Visualisation of PCMs through AR

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Chapter 1 Contents

Chapter 2 – graduation plan

2.1 Problem Statement

Buildings are responsible for a 35% emission of the greenhouse gasses (Al-Absi et al., 2022). a majority of the emission is through raising or lowering the temperature of a building (Mehdaoui et al., 2019). The temperature inside a building is affected by the temperature on the outside of the building. In case of higher indoor than outdoor air temperature, the heat flows through the wall from the indoors to outdoor and is released on the outside of the wall. A measure that has been taken is putting insulation material in the wall and improving the air tightness of the building envelope to prevent heat loss. However, with modern insulation standards in temperate climate, also preventing overheating in summer becomes more and more important. A measure that can be taken to reduce energy consumption and prevent overheating in summer is to make use of thermal mass.

An example of a modern way of doing this is to add a panel of phase change material (PCM) in the wall (Jeon et al., 2013). A PCM can absorb significant amounts of heat or release it latently when undergoing a phase change, often from solid to liquid and vice versa. The temperature where such phase change takes place is called the phase change temperature. In certain experiments in which PCMs were used as thermal storage material, an energy reduction of 17% has been found (Chen et al., 2008). Even though this is a substantial reduction in energy consumption, PCMs are not commonly seen in the building environment, yet. There are several reasons for the absence of PCM products. One of them is that most of the organic PCMs are flammable and the inorganic PCMs see a reduction of their enthalpy over time (Kosny, 2015), which is explained later in the paper.

Monitoring the PCM inside a wall would be a solution to track the performance of the wall and feedback of some sort would be able to send a warning in case of a start of a fire or in case of underperforming PCM. Monitoring and measuring the wall would also be beneficial for research goals, because there is no general test yet for PCMs in a wall. A system that would measure, track and process the data of a PCM wall would lead to a lot of data and case studies if it were incorporated in new walls for customer use. An addition to this data would be the visualisation of the operation of a PCM wall. This would be an advantage for insight and accessibility of the data of a wall. A way to visualize it is through an smartphone, this type of visualization is known as Augmented Reality (AR).

2.2 Research Question

These problems lead to the following research question: *“How does visualization with augmented reality contribute to the understanding of the behaviour of PCM for science, maintenance and customer groups of people?”*.

This question will eventually lead to a setup that can measure the temperature on different locations in the wall, an application for a mobile phone that can convert the data of the sensors in to a visual output and different user interfaces UI for the group of users.

The research question can be divided in sub questions. The first sub question is to find a most suitable setup for tracking the behaviour of the PCM and the temperature of the wall, so the question is *“How to monitor and collect data of a PCM wall?”*. The second sub question is about converting the data towards useful data for research and for the application, the question will be *"How to convert the data for the application?"*. The last sub question is *"What is a suitable User interface for different groups?"*. This question goes more in depth about the users of the application and how the user interface should be per user.

2.3 Objective and Relevance

The objective of this research serves multiple purposes. One of the purposes is to develop a method to track the performance and the behaviour of PCMs in walls. If the existing methods of tracking the performance of a wall are not suitable a new method has to be developed. This method might be a way to make a uniform test for PCM walls. A uniform test would make comparing PCMs more convenient. Another purpose of this research is to visualize the behaviour and the data of the PCM wall. This is to serve different users their interests. The users for this application are scientists, manufacturers/maintenance workers and customers. For scientists the raw data and the values of the temperature around and in the wall are useful to get more insight in the behaviour or performance of different types of PCMs or PCMs in different situations. For manufacturers or maintenance workers it is important to be able to monitor the performance of the PCM wall. Through effects of super-cooling and phase segregation, PCMs walls lose their effectiveness (Wang et al., 2009). If the PCM wall performs under a set level they can repair or replace the wall. For the customer the requirements are similar as for the manufacturer or maintenance worker, because they can track the performance of the product they bought. Another insight that the application can give to the customer is if the wall is storing or releasing heat and how much energy it saved them. This makes a PCM wall more appealing. The relevance of this research towards society is that it gives more insight in the performance and behaviour of PCM walls overall. This insight can be used to improve the products. The visualization of the effect of PCM walls makes it also more attractive to apply in more buildings. This correct application of PCM walls in buildings makes buildings more energy efficient, thus more environmental friendly.

2.4Methods

For each sub question there is a set of research methodologies that will be applied. The first sub question is about monitoring the wall. The first step is to read the literature on different monitoring/ analysis/ tracking methods. In this question the main keywords will be *PCM, Monitoring, Wall, Analysis*. The literature is that is being used is relevant and reliable. This is done by checking the literature on its date of publication, author and publisher. The literature is separated into 3 categories. The first one being PCMs, to get knowledge of PCMs overall. The second literature study is about analysis methods for PCMs. A variety of methods are going to be compared. And the third category is the setup of an AR environment. After the literature research, an experimental research will be conducted to see if the setup is suitable. For this experiment a setup of a PMMA box will be constructed. This box will contain PCM and thermocouples type T. Thermocouples type T have the highest measure accuracy. The Thermocouples are connected to a DAQHAT that can read out the small currents in the PCM that are caused by the Seebeck effect. The measurements taken up from 1 hour to a day, depending on the time that the phase chance transition takes. The DAQHAT will send the data to a raspberry pi which can log the data of the experiment. The data can later be studied and analysed to validate the experiment. Another method to validate the experiment is to do a simulation. This simulation will be done in Comsol. This is a Multiphysics program that can perform thermodynamic calculations. The settings of Comsol will be described in a later chapter

For the second question, about converting and processing the data, also a literature study will be done to obtain information about the methods of converting the data. This is to confirm the experiment. The last sub question about the UI will also start with a literature study.

2.5 planning

The research will be done by starting with literature research in all the aspects from PCMs, towards PCM walls, methods of analysing the performance of a PCM wall, data collecting and conversion and the last aspect of research through literature is the how to set up a user interface with augmented reality. When most of the literature study has been done, the experimental phase will start. In this phase there will be parallel experiments going on. The first experiment will start with the setup of the sensors in the wall. At the same time a way of obtaining the data and reading the data has to be developed. These two experimental phases will be done at the same time. Once the monitoring set up, the data collection and conversion of the data are finished the application and user interface through augmented reality will be created. This process will be experimental and make use of interviews with groups. Afterwards all the aspects will be assembled in a PCM wall with a sensor set up and an application that visualizes the data through augmented reality with different interfaces per user.

Chapter 3 – Literature study

The literature study is divided in 3 categories. In the first category PCMs are explained. Here it will be stated how PCMs operate, what type of PCMs there are and the differences between types of PCMs. The second category is about analysis methods for PCMs and walls. Different types of analysis methods will be explained in how they are used and to which scales they are applicable. This literature study will also consider if there are suitable analysis methods to apply in the wall to measure and track the data of the wall. The final category is the setup for the augmented reality and how to design a user interface for different types of users.

3.1 Phase change materials

In this category first the properties of phase change materials that allows them to store heat is explained. After that different types of PCMs are described including their advantages and disadvantages.

3.1.1 Principle of a PCM

Like every material also PCMs are affected by their environment. The difference between other materials and PCMs is that PCMs alter their properties according to the environmental changes. A PCM has the ability to store and release heat when the phase of the material changes (da Cunha & de Aguiar, 2020). In case of energy absorption, a PCM will start to heat up. At some point it has absorbed enough energy to start changing phase. During this moment the PCM almost stops heating up and starts changing phase. After the PCM has changed from phase completely it will start to heat up again if more heat is absorbed. A graph of this phenomenon would look like figure 1.

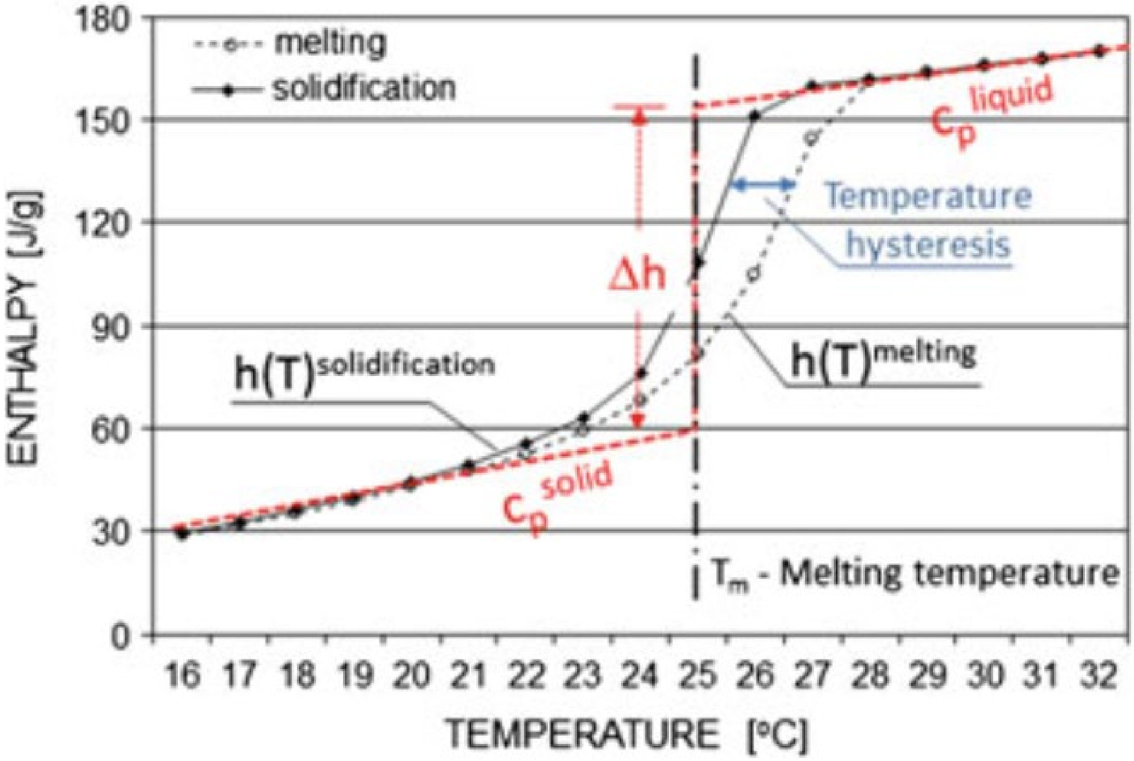


Figure 1. Enthalpy and temperature graph of a PCM (Kośny, 2015)

Figure 1 also displays what happens if the surrounding temperature decreases and the PCM releases heat. The PCM will return to his original state by first dropping in temperature, then changing phase again and then again dropping in temperature. During this change the PCM is releasing the heat that it collected during the absorption. For this example a solid-liquid PCM was used.

This principle can be used to dampen out temperature fluctuations and reduce energy consumption in buildings (da Cunha & de Aguiar, 2020; Kośny, 2015; Paroutoglou et al., 2019).

3.1.2 Types of PCMs

PCMs can be classified in different categories. The first distinction that can be made is the type of phase change the material does. The first type of phase change is the solid to solid transformation (Fallahi et al., 2017), where the molecules rearrange to store and release the

energy. The solid to liquid change is the most common type that is used in the built environment (Su et al., 2015). The last type is liquid to gas (Demirbas, 2006). Only the solid to liquid phase change material is treated in this chapter.
The solid to liquid PCM can be further categorised in the following types. According to Kośny (2015) there are 3 main categories of PCMs. These categories are based on the types of materials that are used in the PCM. The categories are the organics, inorganics and eutectics. The organic PCM group contains paraffinic PCMs, Bio-Based PCMs and other non-paraffinic compounds, as can be seen in figure 2. These PCMs are paraffins, fatty acids, fatty-acid esters or sugar alcohols (Kośny, 2015). For the Inorganic category salt hydrates and metallics. Salt hydrates consist of an inorganic salt with water molecules. An example of such a salt hydrate is sodium sulphate decahydrate ($Na_2SO_4 \cdot 10\ H_2O$). These inorganic salt water solutions make a crystalline solid. The metallics are rarely used in PCM products, but 2 metals that have a melting point useful for the built environment are gallium and mercury. Eutectics are a combination of PCM types. This can be organic and inorganic but as well as 2 organic PCMs as is shown in figure 2.

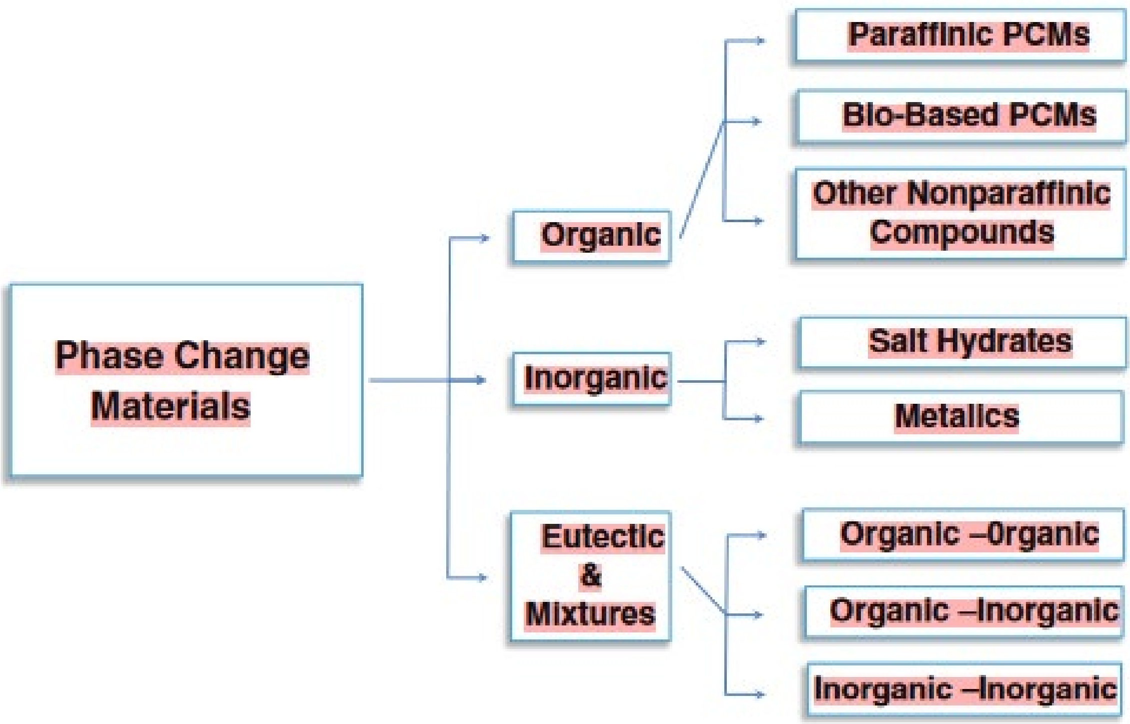


Figure 1. Types of PCM. (Kośny, 2015)

3.1.3 Characteristics of different types of PCMs

The organics and inorganics both have their advantages and disadvantages. Organic PMCs have an advantage of being more durable than other PCMs. And organic PCMs are more stable and can do repeated thermal cycles without segregation or corrosion (Kośny, 2015; Paroutoglou et al., 2019). The main disadvantages of organic PCMs is that they are flammable (Morris & Langari, 2021), which is a risk for buildings. The other two disadvantages are the relatively low thermal conductivity and the volume change between solid and liquid phase (Paroutoglou et al., 2019). The most used PCMs are the inorganics. The reason is that inorganic PCMs have a high heat storage density, are cheaper than organic PCMs and there are no safety hazards according to Kośny (2015). The drawback of inorganic PCMs is that they are less consistent in performance as compared to organic PCMs. This is because of phase segregation and semi-congruent or incongruent melting (Kośny, 2015; Paroutoglou et al., 2019). These are the main difference between the types of PCMs. Other effects that can cause a inaccuracies during the monitoring are super-cooling, hysteresis and the limit temperature of the PCM material. Hysteresis is when a the phase change temperature of a material is different in solidifying and liquifying. This is also depicted in figure 1. This means that the material is behaving differently in the cooling or heating process. This should be taken in account during the measurements. Super-cooling is a phenomenon that the PCM stays liquid under its freezing point. This enhances the thermal energy storage but makes the PCM also unreliable. Inorganic PCMs are less prone to this effect than organic PCMs, because inorganic PCMs have heterogenous crystalline structure. The PCMs have a service limit temperature. This is the maximum and minimum temperature of the material. If the material gets exposed to temperatures out of its range it suffers from thermal decomposition.

3.1.4 Conclusion

For the research, a PCM has to be chosen to make a test panel. As can be read in the part about the characteristics of PCMs that they have different properties. For the purpose of this research an inorganic PCM is going to be used. There are several reasons for this choice. One is that the inorganic PCMs are not flammable and thus more suitable for building components. In addition for this research the PCM wall is going to be tracked, and there is a chance that phase segregation can be detected.

3.2 Analysis methods for PCM walls

The PCM has to be monitored before it can be visualised. Kośny (2015) mentions several methods. The methods of analysis vary in application, some are only applicable on a sample of a PCM and some are suited for a larger wall section. Their analysis methods are best separated on the scale they are applied on. The scale starts at material level and ends on building level. The existing methods are listed here and are sorted from the smallest scale to the largest scale:

DTA (Differential Thermal Analysis)
DSC (Differential Scanning Calorimetry)
T-history
DHFMA (Dynamic Heat Flow Meter Apparatus)
Dynamic Hot-Box testing
Dynamic guarded hot plate method

These analysis methods are explained per method and in the end there will be a conclusion if there are suitable methods for the AR setup.

3.2.1 Differential Thermal Analysis (DTA)

Differential thermal analysis is an analysis method for a sample of PCMs. It operates as following, first a sample of the PCM is subtracted from the PCM batch. This specimen is put in a furnace. This furnace contains a reference specimen and 2 thermocouples as can be seen in figure 3. One of the thermocouples is placed in the centre of the furnace while the other sensor is put in the reference and the test specimen. The temperature of the reference and the test material are measured through time as the furnace heats up. The measurements of the reference and test specimen are acquired by a data acquisition system. The analysis apparatus is uncomplicated (Kośny, 2015).

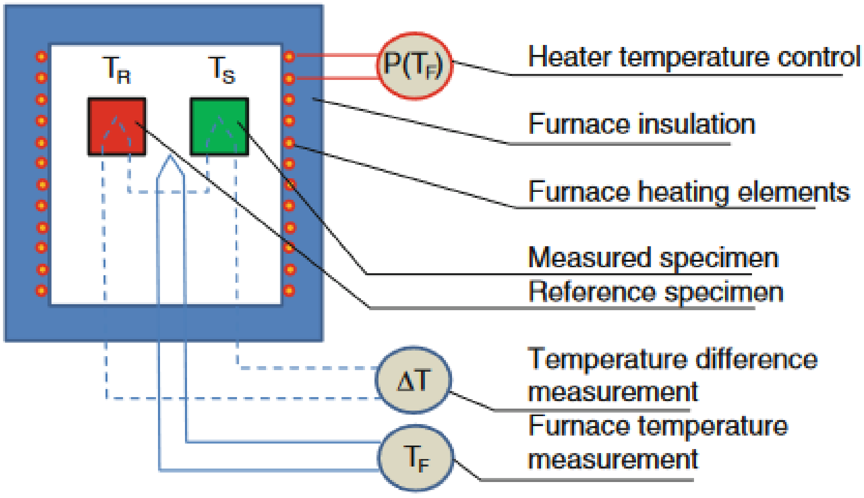


Figure 2. typical setup for a DTA. (Kośny, 2015)

The data of this analysis method is temperature measured through time. The data is best shown in a Temperature-time graph, a typical one is shown in figure 4. This test is typically done to get data of the thermal characteristics of a PCM.

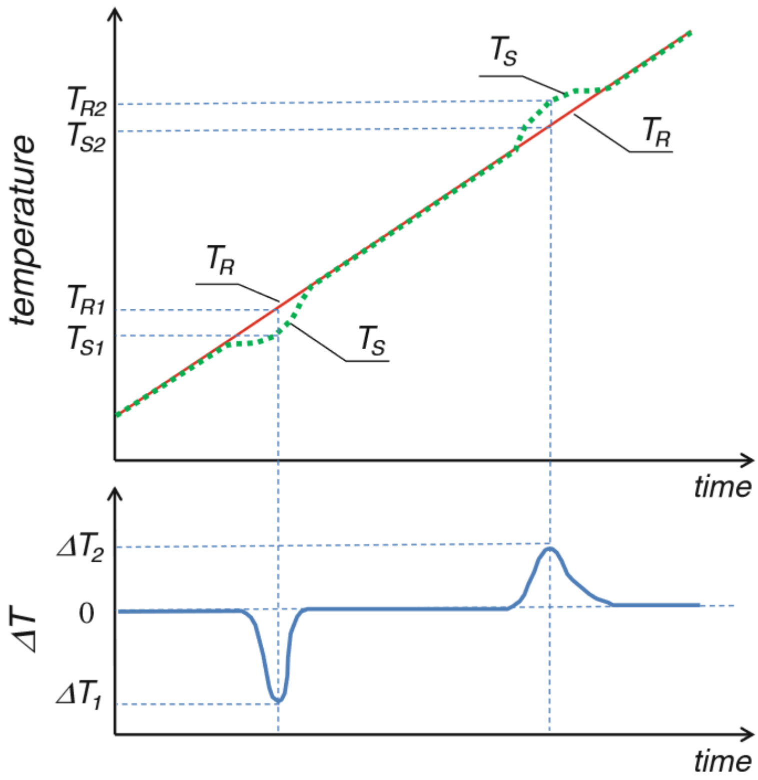


Figure 3. a general DTA temperature-time curve. (Kośny, 2015)

This method was one of the earliest methods of gathering thermal data from different types of material. It is used in the field of analytical chemistry for 2 purposes. The first one is to identify chemical compositions and the second purpose of this method is to analyse the quantities of chemical substances.

3.2.2 Differential Scanning Calorimetry (DSC)

Differential scanning calorimetry is a method where the amount of heat is measured to raise the temperature of the test specimen and the reference specimen. The temperature of the furnace is raised in intervals. By comparing the reference material and the test material data through set intervals, a materials thermal characteristic can be defined. This method is applied on material scale, just as the DTA method. The setup for this analysis method is a furnace with the test specimen and a reference specimen. The temperature of both specimens is measured through the experiment (Kośny, 2015; Shukla et al., 2012). A certain setup would look like figure 5.

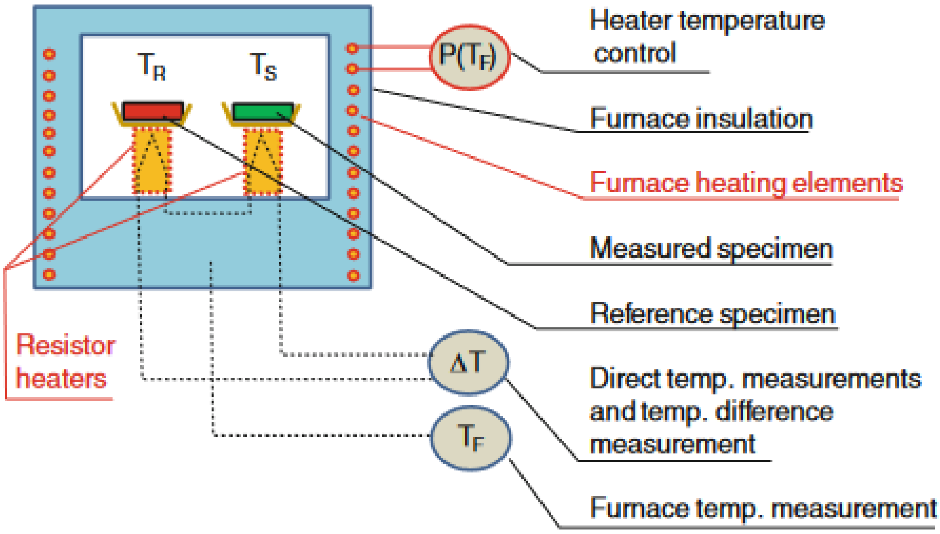


Figure 4. typical setup for a DSC. Kośny (2015)

This analysis method is the most frequently used in a variety of research fields (Barreneche et al., 2013), because it provides a generous amount of thermal data (Kośny, 2015).
The DSC analysis method is applicable in 2 ways: there is a dynamic method and a step method (Barreneche et al., 2013; Kośny, 2015).
The dynamic method differs from the step method in the way heat is added. The heat in the dynamic method is raising in a smooth curve, whereas in the step method the temperature is raised with a certain interval. Both methods have their specific uses. The dynamic method is widely used because of the continuously raising of the temperature the test can be performed faster than the step test.

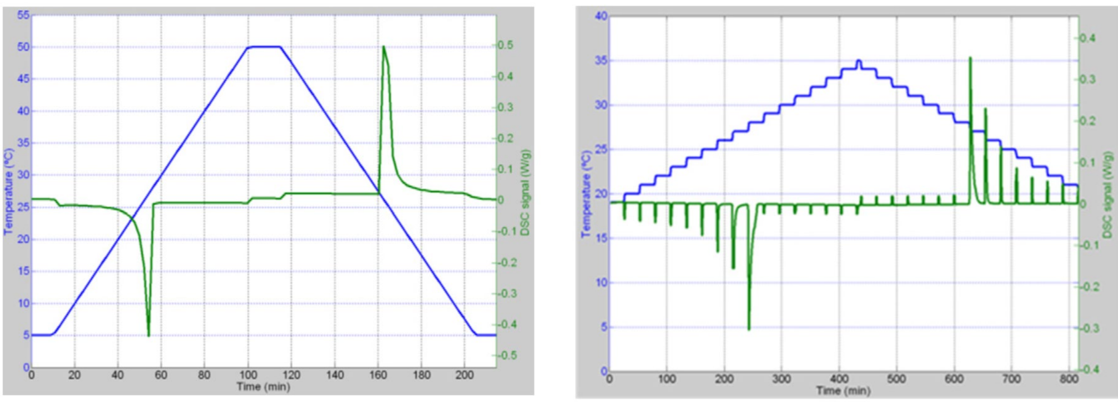


Figure 5. Dynamic(r) and step(l) DSC method. (Barreneche et al., 2013)

The drawback of a dynamic test is that it is hard to determine if there is a thermal equilibrium in the specimen. The values from the analysis are not certain without this equilibrium. The step method ensures with isothermal steps that the specimen of the PCM reaches a thermal equilibrium. This makes the step method more accurate than the dynamic method although it takes more time (Kośny, 2015).

3.2.3 T-History

T-history is suitable for larger samples of PCMs or PCM components to be tested (Kośny, 2015). The installation of this method operates as following: according to Solé et al. (2013), there is 1 or there are multiple tubes filled with a PCM and one tube filled with a well-known material)thermo-physical characteristics). All tubes contain a thermocouple to measure the temperature inside the tube. A material with well-known thermo-physical properties is distilled water. Distilled water is often used as a reference material. Next, the tubes are placed in a bath with preheated water. The temperature of the water is higher than the melting temperature of the PCMs. Once all the PCMs are molten, all the tubes get raised out of the bath at the same time and exposed to the temperature of the surrounding. The temperature changes of the PCM specimen and the reference specimen get recorded. This will lead to a T versus t graph. With this information the specific heat, melting point, fusion heat, degree of sub-cooling and thermal conductivity can be determined (Kalnæs & Jelle, 2015; Kośny, 2015; Solé et al., 2013). The first proposed setup is shown in figure 7.

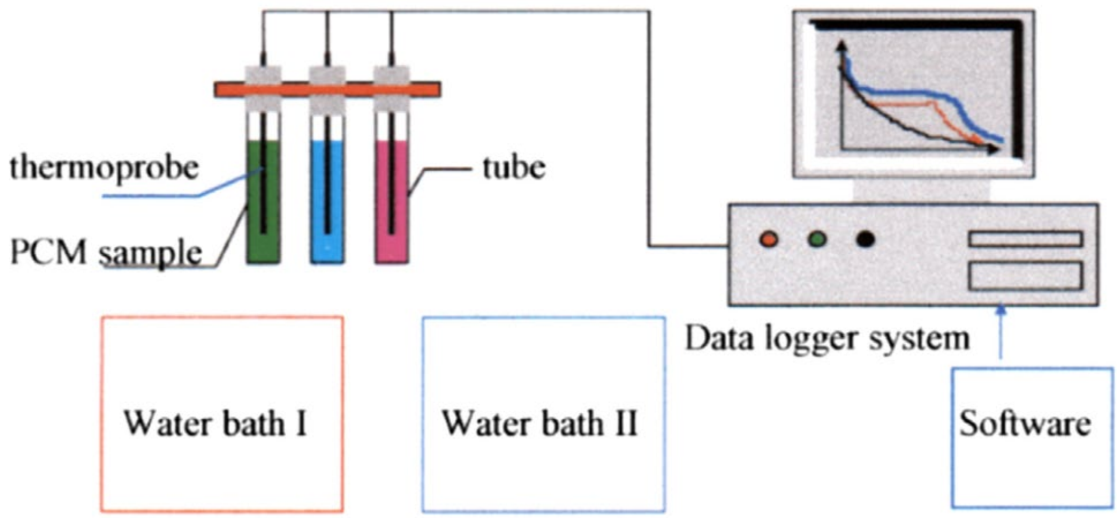


Figure 6. The first T-history setup.(Yinping et al., 1999)

This method has several advantages. The method is simple, suitable for bigger components, it allows for obtaining multiple thermo-physical properties and can be done with multiple PCMs at once. This makes it a very useful method in analysing PCM products as well.

3.2.4 Dynamic Heat Flow Meter Apparatus (DHFMA)

The dynamic heat flow meter apparatus is suitable to test PCM components (Shukla et al., 2012). Kośny (2015) explains the apparatus of the method. the apparatus consists of two isothermal thermal plates. The temperature of the plates is regulated with thermo-electric elements for heating and water chillers for cooling the plates. There are also heat flux transducers bonded to each plate to measure the temperature of the plate. The test specimen is located between the two plates. In figure 8 a DFHMA is depicted.

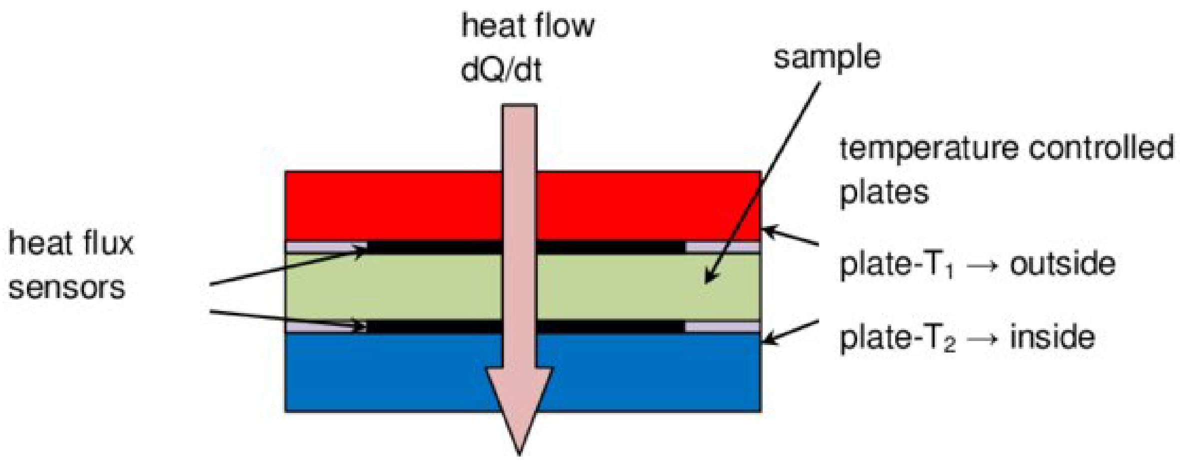


Figure 7. schematic of DHFMA. (Konstantinidou et al., 2014)

With this method the plates are set to the same temperature. The plates simulate the inside and outside of a building. The outside plate is getting gradually cooler, where the top plate is heated up. The method simulates the heat flow through a wall, this makes this test a very reliable test on testing building components (Kalnæs & Jelle, 2015). The test is similar to the DSC method but the DHFMA is applicable on larger specimens or components (Kośny, 2015). The heat capacity, peaks of the solidification and melting cycles, the quantity of sub-cooling and the latent heat within a certain temperature range can be determined with this method (Shukla et al., 2012).

