of test, high voltage and mechanical system are all contain the potential for injury or even death.

3.5.1 List of maintenance

Below is the table of items which need to be maintained and the time when to operate that. This table was made based on the main function of the thermal cycling testing chamber.

Item	How often
Valves	Once per year
Pipes	Once per year
Wire covers	Twice per year
Chamber’s interior	Once per year
Relay	Twice per year
Wire connections	Twice per year
Compressor oil level	Twice per year
Fans operation	Twice per year
Radiator	Twice per year

3.5.2 Preventive maintenance

To keep this machine in good condition and prevent accident during the test, maintenance should be operated with carefulness and regularly.

For valves:

There are several things to check for valves. There should be no mineral build up inside the valve, because it could alternate the flow rate which might decrease the accuracy of the test. There should be no leakages internal or external. It should be operating when power is ON.

For pipes:

There should be no leakage and the connection with valves should be intact.

For wire covers:

Wire covers should be always in good condition.

For chamber interior:

There should be no leakage anywhere. Because the chamber is the biggest part of this machine, so even small leakage could lead to unwanted result.

For relay:

Relay coils usually consist of a single coil. If a relay fails to operate, the coil should be tested for open circuit, short circuit, or short to ground. An open coil is a common cause of relay failure.

Wire connections:

Check for wires connections in terminal blocks and PLC output gates. All connections should be intact.

For compressor oil level:

Do not remove or add oil unless there is a leakage in the system. Oil level should be check through compressor sight glass and it should always be more than a half.

For fans operations:

Fans should always be dust-free, otherwise, the testing might be affected.

For radiators:

Treat the radiators the same way as motor fans for they shared the same position and have similar material.

3.5.3 Preventive maintenance check list

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Valves					x							
Pipes					x							
Wire covers			x						x			
Chamber’s interior					x							
Relay			x						x			
Wire connections			x						x			
Compressor oil level			x						x			
Fan operations			x						x			

Radiators			x						x			

It was recommended that user should keep this check list nearby the machine to use as references in the future.

3.6 **Safety**

Make sure that no harmful materials allow to place inside the chamber.

Materials that considered to be harmful are:

- Explosive materials: such as nitroglycol, nitrobenzene, etc.
- Combustible materials: such as metal lithium, phosphor sulphide, oxides, etc.

Best suitable materials for this thermal cycling testing chamber are construction materials such as concrete, wood, etc.

Check electrical connection before use.

Before operate maintenance, make sure that power has been disconnected and all system reached its end phase and all freeze.

Machine must be grounded before use, put in stable ground.

Place in where temperature always in the range from 10 to 25 degrees to prevent temperature sensor from providing incorrect value.

Do not open the chamber’s door during testing time or immediately after finishing the test.

Always use gloves when remove specimens out of the chamber to prevent frostbite or burn although the recommendation usage temperature range is -20 degrees to +20 degrees, but users might need to expand the range.

Power supply must be turn on at least 2 hours before use, because one of the main parts of this thermal cycling testing chamber is the cooling system which is using similar structure as the refrigerator.

4 CONCLUSION

It is important to acknowledge the significance of the testing machine in general for better understand this thermal cycling testing machine. Although testing might take effort and patience to reach the goal, what it offers is worth it, it helps to save money and energy as well as the fact that it helps increase the reliability of the products.

This thesis hopefully brought the clarity out of the complexity the machine itself would make. It might be a helpful source for those who need a complete foundation to build and update a thermal cycling testing machine and bring it to the next level.

Readers might find it necessary after went through every line of this material since the idea about all the inputs should be collected in more comprehensible way will add a huge amount of weights into the renovation bank, although it would be required more work from the engineers.

To be more specific, regardless the requirement of this project was only make the cycles operate from -20 degrees to +20 degrees and back, plenty of space was left to update the machine with more flexibility and effortlessness to approach the end user by presenting the HMI usage to collect input data instead of hard-coding the program. This small gesture would make a considerable improvement to the cycling testing machine.

The main objective of the project was to ensure that all the components still worked as the first version was built quite a long time ago, and some of the given components remained unknown. Safety was also one of the most challenging aspects because all the previous documents of this machine were completely missing, which made it difficult to analyse and integrate some of the safety parts into the program.