3.2.5 Dynamic Hot-Box Testing

The hot-box testing method is used for full-size, system-scale building envelope assemblies. This method was specially developed to measure the steady-state heat transfer through a complete envelope assembly (Kośny, 2015). The dynamic hot-box setup is depicted in figure 9.

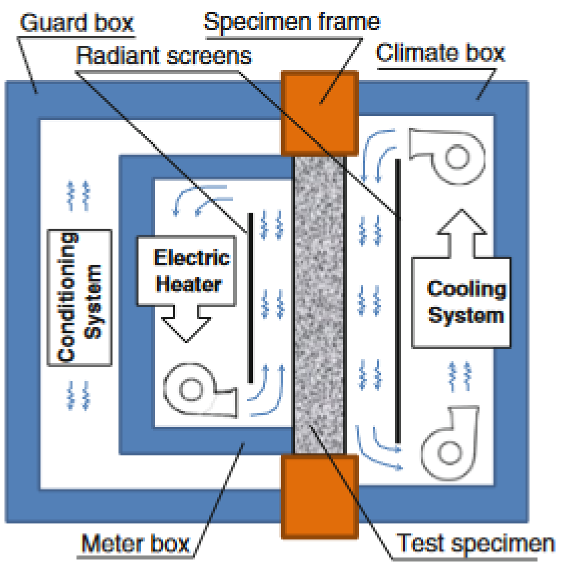


Figure 8. setup for dynamic hot-box testing. (Kośny, 2015)

The method has 2 chambers that are separated with the test specimen. In one chamber the temperature is raised and in the other chamber the temperature is lowered. The temperature in the warm section can be 30 ^{o}C and in the cold section -20 ^{o}C. These temperatures are provided by electric heaters and fans. This is maintained until the test specimen is in a steady state (Kalnæs & Jelle, 2015). The space around the metering box is also heated to the same temperature as the heated box. This is to prevent heat loss through the wall of the metering box. Once the specimen reaches a steady-state, the metering box starts measuring the heat that passes through the wall.
The dynamic hot-box test is suitable for obtaining the several thermal characteristics of a wall component. It can determine the heat storage capacity and the time the envelop responses to the temperature change (Kośny, 2015).

3.2.6 Dynamic guarded hot plate method

The final method is the dynamic guarded hot plate method (Kalnæs & Jelle, 2015). This is a method that is used to measure thermal physical properties of components that contain PCM materials. The apparatus for this method works in the following manner. It is again an apparatus with a hot and a cold plate, just like the DHFMA. The outside of the plates are with an insulation ring that guards the plate from thermal losses (Pomianowski et al., 2014). This makes the apparatus accurate (Pomianowski et al., 2014). The test specimen is kept in a frame to minimize the thermal losses through the side of the sample. Just as the dynamic hot-box testing this frame can be used to measure the sample on the side of the sample.

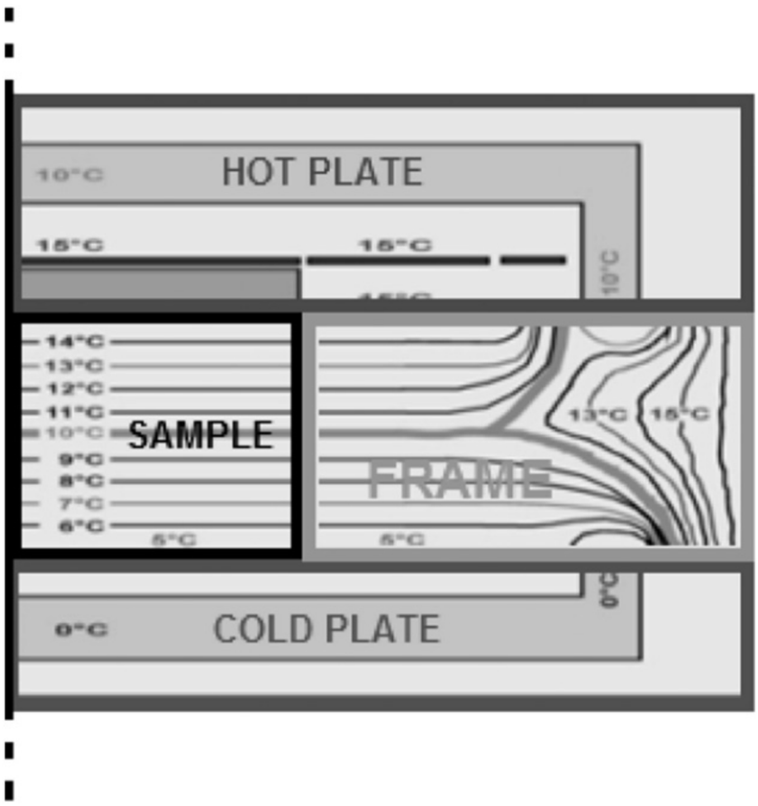


Figure 9. a schematic section of a dynamic guarded hot plate method.(Pomianowski et al., 2014)

This apparatus can measure dynamic temperature changes as well as steady state situations. The benefits of this method is that the temperature can be changed slowly and with precision. This makes it suitable for accurate measurements (Kalnæs & Jelle, 2015; Pomianowski et al., 2014).

3.2.7 Suitability of method(s)

This literature research was done to see if there are already suitable methods for measuring through a PCM wall. The DTA, DSC and T-history are not suitable to measure or track the temperature through a wall. The reason that they are not suitable is that they can only contain a sample of the wall. According to Shukla et al. (2012) neither of the methods is even suitable for measuring PCMs thermal behaviour in a wall. He argues that the samples are not a reliable reflection of the entire component in the wall. The sample needs to have a uniform compound of chemicals to be reliable and the wall itself also alters the behaviour of the PCM (Shukla et al., 2012). The DHFMA, dynamic hot-box testing and the dynamic guarded hot plate method are suitable ways of testing a wall section. The drawback of these systems is that they are surrounding the components. It is impossible to do this within a wall in a building. It seems that none of the setups is suitable for the purpose of tracking a wall in-situ, but all the methods have given insight in the way of measuring and determining the performance of a wall or PCM.

3.2.8 conclusion

The aim is to measure through a wall. The physical properties that need to be regarded are the temperatures, heat fluxes and irradiances (Favoino et al., 2014). These properties determine the thermo-energetic behaviour of such walls in-situ. To gather this information at least thermocouples and heat flux transducers are necessary according to the above mentioned. For tracking the irradiances on the wall Favoino et al. (2014) made use of a pyranometer. These sensors give an accurate depiction of the behaviour of a PCM wall in-situ. The set-up of Favoino is depicted in figure 11.

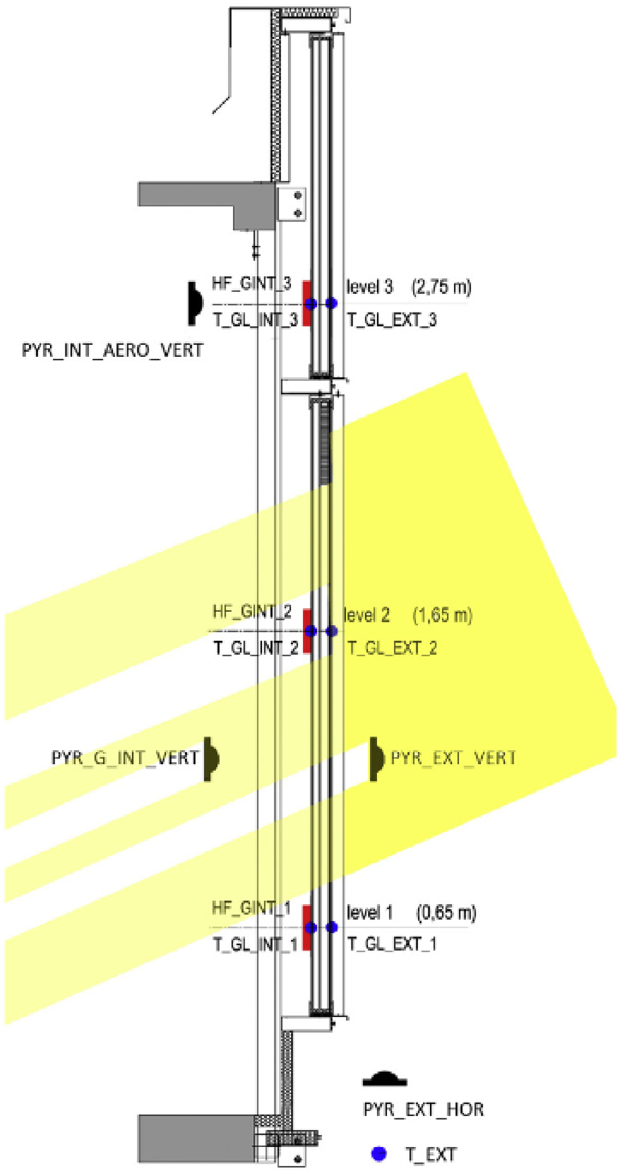


Figure 10. Analysis of a panel. (Favoino, 2014)

In the figure a panel is being studied on its thermal performances. The black hat symbols are pyrometers. These measure the heat flux, which is the flow of thermal energy through a wall. The blue dots are thermocouples to measure temperature on the spot.

3.3 Augmented reality setup

For this part of the literature research is about augmented reality (AR) and the application. AR has been applied to the building environment and proven to be useful in the development and maintenance process (Wang et al., 2013; Zhao et al., 2023). It is a tool to communicate and analyse components of a building. An in-situ analysis is important to capture the behaviour and the performance of PCMs, because numerical models are not sufficient in proving the behaviour of a module (Belusko et al., 2012).
This research is used to get knowledge about the design process of an AR design. AR is chosen because the data has to be conveniently accessible. According to a study on extended reality a test has been done on groups that used AR, mixed reality, virtual reality

and as a test group there was also a group that used paper (Zhao et al., 2023). This study showed that AR has the highest usability score compared to the other methods. Some argue that AR is the ultimate display (op de Beek, 2018). According to Wang (2012) AR has 5 technological components. The first is media representation, this is about the way the media is displayed. This can be a text, symbols, 3D data and animations (Wang et al., 2013). The second component is the interaction device. This is the way the interaction between the user and the media representation. The third is the feedback display. The feedback display works in combination with the 4th and 5th component, being the trackers and computing units. The feedback display depicts the correct animations according to the tracked data. This is data is processed in the computing component and displayed. In case of changes in the data, the animations can change as well.
These are the components that are necessary for a AR device in the building environment. AR technology has been used to visualise the thermal distribution of an indoor environment. Some research has already been done with AR. In an research of improving the thermal performance and comfort the indoor environment was set up with sensors to scan and display the thermal distribution (Fukuda et al., 2019). In this case the media representation was a BIM model and the data was tracked by a computational fluid dynamic (CFD) analysis (Hartog et al., 2000). The CFD gave the data that later was computed towards 3D visuals. These visuals are depicted in figure 11.

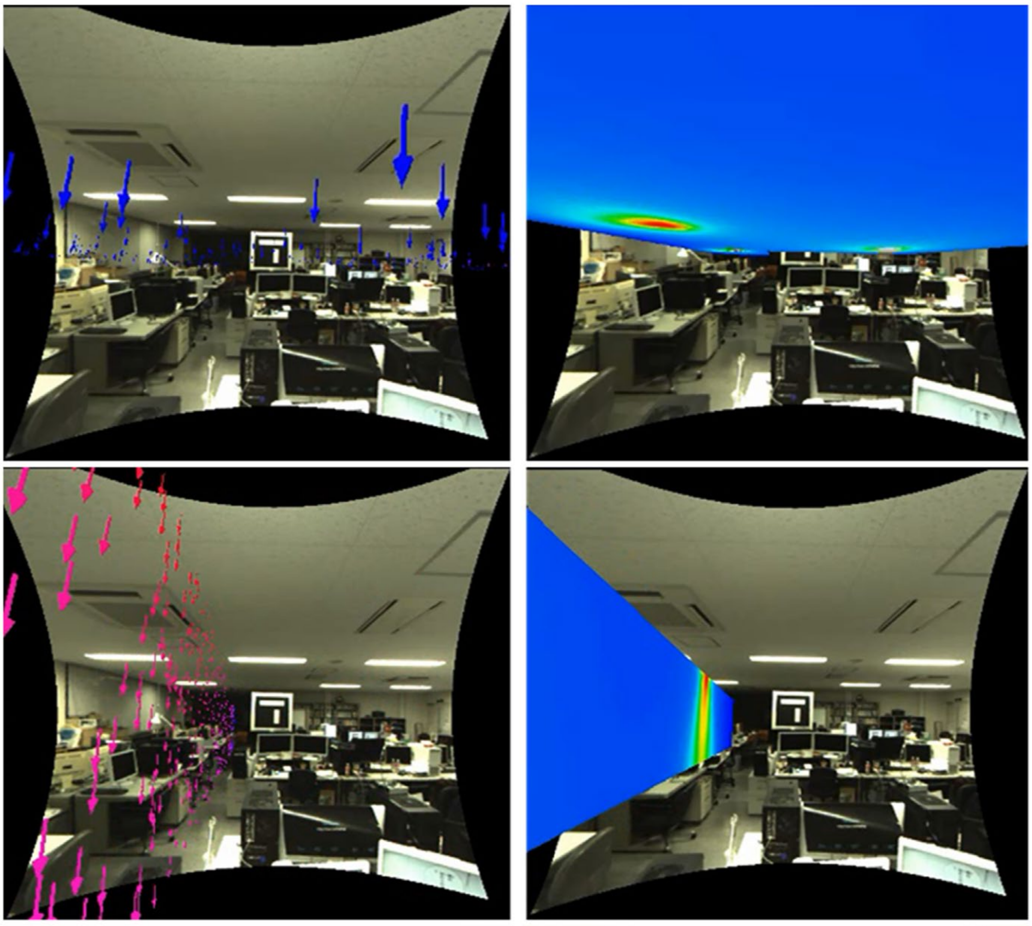


Figure 11.CFD Feedback displayed.(Fukuda et al., 2019)

This figure shows that envisioning heat maps and wind directions is a possibility. Another group teste the illuminance performance of a building via AR (Zhao et al., 2023). This model was a BIM model with a they were enhancing the illuminance performance of a building. This was not an analysis on a physical building like Fukuda et al. (2019). In this research they made an interface where the researchers could adapt the design of the building and see the consequences on the illuminance performance of the building. This is in the development process, whereas Fukuda et al. (2019) are working with an existing building that needs maintenance.
For this research the experiment of Fukuda is more suitable then the research of Zhao. The flowchart of components working together shown in figure 12. As can be seen revit was used to make a model.

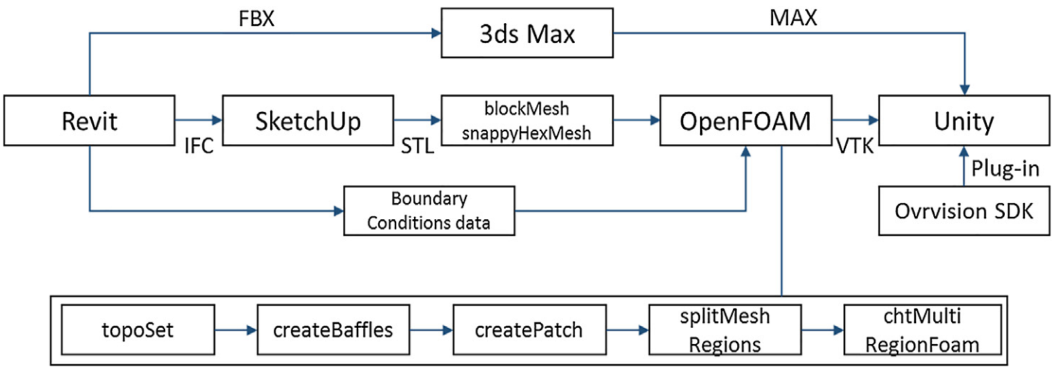


Figure 12. data flow for AR.(Fukuda et al., 2019)

A BIM-model was created with revit. To make the BIM-model suitable for the OpenFOAM CFD analysis, the BIM had to be converted to a mesh to set the boundaries. OpenFOAM runs the CFD simulation and starts giving feedback to the AR application, which in this case is Unity.

3.3.1 conclusion

To make an AR application and set up 5 components are necessary. These are 1. Media representation 2. Interaction device 3. Feedback display 4. Trackers and the final component is the 5. Computing component. For this research the method of Fukuda et al. (2019) is more suitable. This research is also based of 5 steps to make the application work as desired. First create a BIM model, then make a mesh from the model. Set the boundaries for the mesh and export the mesh to a program that does CFD analysis. Run the analysis and make it communicate with the AR application to visualise the results.

Chapter 4 Simulations

It will be necessary to run two simulations of PCM behaviour. The first simulation will be representative of the experimental setup, and serve as a prediction and potential validation of the experimental result. The second simulation will be more representative of a use case of PCM's as a thermal isolation, simulating a sheet filled with PCM in a brick wall.

The simulations are one in Comsol, a multi-physics finite element analysis simulation software. During heating, after parts of the PCM have tuned to liquid, local differences in temperature will result in locally different densities. This will drive a convective flow, which means that the simulations will have to combine a thermal model and multi-phase flow model to study a PCM's behaviour in an enclosed volume. These studies will also allow us to identify where to place the temperature sensors, as to best capture the transient response of the PCM under heat load.

4.1 Setup of the simulation

The setup of the Comsol simulations is going to be explained in this section. First the geometry and the material are going to be described for the first simulation, of the experimental setup. After that the physics included in the model will be introduced. Finally the simulation results are going to be interpreted and discussed.

4.2 Material and geometry

The geometry of the enclosure must match that of the experimental setup, thus it needs an outer width and height of 508 mm and outer depth of 23 mm. The walls are made out of PMMA (plexiglass) with a thickness of 4 mm, leaving a 500x500x15 mm volume for the PCM. The material properties for the PMMA are taken from Comsol's built in library of material properties. The relevant material properties are given below in table 1.

Property	*Variable*	*Value*	*Unit*
Thermal conductivity	k	0.25	$W/(m \cdot K)$
Density	ρ	1190	kg/m^3
Heat capacity at constant pressure	C_p	1488	$J/(kg \cdot K)$

Table 1: Relevant material properties of PMMA for the experimental setup simulation

The properties of the PCM were entered manually, as the PCM in question, C28, is not present in Comsol's material library by default. The material properties of C28 were obtained from the supplier's website [XX CITAAT HIER], and the relevant constants are given in table 2 below. The density and dynamic viscosity have a temperature dependence, which is important to take into account. This is because the change is density is the driving force behind the convective flows that will occur, and the dynamic viscosity affects the flow velocity. Figure 14 shows the density of C28 over temperature, and figure 15 shows the same for the dynamic viscosity.

Property	*Variable*	*Value*	*Unit*
Thermal conductivity	k	0.6	$W/(m \cdot K)$

Table 2: Relevant constant material property of C28, the PCM being used in the experimental setup

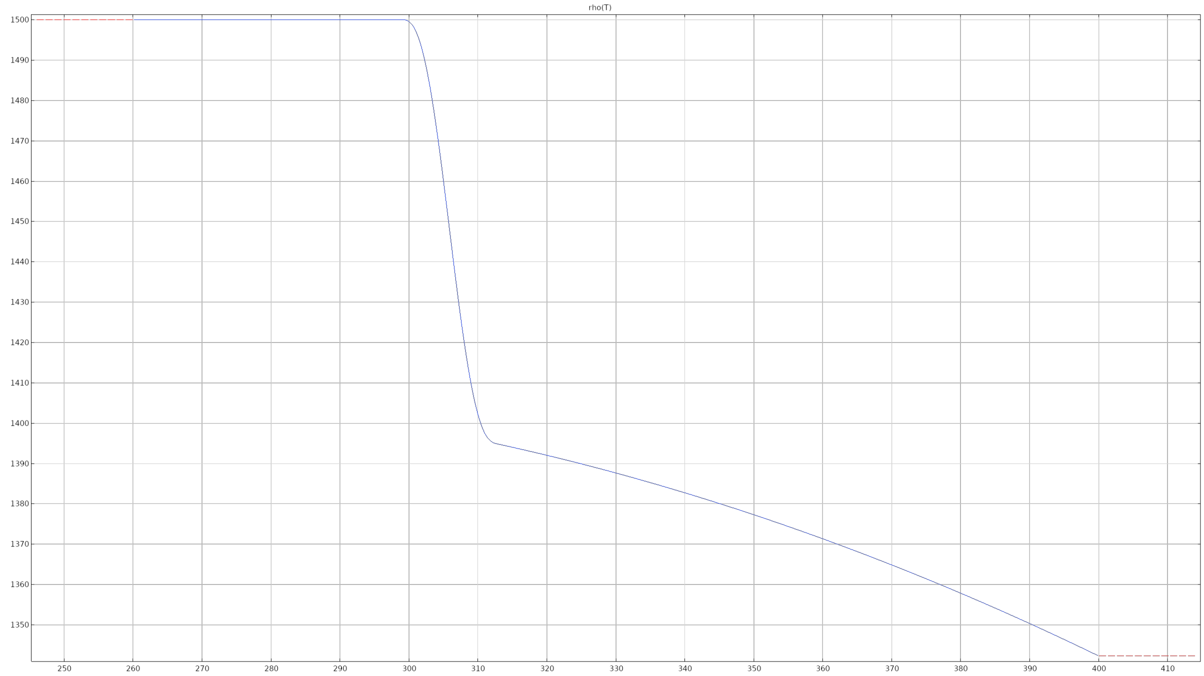


Figure 14: Temperature dependence of the density of C28

Figure 15: Temperature dependence of the viscosity of C28

The PCM has different heat capacities depending on whether the material is absorbing or emitting heat. Therefore two different heat capacities, $C_{p,heating}$ and $C_{p,cooling}$, need to be defined. Figure 16 and 17 show the temperature dependence of $C_{p,heating}$ and $C_{p,cooling}$. The difference between $C_{p,heating}$ and $C_{p,cooling}$ is caused by a material hysteresis, which allows it to store heat more effectively.

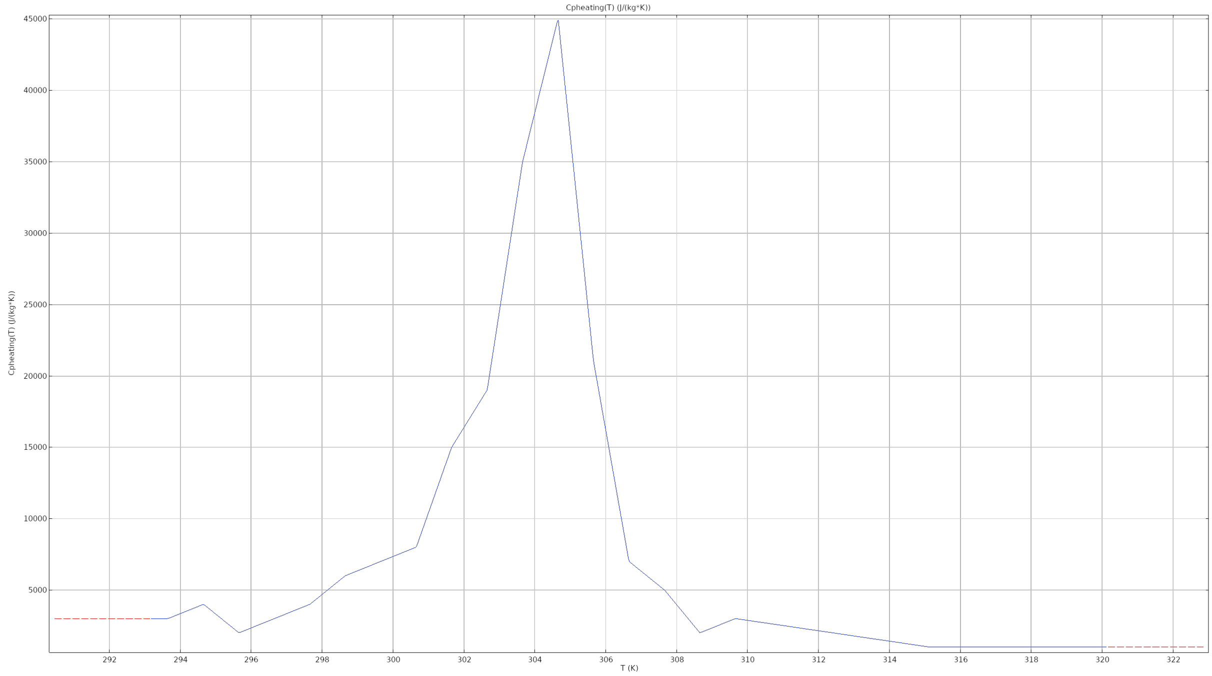


Figure 16: Temperature dependence of heat capacities $C_{p,heating}$ for C28

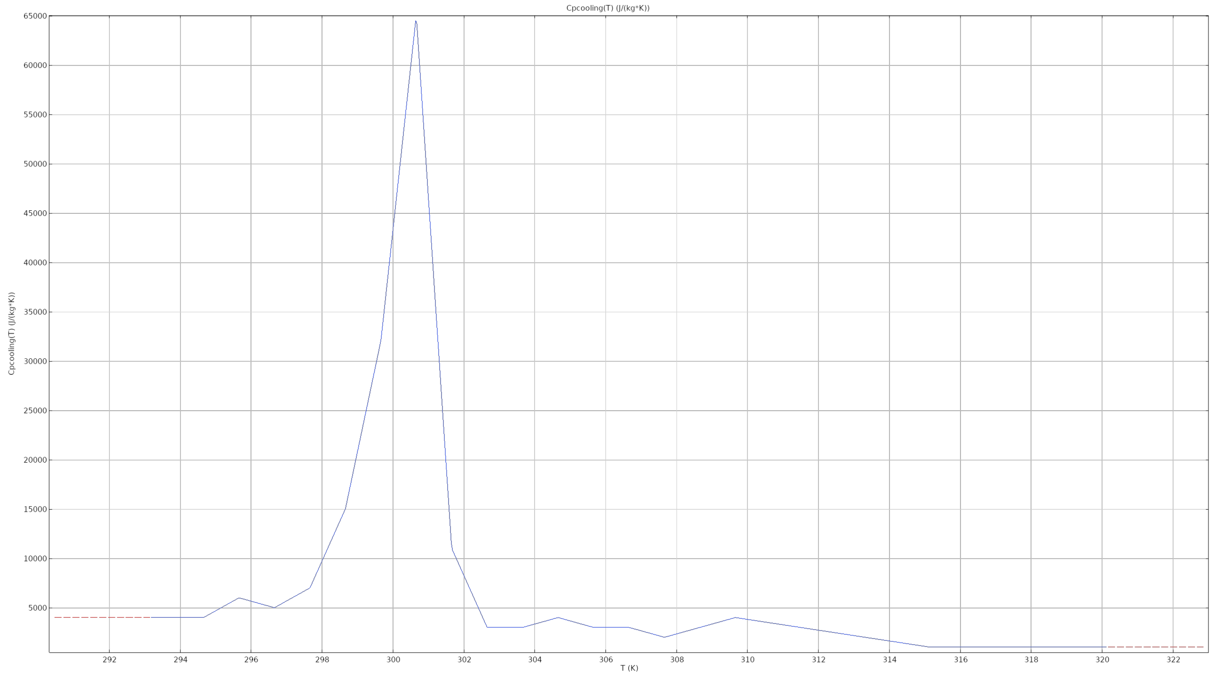


Figure 17: Temperature dependence of heat capacities $C_{p,cooling}$ for C28

The thermal expansion is of C28 negligible, so it will not affect the flow or the heat transfer. For that reason the value of thermal expansion can be set to 0.

With these values of the geometry and material properties the relevant parameters and boundary condition of the simulations are defined and the physics modules can be added to the simulation.

4.3 Physics and modules

The necessary physics are described and the settings of certain modules explained. There will be an explanation about the simulation of heating and cooling the PCM. First the general settings of the setup for the simulation,. followed by the details of the settings for the heating simulation. After that the cooling simulation will be exemplified.

4.3.1 General settings

The physics that are relevant for this simulation are the 'heat transfer in solids and liquids' and the 'Laminar flow' module. These physics modules, along with other boundary conditions, as implemented in Comsol, are shown in figure 15.

The heat transfer module entails a solid, which is the PMMA enclosure, a fluid, which will model the PCM, the initial conditions of each, and the thermal boundary conditions. The phase transition of the PCM will be modelled by applying a jump in the dynamic viscosity from a high to a low value after the phase transition has occurred. The temperature dependent material properties are also included in the heat transfer module. One of these is the coefficient of thermal expansion, but as mentioned earlier thermal expansion will be neglectable for this simulation.

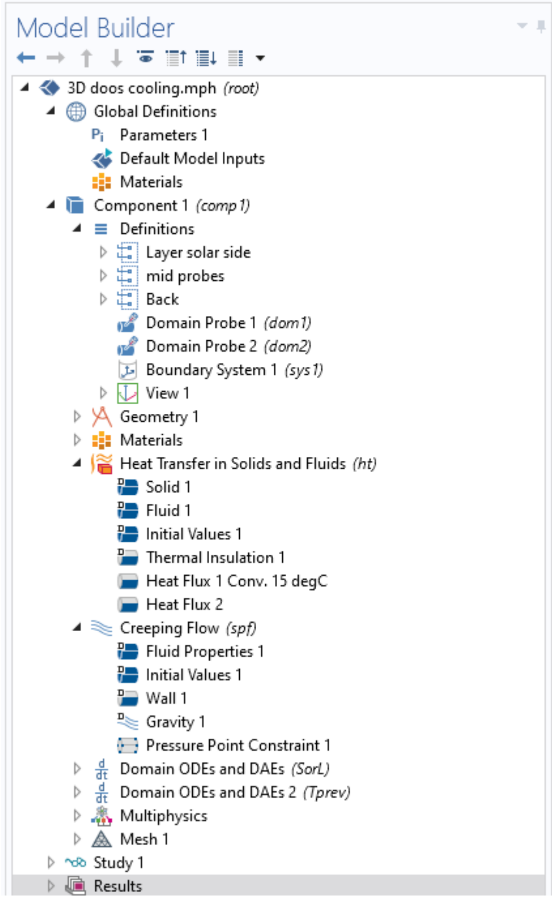


Figure 13. COMSOL Model Builder

As mentioned earlier the fluid will model the PCM's behaviour. In order to do so, it is first set to 'gas/liquid'. The phase transition from solid to liquid of the PCM will be modelled by applying a jump in the dynamic viscosity from a high to a low value after the phase transition has occurred. The initially higher dynamic viscosity ensures that no convective flow will start below the phase transition temperature.

The sides, top and bottom of the PMMA will be insulated, which will be added to the heat transfer module. At the back and front plane of the PMMA enclosure heat transfer can occur. At both the front and back panel, shown in blue in figure 18, natural convective heat transfer with air will occur, which is modelled by including the proper heat flux module in heat transfer module.

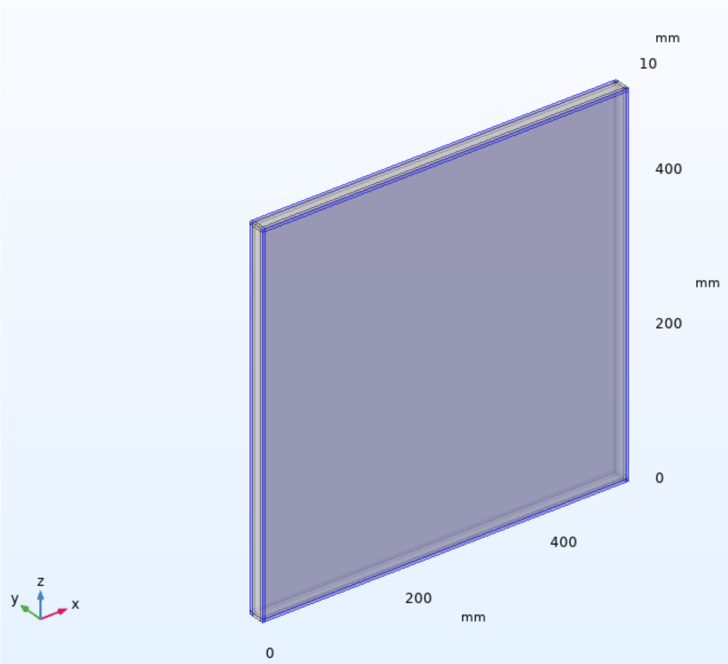


Figure 18. COMSOL PMMA box with C28

The second heat flux module is used to describe the heat flow caused by radiation. Radiation is the natural radiative loss of heat of the material or energy gain from solar radiation. In this case it will represent the applied heating from the heating element.

In order to realistically model the behaviour of the PCM the flow model needs to have the proper settings. First the domain of the PCM must be selected. After that the module laminar flow needs to be set up to describe slow moving flows, as the PCM in liquid phase is very viscous. This means that the options 'stokes flow', intended for modelling very slow moving flows, and 'include gravity', necessary to compute the buoyancy differences leading to convective flow, have been selected. This also caused Comsol to change to the 'creeping flow' module, which is appropriate, as the flow reaches a top velocity of only 1.0×10^{-3} m/s. The reference pressure is set to 0 Pa. The initial temperature is set to the ambient temperature, and all other temperature dependent initial conditions are also derived from the ambient temperature. The initial flow velocity is set to zero. The friction between fluid and solids is neglected, for which the 'no slip' condition needs to be selected in Comsol. The friction can in this case be neglected because of the low flow velocity. The gravity is set to -9.81 m/s in the z-direction. Additionally the absolute pressure differences within the liquid will be relatively low, which will allow for a uniform reference pressure to derive the relevant material properties with. This is set with the 'pressure point constraint' module. The reference pressure will be set at 0 Pa. This sums up the creeping flow settings.

Then there are the *SorL* (Solid or Liquid) and T_{prev} (previous temperature) variables. Those are determined with custom formulas. The *SorL* is binary variable that indicates the direction of the temperature gradient. If it equals 0, the PCM is heating; if it equals 1, it is cooling. The state of *SorL* is based on T_{prev}, which is the temperature of the previous time step. More information on how to determine *SorL* can be found in Tenpierik et al. (2023).

Throughout the domain of the PCM temperature probes have been placed. The probes register the temperature at set locations. These probes are placed in a grid and the coordinates range from 4, 4, 4 in x, y, z to 504, 504, 504 in x, y, z. The locations of the probes are indicated in figure 17. There are 3 nodes in each dimension, which make up for a grid of 3x3x3 and a total of 27 probes. There will also be a temperature probe to measure the average temperature of the PCM domain, also called the domain probe. This domain probes is there to compare with the other point probes. With the simulation data the best suited probes to represent the state of the PCM can be determined.

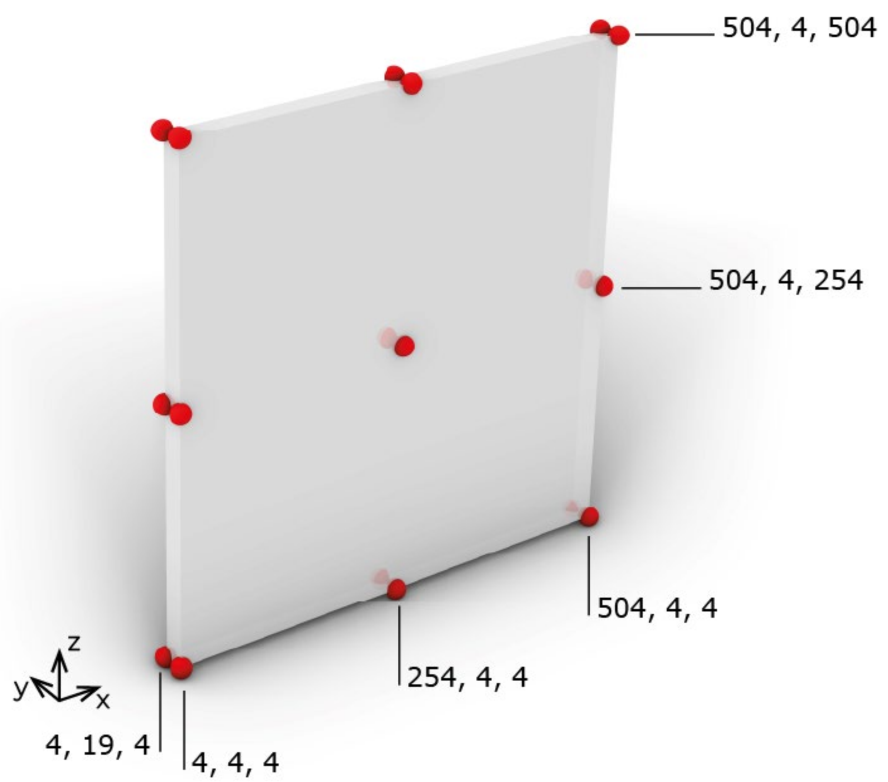


Figure 1914. Location of the temperature probes

The remaining settings for Comsol are Multiphysics, which is set to default, and the mesh, which is set to normal. The details of the specific heating and cooling simulations will be described next.

4.3.2 Heating / melting process

For the heating process and the simulation of melting the PCM, several modules have to be filled in. The PCM that is used in the simulation, C28, has a phase change temperature around 28 ^{0}C. To simulate this process, the initial temperature of the PCM and PMMA is set to 15 ^{0}C, as is the reference. Then the heat flux for convection and for radiation need to be specified. For the heat flux of natural convection in air, the air temperature is set to 40 ^{0}C. This is an abnormal temperature for countries like the Netherlands, but it is done to speed up the simulation. In the heat flux module for radiation an irradiance of 300 W/m^2 is set.

This is an average solar irradiance value that is common for countries like the Netherlands. In the module 'study' the time of simulation and the intervals are set. The simulation runs from t = 0 s to t = 14400 s. 14400 seconds is equal to 4 hours. The interval is 60 seconds.

4.3.3 Cooling / solidifying process

For the cooling process the initial and reference temperatures for all materials are set to 30 ^oC. The heat flux for the convection is again set on external natural convection in air. The air temperature is set to 15 ^oC during this simulation. The radiative heat transfer will be heat loss to the environment, instead of heating, and will be described with a linearised heat transfer coefficient of 5 $W/(m^2\ K)$. The settings for the creeping flow module remain unchanged. The time that is set for this simulation starts at 7200 seconds and ends at 36000. The intervals are set to 600. This is done because the solidifying process is slower than the melting process.

4.4 Results

This simulation was done to compare the results of the simulation to the behaviour of the material and find representative probes for the experiment. In the simulation of the PCM each probe that was placed in the grid, that was stated earlier, gives the temperature value of the PCM at the set coordinate. The coordinates with their results are shown in the figure . The first step that was taken was to search the best fitting point probe compared to the domain node. The results from the point probes of the heating simulation are shown in graph 20, 21 and 22. The results have a considerable deviation. A conclusion from this result was that there is a big temperature difference within the PCM panel during the simulation. The probes in the corners measured a significantly higher temperature in the experiment than the probe that was placed in the middle of the bottom plate (254, 11.5, 4).

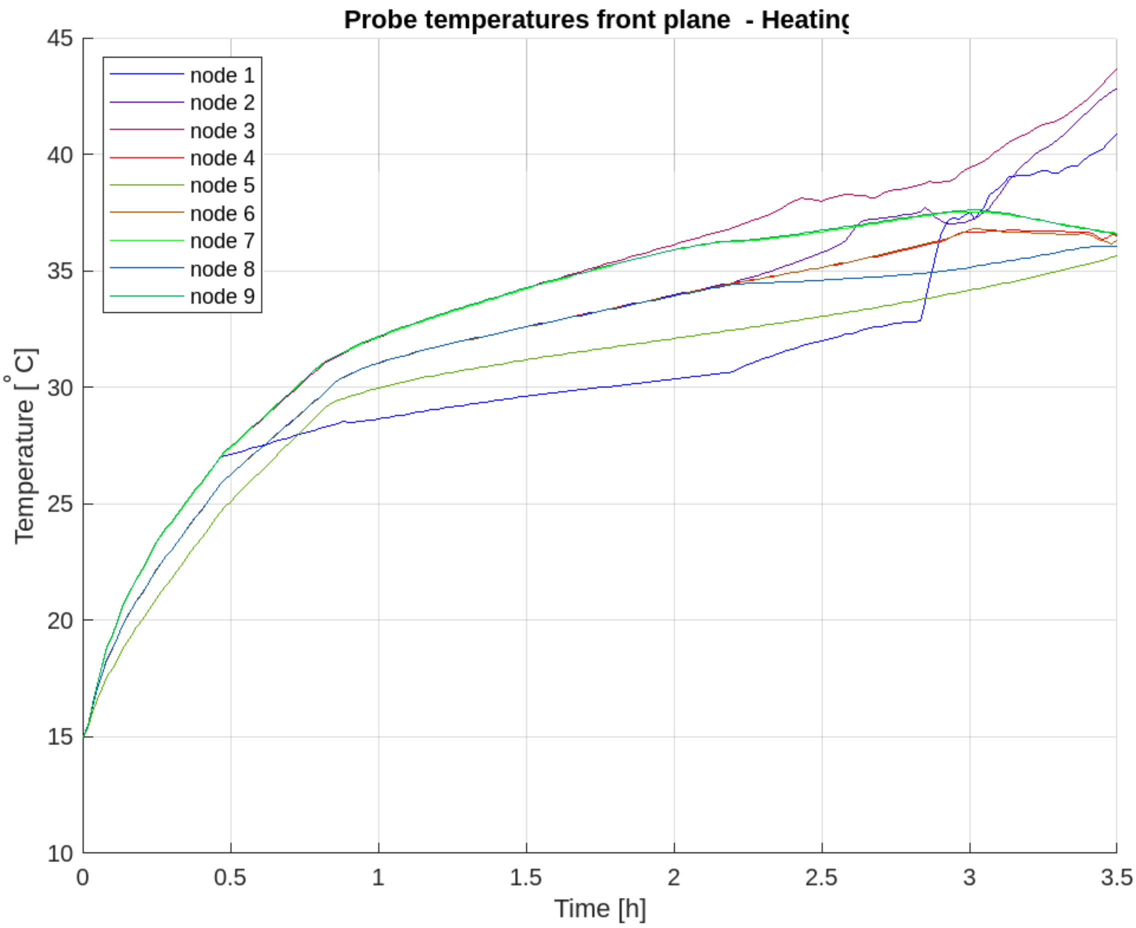


Figure 20. RESULTS of frontpanel nodes in heating process

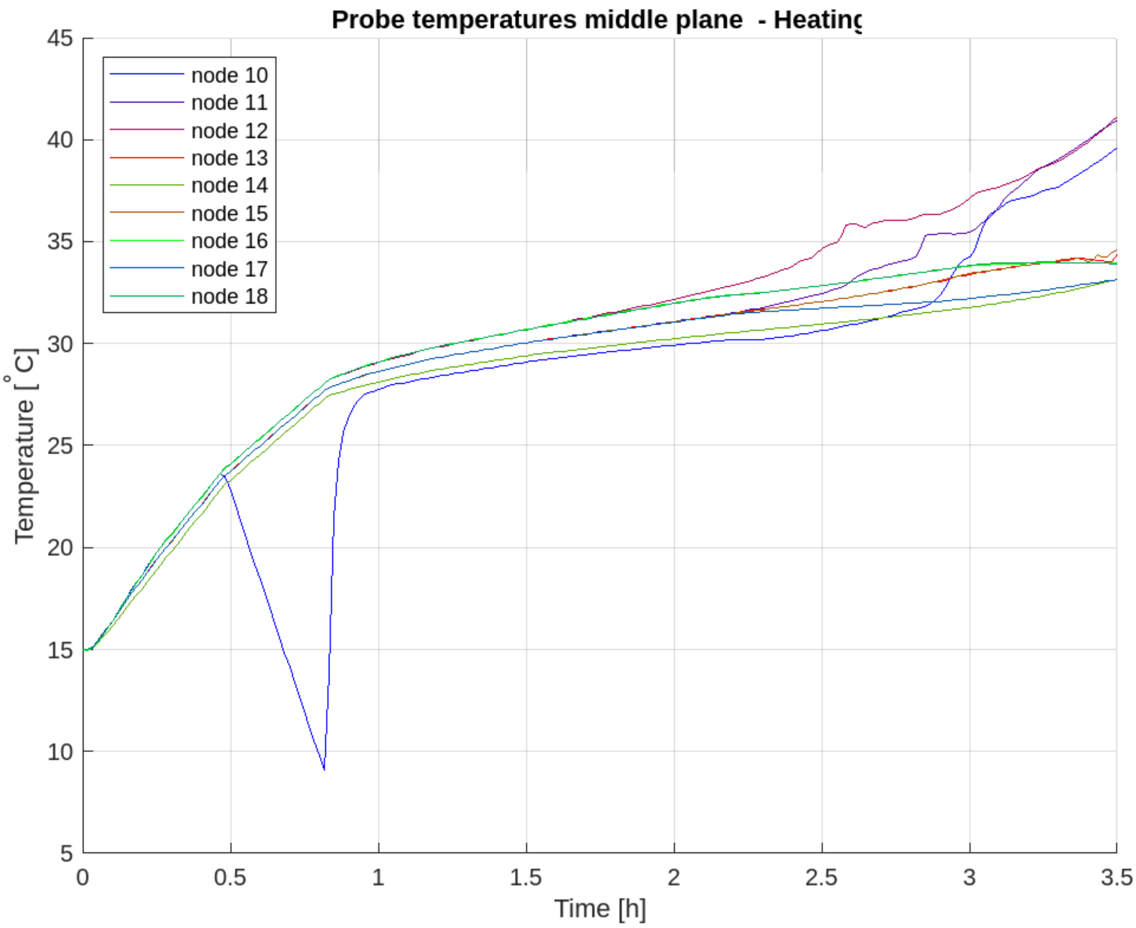


Figure 21. RESULTS of middle nodes in heating process

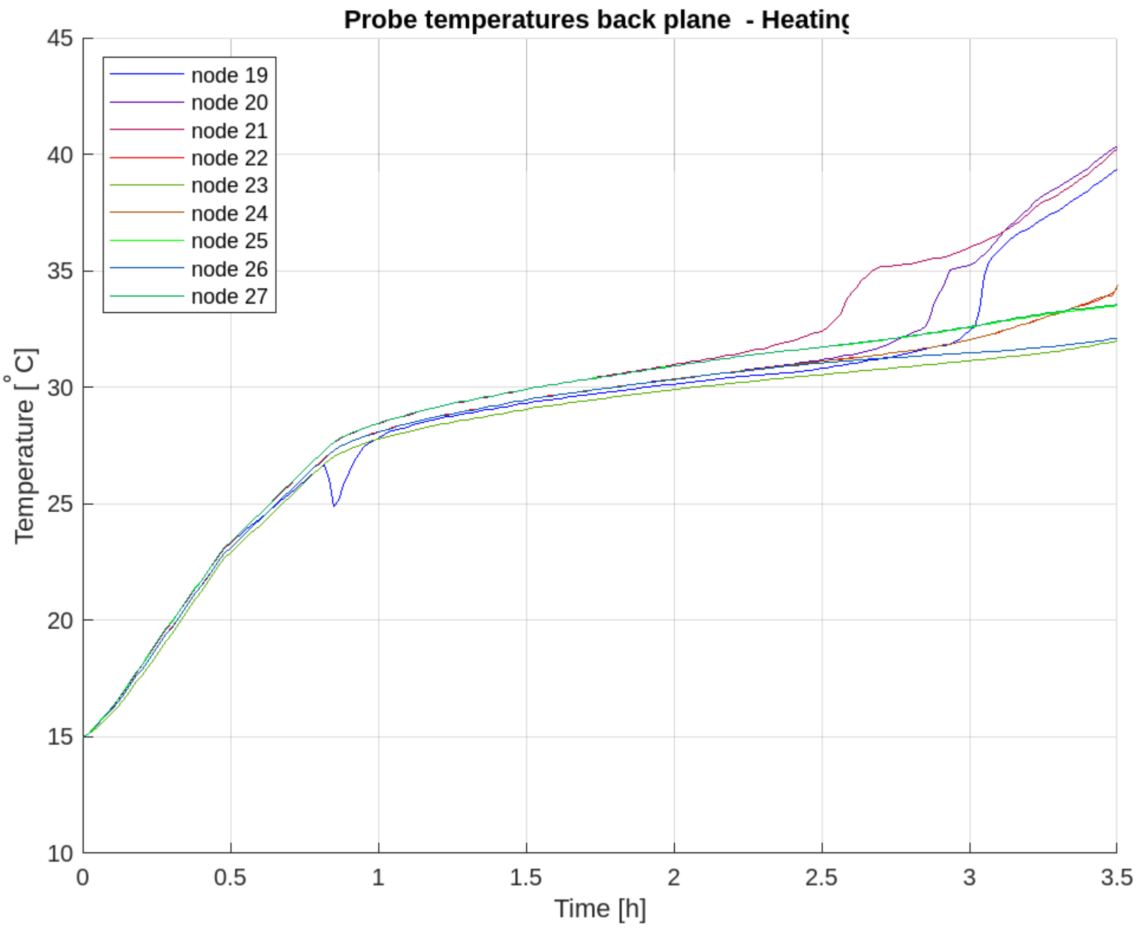


Figure 22. RESULTS of backpanel nodes in heating process

The results of these probes were compared to the domain probe results. The measurements of the domain probe can be seen in the graph of figure 23.

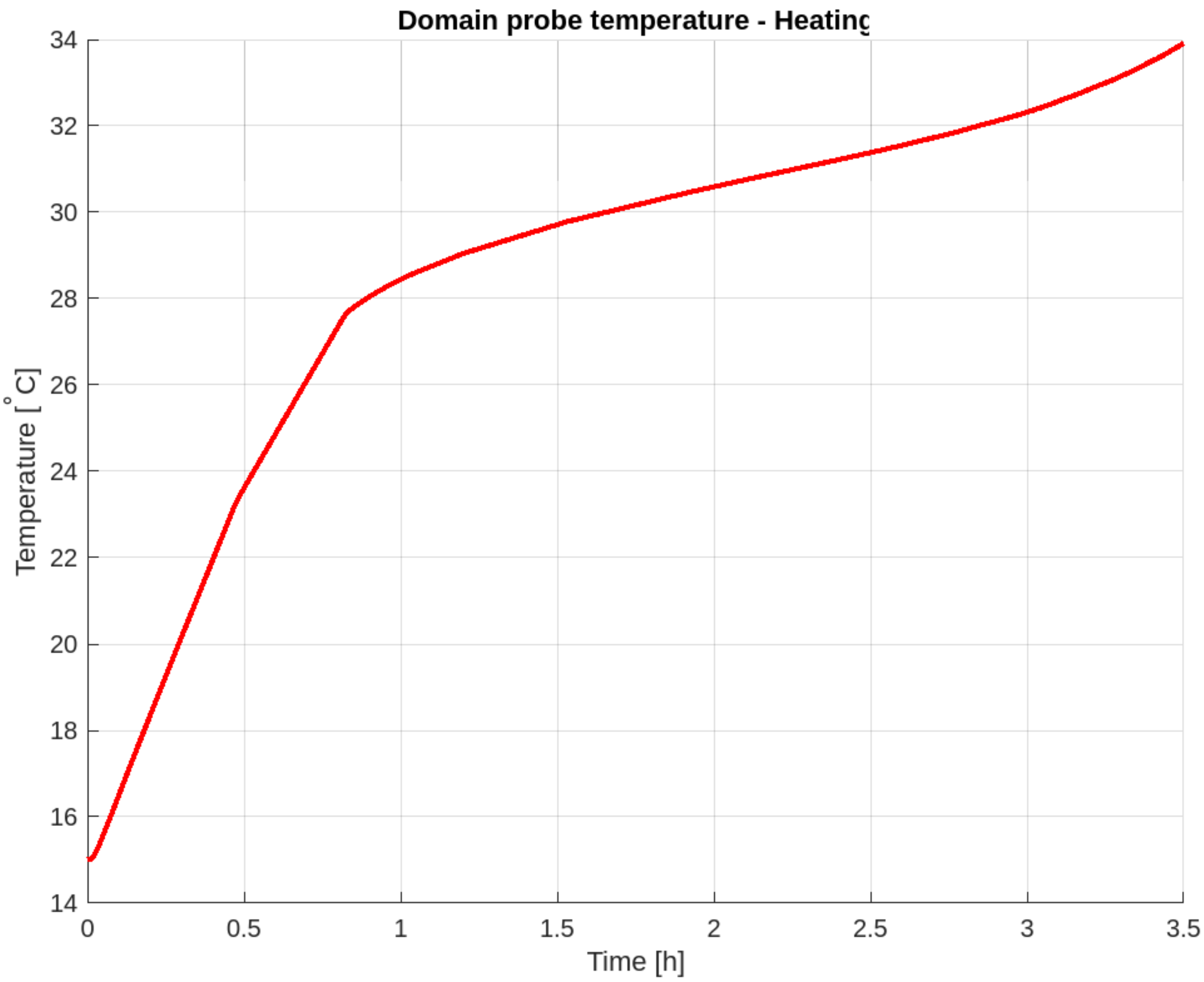
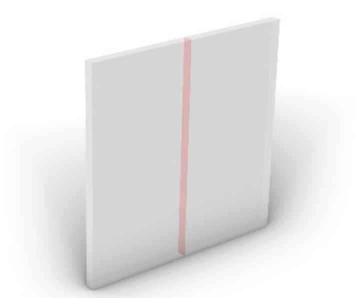


Figure 2315. RESULT domain probe heating

The comparison was done by reading out the tables with the measured values from COMSOL. These values are shown in the appendix. With Excel the tables were analysed and compared. The comparison was done by checking the mean difference of the measurements. The results would range from 186.5 to 978.7. The smallest number has the smallest deviation from the average line. The results of this method did not lead to a reliable way of measuring the PCM.



Another strategy that was used to find a reliable way of representing the average temperature in the PCM panel was to measure sections of the panel. Picture 24, 26, 27 and 30 show the sections that were picked. The results of all the nodes that are in the section were added up and divided by the amount of nodes that were in the section. With a grid of 3 x 3 x 3 the section can only go through a maximum of 9 nodes. The graphs of the individual results are in the appendix but the mean result is shown in the figures 25, 27, 29 and 31. The first section was taken over the vertical-axis. The first hypothesis about this value was that it would be reliable because the middle part reacts slower compared to the corners and the data together would give a result that is similar to the average. By taking the average of the results of the combined a graph was made. This graph was comparable to the average results. The graph is slightly slower in reacting to the temperature change. The reason is that the ratio between the length of the edge compared to the surface of the panel is small. The edges of the panel react quicker to heating than the surface. By making the panel wider the results of the vertical nodes in the centre should become relatively more accurate. The results of the average data is very comparable with the domain probe and only deviates from the line by 1 Kelvin at most.

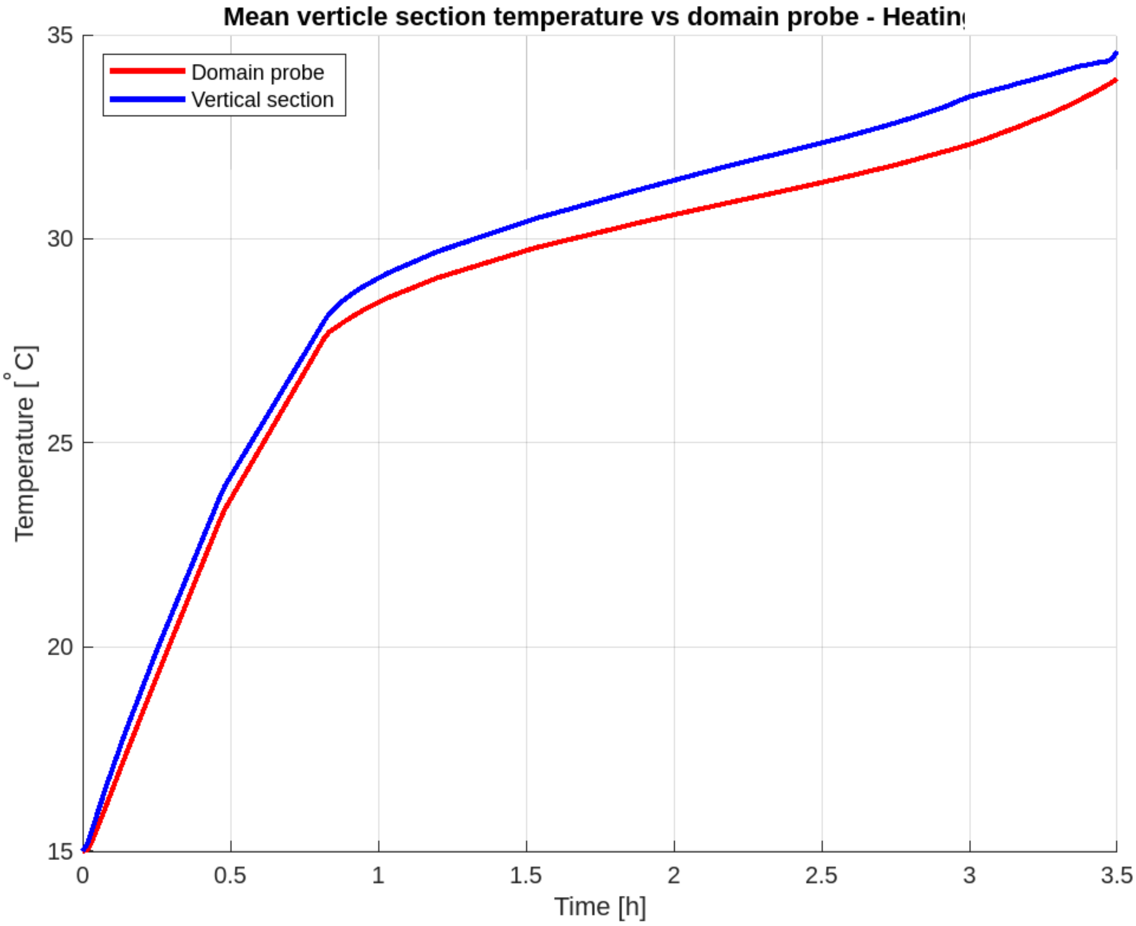
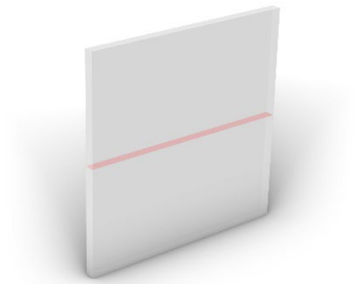


Figure 175. Mean value vertical nodes

The second option of taking a horizontal section of the panel is depicted in figure 26 . The section is taken through the middle of the panel in the horizontal direction. 9 probes were used to average the data. The hypothesis for taking a section in the horizontal direction is that the temperature difference in the middle is more similar than the temperature difference in the vertical direction. By taking the probes on the edges and the middle, an average result was produced. This result is visible in the graph depicted in figure 27. Also these results are close to each other, but the measurements of the probes show a slower temperature increase around 304 Kelvin. This is caused by the fact that all the sensors are at the same height. Once the convective flow stops the temperature will flatten for a short period.



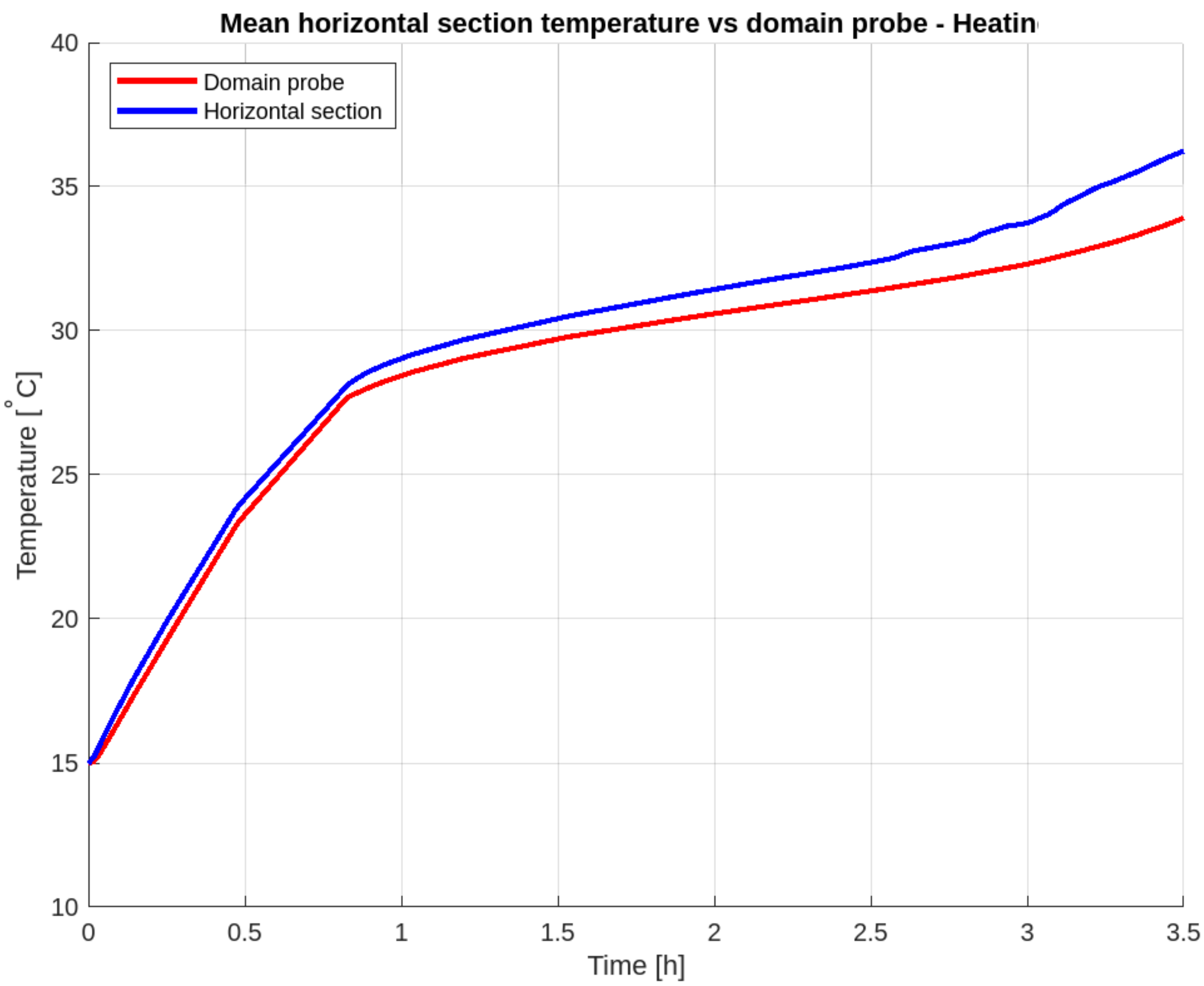


Figure 197. Mean value horizontal nodes

The diagonal and horizontal measurements both have results that are comparable to the domain average probe. With the diagonal measurements the biggest distance between the probes was the biggest. The hypothesis was that by measuring in temperatures that were further apart a more reliable result would come out. Also the corners would react even faster than the edges to temperature raise. In figure 28 the red line represents the diagonal axis and the location of the probes. The hypothesis was that the probes in the corner would cancel out the slower rising temperature in the middle. The results are visible in graph of figure 29. The hypothesis was true, but the effects of the corner are overcompensating for the delay of the probes in the middle. The average line is rising quicker than the domain probe. The difference in temperature is too big to be reliable.