For a future implementation, the second terminal block should be replaced by a new one to make the wire connections easy to be handled and maintained.

Even though the testing operation failed to be executed due to one component missing and the connections required a qualified electrician to approve the connections beforehand; the user manual was still beneficial as a source of idea to improve the functions of the machine.

5 SUMMARY

This thesis has described the fundamentals of a thermal cycling testing chamber as well as how it works, how to use it and how to maintain it in an easy-to-follow writing structure.

The definitions and examples of different kinds of thermal testing procedures and the testing method were mentioned at the very beginning of the thesis, for it required transparent and straightforward knowledge before drilling down to more specific details and functionalities of the machine. Moreover, the user manual was one of the main parts of this project, the importance of it was also brought out to be discussed here in the first part of this thesis.

The second chapter introduced the thermal cycling testing machine by indicating its purpose, the main idea of how it would work with a clear-cut working process by bullet points as well as flow chart. Following that, for the user manual to be more transparent and effective, the machine, which was the primary focus of the project, was separated into many small components and each of them had its own function and duty to make the whole system work as seamlessly as expected. After all the separated fragments were introduced, a question was raised about the integrations and the relationships between these fragments. That led to the last topic of the second chapter that described the connection between all the components and presented with a hand-drawn diagram, which was simple yet easy to approach and comprehend.

Everything led to the largest and most crucial part of this thesis, the user manual. According to the significance of the user manual itself, six sub-chapters were introduced in this one big section, to help increase the comprehension. From the top down, the user manual helps readers walk from the exterior design of the machine, to installation, setup, operations, maintenance and safety. The user manual covers nearly all the aspects that are required from a basic machine user manual.

After completing this thesis, significant in-depth knowledge has been gained by the author from completely rudimentary definitions to a higher notion which might take days to comprehend thoroughly. Mostly, the knowledge was related to the components and the usage of each as well as the main purpose it provided to the machine, which took time to examine and filter the data to make the outcome the most useful source of information.

The project started by analysing the machine from inside to outside, then from the largest part to the smallest one, which led to many fields of study that needed to be considered. One of these was examining testing methods and thermal testing to gain a strong statement about the idea of the operations of this machine, the other was about how to deliver a clear and helpful user manual, from which users can easily find information without any confusion, the last one was to make a program to control the whole system with effectiveness.