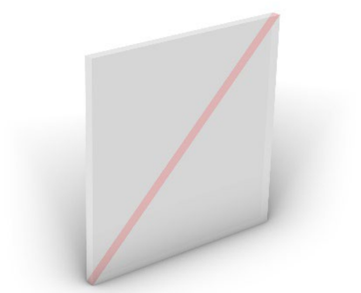


Figure 208. Location of nodes in diagonal

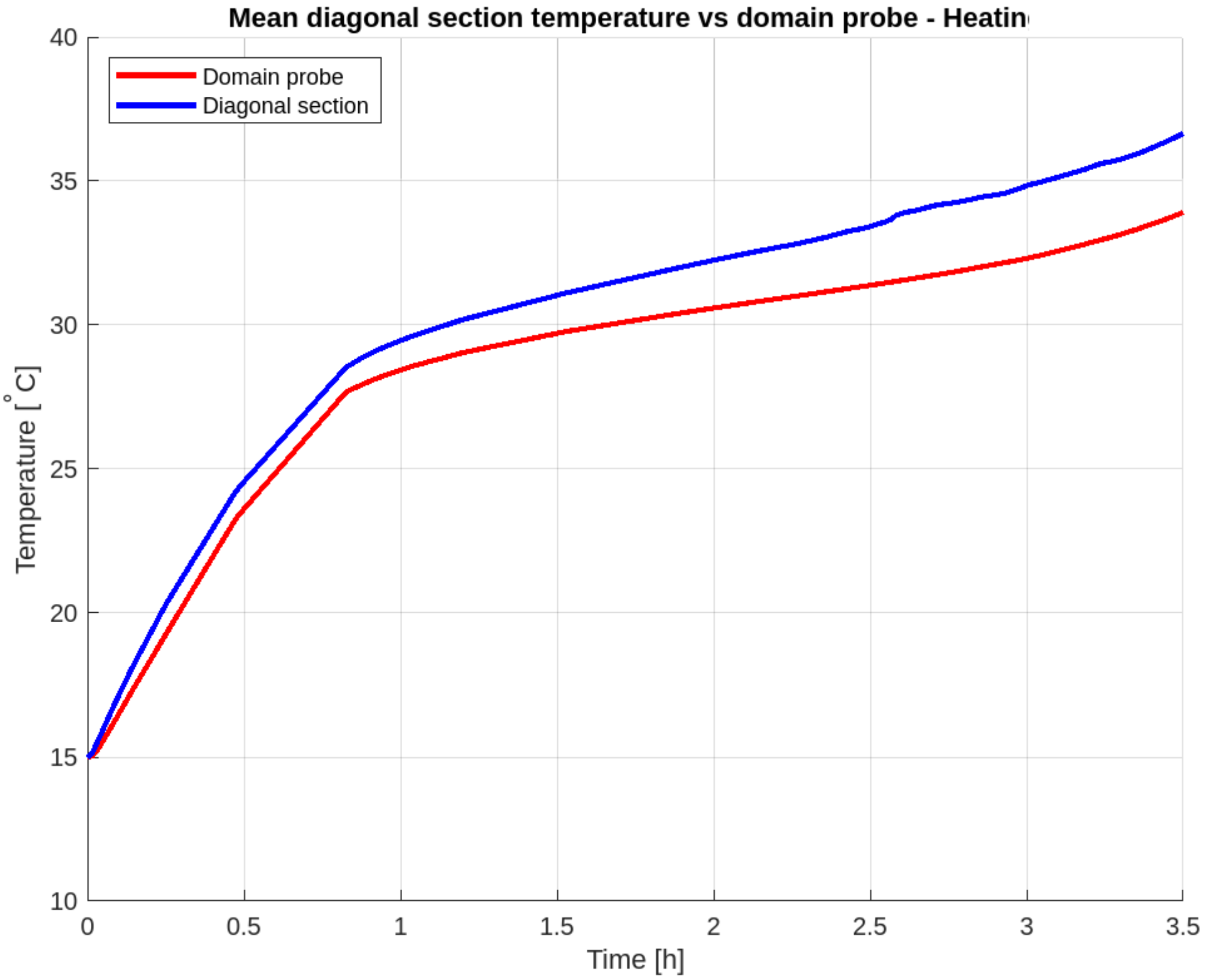


Figure 219. Mean value diagonal nodes

A forth option was tested and this was the one where only two probes were used. The probes (254, 4, 254) and (254, 19, 254) resulted in a very accurate result that is similar enough to the domain probe to be used. In figure 30 the locations of the probes are shown. The theory of only using 2 probes on the surface of the PCM in the middle is that the effects of the edges and corners will be reduced by scaling up the model. This makes the sensors in the middle relatively more accurate. In figure 31 are the results of the average measurements of the 2 probes. The average point measurement is a delayed by 1 Kelvin per 400 seconds on the largest difference. This is an acceptable value.

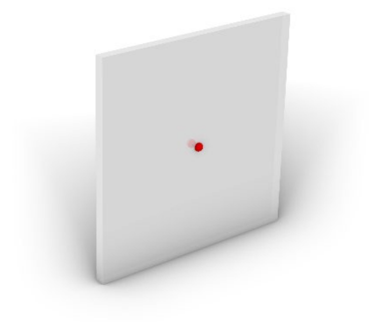


Figure 30. Location of point nodes

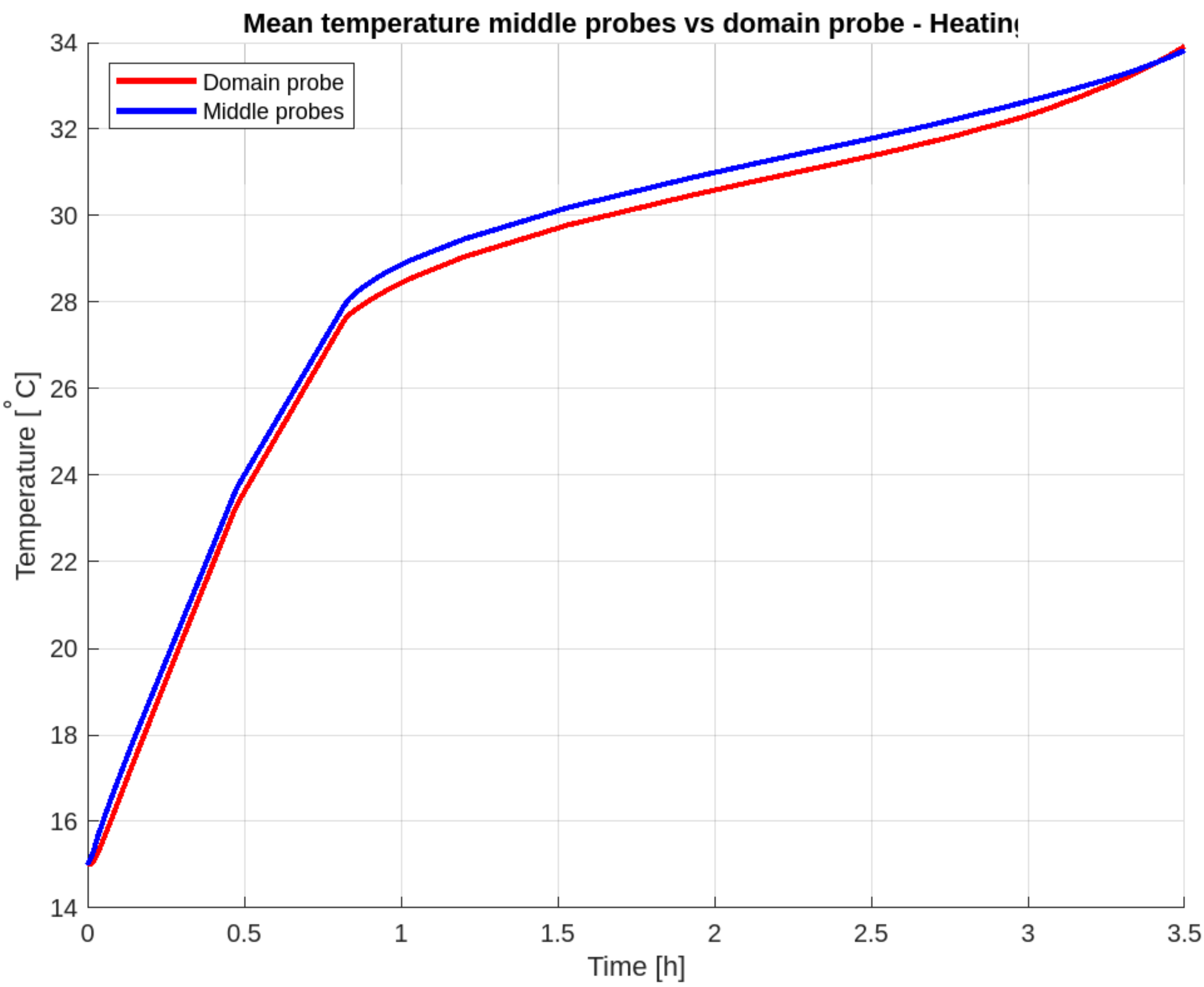


Figure 31. mean value point nodes

The same comparison was done for the cooling process. For the comparison, the same probes and sections were used. The behaviour of a PCM that is cooling down is different from a PCM that is heating up. This meant that certain settings of the experiment had to change. The settings for the cooling simulation were already described, but cooling down a PCM is a longer process. This meant that the start time of the simulation was around 2 hours (or 7200 seconds). This was done, because the temperature-time curve of the PCM did not vary in slope. Soon After the 2 hours the PCM started to show a change in slope, which means that the solidifying process was starting. The process of solidifying, with the simulation settings, takes more than 6 hours. In figure 32 the domain probe is depicted and in figure 33, 34 and 35 the results of the probes are visible.

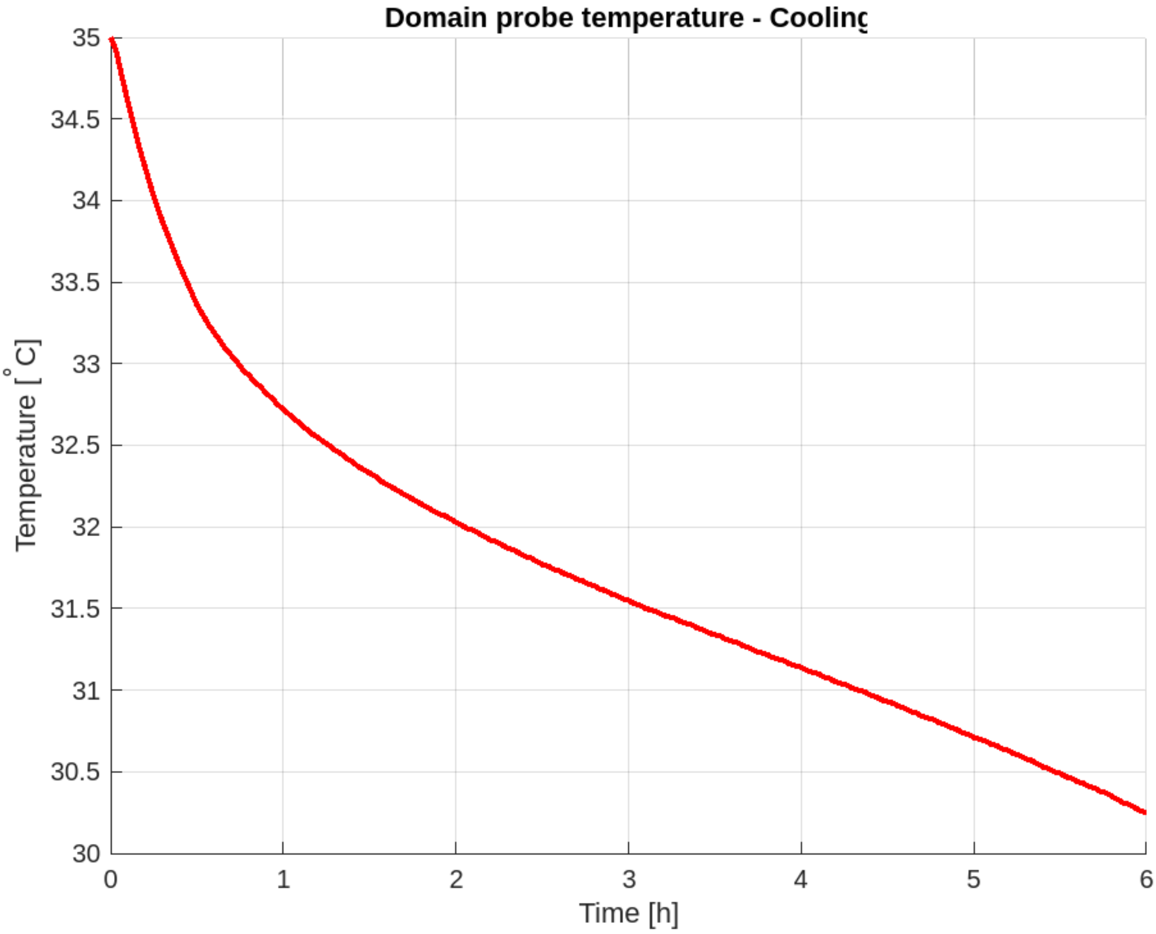


Figure 32. RESULTS domain probe cooling

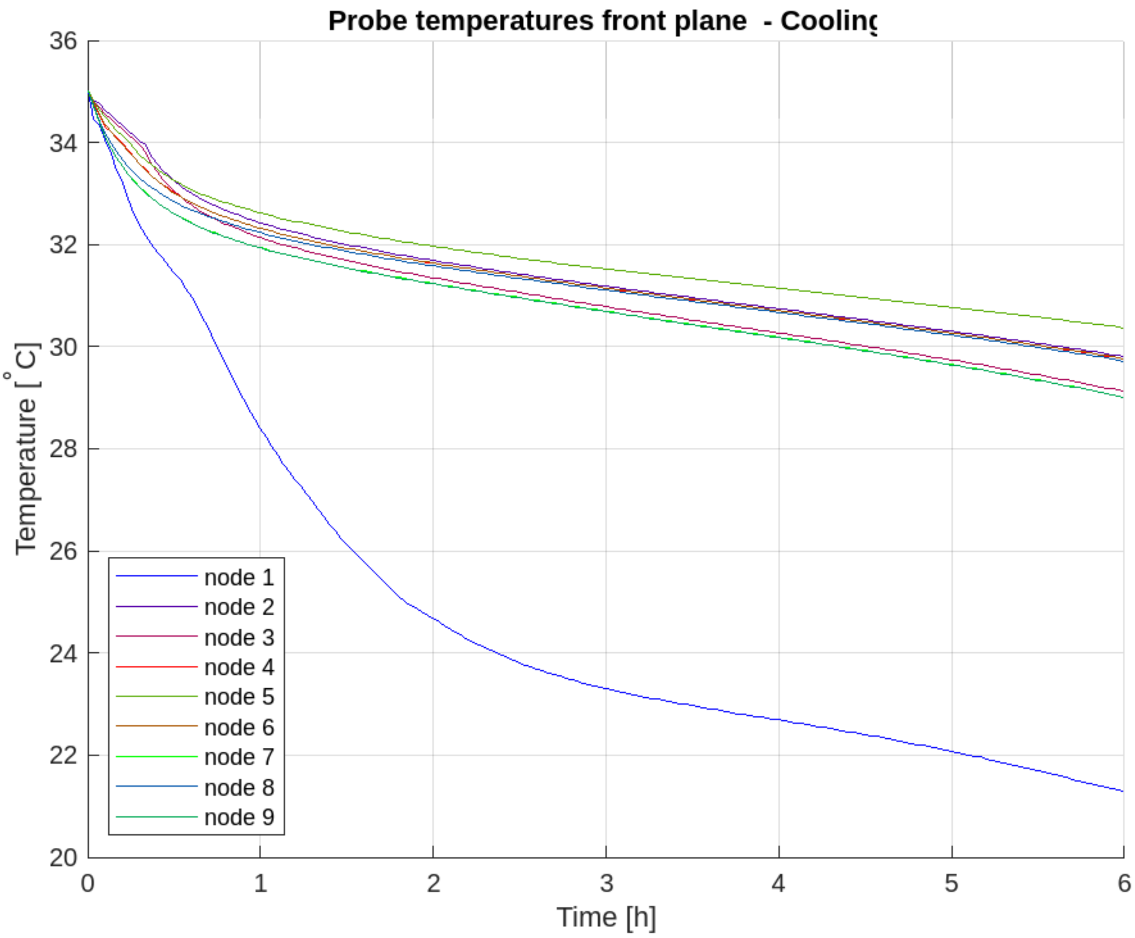


Figure 33. RESULTS frontpanel probes cooling

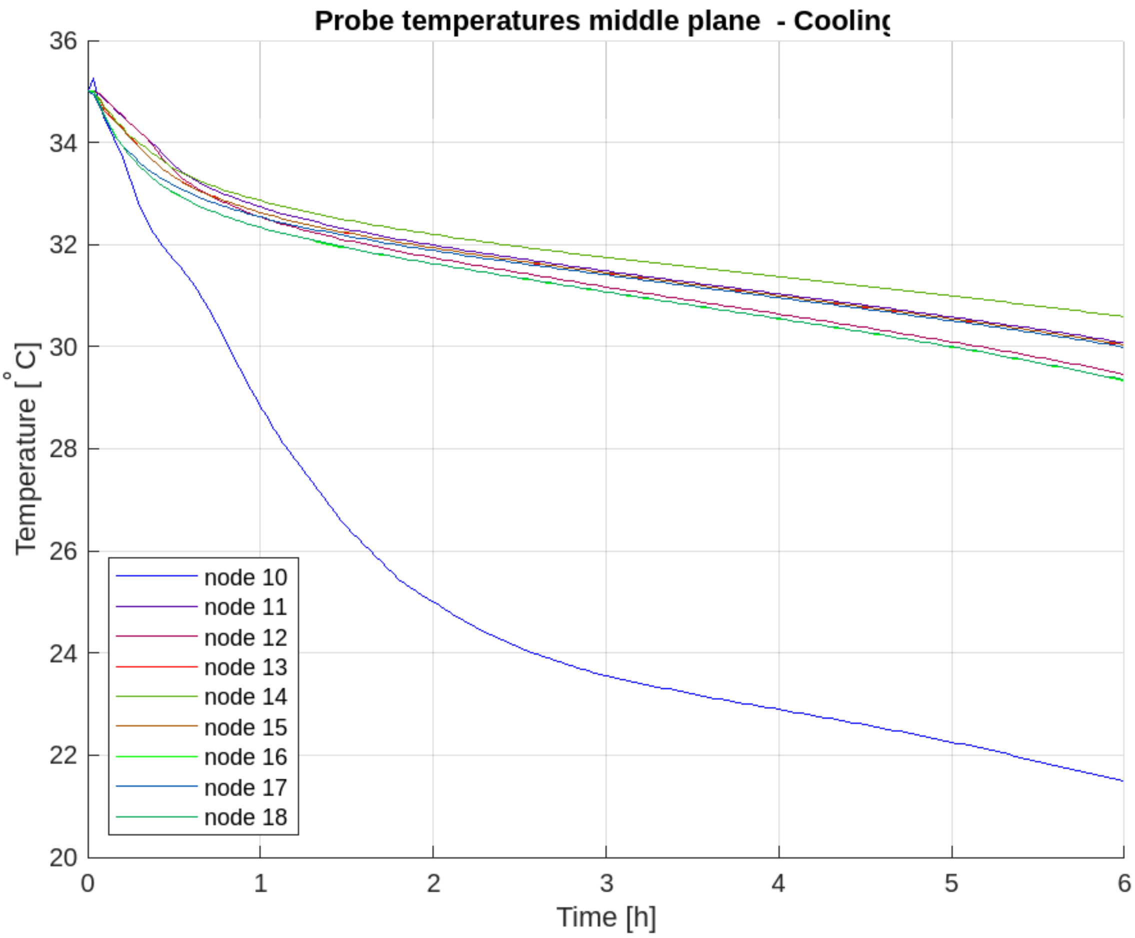


Figure 34. RESULTS middle probes cooling

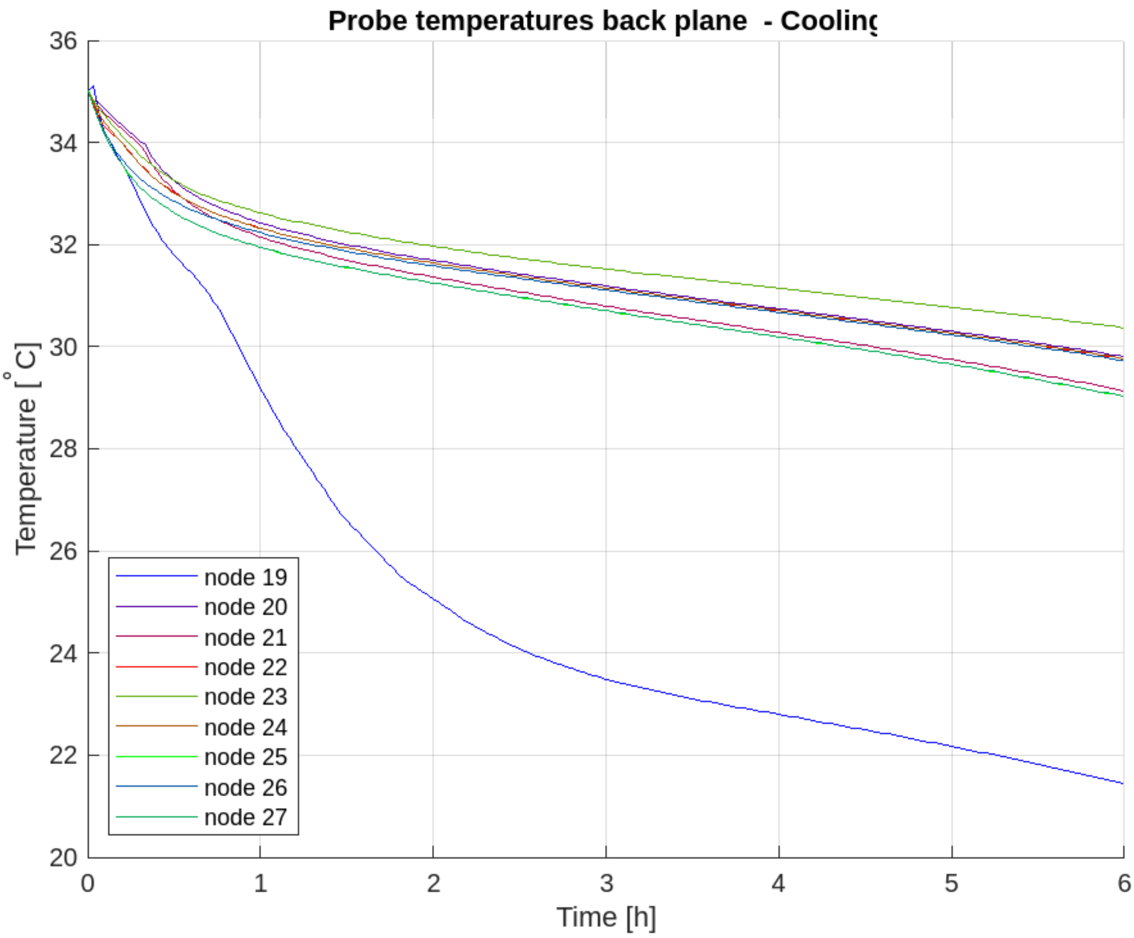


Figure 35. RESULTS backpanel probes cooling

figure 32 shows the results of the domain probe and the point probes through the vertical section of the panel. The results are very comparable and the difference between the 2 graphs is very small. This is because the temperature distribution throughout the PCM during the cooling process is more uniform .

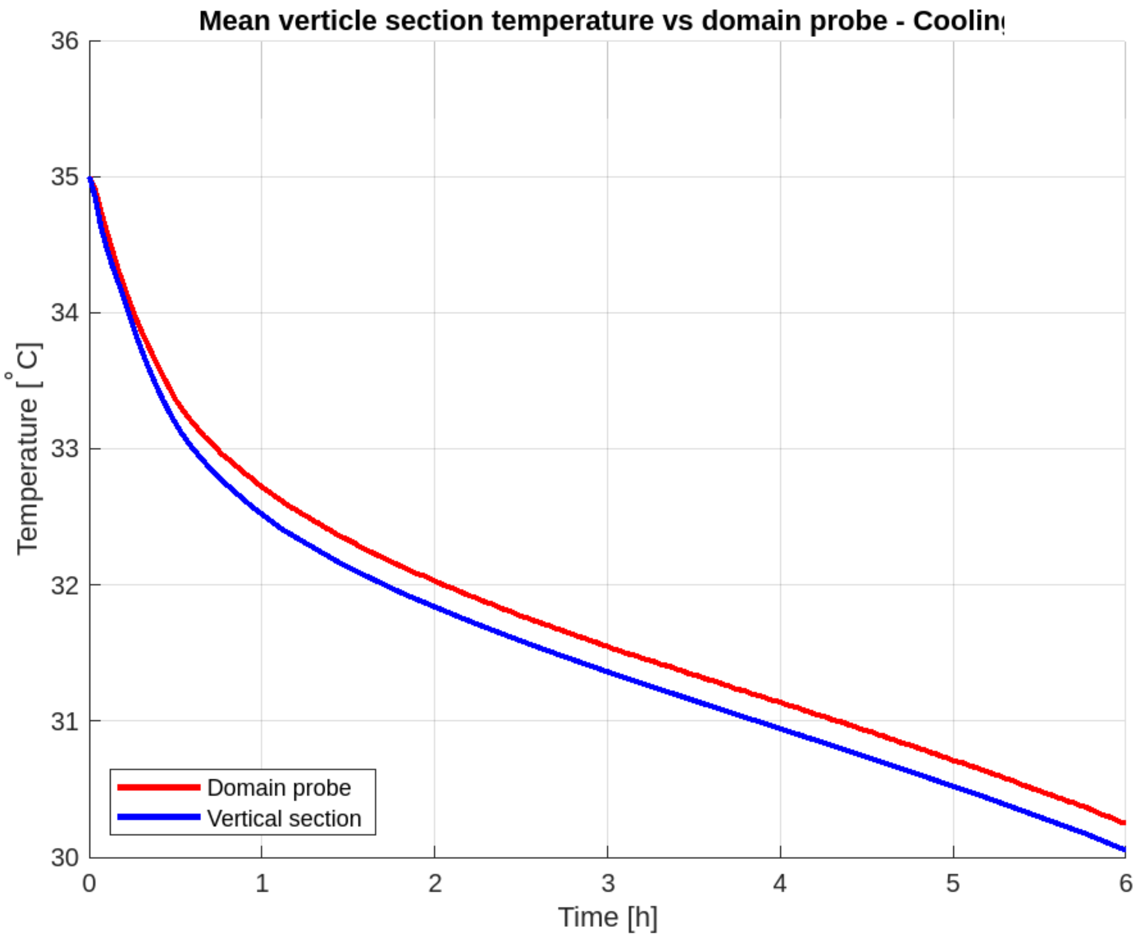


Figure 36. Mean value vertical nodes

The next graph is from the horizontal section of the panel. Figure 36 has similar results as graph 37. The similarity is caused by the absence of significant convection effects.

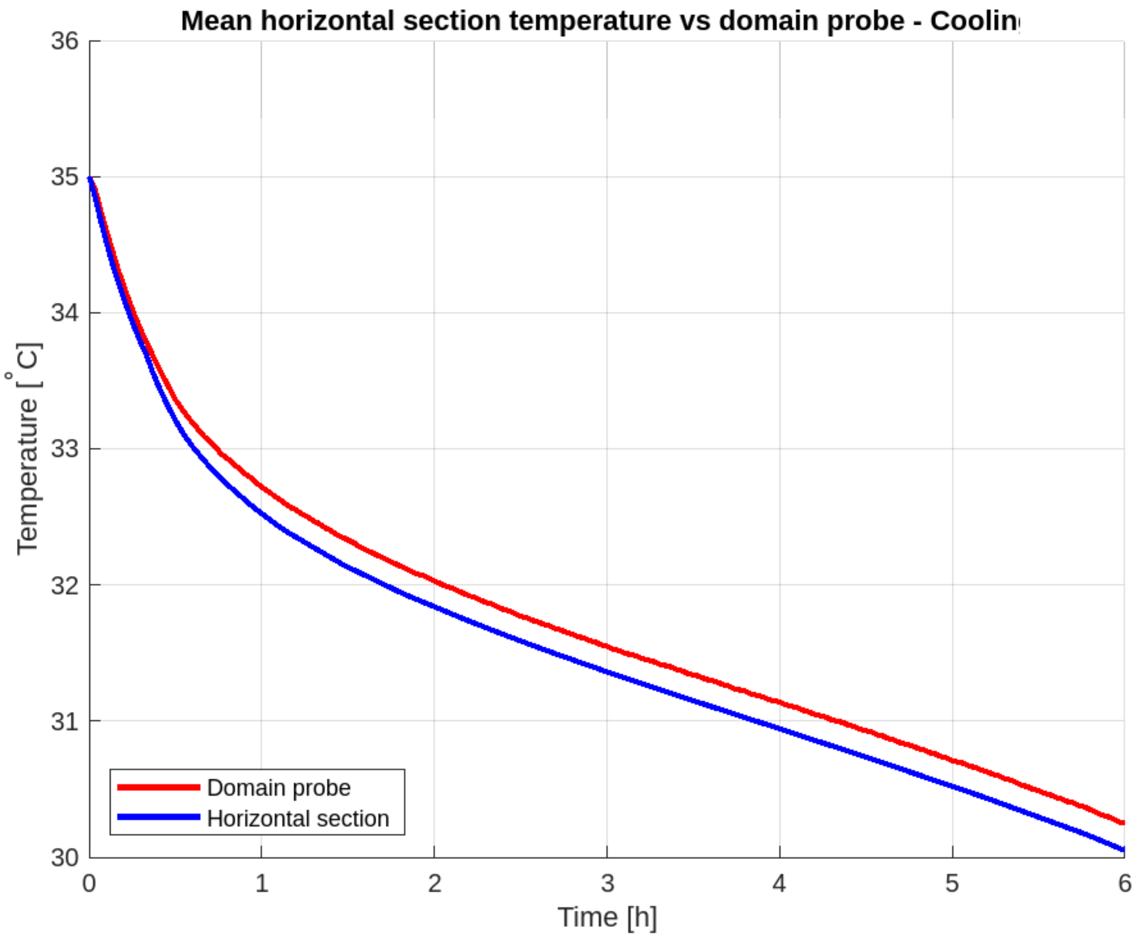


Figure 227. Mean value horizontal nodes

Figure 38 is the result of the diagonal section. The diagonal graph diverges more from the domain average than the previous sections. This is because the temperature change in the corners is faster, the same as was found for the heating process. Where the horizontal and vertical section only diverge 0.2 Kelvin, the diagonal differs 1 Kelvin.

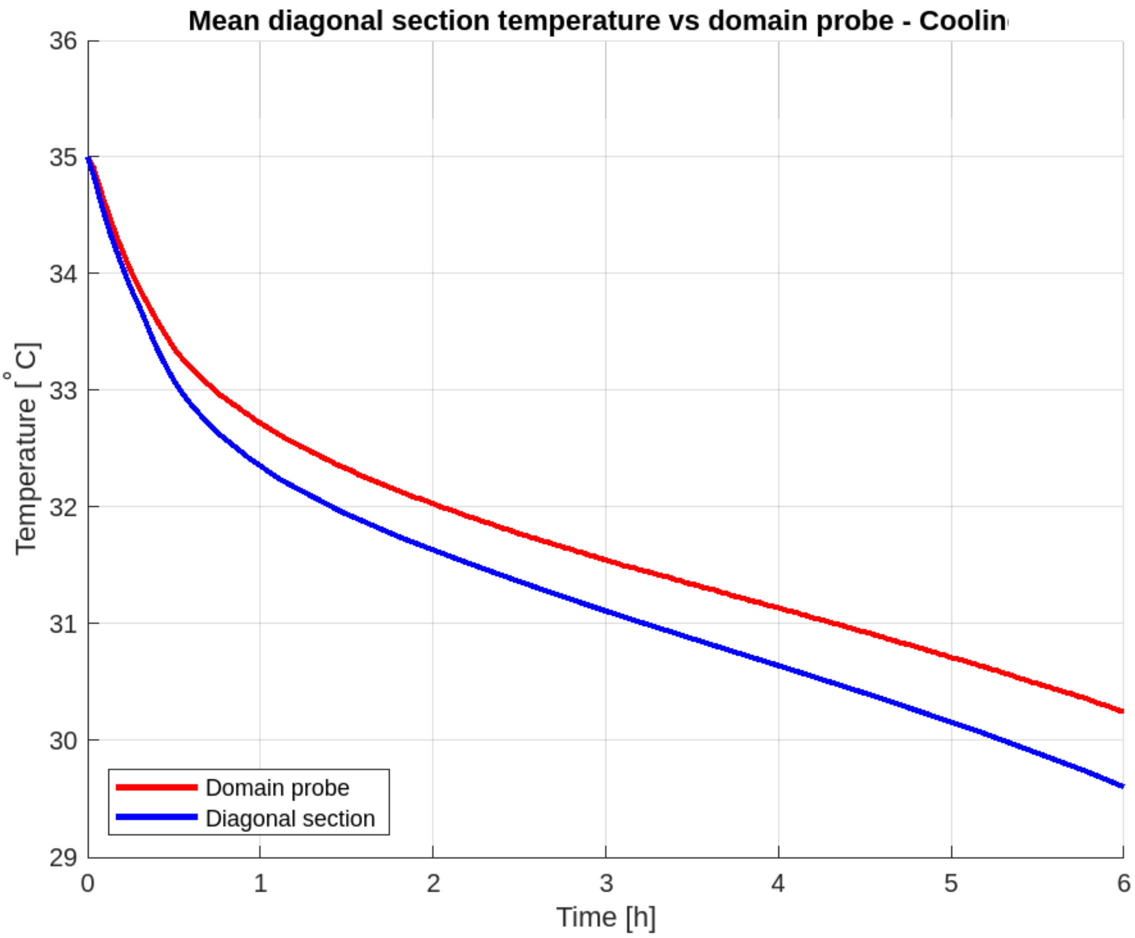


Figure 238. Mean value diagonal nodes

The last graph is the graph from the 2 middle points on the surface .

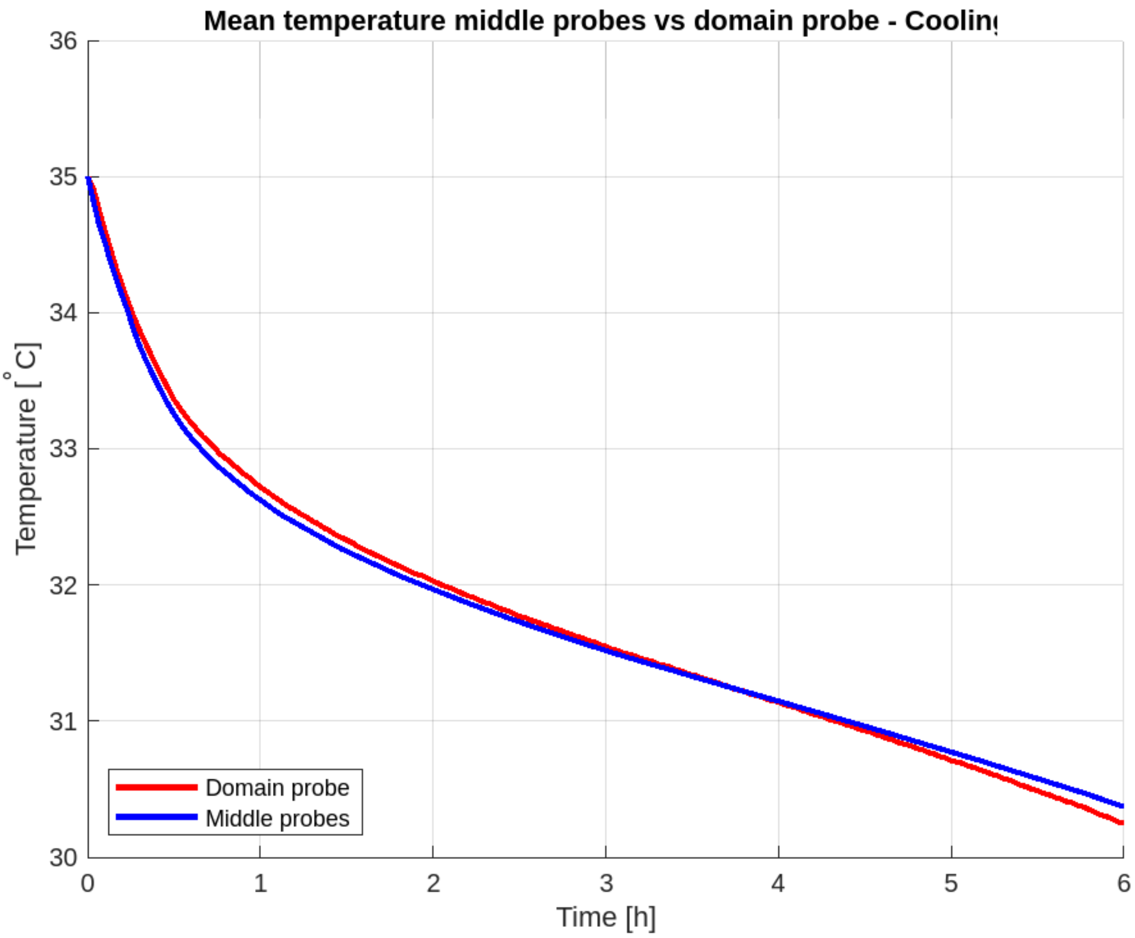


Figure 249. value of the 2 middle nodes

4.5 Evaluation and conclusions

A variety of sensor placements has been tested. The aim of this simulation was to find reliable locations for the sensors and to see how many sensors were needed to come to an accurate result. The 4 iterations of sensor placement are in vertical line through the middle, a horizontal line through the middle, a diagonal line and a 2 point measurement in the middle of the panel on the surface. The best measurement iteration is determined by comparing the graphs and results of the iteration to the line of the domain probe (average over the entire volume of PCM). The values that are considered are the tangency of the line and the absolute value. The vertical measurements are accurate and very similar in tangency compared to the domain average line in the melting and solidifying process. The measurement in the melting process is more accurate than the horizontal measurement due to the effect of heat that is rising. The temperature difference that is caused by convection is the reason that the vertical measurement is more accurate. The 2 point measurement is accurate enough to be considered an option. The reason that this iteration is more reliable than the horizontal measurements is because the average temperature at the set height and the amount of sensors of the horizontal measurements are influencing the mean value in a negative way and are representing a temperature value that is representative for the middle section, but not for the panel. By reducing the amount of sensors, the middle 2 sensors have a more accurate average value. The diagonal measurements are not reliable, this is caused by the effect of the corners. The surface of corner that absorbs the heat is projected in the corner of the PCM. Measuring there causes values that are to extreme, if compared with the domain average.

The conclusion is that the best outcomes are with the vertical measurement and the 2 point measurement. The vertical measurements are more reliable because they measure through a multitude of temperatures. There is a considerable difference in temperature between the bottom and top part of the panel. If the mean value of these differences is taken a representative result is produced. On the contrary this method requires 9 sensors, whereas the 2 point measurement has a similar outcome. The vertical measurement has the most accurate absolute value, but the 2 point measurement is more representative in the change of temperature, seen its tangency.

For this experiment the 2 point measurement is considered the best possibility. It has the smallest amount of sensors and an accurate enough depiction of the domain average and those are higher valued then the absolute value.

4.6 Reflection on simulation and result

On hindsight the simulation can be improved. During the process the locations of the nodes were picked with the thought that for measuring the average temperature the corners together would with the middle be a reliable way to get the average temperature. Later in the study, it was found out that dividing the panel in sections and measure and placing the probes in the middle would be a better way of measuring an average temperature of a panel.

The temperature is an aspect of the simulation that can also be considered as unrealistic. In the simulation the assumption was made that there will be a perfect heat gain. With this there were no considerations made with temperature fluctuations that happen in real situations. Also the height of the temperature is unrealistic for a real situation, but for the simulation it would not matter. It was done to speed up the process.

The result is that the 2 point measurement is the best option for a size of 500x500x15 mm. On bigger scale more simulations have to be done but it is expected that still two sensor option would provide an accurate enough temperature result . The section method mentioned in the reflection might be a way to use minimum sensors, but still remain an accurate depiction of the temperature of the wall.

Chapter 5 Experiment

The experiment for this research is to measure the PCM in the PMMA box and measure the temperature of the PCM with thermocouples. This experiment is done to compare to the simulation and see if the values are ultimately usable for the augmented reality. In this chapter the components of the experiment are described first. After that the setup of the experiment is explained. Next, the results are shown and the final section draws a conclusion and a reflection on the experiment. The conclusion will be about the usability of the results for the augmented reality.

5.1 Components

The experiment requires several components. The components will all be described and explained. There are components:

1. Climsel c28 (The PCM)
2. Raspberry pi 4
3. Daqhat mcc 134
4. Thermocouple type T
5. PMMA box
6. Polystyrene box

The components will be explained in this order.

5.1.1 Climsel c28

Climsel c28 is the Phase change material in this experiment, it is shown in picture. The material was provided by the TU Delft. Climsel c28 liquefies at 31 ^{o}C and solidifies at 28 ^{o}C. The density of the material is 1500 kg/m^3. The material consists out of sulphate, soda, water and additives. The latent heat of fusion is 43Wh/kg which is equal to 154.8 J/g in picture # and # the enthalpy steps and curve are shown. The values of the enthalpy can be used to program the material in COMSOL. The enthalpy stays consistent as long as the product is used as prescribed in the guidelines. It is packed in an aluminium package to conduct the heat and to package it.

Picture 1. Picture of C28 in the package

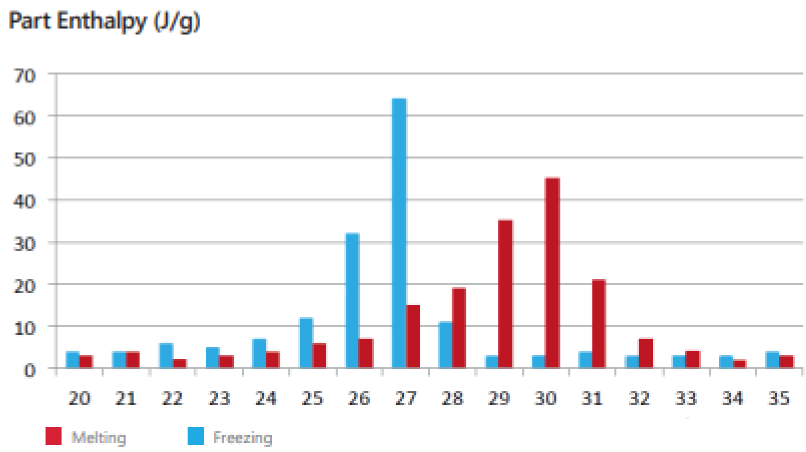


Figure 41. Enthalpy of C28 in steps

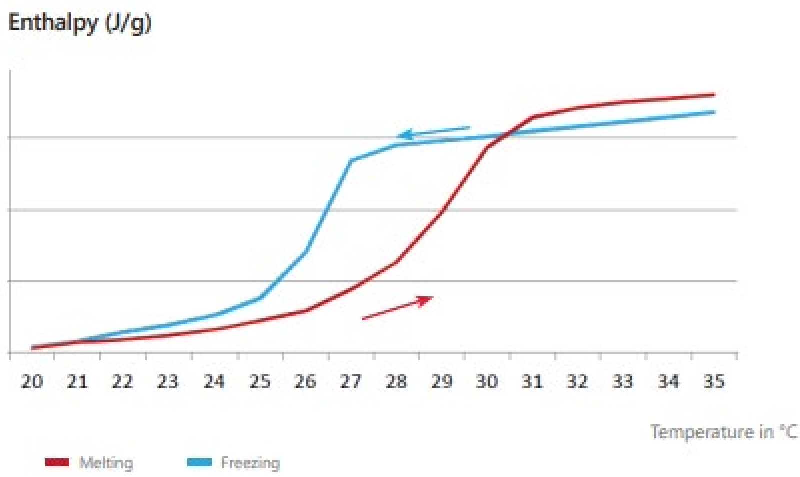


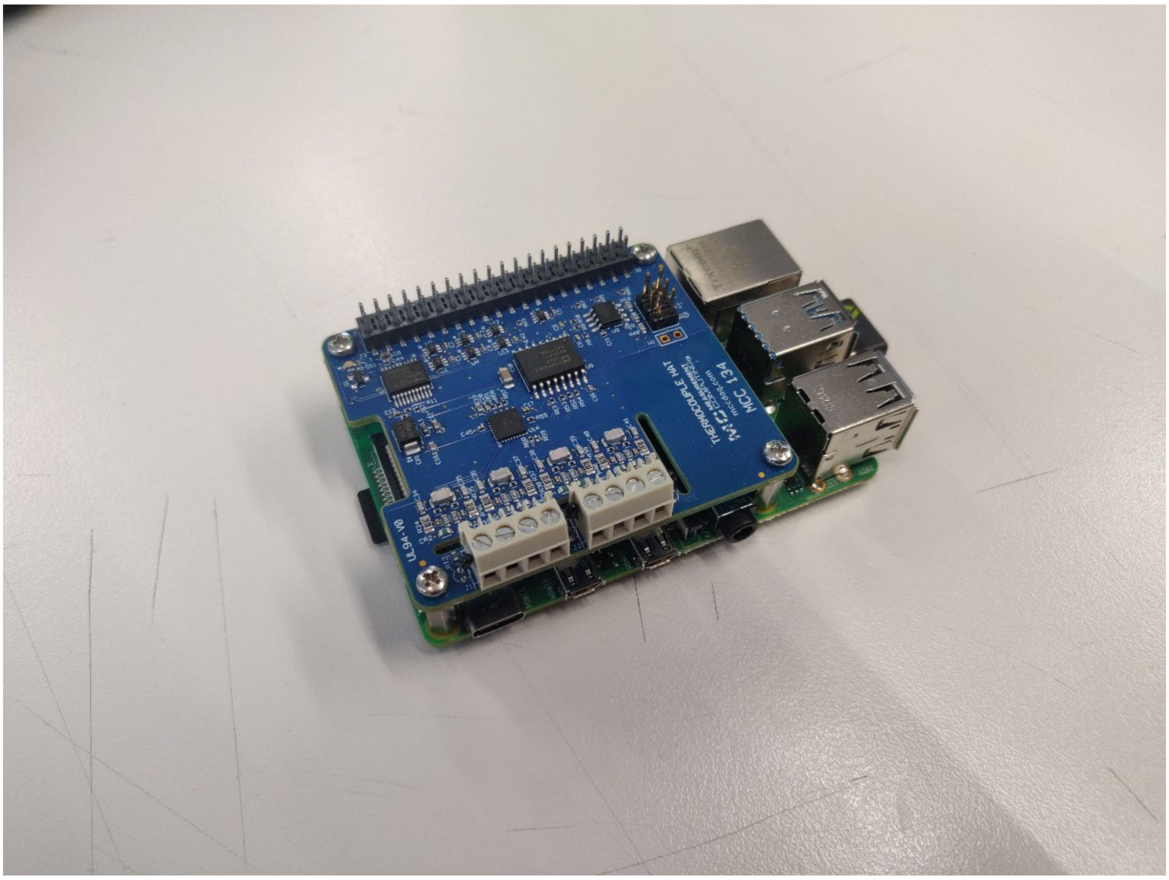
Figure 42. Enthalpy of C28

5.1.2 Raspberry Pi 4 version B

The raspberry pi 4 version b is used for this experiment. Most raspberry computers are suitable for this experiment, but the raspberry pi has the most capacity to work with is the amount of data. The raspberry pi allows to work over a network and sent data from one device to another. For the experiment this is not necessary, but for the augmented reality part this would be essential. Also logging the data is an option for the raspberry pi, which makes it very suitable for a long running experiment. The raspberry pi can add more functions by connecting it to a HAT. A HAT is separate piece of hardware that makes it possible to extend the use of the raspberry pi. HAT stands for 'Hardware Attached on Top'. The DAQHAT MCC134 is such a hat. The compatibility with the DAQHAT MCC 134 allows it to measure temperatures with an high accuracy.

5.1.3 Daqhat mcc 134

The DAQHAT MCC 134 is a HAT. This HAT makes it possible for the raspberry pi to read out the values of thermocouples. The MCC 134 has 4 channels that can connect 4 thermocouples to it. It can be any type of thermocouple. Then it also comes with a built-in example program. These examples are a quick setup to read out the value of one or more channels. The DAQHAT uses python and C as programming language. These programs also come with an interface and logging options. It can log data in its memory as a .csv (comma separated values) file or directly send it to google sheets via an application called IFTTT and webhooks. A picture of the Raspberry pi an DAQHAT is shown in picture 2.



Picture 2. Rasperry pi with DAQHAT 134

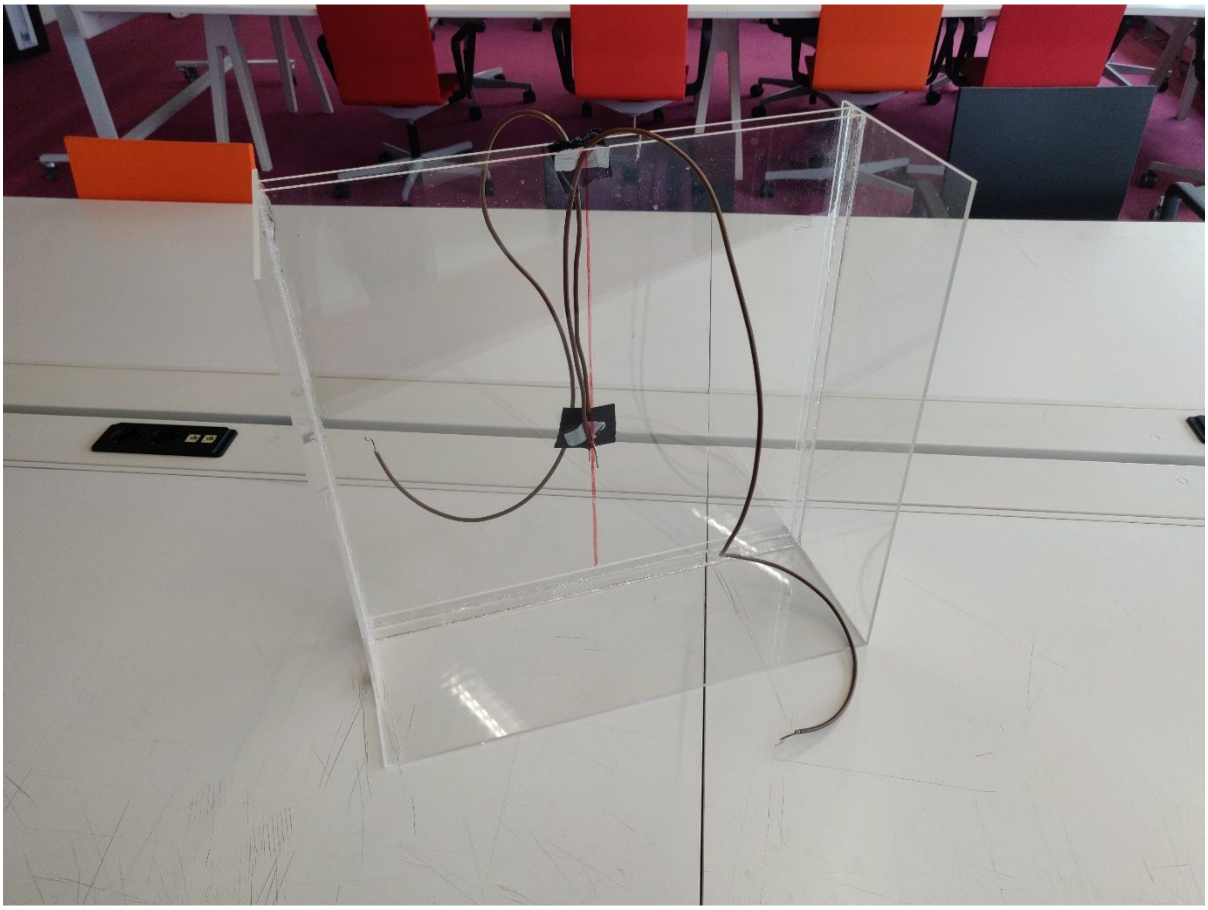
5.1.4 Thermocouple type T

A thermocouple is a cable used to measure temperature by utilizing the phenomenon of thermoelectricity. It consists of two dissimilar metal wires, typically made of different alloys, that are joined together at one end to form a junction. The two wires are referred to as the "legs" or "arms" of the thermocouple. When the junction of a thermocouple is exposed to a temperature gradient, an electric potential is generated across the two legs of the thermocouple due to the Seebeck effect. This electric potential is proportional to the temperature difference between the two junctions, and can be measured using a voltmeter, in this case the DAQHAT MCC 134. By knowing the characteristics of the thermocouple and the voltage output, the temperature at the junction can be determined. Here the thermocouple Type T is used. These thermocouples are made from copper and constantan and have a temperature range of -200°C to 350°C. They have a low output voltage. Thermocouples are widely used in a variety of applications, from industrial processes to scientific experiments. However, thermocouples can be sensitive to environmental factors, such as electromagnetic interference or oxidizing atmospheres, which may affect their accuracy and reliability. In this experiment the PCM corrodes the thermocouple. By adding nail polish on the arms of the thermocouple this can be prevented. In the picture 3 a thermocouple is shown. The right end is what is connected with the DAQHAT and the left is intertwined. The white cable contains the constantan and the brown cable contains the copper.

Picture 3. Thermocouple type T

5.1.5 PMMA Box

The box that is going to contain the PCM is made from transparent PMMA (polymethyl methacrylate). The outer dimensions of the box are 504 mm in height and 504 mm in width. In depth the box is 23 mm if only counting the containing part of the box. In inner dimensions of the box are 500 mm by 500 mm by 15 mm. The thickness of the wall is 4 mm. The box is glued together with acrifix 192. Acrifix 192 is a clear adhesive that is also used to make watertight connections between PMMA panels. The adhesive is cured under UV-light. PMMA was used because of the option of transparency to have a visual confirmation on the state of the PCM in the box. PMMA was used instead of glass because it is easier to handle and also cheaper. Also PMMA does not react with materials with a higher or lower pH than 7.



Picture 4. PMMA box with thermocouples

5.1.6 Polystyrene box

For the experiment the PMMA box is placed in a polystyrene box. This box has the outer dimension of 1 m, by 1 m, by 1 m. The wall of the box is 10 cm thick. this is to insulate the box and reach a consistent temperature. There is a gap in the box to observe the experiment. The gap is 500 mm by 500 mm. Polystyrene is a light material that has a relative high insulation value. The box contains 2 light bulbs to produce heat in the box. One of the lights is covered in aluminium to reduce the heating through radiation. A picture of the box can be seen in picture 5.

Picture 5. Polystyrene box with setup

5.2 Setup of the experiment

In this chapter the setup of the experiment is going to be explained. From the assembly to the settings during the experiment.

The first step is to prepare the thermocouples and the raspberry pi with DAQHAT. The thermocouples need to be cut in a length that they are long enough to reach the centre of the material in the PMMA box. Then the first layer of the outer cable has to be removed. After the removal of the outer cable 2 insulated inner cables appear. These insulated inner cables contain the constantan and the copper. By removing the insulation form the inner cables the metals are revealed. This is done for both ends of the cable. On one end of the cable the 2 metals get twisted firmly so they connect well. The other end is put in the DAQHAT MCC 134. By this time the DAQHAT MCC134 should be attached to the raspberry pi. Start the raspberry pi and install the packages for the DAQHAT MCC 134. This is done by opening a terminal and typing the following commands:

1. `sudo apt update`
2. ```
   sudo apt full-upgrade
   sudo reboot
   ```
3. `sudo apt install git`
   ```

4. ```
   cd ~
   git clone https://github.com/mccdaq/daqhats.git
   ```

5. ```
   cd ~
   git clone https://github.com/mccdaq/daqhats.git
   ```

6. ```
   cd ~/daqhats
   sudo ./install.sh
   ```

This should enable the raspberry pi to make use of the DAQHAT. In the example folder are a few options on using the DAQHAT. For this experiment the [logger] is used. This allows to create a graph and store data as a .csv file.
For the final use the DAQHAT will use the raspberry pi to send data to a Google Sheets. By sending it to Google Sheets the data is online available and can be obtained by a third party, in this instance it would be unity.

For the setup of the experiment the PCM package is removed from the PCM and put in the PMMA box. The PMMA box is equipped with the thermocouples in the centre and against the wall. The location is used because in the simulations these points give a reliable image of the temperature in the PCM. The thermocouples are attached to the wall with duct tape. The PMMA box is placed in the polystyrene box that is equipped with 2 light bulbs that emit radiation heat. The box will reach a temperature of 41°C. The PCM C28 needs a temperature of 31°C to melt. The 0.5 by 0.5 meter hole in the box is sealed with a sheet of polystyrene to reduce heat loss from the box to the environment.

5.3 Process

For the experiment the PMMA box with C28 was placed in the polystyrene box. The thermocouples are mounted in the middle of the PMMA box in the PCM and there is a thermocouple measuring the air temperature in the box. The thermocouples are plugged in the DAQHAT and the hole in the box is sealed off. The next step is to start the measurement to check the inside temperature of the air and the PCM. Once those measurements are stable the heating can start. This is done by turning on the lights inside the box. Every minute or 2 minutes the Raspberry pi measures the temperature. The data of the raspberry can be read out afterwards. After the heating process. The cooling process would be initiated. By turning off the lights and removing the top part of the polystyrene box the temperature would drop fast and the recording of the temperature would continue.

5.4 Results

The results are seen in the figure 43 and figure 44. In the figure 43 the heating process is visible. The point where the PCM is changing phase and absorbing the heat is visible. The temperature in the box raises to 38 °C. At the point where raising of the graph starts to decrease the PCM is using its latent heat storage. According to the data of the manufacturer the C28 material should absorb the most heat from 27 °C, however in the results of the experiment it is clearly visible that temperature direction on the graph line of the PCM starts to change direction around 29 °C . After being exposed to the heat for 1.9×10^4 seconds the
   ```

PCM continues to raise steeper again.

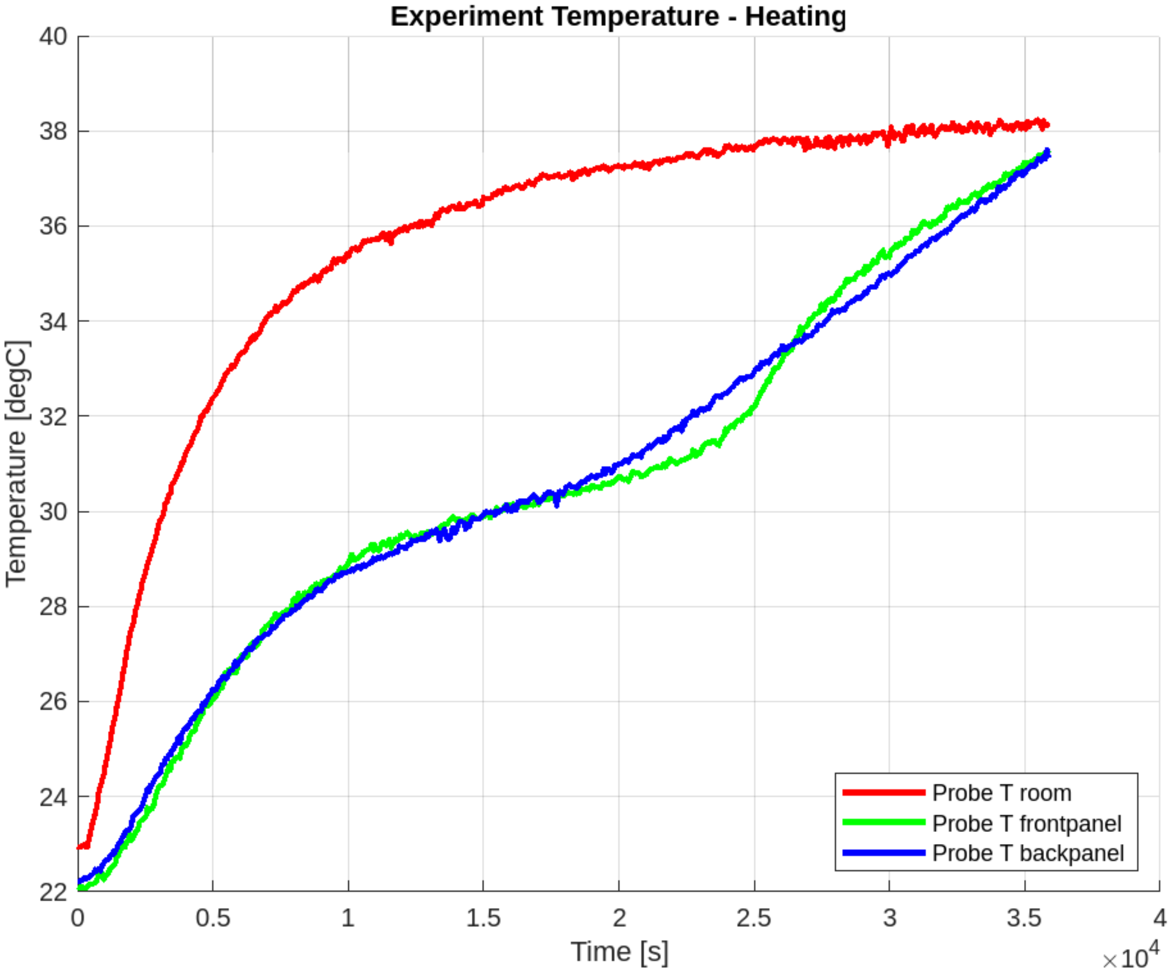


Figure 43. Results experiment heating

For the cooling experiment the temperature starts at 38 °C. After removing the top part of the polystyrene box the temperature of the air drops to 23 °C. The temperature of the PCM drops to 26 °C and then rises to 29.5 °C. This phenomenon can be explained. This effect is called super-cooling, this means that the PCM is not solidifying at its regular phase change temperature, this is caused by the absence of nucleation sites which provide a surface for the molecules to rearrange themselves and become a solid material. The moment when the PCM reaches the 26 °C the solidifying process is starting and the stored heat is released. This is also explains why the temperature rises again. After 5 x 10^4 seconds the PCM released all its energy and is back to the solid state.