6 REFERENCES AND APPENDICES

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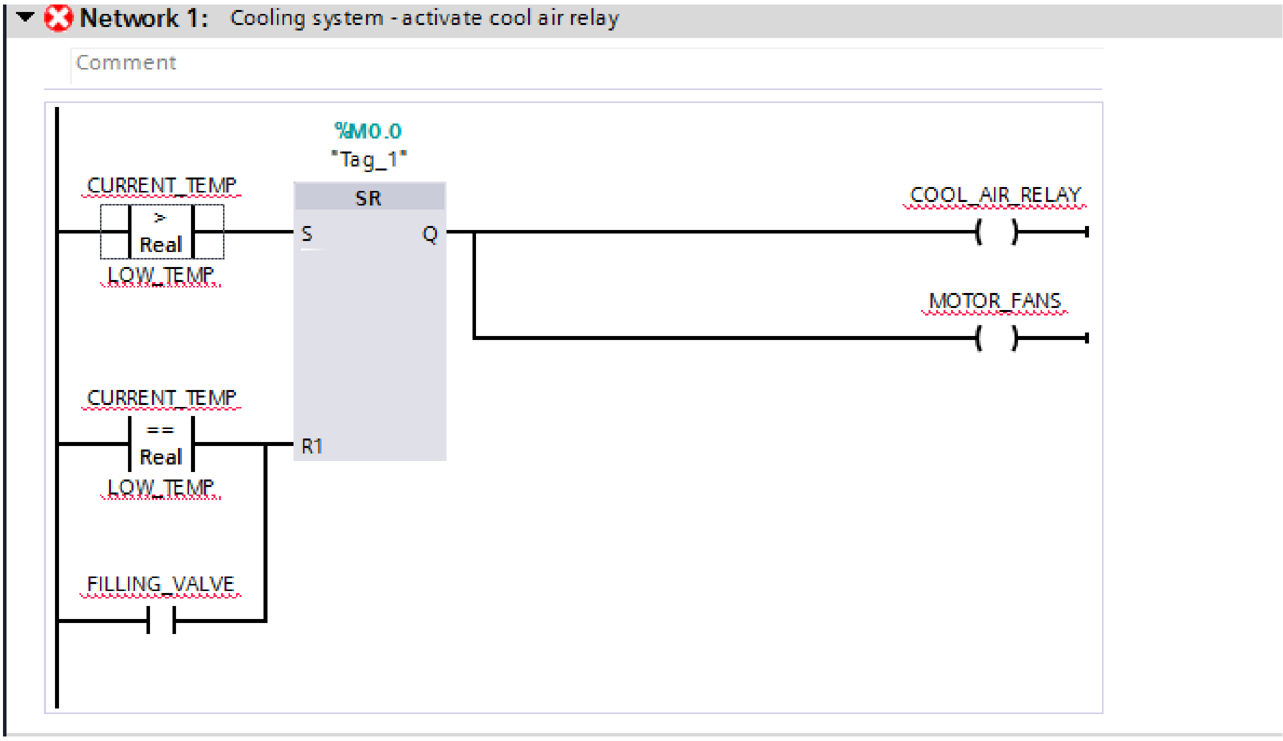
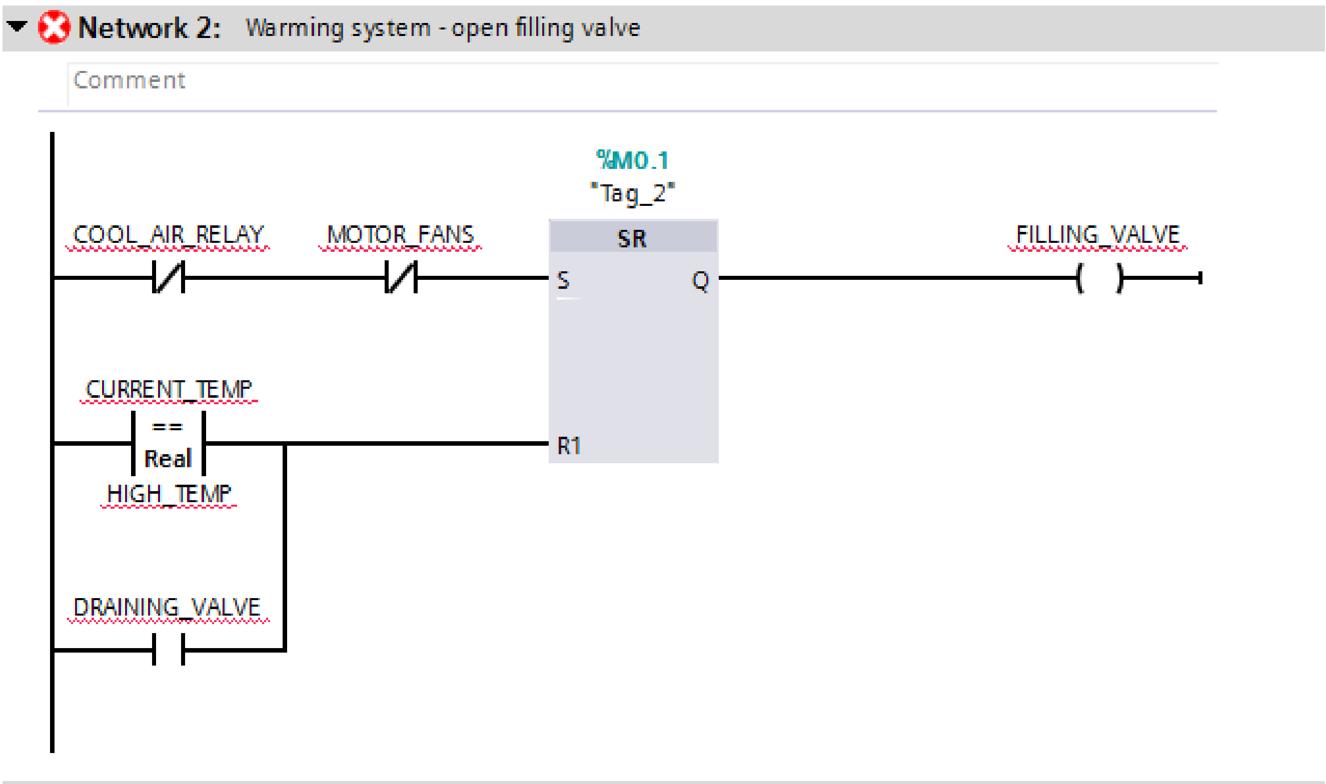
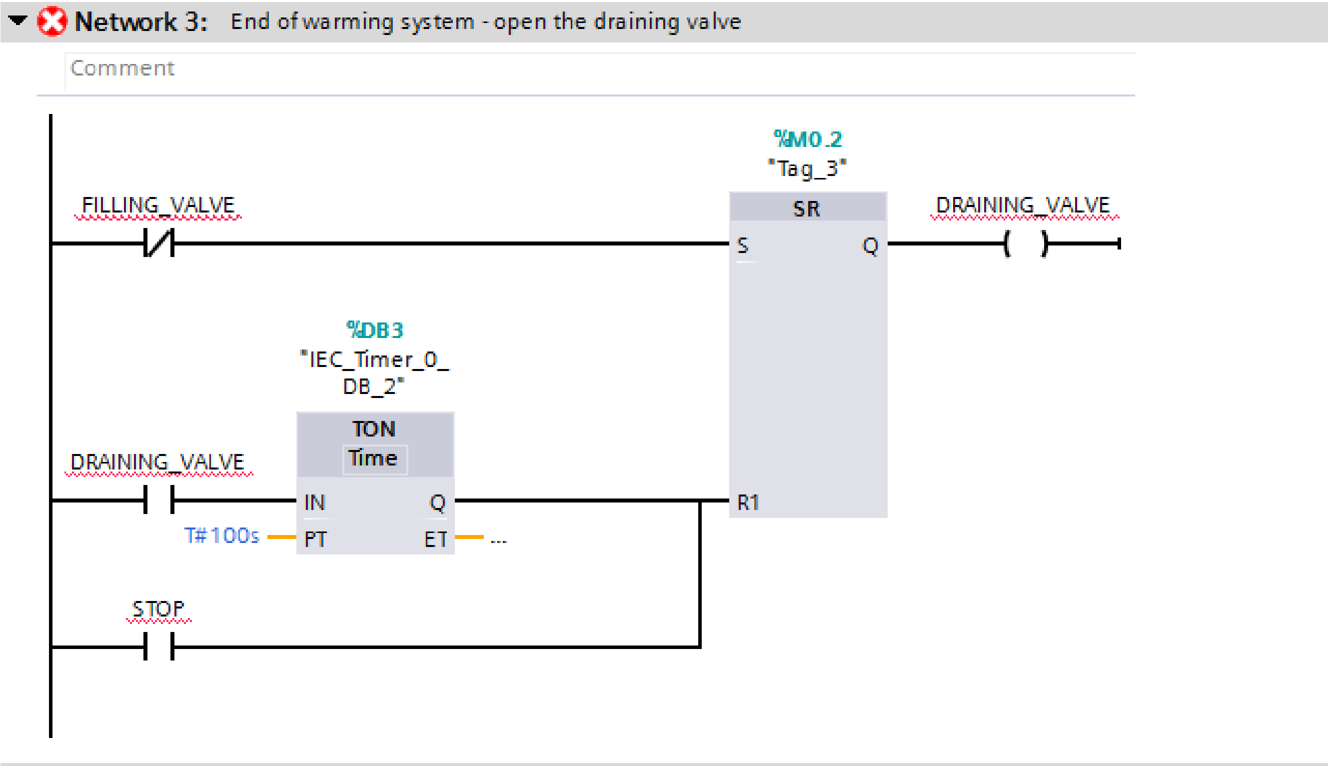
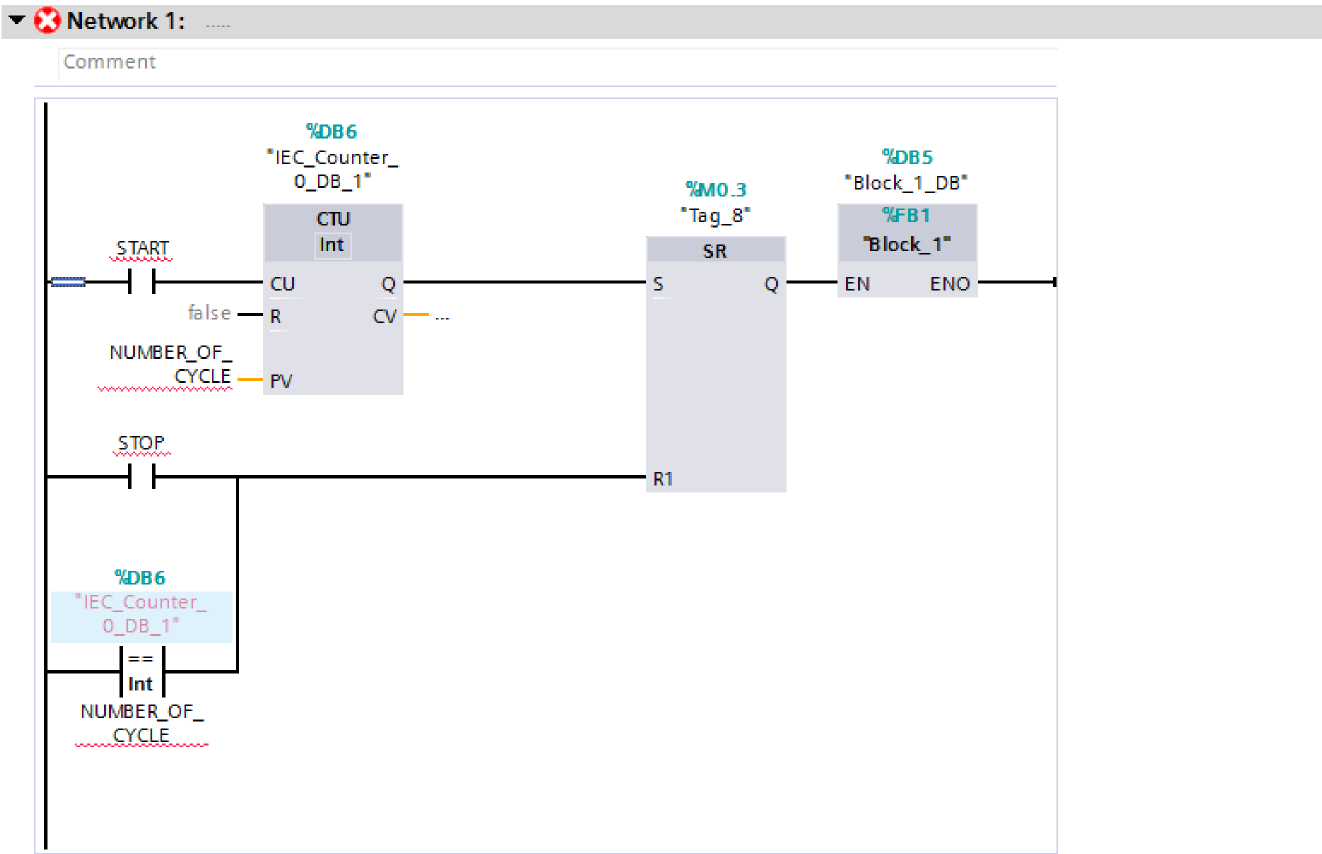
Appendix 1

LADDER DIAGRAM CREATED WITH TIA PORTAL SOFTWARE






Network 3: End of warming system - open the draining valve
Comment
%M0.2
"Tag_3"
SR
S
Q
R1
FILLING_VALVE
DRAINING_VALVE
%DB3
"IEC_Timer_0_
DB_2"
TON
Time
IN
Q
PT
ET
T#100s
...
DRAINING_VALVE
STOP


Network 1: .....
Comment
%DB6
"IEC_Counter_
0_DB_1"
CTU
Int
CU
Q
R
CV
PV
START
false
...
NUMBER_OF_
CYCLE
%M0.3
"Tag_8"
SR
S
Q
R1
%DB5
"Block_1_DB"
%FB1
"Block_1"
EN
ENO
STOP
%DB6
"IEC_Counter_
0_DB_1"
==
Int
NUMBER_OF_
CYCLE