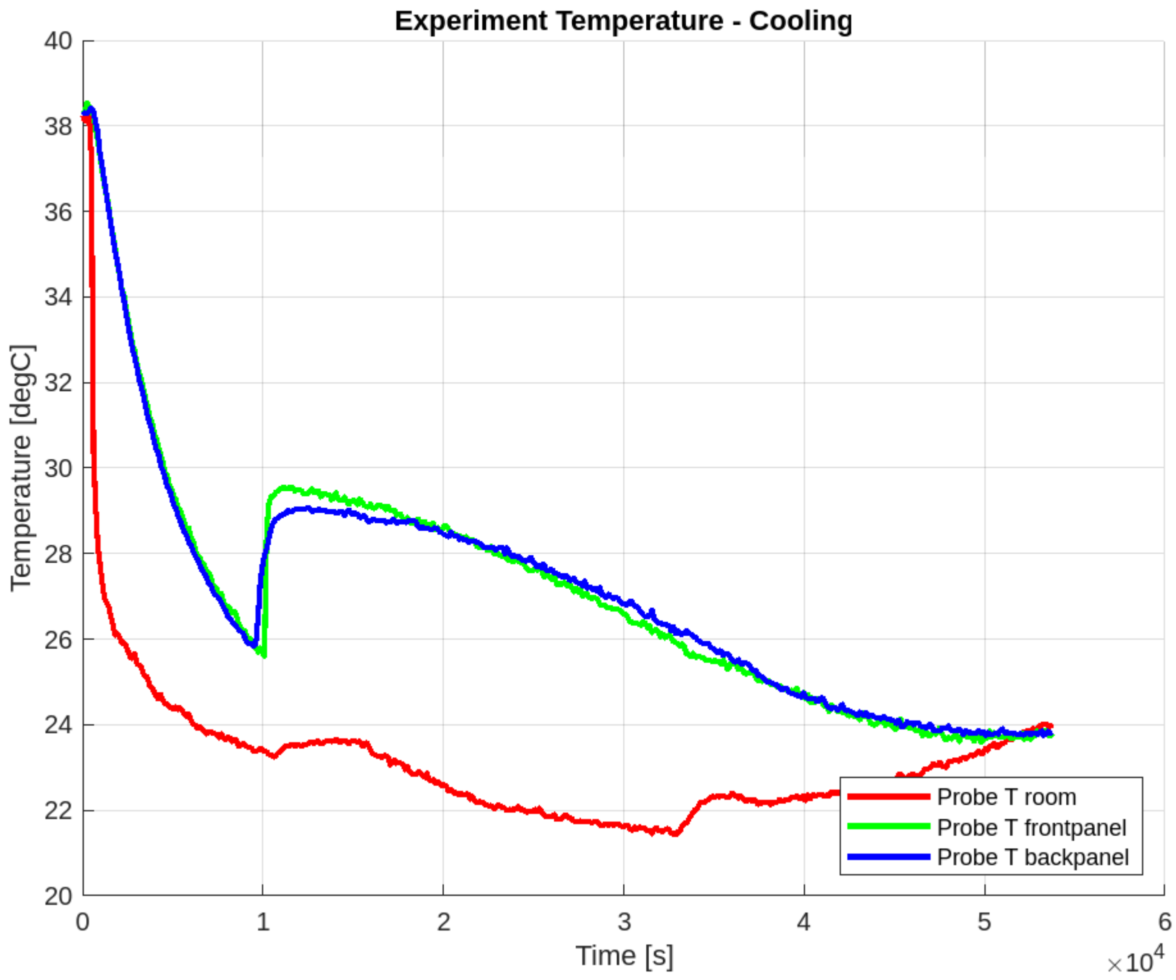


Figure 44. Results experiment Cooling

Conclusion

This experiment was done to compare to the simulation and see if the values are ultimately usable for the augmented reality. The results are not similar but are comparable to the simulation. This is because the changes of direction in the curves of the experiment are similar to the changes in the simulation. Although the simulation did not suffer from super-cooling because it is a 'perfect' proportions, the cooling simulation and experiment are similar.

The experiment was also done to see if the results are usable for AR. A short conclusion would be, these results would be usable for AR, but the results of an experiment that was not in a laboratory might provide unusable data. The data of this experiment is usable because there is a clear heating and cooling process going on. In a experiment that is not in a laboratory the experiment would be exposed to less extreme temperatures. Depending on the temperature outside temperatures the PCM would be more likely to stay around the same temperature. This causes a problem to see if the material is heating or cooling and thus inaccurate to see if the material absorbing heat or releasing heat. This could be solved if the air or surrounding temperature is also measured, because this would indicate if the material is exposed to a heat higher than its own temperature or lower than its own temperature. From this information it can be derived if the material is cooling or heating.

5.5 Reflection

The experiment eventually gave reasonable results but there are some aspects of the experiment that have to be reflected on. The setup and results will be reflected on. To start of is the PCM C28 that was used in the experiment had a manual that stated how to handle the PCM if the established properties of the material had to be maintained. This was to keep the material in the aluminium package and to keep the temperature of the PCM below the 38 ^{o}C. For the experiment it was inevitable to neglect the instructions of the manufacturer. The PCM had to be put in a PMMA box, but the aluminium package exceeded the dimension to fit in the box. Therefor the package was removed. To fit the PCM in the PMMA box it had to melt so it would form itself to the PMMA box. While melting the temperature exceeded the 38 ^{o}C. This caused the evaporation of water that was in the PCM and dried out the material. The results from these experiments showed no enthalpy or latent heat storage. See figure # and # for the results of the dried out PCM. To resolve this problem water needed to be add. By adding purified water the PCM was hydrated and this gave the results that were seen in the experiment. The consequence is that the ratio of water and the salt is different than the manufacturer produced it with.
Another thing that may have caused inaccuracies in the experiments is that the tip of the thermocouples have been painted with nail polish. The fact that there is a sealing to protect the thermocouples from oxidizing means that the thermocouples do not directly measure the PCM. The PCM was also exposed to the open air because the top part of the PMMA box could not fit on as a result of the thermocouples that had to be installed in the PCM. The results of these experiments are visible in figure 45 and 46.

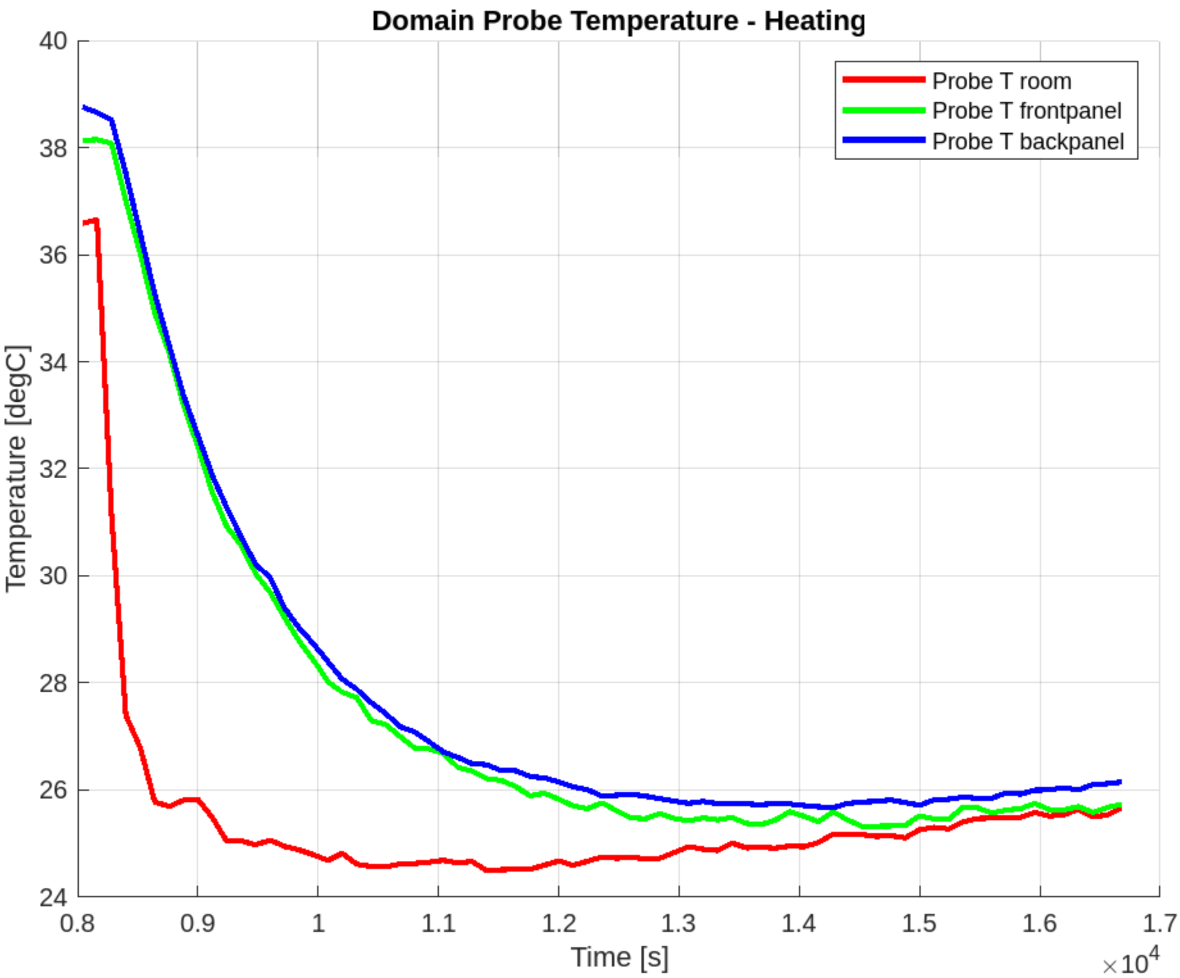


Figure 45. Results experiment Cooling

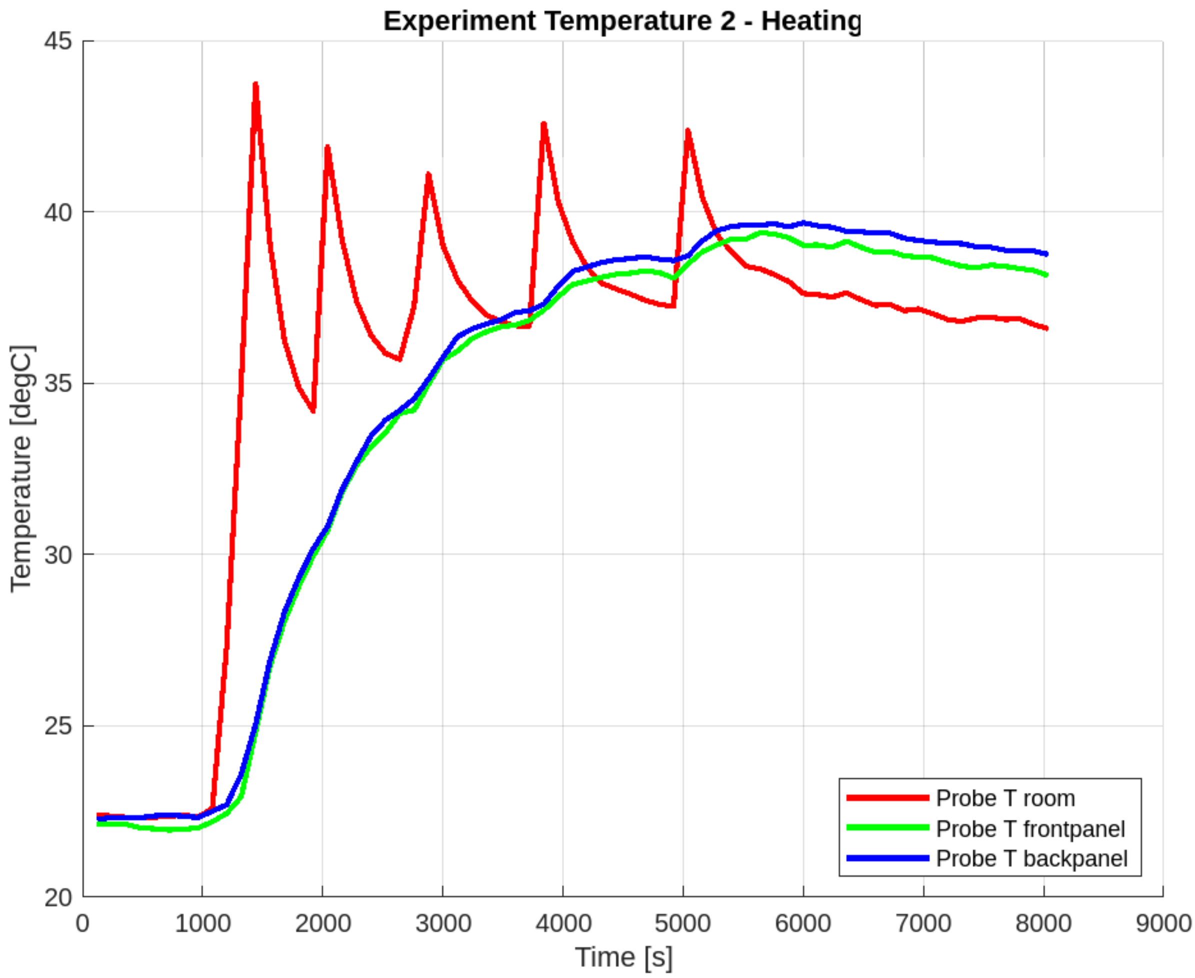


Figure 46. Results experiment Heating

Chapter 6 User Interface

Another aspect of this research is to depict the PCM and data. The user interface has to be designed for the targeted groups. The groups are scientists, maintenance/manufacturers and users of a PCM product. These 3 groups are the actors with the most concerns in the application. The researcher group get more data in via this application on the PCM that are used in buildings, whereas maintenance can analyse the wall for the main reason to ensure quality of the product. For the customers it is more important what the effect of the wall is instead of the data of the wall therefor in this chapter the topics are the requirements for the group, the logistics of data, how it is send and retrieved, and a user interface design per group. In the end there is a conclusion and a reflection on the process.

6.1 Requirements per group

The application is designed to be used by 3 groups. These groups are best defined by their interest in PCMs. The first group are people who are going to use the application for scientifical purposes.
Scientists need accessible data for research and analysis on PCMs. In the user interface for scientists, there will be graphs that display the temperature data of the PCM over different days. The graphs can be displayed on top of each other and selected. This makes comparing data between different days convenient. Also the values of different days are logged and saved in a Google Sheets. An analysis can be done to see how PCMs behave or perform in different settings or weather conditions. The tables are accessible through the app and can be downloaded as a .CSV or an excel file. For scientific purposes the logging of data is more important than the real time access.

For the group that does maintenance or is responsible for a product that contains PCM, it is important to see the degradation of the performance of the material. For this group it is also important to have access to the logged data. They can perform an analysis to see if the PCM has suffered too much of the phase segregation effect. According to Tan et al. (2020). the curves of a PCM that suffered too much phase segregation are rounded of more than a PCM that has not suffered from phase segregation. By comparing logged data on days with similar temperature profiles the degradation of the material can be perceived. If the PCM is in a wall or another object that obstructs the vision, unusual data can be an indicator that there is something wrong with the PCM. A contamination or a leakage in the package would show reduced performance and is a sign that the PCM needs maintenance or repair.
The group that is a user of the PCM wall or a customer has other interests then the 2 groups mentioned before. For a customer it is more important to see the benefits of the PCM product or tips on how to use the characteristics of PCM to their advantage. The aspects that matter to them are the state of the PCM at the moment they are looking at it. The UI will show contours of the temperature in the PCM. It will also depict if the wall is storing heat or releasing heat. It will also indicate if the wall is ‘fully charged’ in which case the material has completely changed phase. The user interface will also hint the user on how to use their heating system. This to further improve the sustainability of their building.

The requirements to make a user interface with these options are:

- data collection
- data tracking
- data conversion
- data broadcasting / presenting
- real-time measuring

6.2 Data Logistics

The requirements for the data logistics are stated above. For the project the data of the thermocouple needs to be delivered to the unity application. In this text the logistics is explained step by step. In the diagram below, the steps are visualized in figure 47.

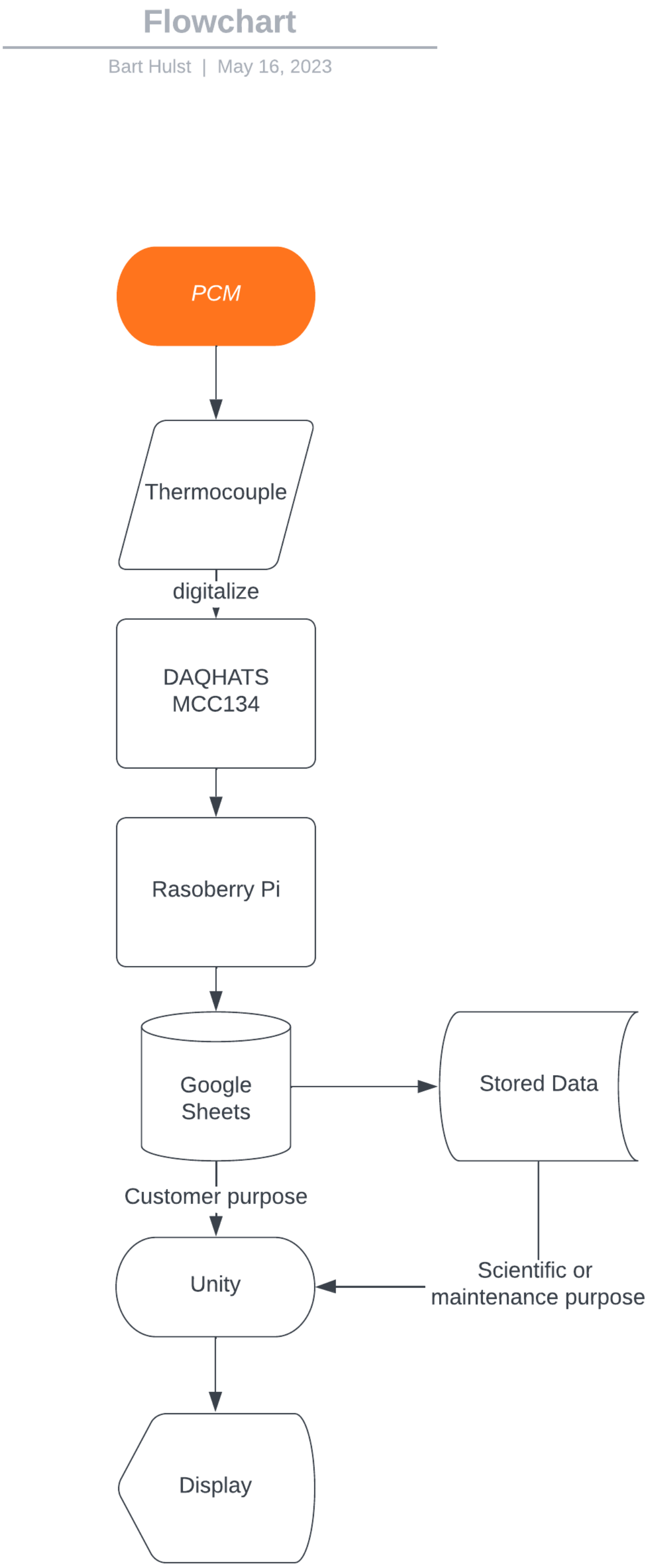


Figure 47. Dataflow from PCM to Display.

The process starts with retrieving data from the PCM, in this case the temperature of the PCM from the thermocouples. The temperature is measured with a thermocouple type T. An electric current is generated at the junction of the thermocouple. The current from the thermocouple is read by the DAQHAT MCC 134 and converted to a temperature. The DAQHAT sends this information to the raspberry pi via the GPIO (general purpose input/output). Here the physical data is converted to digital data. This data is readable for the raspberry pi. With the coding languages C or Python, the data can be manipulated, logged or visualized. Via a Python script the data is send to google sheets. Google sheets is chosen for this project because it is able to be publicly accessible. Google sheets allows to log the data and save it as different types of files, files being .CSV or Excel files. The information is sent to google sheets with the following python code:

```
from __future__ import print_function
import time
import sys
from daqhats import mcc134, hat_list, HatIDs, TcTypes
import requests
import json

# Google Sheets API values
SPREADSHEET_ID = "<your_spreadsheet_id>"
API_KEY = "<your_api_key>"
RANGE_NAME = "Sheet1!A1:B1"

def append_to_sheet(values):
    """ Append values to Google Sheets. """
    url =
f"https://sheets.googleapis.com/v4/spreadsheets/{SPREADSHEET_ID}/values/{RANGE
_NAME}:append"
    params = {
        "key": API_KEY,
        "valueInputOption": "USER_ENTERED"
    }
    data = {
        "range": RANGE_NAME,
        "majorDimension": "ROWS",
        "values": [values]
    }
    headers = {
        "Content-Type": "application/json"
    }
    response = requests.post(url, params=params, data=json.dumps(data),
headers=headers)
    if response.status_code != 200:
        print(f"Failed to append data to Google Sheets. Status code:
{response.status_code}")

def main():
```

```
    """ Main function """
    log_period = 1*60
    channel = 0
    tc_type = TcTypes.TYPE_T

    # Find the first MCC 134
    mylist = hat_list(filter_by_id=HatIDs.MCC_134)
    if not mylist:
        print("No MCC 134 boards found")
        sys.exit()

    board = mcc134(mylist[0].address)

    # Configure the thermocouple type on the desired channel
    board.tc_type_write(channel, tc_type)

    # Set library update interval to a longer time since we are not reading
often.
    if log_period > 255:
        board.update_interval_write(60)
    else:
        board.update_interval_write(log_period)

    print("Logging temperatures, Ctrl-C to exit.")

    while True:
        # Read the temperature
        temperature = board.t_in_read(channel)

        # Check for errors
        if temperature == mcc134.OPEN_TC_VALUE:
            temp_val = "Open"
        elif temperature == mcc134.OVERRANGE_TC_VALUE:
            temp_val = "Overrange"
        elif temperature == mcc134.COMMON_MODE_TC_VALUE:
            temp_val = "Common mode"
        else:
            temp_val = "{:.2f}".format(temperature)

        # Append temperature data to Google Sheets
        append_to_sheet([time.strftime("%Y-%m-%d %H:%M:%S"), temp_val])

        time.sleep(log_period)

if __name__ == '__main__':
    main()
```

As can be seen, the spreadsheet ID and API Key is needed to be able to manipulate the sheet. This is also true for sending data to Google sheets. The Spreadsheet ID is obtainable by coping the text that is on the position of / "<ID> ". A link will look like this: https://docs.google.com/spreadsheets/d/ "<ID> "/edit#gid=0. This is filled in in the SpreadSheet_ID command. For obtaining the API (application programming interface) an account on console.cloud.google.com is required. By connecting the Google sheets to the Google sheets API a key is generated. With this key uploading data is possible. The data uploads in column A:A. In this code data is retrieved every minute, next to the temperature also the time and data is recorded and send to the Google sheets. The intervals can be changed by adjusting the code.

The data is now logged. The application requires to show data to the user in real time. This live feed is possible with the program Unity. With a C#-script a 'GameObject' can be manipulated by data of Google sheets. With the code in the appendix the last measured temperature is displayed as a text in the middle of a screen. The data is retrieved every 30 seconds. The last temperature is sent because the script retrieves the data that is in the last row of the column, being the last uploaded temperature. The result of the code is shown in figure 48.

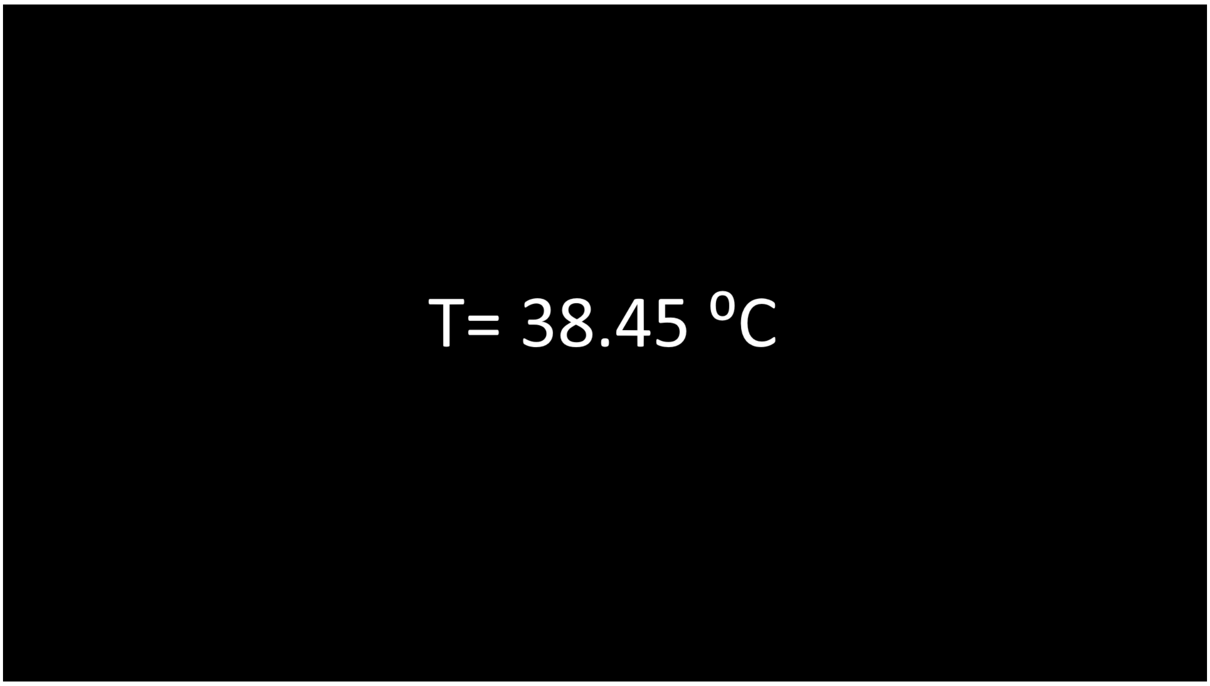


Figure 48. Display of data

Via this script the 'GameObject' is displayed on the wall that is scanned:

```
using System;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.XR.ARFoundation;
using UnityEngine.XR.ARSubsystems;

[RequireComponent(typeof(ARTrackedImageManager))]
public class PlaceTrackedImages : MonoBehaviour {
    // Reference to AR tracked image manager component
    private ARTrackedImageManager _trackedImagesManager;

    // List of prefabs to instantiate - these should be named the same
    // as their corresponding 2D images in the reference image library
    public GameObject[] ArPrefabs;

    // Keep dictionary array of created prefabs
    private readonly Dictionary<string, GameObject> _instantiatedPrefabs = new
Dictionary<string, GameObject>();

    void Awake() {
        // Cache a reference to the Tracked Image Manager component
        _trackedImagesManager = GetComponent<ARTrackedImageManager>();
    }

    void OnEnable() {
        // Attach event handler when tracked images change
        _trackedImagesManager.trackedImagesChanged += OnTrackedImagesChanged;
    }

    void OnDisable() {
        // Remove event handler
        _trackedImagesManager.trackedImagesChanged -= OnTrackedImagesChanged;
    }

    // Event Handler
    private void OnTrackedImagesChanged(ARTrackedImagesChangedEventArgs
eventArgs) {

        // Loop through all new tracked images that have been detected
        foreach (var trackedImage in eventArgs.added) {
            // Get the name of the reference image
            var imageName = trackedImage.referenceImage.name;
            // Now loop over the array of prefabs
            foreach (var curPrefab in ArPrefabs) {
```

```
                // Check whether this prefab matches the tracked image name,
and that
                // the prefab hasn't already been created
                if (string.Compare(curPrefab.name, imageName,
StringComparison.OrdinalIgnoreCase) == 0
                    && !_instantiatedPrefabs.ContainsKey(imageName)) {
                    // Instantiate the prefab, parenting it to the
ARTrackedImage
                    var newPrefab = Instantiate(curPrefab,
trackedImage.transform);
                    // Add the created prefab to our array
                    _instantiatedPrefabs[imageName] = newPrefab;
                }
            }
        }

        // For all prefabs that have been created so far, set them active or
not depending
        // on whether their corresponding image is currently being tracked
        foreach (var trackedImage in eventArgs.updated) {
            _instantiatedPrefabs[trackedImage.referenceImage.name]
                .SetActive(trackedImage.trackingState ==
TrackingState.Tracking);
        }

        // If the AR subsystem has given up looking for a tracked image
        foreach (var trackedImage in eventArgs.removed) {
            // Destroy its prefab
            Destroy(_instantiatedPrefabs[trackedImage.referenceImage.name]);
            // Also remove the instance from our array
            _instantiatedPrefabs.Remove(trackedImage.referenceImage.name);
            // Or, simply set the prefab instance to inactive
            //_instantiatedPrefabs[trackedImage.referenceImage.name].SetActive
(false);
        }
    }
}
```

This script needs a recognisable pattern like a QR-code or a play card to display the ‘GameObject’. Unity makes the camera recognize the pattern. An anchor coordinate is placed on the reference object to place the ‘GameObject’ on the right position.
With this knowledge it is possible to make a user interface for each group. For now a QR-code is used to access the database, but for future use GPS locations can be added to a wall in a building. This would make using the application more convenient. The database contains the information about the PCM, the location of the wall and the state of the temperature.

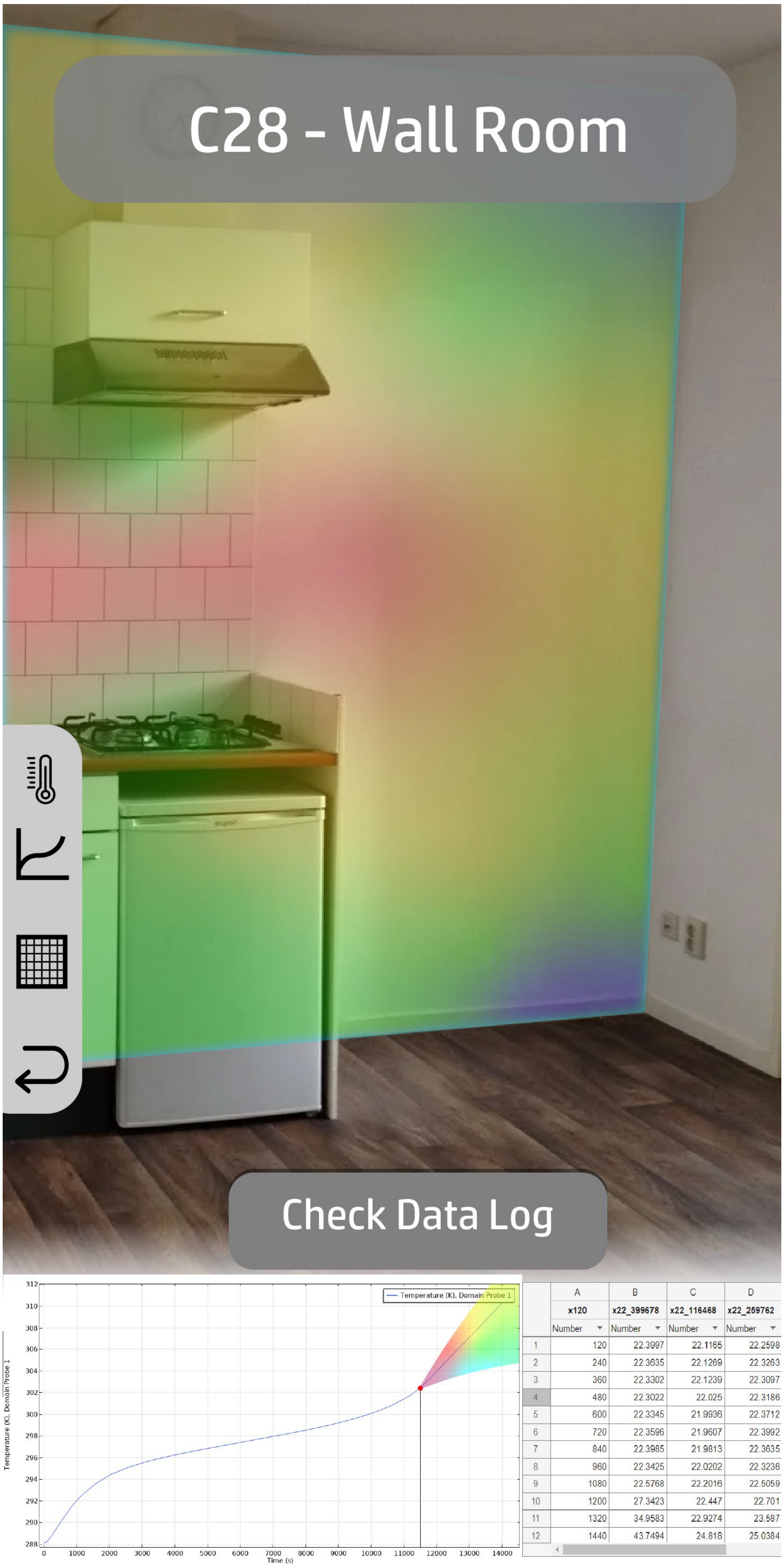
6.3 Design of the user interface

The user interfaces differ for each user group. The requirements are stated in requirements per group. The next step is to visualise the required data. For each requirement it is possible to design a specific tab in an application.

As stated earlier, the collected data is more important than the current data of the wall for scientific purposes. For researchers the access through an augmented reality application is to make it accessible. The application will give an option to pick the user profile. For the user profile of the scientist these things will be depicted:

- The wall that is scanned
- Type of PCM that is used in the wall
- Graph that shows temperature profile of the current day
- Temperature of the PCM
- An icon that will direct to the Google sheet tables.

Each requirement needs to be visualised. The visualisation is done through the camera of a phone that uses the current view with the phone together with the information that is provided with the cloud. This information is visualised as following. The wall that is scanned has a name, that name can be changed by the owner or maintenance. This name is depicted on top of the screen, also the wall will be outlined to provide a clear image of the size and location of the wall. The type of PCM that is stored in the wall is written next to the name of the PCM panel. The information about which PCM it is, is stored in the google sheets. A graph of the temperature is depicted in the bottom of the screen and allows for insight in the temperature changes of the material and of the space around the PCM. The temperature of the PCM is depicted in the graph that is shown at the bottom of the screen but also in the colours of the wall with a legend that states the temperature per colour. The icon that refers to the tables of google sheets has to be understandable and therefor will be depicted in a simple and clear design. The interface for the science group is shown in figure 49.



	A	B	C	D
	x120	x22_399678	x22_116468	x22_259762
	Number	Number	Number	Number
1	120	22.3997	22.1165	22.2598
2	240	22.3635	22.1269	22.3263
3	360	22.3302	22.1239	22.3097
4	480	22.3022	22.025	22.3186
5	600	22.3345	21.9936	22.3712
6	720	22.3596	21.9607	22.3992
7	840	22.3985	21.9813	22.3635
8	960	22.3425	22.0202	22.3236
9	1080	22.5768	22.2016	22.5059
10	1200	27.3423	22.447	22.701
11	1320	34.9583	22.9274	23.587
12	1440	43.7494	24.818	25.0384

Figure 49. UI science group

The maintenance group interface requires different graphics than the scientists. They need the information if the PCM is working accordingly. If this is not the case the wall will show a state of degradation. From green to red is a way to indicate the state of the wall, whereas green means that the wall is working properly and red means that is has degraded too much. Also information about how to restore or maintain the PCM can be shown in AR an example would be a location where the PCM can be drained and a location where the PCM container can be filled. The information that will be depicted for the maintenance group will be:

- The scanned wall
- Type of PCM
- Graphs that show the performance of the wall over time
- A state of degradation
- Information and instructions on the service of the wall

For the scanned wall and the type of PCM the design is described in the requirements for the scientists. This interface also contains the specific requirements for the maintenance group. The graph will show the sensible temperature of the PCM material, but also graphs of the past. The performance of the material can be analysed if the application shows multiple graphs of the days in the past that have the same temperatures throughout the day. The wall will be depicted green if it is still in a good state, but when the wall turns red it needs servicing. The redline in the graph and in the legend give is a warning when the wall is in need for a service. If the wall needs to be serviced the application will also show the maintenance group where they can drain and refill the container. The method of servicing is different per PCM. For salt hydrate the most common process that degrades the material is phase segregation and the evaporation of water. This can be solved by pumping in new phase change material. The points were the material can be refilled and serviced will be depicted as a clear indicator like an arrow. The UI for maintenance is depicted in figure 50 and 51.

Figure 50. UI maintenance group

Figure 51. UI maintenance group

The customer group has different requirements then the previous groups. The customer group would most likely purchase a PCM product to reduce energy cost and make their home more sustainable. Also the actual state of the wall is useful information for the customer. It provides information about the saturation of the wall, which is derivable from the direction of the curve. The saturation is the amount of PCM that has changed phase. After it changed phase, the curve will rise quicker until it reaches the environmental temperature. What will be depicted in the wall for the customer are:

- The scanned wall
- The type of PCM or custom name that has been given to the wall
- The temperature of the wall
- The saturation of the wall
- The amount of energy saved by the wall
- Information on how to use other indoor climate devises, like heating

The specific requirements for the wall of the customer are the saturation, which means how much heat the PCM can still store or how much heat it can release. Another aspect of the wall is the amount of energy that is saved by the wall. This will be defined in Wh and displayed on the wall. A the table contains examples of other heating systems or examples of how much energy the customer has saved with its wall during the day. The application is going to give advice to the customer if the he needs to turn off or turn down is other heating or cooling systems to have the most benefits of the PCM wall. This will be written in the screen as a notification to the customer. The interface for the users is visible in figure 52 and 53. In figure 52 the releasing of the heat is shown and in figure 53 the absorbing of heat is depicted.

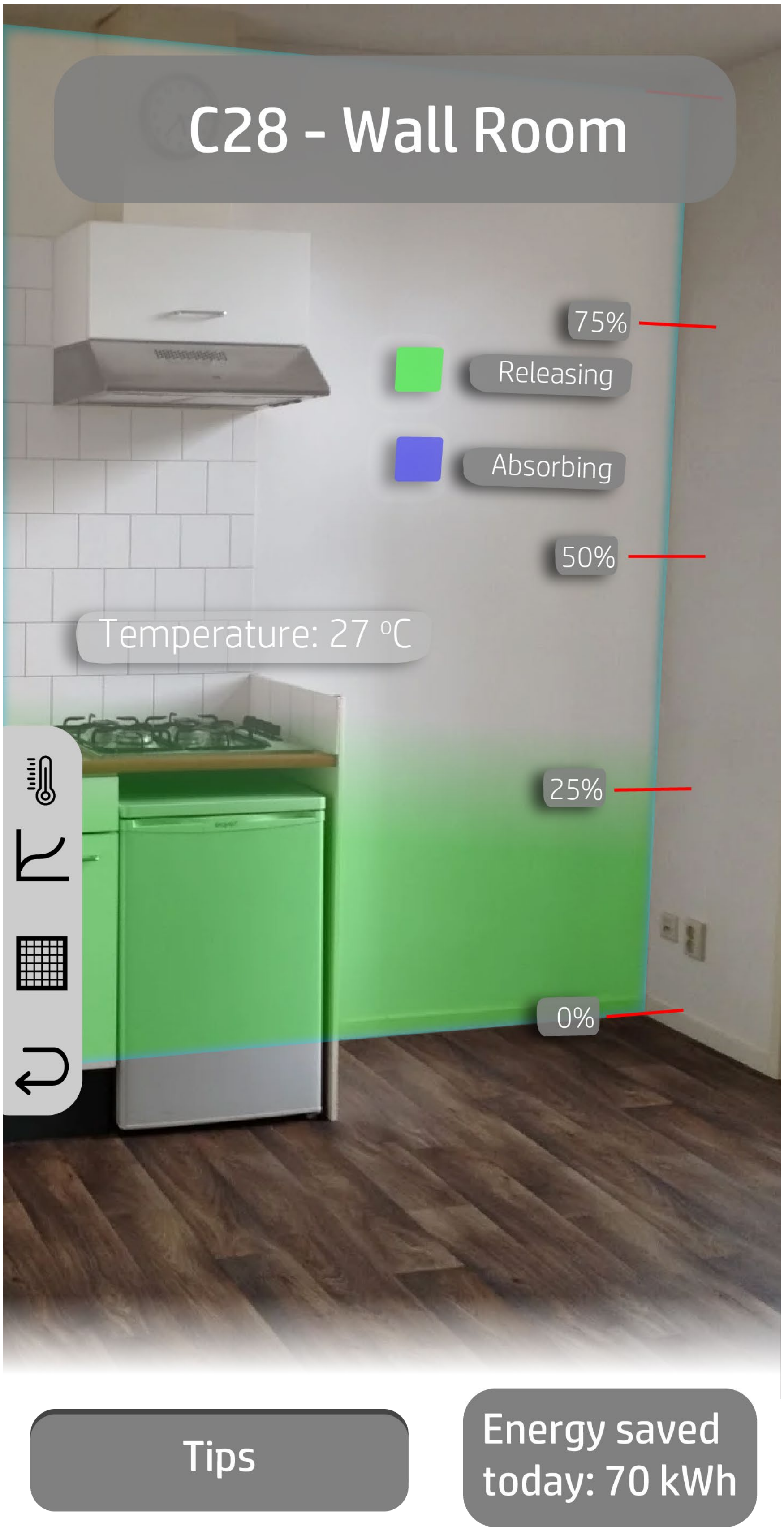


Figure 52. UI User group

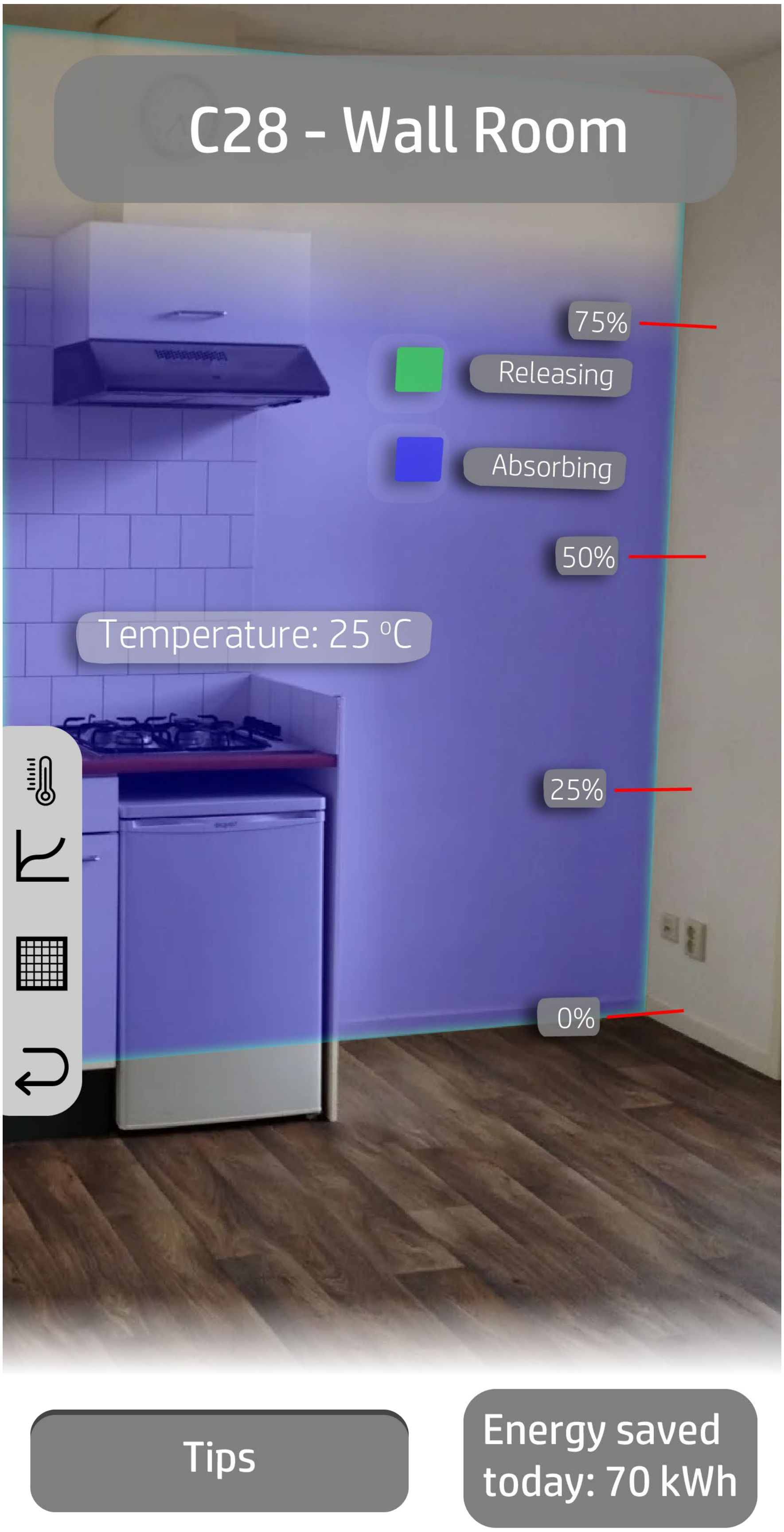


Figure 53. UI User group

Chapter 7 – Conclusion & Reflection

This chapter contains the conclusion of and a reflection on the research. The conclusion will be based on the partial conclusions that have been discussed throughout the report at the end of each chapter. The partial conclusion will be summarized in this chapter. After the conclusion there will be a reflection on the research. This will reflect on the process, the technical aspect and the global impact of this research.

7.1 Conclusion

The objective of this research was to investigate the contribution of visualization with augmented reality to the understanding of the PCMs for various user groups, including scientific, maintenance, and customer groups. To address this research question, a literature review was conducted to explore existing methodologies for analysing PCMs. The findings of this review indicated that the methods employed in previous studies were not suitable for the present experiment, thus necessitating the development of a customized setup for PCM analysis. It is important to note that the custom setup lacked validation, which required the need for simulations to ensure accuracy and reliability in the experimental setup.

The simulations were conducted to validate the experiment and determine an appropriate setup that would give accurate and reliable results. Based on the simulations, it was determined that utilizing a PMMA panel along with two thermocouples of type T, positioned as described and depicted in Chapter 3 and the simulation section, produced the most reliable and accurate outcomes. The mean results obtained from the thermocouples located at positions 254,4,254 and 254,19,254 closely matched the average results of the domain average probe for both the heating and cooling processes. Therefore, it was concluded that the use of two thermocouples was sufficient for obtaining reliable and accurate information in this context.

Upon conducting the actual experiment, it was observed that the results did not immediately align with those obtained from the simulations. This discrepancy arose due to the actions taken to fit the PCM in the PMMA box, which deviated from the instructions that ensured the PCM's optimal performance. Consequently, the phase change temperature of the material was altered, albeit the resulting curves exhibited similarities to the projections made by the manufacturer. Although the curves had shifted, the overall trend remained consistent with the simulation results. As a result, the experimental setup was deemed usable; however, it should be noted that it introduced a degree of inaccuracy when compared to the simulation. Nevertheless, for practical purposes, the setup proved sufficiently accurate to analyse the performance of the wall under consideration.

In conclusion, the research aimed to explore how visualization with augmented reality contributes to understanding the behaviour of PCMs among various user groups. A literature study was conducted to identify suitable methodologies for PCM analysis, leading to the development of a custom experimental setup due to the inadequacy of existing methods. Simulations were employed to validate the experiment and determine an accurate and reliable setup, which involved utilizing a PMMA panel and two thermocouples positioned at specific locations. The results obtained from the thermocouples closely approximated the average results of the domain average probe, indicating their reliability. However, deviations between the experimental and simulation results arose due to actions taken during PCM fitting, resulting in a shift in phase change temperature. Despite the difference, the experimental setup remained usable, providing sufficient accuracy for practical analysis of the wall's performance.

For the application, the requirements were a live feed and data logging. In the literature study, it was concluded that augmented reality is a very effective way of visualizing data. With this information a user interface and data flow had to be developed. The data flow exists out of a connection between different systems that are used to process the data towards data that can be read out by Unity.
The data flow is depicted in the section 'user interface' of chapter 3. The data is transported to Google sheets because this allows to upload live data and to log the data. Google sheets also allows third parties to retrieve data. In this case the temperature of the PCM. This is then visualized with unity. The user interface had to be designed per user group because each group has their own requirements and interests in the wall. The designs are visible in the section 'design of user interface'. The groups with the most interest in an app that can read out data from a PCM product are the researchers group, maintenance group and customer group. For each group there were different requirements. For the group with a scientifical interest in PCM the data that had to be visualised was the behaviour of the PCM. This data needed to be stored and saved, but it also needed to be accessible and clear. The UI for the researchers group contains the logged data in form of a table, a graph that shows the temperature versus time of the PCM. For the maintenance group the service and performance of the wall is their greatest concern. Therefor a UI has been designed that shows the performance of the wall and graphs of the past. The graphs of the past are used to derive information about the state of the wall and its deterioration. There is also a mark that indicates when the wall needs maintenance. The application supports the maintenance group by informing how to execute the maintenance and if needed how to refresh the PCM in a wall. Finally the customer group. The customer group is mostly interested in the benefits of the wall towards energy saving and how to use the wall to their advantage. The application shows the energy saturation of the wall and also shows if the wall is absorbing the heat or releasing the heat. It shows the temperature of the wall and the energy that has been saved by the wall during a day. The interface also has a button which leads the customer to tips on how to use their other heating systems in combination with a PCM wall.

With these conclusions it can be stated that the visualization of PCM with augmented reality gives an insight in PCMs and their behaviour during a day. The data that can be gathered with thermocouples is accurate enough to use in combination with augmented reality. The augmented reality makes the data clear and accessible by displaying it on the screen of an tablet or phone. The logged data gives insight in the behaviour of PCMs and how a PCM works in different settings and in different environmental conditions. For maintenance it helps with determining when servicing the PCM products in a wall is needed. The application gives instructions and shows where and how to service a wall. For the customer it shows the state of the wall and how they can use it to their advantage to save energy. This helps each group and gives insight in the behaviour of PCM. Therefor AR adds insight to the behaviour of PCMs for each group in a different manner.

7.2 Recommendation

As for every experiment or research, this thesis lead to more questions. Here are recommendations for future research that came up during the thesis.
In this experiment there was a custom setup used to measure the temperature of the PCM. This used thermocouples only for measuring the temperature of the PCM and the air temperature, but there are more options in sensors that are used to research the thermal properties of materials and composed wall sections. Thus, for future research there can be looked in to the sensors to increase the accuracy of the measuring experiments.
Another suggestion for future research is to investigate on using the application on different PCM components. Now the setup was build to measure the temperature of a wall, but the wall is not an ideal location for a PCM product. Ceilings or PCM products can also be visualised through AR.
The final suggestion for further research is the combination of different systems that influence the thermal indoor quality and sustainability of a building. By combining different systems energy of a building can be reduced. By having information of the outdoor temperature, indoor temperature, blinds, energy saved in a PCM wall, ventilation system and heating system a protocol for a program can be written to maintain a excellent indoor quality. This requires more than one study, but might be the ultimate goal for indoor climate design.

7.3 Reflection

The process
At the start of the thesis I concluded the types of sensors I needed, according to research on previous experiments. During the experimental period it was found out that only thermocouples would be enough to make the experiment work.

I had no knowledge of working with thermocouples so setting up the experiment took more time than expected. It was hard to find out which components there were needed to make collect and log the thermal data. There were multiple options, ranging from easy to set up but being very expensive too a very manual set up that costed less. Eventually the DAQ-HAT MCC 134 was picked. The DAQ-HAT MCC 134 was picked because it was compatible with the raspberry pi and the same dealer also supplied the thermocouple. Another valuable fact was that it was less time consuming to setup the module on the raspberry pi.

The set up took more time than expected to work. Therefore there were no results for the P4 presentation. This delay and troubleshooting session made a problem in my schedule. This problem caused a lack of time to work on the design of the user interface.

Technical
In the experiment of the thesis, it is important to consider the impact of the cable of the thermocouple on the characteristics of the phase change material (PCM). The cable has a significant influence on the thermal behaviour of the PCM due to its differing heat conduction and insulation values compared to the PCM. This causes the PCM to behave differently around the cable of the thermocouple, affecting its phase change behaviour. However, further investigation is required to determine the exact effect of the cable on the

phase change behaviour of the PCM, whether it causes the PCM to change phase quicker or slower.

Another way the cable influences the thermal characteristics of the experiment is through the container's transparency. The container used for the experiment is made of transparent PMMA, which allows light to pass through and reach the cable. The light energy is converted into heat the moment it comes into contact with the cable, resulting in an increase in temperature around the cable. This temperature increase is then absorbed by the PCM around it, leading to inaccuracies in temperature measurements by the thermocouples.

Overall, the influence of the cable on the characteristics of the PCM is an important factor to consider in the experiment. Understanding these effects can help to improve the accuracy and reliability of the temperature measurements, ensuring more accurate results for future experiments. Further research is required to reduce the effects of these problems.

Another important aspect of the thesis that needs considering is the fact that the experiment is done with an ideal raise in temperature which leads to a known curve. This known curve is an ideal curve in this experiment and makes the behaviour of PCMs more predictable then when a realistic temperature curve is used. It is very hard to tell how much heat the PCM has been absorbing if the temperature changes slightly around the phase change temperature. This makes it also very hard to predict the characteristics of the PCM throughout its operation during a day. This might eventually cause the AR-application (Augmented Reality) to visualise unreliable data. This problem might be solvable through prediction of the temperature around the PCM after benchmarking the amount of heat it absorbs in certain environments. With this information it is possible to do a prediction of the PCM characteristic.

Then there is the grid of the Thermocouples. The set up is mounted with a matrix of thermocouples. The thermocouples in the x and y direction are set apart 150 mm over a surface of 500 mm by 500mm. An offset of the side of 100 mm. In the z-dimension they are spaced 11,5 mm. This is shown in figure 1.

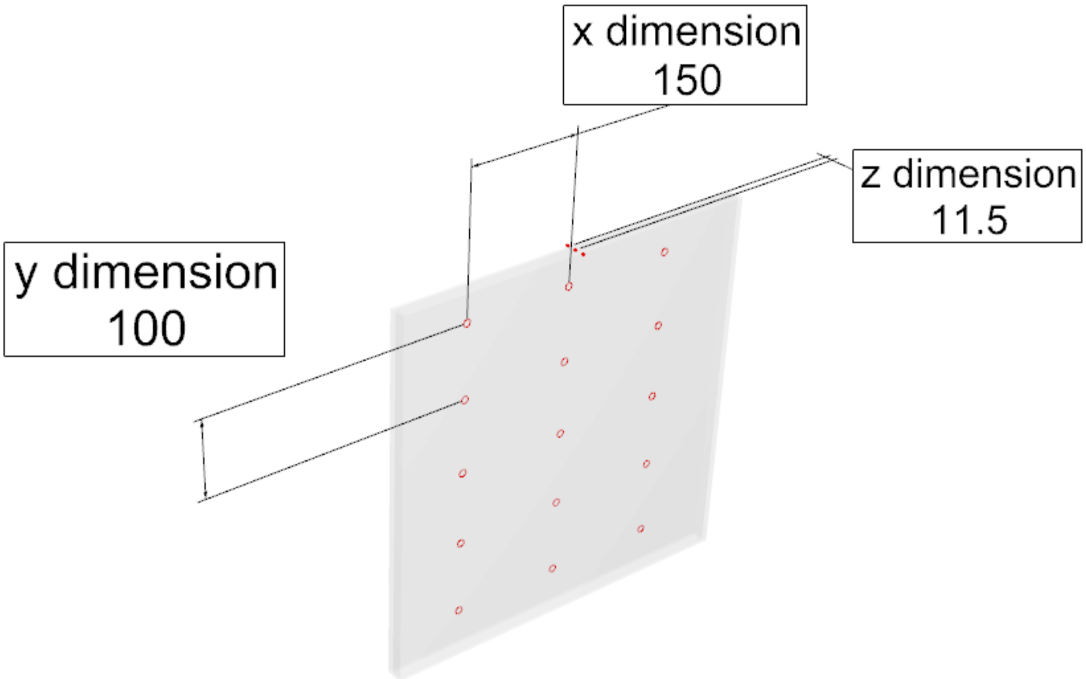


Figure 25. Dimensions of the thermocouples on the PCM container

It is difficult to estimate the minimum amount of thermocouples through the PCM container to get an accurate result without the thermocouple cables intervening with the results. Further research has to be done to get a better insight in the effects of the matrix.

Reflection on the conclusion
The conclusion of the research is that augmented reality does contribute to the understanding of PCM. During the experiment there was also a realization that augmented reality can work, but to get the right visuals more data was needed than just temperature. To get a clear image more information about the indoor and outdoor temperature is needed. A heatflux sensor is needed to determine accurately how much energy has been saved by the PCM component in a wall. These can be reduced by extensive analysis on PCMs that creates a library of data that will needs a few parameters to find determine the state of the PCM. This data is called metadata. Dummy data is an option, this makes use of the data gathered by simulations to estimate the performance of the PCM in the wall.

Reflection on the research topic
The research is a step in the direction to get more insight in the behaviour of PCM. Awareness of the sustainable effects of PCM is very important, regarding the climate crisis we are facing. The correct usage of PCM is can make a building 30% more energy efficient. This is especially true for lightweight structures that lack a thermal mass. In my personal opinion I think lightweight buildings have a lot of potential. The material is lighter and therefore easier to transport and handle. Most of the time these buildings are also easier to

rebuild or adapt. By giving these lightweight buildings an artificial thermal mass without being heavy is a big development. A side note is that this is only possible when the inorganic PCM become more stable and will not suffer from phase segregation or hyper cooling or when the organic PCMs are not as flammable as they are now.
For societal consequences this research is a step in the direction to make lightweight buildings more sustainable. PCMs can reduce energy consumption of a building. This is exciting because this means that the cost of living is going down, but also the CO_2 emissions are being reduced. Depending on the cost of PCM, this is a way to make the building a more environmental friendly product.

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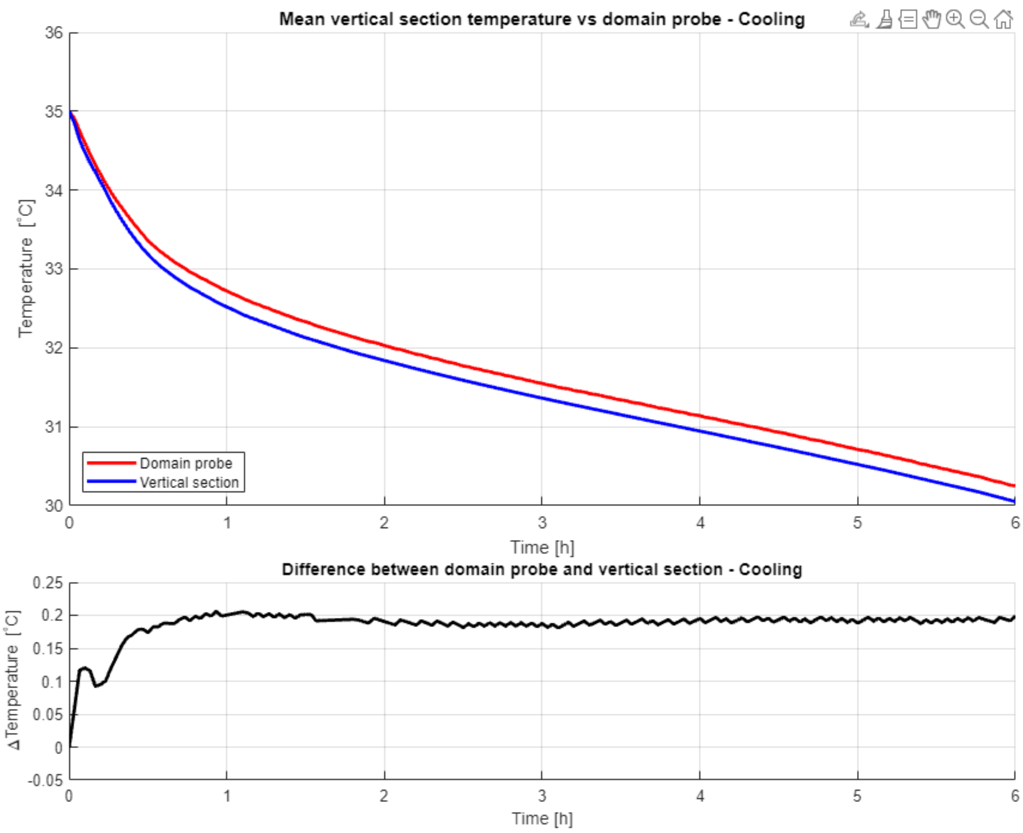
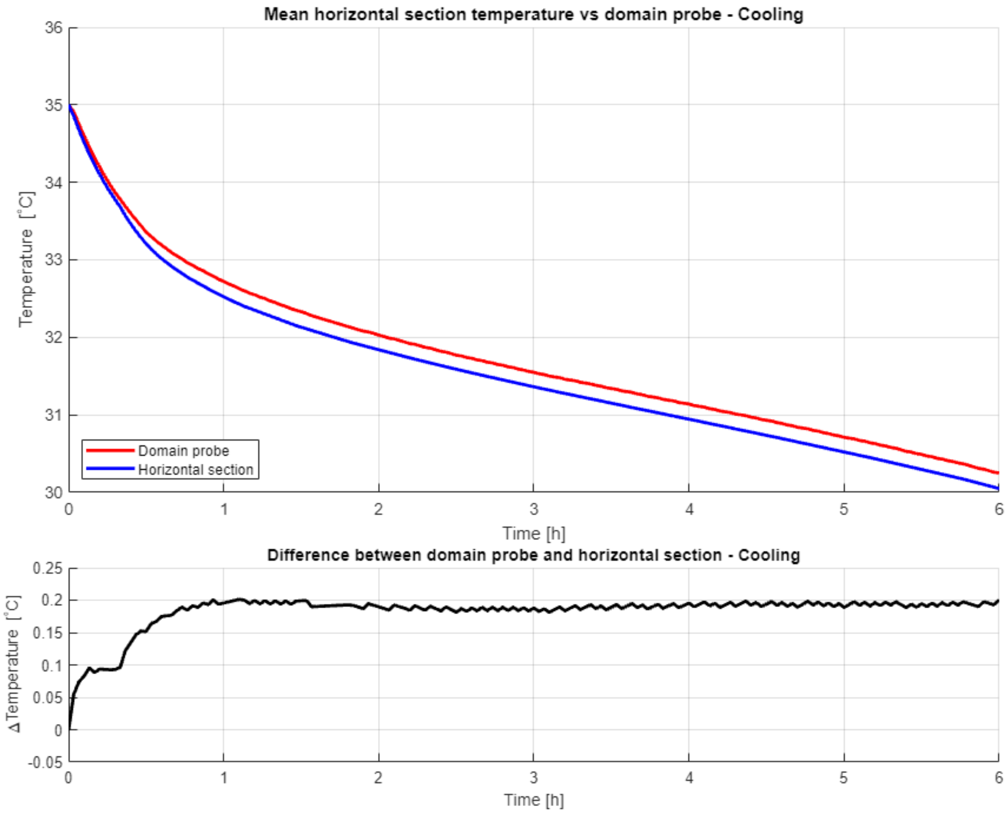
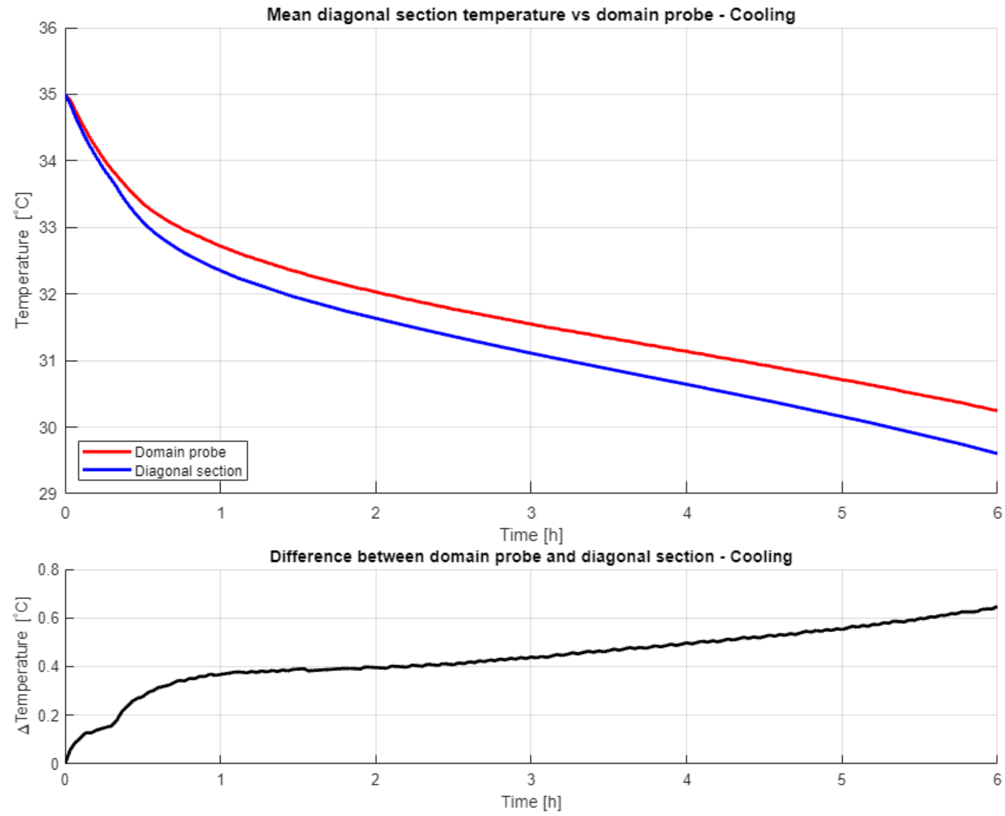
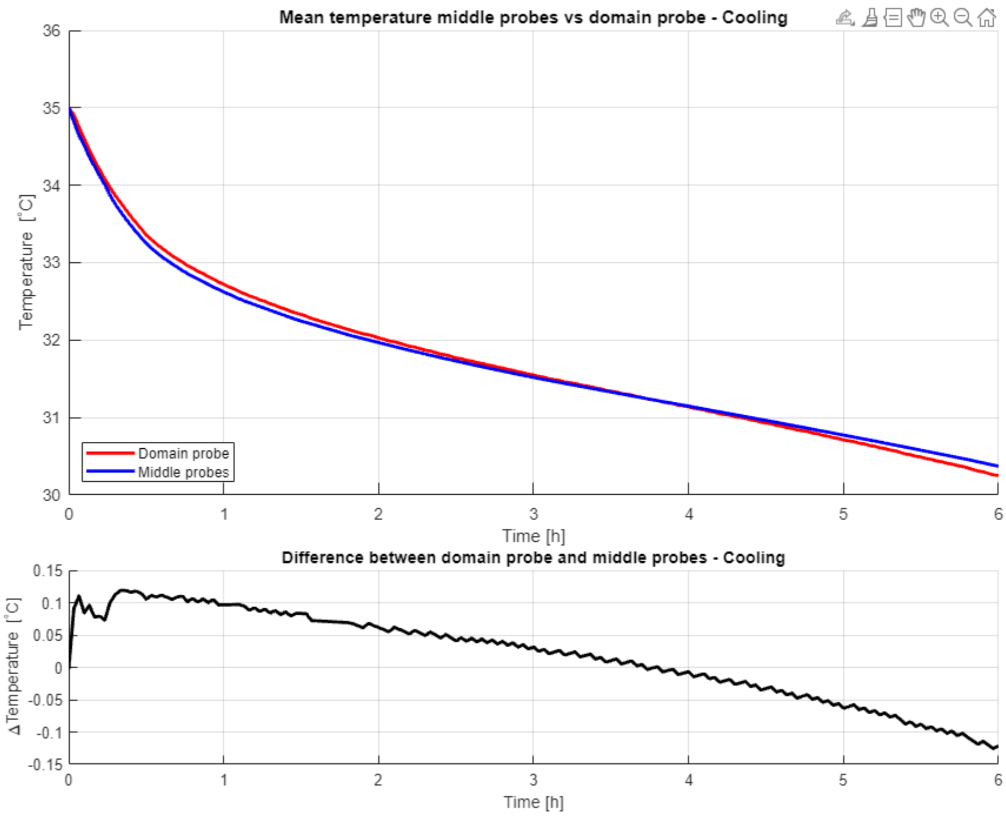
Chapter 8 Appendix

Graphs of difference between domain probe and average of grouped node:




Mean horizontal section temperature vs domain probe - Cooling
Temperature [°C]
Time [h]
Domain probe
Horizontal section
Difference between domain probe and horizontal section - Cooling
ΔTemperature [°C]
Time [h]


Mean diagonal section temperature vs domain probe - Cooling
Temperature [°C]
Time [h]
Domain probe
Diagonal section
Difference between domain probe and diagonal section - Cooling
ΔTemperature [°C]
Time [h]



Domain probe temperature measured over 14400 seconds, the heating process.

Domain Probe temperature		
tijd (t)	T(Celcius)	T(Kelvin)
0	14,99945	289,1495
60	15,99945	290,1495
120	16,99945	291,1495
180	17,99945	292,1495
240	15,67938	289,8294
300	15,93852	290,0885
360	16,20188	290,3519
420	16,47856	290,6286
480	16,75524	290,9052
540	17,03193	291,1819
600	17,30003	291,45
660	17,55524	291,7052
720	17,81046	291,9605

780	18,06568	292,2157
840	18,3209	292,4709
900	18,53298	292,683
960	18,73373	292,8837
1020	18,93448	293,0845
1080	19,13523	293,2852
1140	19,33598	293,486
1200	19,51883	293,6688
1260	19,66911	293,8191
1320	19,81939	293,9694
1380	19,96966	294,1197
1440	20,11994	294,2699
1500	20,27022	294,4202
1560	20,42049	294,5705
1620	20,53299	294,683
1680	20,64301	294,793
1740	20,75303	294,903
1800	20,86305	295,013
1860	20,97307	295,1231
1920	21,08309	295,2331
1980	21,1931	295,3431
2040	21,29024	295,4402
2100	21,36518	295,5152
2160	21,44012	295,5901
2220	21,51507	295,6651
2280	21,59001	295,74
2340	21,66495	295,815
2400	21,73989	295,8899
2460	21,81484	295,9648
2520	21,88978	296,0398
2580	21,95655	296,1066
2640	22,01265	296,1626
2700	22,06874	296,2187
2760	22,12483	296,2748
2820	22,18093	296,3309
2880	22,23702	296,387
2940	22,29312	296,4431
3000	22,34921	296,4992
3060	22,40531	296,5553
3120	22,4614	296,6114
3180	22,51749	296,6675
3240	22,56163	296,7116
3300	22,6043	296,7543
3360	22,64698	296,797

3420	22,68966	296,8397
3480	22,73234	296,8823
3540	22,77501	296,925
3600	22,81769	296,9677
3660	22,86037	297,0104
3720	22,90304	297,053
3780	22,94572	297,0957
3840	22,9884	297,1384
3900	23,03107	297,1811
3960	23,07088	297,2209
4020	23,1072	297,2572
4080	23,14352	297,2935
4140	23,17983	297,3298
4200	23,21615	297,3662
4260	23,25247	297,4025
4320	23,28879	297,4388
4380	23,32511	297,4751
4440	23,36143	297,5114
4500	23,39775	297,5478
4560	23,43407	297,5841
4620	23,47039	297,6204
4680	23,50671	297,6567
4740	23,54303	297,693
4800	23,57935	297,7293
4860	23,61354	297,7635
4920	23,64712	297,7971
4980	23,68069	297,8307
5040	23,71426	297,8643
5100	23,74784	297,8978
5160	23,78141	297,9314
5220	23,81498	297,965
5280	23,84856	297,9986
5340	23,88213	298,0321
5400	23,9157	298,0657
5460	23,94928	298,0993
5520	23,98285	298,1329
5580	24,01642	298,1664
5640	24,05	298,2
5700	24,08357	298,2336
5760	24,11714	298,2671
5820	24,15072	298,3007
5880	24,18415	298,3342
5940	24,21742	298,3674
6000	24,25069	298,4007

6060	24,28395	298,434
6120	24,31717	298,4672
6180	24,35035	298,5004
6240	24,38354	298,5335
6300	24,41672	298,5667
6360	24,44997	298,6
6420	24,48322	298,6332
6480	24,51647	298,6665
6540	24,54972	298,6997
6600	24,58302	298,733
6660	24,61641	298,7664
6720	24,65044	298,8004
6780	24,6836	298,8336
6840	24,71673	298,8667
6900	24,7501	298,9001
6960	24,78348	298,9335
7020	24,81694	298,9669
7080	24,85045	299,0004
7140	24,88406	299,0341
7200	24,91774	299,0677
7260	24,95151	299,1015
7320	24,98531	299,1353
7380	25,01918	299,1692
7440	25,05314	299,2031
7500	25,0873	299,2373
7560	25,1216	299,2716
7620	25,15611	299,3061
7680	25,19088	299,3409
7740	25,22598	299,376
7800	25,26139	299,4114
7860	25,2971	299,4471
7920	25,33314	299,4831
7980	25,36954	299,5195
8040	25,4063	299,5563
8100	25,44347	299,5935
8160	25,48101	299,631
8220	25,51894	299,6689
8280	25,55727	299,7073
8340	25,59603	299,746
8400	25,63516	299,7852
8460	25,67474	299,8247
8520	25,71478	299,8648
8580	25,75529	299,9053
8640	25,79628	299,9463

8700	25,83791	299,9879
8760	25,88012	300,0301
8820	25,92331	300,0733
8880	25,96727	300,1173
8940	26,01189	300,1619
9000	26,05716	300,2072
9060	26,1031	300,2531
9120	26,14971	300,2997
9180	26,19688	300,3469
9240	26,24472	300,3947
9300	26,29329	300,4433
9360	26,3427	300,4927
9420	26,39292	300,5429
9480	26,44397	300,594
9540	26,49563	300,6456
9600	26,54808	300,6981
9660	26,60152	300,7515
9720	26,65615	300,8062
9780	26,71228	300,8623
9840	26,77006	300,9201
9900	26,82938	300,9794
9960	26,89018	301,0402
10020	26,95244	301,1024
10080	27,01612	301,1661
10140	27,08142	301,2314
10200	27,14854	301,2985
10260	27,21773	301,3677
10320	27,28853	301,4385
10380	27,36115	301,5112
10440	27,43605	301,586
10500	27,51304	301,663
10560	27,59236	301,7424
10620	27,67393	301,8239
10680	27,75723	301,9072
10740	27,84285	301,9929
10800	27,93144	302,0814
10860	28,02375	302,1738
10920	28,11873	302,2687
10980	28,21581	302,3658
11040	28,31665	302,4666
11100	28,42235	302,5723
11160	28,53394	302,6839
11220	28,65011	302,8001
11280	28,77269	302,9227

11340	28,90467	303,0547
11400	29,0468	303,1968
11460	29,19837	303,3484
11520	29,35804	303,508
11580	29,52233	303,6723
11640	29,68984	303,8398
11700	29,86189	304,0119
11760	30,03713	304,1871
11820	30,21544	304,3654
11880	30,40183	304,5518
11940	30,59748	304,7475
12000	30,79874	304,9487
12060	30,99331	305,1433
12120	31,18503	305,335
12180	31,37592	305,5259
12240	31,566	305,716
12300	31,75535	305,9054
12360	31,94411	306,0941
12420	32,13244	306,2824
12480	32,3205	306,4705
12540	32,5084	306,6584
12600	32,69628	306,8463
12660	32,88421	307,0342
12720	33,0723	307,2223
12780	33,26056	307,4106
12840	33,44906	307,5991
12900	33,63786	307,7879
12960	33,827	307,977
13020	34,01654	308,1665
13080	34,20646	308,3565
13140	34,39679	308,5468
13200	34,58755	308,7375
13260	34,77872	308,9287
13320	34,97033	309,1203
13380	35,1624	309,3124
13440	35,35489	309,5049
13500	35,54784	309,6978
13560	35,74125	309,8912
13620	35,9351	310,0851
13680	36,1294	310,2794
13740	36,32415	310,4742
13800	36,51935	310,6694
13860	36,71501	310,865
13920	36,91113	311,0611

13980	37,1077	311,2577
14040	37,30473	311,4547
14100	37,50221	311,6522
14160	37,70014	311,8501
14220	37,89854	312,0485
14280	38,09742	312,2474
14340	38,29675	312,4468
14400	38,49655	312,6466

Point probe results of heating process on the coordinate (###, 4, ###)

Temperature (K), Point: (4, 4, 504)	Temperature (K), Point: (254, 4, 504)	Temperature (K), Point: (504, 4, 504)	Temperature (K), Point: (4, 4, 254)	Temperature (K), Point: (254, 4, 254)	Temperature (K), Point: (504, 4, 254)	Temperature (K), Point: (4, 4, 4)	Temperature (K), Point: (254, 4, 4)	Temperature (K), Point: (504, 4, 4)
738,8338612	1104,62158	1515,272285	710,0320221	239,9463851	707,8082404	973,0624873	675,2493139	978,7174012
288,1530805	288,1454921	288,1511367	288,1456289	288,1399754	288,1460309	288,1469368	288,1456858	288,1511069
288,5865067	288,6367146	288,6259006	288,6348597	288,5517545	288,6410101	288,5931737	288,6343295	288,6285702
289,5402787	289,4984092	289,5812477	289,4967915	289,2284022	289,4962838	289,5544535	289,4976429	289,5819757
290,4265334	290,2272557	290,4555213	290,2266597	289,7497628	290,2237418	290,4275756	290,2277128	290,4596787

291,28 52999	290,93 42732	291,30 32342	290,93 45802	290,26 06992	290,92 9502	291,27 47528	290,93 58399	291,31 08839
291,99 97538	291,52 66887	292,01 1504	291,52 72756	290,71 69085	291,52 13488	291,98 57196	291,52 87673	292,02 2975
292,65 86338	292,07 26943	292,66 54902	292,07 34159	291,14 49532	292,06 68342	292,64 10993	292,07 51658	292,68 01747
293,14 15298	292,47 1735	293,14 75786	292,47 2132	291,48 38095	292,46 55081	293,12 04535	292,47 42232	293,16 35518
293,62 44257	292,87 07758	293,62 9667	292,87 08481	291,82 26658	292,86 4182	293,59 98078	292,87 32805	293,64 69289
294,10 73217	293,26 98165	294,11 17554	293,26 95641	292,16 15222	293,26 28559	294,07 9162	293,27 23378	294,13 0306
294,51 67335	293,62 36204	294,52 10095	293,62 31723	292,46 82622	293,61 6459	294,48 85618	293,62 61513	294,54 13649
294,81 59191	293,90 95691	294,82 10122	293,90 91188	292,72 68276	293,90 24558	294,79 303	293,91 20989	294,84 39466
295,11 51047	294,19 55178	295,12 10149	294,19 50652	292,98 53931	294,18 84526	295,09 74982	294,19 80466	295,14 65282
295,41 42903	294,48 14665	295,42 10176	294,48 10117	293,24 39586	294,47 44494	295,40 19664	294,48 39942	295,44 91099
295,71 34759	294,76 74152	295,72 10203	294,76 69581	293,50 2524	294,76 04461	295,70 64345	294,76 99419	295,75 16915
295,85 27457	294,98 0254	295,94 51589	294,97 96424	293,71 21662	294,97 31078	295,93 21657	294,98 26932	295,97 79707
295,95 00173	295,17 38922	296,14 93736	295,17 30862	293,90 89599	295,16 65098	296,13 72185	295,17 62213	296,18 42109
296,04 7289	295,36 75303	296,35 35883	295,36 653	294,10 57536	295,35 99118	296,34 22713	295,36 97493	296,39 0451
296,14 45607	295,56 11685	296,55 78029	295,55 99738	294,30 25473	295,55 33138	296,54 73241	295,56 32774	296,59 66912
296,24 18324	295,75 48067	296,76 20176	295,75 34175	294,49 9341	295,74 67158	296,75 23769	295,75 68054	296,80 29313
296,25 42426	295,92 8831	296,94 94264	295,92 72232	294,67 4451	295,92 04333	296,94 01746	295,93 07167	296,99 1732
296,11 21713	296,06 71501	297,10 62415	296,06 52797	294,81 00881	296,05 83174	297,09 65612	296,06 89176	297,14 8786
295,97 01	296,20 54693	297,26 30567	296,20 33362	294,94 57253	296,19 62014	297,25 29478	296,20 71186	297,30 58399
295,82 80287	296,34 37884	297,41 98719	296,34 13927	295,08 13624	296,33 40855	297,40 93345	296,34 53195	297,46 28939
295,68 59574	296,48 21076	297,57 66871	296,47 94492	295,21 69995	296,47 19696	297,56 57211	296,48 35204	297,61 99478
295,54 38861	296,62 04268	297,73 35023	296,61 75057	295,35 26367	296,60 98536	297,72 21077	296,62 17214	297,77 70018
295,40 18148	296,75 87459	297,89 03174	296,75 55622	295,48 82738	296,74 77377	297,87 84944	296,75 99223	297,93 40557

295,3437653	296,8685809	298,0033522	296,86551	295,5870637	296,8576136	297,9920662	296,8697673	298,0471658
295,2912332	296,9765455	298,1135121	296,9736119	295,683434	296,9656504	298,1028265	296,9777503	298,1573903
295,2387011	297,08451	298,223672	297,0817139	295,7798043	297,0736872	298,2135868	297,0857332	298,2676147
295,1861689	297,1924746	298,3338319	297,1898158	295,8761746	297,181724	298,3243472	297,1937162	298,3778392
295,1336368	297,3004392	298,4439918	297,2979178	295,9725449	297,2897608	298,4351075	297,3016992	298,4880636
295,0811047	297,4084037	298,5541517	297,4060198	296,0689152	297,3977976	298,5458679	297,4096821	298,5982881
295,0285726	297,5163683	298,6643116	297,5141217	296,1652855	297,5058344	298,6566282	297,5176651	298,7085126
294,9962566	297,6130162	298,7700662	297,6108093	296,2539265	297,6024697	298,7622539	297,6142676	298,814599
294,9987659	297,6901694	298,8682322	297,687834	296,3292526	297,6794642	298,8590342	297,6912655	298,9135571
295,0012752	297,7673225	298,9663982	297,7648587	296,4045787	297,7564588	298,9558145	297,7682635	299,0125152
295,0037846	297,8444757	299,0645642	297,8418834	296,4799049	297,8334533	299,0525949	297,8452614	299,1114733
295,0062939	297,9216289	299,1627302	297,9189081	296,555231	297,9104478	299,1493752	297,9222594	299,2104314
295,0088032	297,9987821	299,2608962	297,9959328	296,6305571	297,9874424	299,2461555	297,9992573	299,3093895
295,0113125	298,0759352	299,3590622	298,0729574	296,7058832	298,0644369	299,3429359	298,0762553	299,4083476
295,0138219	298,1530884	299,4572282	298,1499821	296,7812094	298,1414314	299,4397162	298,1532532	299,5073057
295,0163312	298,2302416	299,5553942	298,2270068	296,8565355	298,218426	299,5364966	298,2302512	299,6062638
295,0280034	298,3026869	299,6522928	298,2993064	296,9244402	298,2906729	299,6323892	298,3025163	299,7027554
295,0516547	298,3689775	299,7475344	298,3654287	296,9826426	298,3567132	299,7271212	298,3685941	299,7960225
295,0753059	298,435268	299,8427761	298,431551	297,0408451	298,4227535	299,8218532	298,4346719	299,8892896
295,0989572	298,5015586	299,9380178	298,4976734	297,0990475	298,4887938	299,9165853	298,5007496	299,9825567
295,1226084	298,5678492	300,0332594	298,5637957	297,15725	298,5548341	300,0113173	298,5668274	300,0758239
295,1462596	298,6341397	300,1285011	298,629918	297,2154524	298,6208744	300,1060494	298,6329052	300,169091
295,1699109	298,7004303	300,2237428	298,6960404	297,2736549	298,6869147	300,2007814	298,6989829	300,2623581

295,1935621	298,7667209	300,3189845	298,7621627	297,3318573	298,752955	300,2955135	298,7650607	300,3556252
295,2172133	298,8330114	300,4142261	298,828285	297,3900597	298,8189953	300,3902455	298,8311385	300,4488923
295,2408646	298,899302	300,5094678	298,8944074	297,4482622	298,8850356	300,4849775	298,8972163	300,5421595
295,2645158	298,9655926	300,6047095	298,9605297	297,5064646	298,9510759	300,5797096	298,963294	300,6354266
295,2965889	299,0296572	300,6935904	299,0244296	297,5521841	299,0150253	300,6680987	299,0269849	300,7219821
295,3296879	299,0934507	300,7816965	299,0880589	297,596383	299,07872	300,7557152	299,090385	300,80772
295,3627868	299,1572441	300,8698027	299,1516881	297,6405819	299,1424147	300,8433316	299,153785	300,893458
295,3958858	299,2210376	300,9579088	299,2153173	297,6847808	299,2061094	300,9309481	299,2171851	300,9791959
295,4289848	299,2848311	301,0460149	299,2789465	297,7289797	299,2698042	301,0185645	299,2805852	301,0649339
295,4620838	299,3486245	301,1341211	299,3425758	297,7731786	299,3334989	301,106181	299,3439853	301,1506718
295,4951827	299,412418	301,2222272	299,406205	297,8173775	299,3971936	301,1937975	299,4073854	301,2364098
295,5282817	299,4762115	301,3103333	299,4698342	297,8615764	299,4608883	301,2814139	299,4707854	301,3221477
295,5613807	299,540005	301,3984394	299,5334634	297,9057753	299,524583	301,3690304	299,5341855	301,4078857
295,5944797	299,6037984	301,4865456	299,5970927	297,9499742	299,5882777	301,4566468	299,5975856	301,4936236
295,6275786	299,6675919	301,5746517	299,6607219	297,9941731	299,6519724	301,5442633	299,6609857	301,5793616
295,6606776	299,7313854	301,6627578	299,7243511	298,038372	299,7156671	301,6318798	299,7243858	301,6650995
295,6932304	299,7948354	301,7476344	299,7874357	298,0806668	299,7789001	301,7154766	299,787143	301,7473662
295,7251208	299,8578687	301,8285934	299,8498598	298,1206519	299,8415731	301,7941973	299,8491206	301,825422
295,7570111	299,920902	301,9095524	299,9122838	298,1606371	299,9042461	301,8729181	299,9110982	301,9034778
295,7889014	299,9839354	301,9905114	299,9747078	298,2006222	299,9669191	301,9516389	299,9730757	301,9815337
295,8207918	300,0469687	302,0714704	300,0371319	298,2406073	300,0295921	302,0303597	300,0350533	302,0595895
295,8526821	300,110002	302,1524294	300,0995559	298,2805925	300,0922651	302,1090805	300,0970308	302,1376454
295,8845724	300,1730354	302,2333884	300,1619799	298,3205776	300,1549381	302,1878013	300,1590084	302,2157012

295,9164627	300,2360687	302,3143474	300,224404	298,3605627	300,2176111	302,2665221	300,2209859	302,2937571
295,9483531	300,2991021	302,3953064	300,286828	298,4005479	300,280284	302,3452428	300,2829635	302,3718129
295,9802434	300,3621354	302,4762654	300,349252	298,440533	300,342957	302,4239636	300,344941	302,4498688
296,0121337	300,4251687	302,5572245	300,4116761	298,4805181	300,40563	302,5026844	300,4069186	302,5279246
296,0440241	300,4882021	302,6381835	300,4741001	298,5205033	300,468303	302,5814052	300,4688962	302,6059804
296,0759144	300,5512354	302,7191425	300,5365241	298,5604884	300,530976	302,660126	300,5308737	302,6840363
296,1078047	300,6142687	302,8001015	300,5989482	298,6004735	300,593649	302,7388468	300,5928513	302,7620921
296,139695	300,6773021	302,8810605	300,6613722	298,6404587	300,656322	302,8175676	300,6548288	302,840148
296,1682095	300,7387763	302,9611409	300,7216212	298,679565	300,7174304	302,890454	300,7144428	302,9125466
296,1957337	300,7997932	303,0409635	300,7812323	298,7184137	300,7780798	302,961629	300,7733634	302,9832859
296,2232579	300,8608102	303,1207862	300,8408434	298,7572623	300,8387292	303,032804	300,8322841	303,0540252
296,2507822	300,9218271	303,2006088	300,9004545	298,7961109	300,8993786	303,1039791	300,8912047	303,1247646
296,2783064	300,9828441	303,2804315	300,9600655	298,8349596	300,960028	303,1751541	300,9501254	303,1955039
296,3058306	301,043861	303,3602542	301,0196766	298,8738082	301,0206775	303,2463292	301,009046	303,2662432
296,3333548	301,1048779	303,4400768	301,0792877	298,9126568	301,0813269	303,3175042	301,0679667	303,3369825
296,3608791	301,1658949	303,5198995	301,1388987	298,9515054	301,1419763	303,3886793	301,1268873	303,4077218
296,3884033	301,2269118	303,5997222	301,1985098	298,9903541	301,2026257	303,4598543	301,185808	303,4784611
296,4159275	301,2879287	303,6795448	301,2581209	299,0292027	301,2632751	303,5310294	301,2447286	303,5492004
296,4434517	301,3489457	303,7593675	301,317732	299,0680513	301,3239246	303,6022044	301,3036493	303,6199397
296,470976	301,4099626	303,8391902	301,377343	299,1069	301,384574	303,6733795	301,3625699	303,690679
296,4985002	301,4709796	303,9190128	301,4369541	299,1457486	301,4452234	303,7445545	301,4214906	303,7614183
296,5260244	301,5319965	303,9988355	301,4965652	299,1845972	301,5058728	303,8157295	301,4804112	303,8321576
296,5535487	301,5930134	304,0786582	301,5561763	299,2234458	301,5665223	303,8869046	301,5393319	303,9028969

296,5810729	301,6540304	304,1584808	301,6157873	299,2622945	301,6271717	303,9580796	301,5982525	303,9736362
296,6085971	301,7150473	304,2383035	301,6753984	299,3011431	301,6878211	304,0292547	301,6571732	304,0443755
296,6347242	301,7751464	304,3162093	301,7342467	299,339986	301,7476532	304,0982533	301,7151878	304,1130633
296,6591599	301,8341345	304,3917947	301,7921716	299,378822	301,8064958	304,1646174	301,7721057	304,1792677
296,6835956	301,8931226	304,46738	301,8500965	299,417658	301,8653384	304,2309815	301,8290235	304,2454721
296,7080313	301,9521107	304,5429654	301,9080214	299,4564939	301,924181	304,2973456	301,8859414	304,3116765
296,7318814	302,0109447	304,6174225	301,9657711	299,4958268	301,9826729	304,3613368	301,9425129	304,3757449
296,7554623	302,0697079	304,691361	302,0234404	299,5353881	302,0410036	304,4242373	301,9989253	304,4388316
296,7790432	302,1284711	304,7652995	302,0811096	299,5749493	302,0993343	304,4871379	302,0553376	304,5019184
296,8026241	302,1872344	304,839238	302,1387789	299,6145106	302,1576649	304,5500384	302,11175	304,5650051
296,8276371	302,2426986	304,9113213	302,1959795	299,6557366	302,2151663	304,6048004	302,1682677	304,6204351
296,8527783	302,2978675	304,9832384	302,2531382	299,6971117	302,2725934	304,6588336	302,2247949	304,6751795
296,8779196	302,3530364	305,0551555	302,3102968	299,7384867	302,3300205	304,7128669	302,281322	304,7299239
296,9031924	302,4084171	305,1270572	302,3675409	299,779928	302,3873205	304,7666013	302,3378349	304,7843589
296,9294554	302,4651157	305,1989011	302,425436	299,8218836	302,443604	304,81783	302,3940474	304,8361722
296,9574529	302,5189792	305,2711111	302,4851287	299,8645295	302,4969088	304,8650489	302,4478734	304,883029
296,9929997	302,5679898	305,3441705	302,547442	299,9076624	302,545197	304,9092934	302,4970842	304,925037
297,0867394	302,6278749	305,418844	302,5978233	299,9514994	302,5884037	304,9490448	302,5376115	304,9638734
297,3528213	302,6914776	305,4953177	302,6363058	299,996161	302,6307807	304,9859814	302,5656894	305,0032709
297,5602619	302,7543357	305,5727163	302,6770916	300,0412673	302,6728111	305,0234083	302,5887778	305,0433221
297,6475042	302,8189583	305,6517196	302,719014	300,0871787	302,7155823	305,0631217	302,6063229	305,0853452
297,7502262	302,8859799	305,732546	302,761734	300,1341422	302,7594769	305,1055203	302,620757	305,1295982
297,8622867	302,9537152	305,8138086	302,8044202	300,1813945	302,8035333	305,1485323	302,6345864	305,1743819

297,9822743	303,0235989	305,8963016	302,8463463	300,2295579	302,8480713	305,1934005	302,6472879	305,2208074
298,0984357	303,0946011	305,9797303	302,8879303	300,2779003	302,8928144	305,2398207	302,6600431	305,2686547
298,219079	303,1667766	306,0643065	302,9296116	300,3254661	302,9379185	305,2882753	302,6739767	305,3184782
298,3400683	303,239388	306,1495298	302,9716735	300,3730271	302,983391	305,3379936	302,6891053	305,3694537
298,4641636	303,3123993	306,2353391	303,0141856	300,420684	303,0292745	305,3887954	302,7054834	305,4214535
298,5792404	303,3858254	306,3217533	303,057395	300,4685724	303,0757056	305,4406995	302,723575	305,4745806
298,6870567	303,4596165	306,4087647	303,1017675	300,5168436	303,1230283	305,4941672	302,7440712	305,5290735
298,7924106	303,5337067	306,4968416	303,1469411	300,5653833	303,1709807	305,5486513	302,765982	305,5843891
298,8911454	303,6081852	306,5890894	303,1931094	300,6142762	303,2197385	305,6041961	302,7891395	305,6406257
298,9844754	303,6828157	306,6900702	303,2403538	300,663639	303,2693285	305,6608542	302,8134213	305,6977958
299,0711672	303,7574691	306,812437	303,2887895	300,7136474	303,3200158	305,7187483	302,8387219	305,7561236
299,1546555	303,8321237	306,9043981	303,3384604	300,7642096	303,3716334	305,7775626	302,8646972	305,8153936
299,2375404	303,9067245	306,939227	303,3893675	300,8153331	303,424158	305,8372734	302,8913518	305,8755471
299,3226673	303,9812755	306,9667996	303,4411595	300,8670841	303,477626	305,8979324	302,9188446	305,9366555
299,4125408	304,0557982	306,9944139	303,4938698	300,9195354	303,5320164	305,9595223	302,9473387	305,9986954
299,5059889	304,1303945	307,024189	303,5475713	300,9725371	303,5872424	306,0220289	302,976928	306,0616292
299,6014867	304,2052244	307,0370221	303,6024316	301,0253506	303,6433421	306,0857502	303,0078275	306,1256847
299,7024746	304,2803255	307,056466	303,6584503	301,0779778	303,7002728	306,1504512	303,0399971	306,1909341
299,8146171	304,3558806	307,092375	303,7152885	301,1305368	303,7579885	306,2161145	303,0735425	306,2577469
299,9347125	304,4317579	307,1445197	303,7729003	301,1831379	303,8164334	306,2829586	303,1084946	306,3265417
300,0690414	304,5082659	307,1797556	303,8314207	301,2358885	303,8757136	306,3508466	303,1451115	306,3979889
300,2244428	304,5852285	307,2186529	303,8906348	301,2888363	303,9356355	306,418803	303,1831426	306,4708439
300,3889828	304,6628662	307,2760825	303,9506691	301,3421008	303,9964024	306,4857557	303,2228494	306,5434933

300,55 8818	304,74 11826	307,33 18809	304,01 15301	301,39 5678	304,05 80215	306,55 04443	303,26 41203	306,61 45439
300,71 70496	304,82 10599	307,39 2963	304,07 33323	301,44 9534	304,12 05963	306,60 83687	303,30 70869	306,68 19376
300,88 84495	304,90 45554	307,46 0405	304,13 60199	301,50 36212	304,18 40958	306,65 26421	303,35 16655	306,73 99735
301,17 23899	305,00 3685	307,51 52418	304,19 99178	301,55 77043	304,24 85887	306,66 63337	303,39 81255	306,77 18797
302,20 00831	305,14 17386	307,57 09987	304,26 46508	301,61 16451	304,31 37563	306,61 46611	303,44 60317	306,76 15521
303,12 87543	305,30 18191	307,62 68697	304,33 03515	301,66 55002	304,37 9778	306,47 73942	303,49 59708	306,64 48792
303,83 90021	305,44 73087	307,68 84902	304,39 69178	301,71 94	304,44 66121	306,38 94237	303,54 76608	306,51 40736
304,41 42188	305,67 06101	307,75 25573	304,46 43751	301,77 33576	304,51 43495	306,33 01729	303,60 09361	306,41 2588
304,76 97938	305,91 20858	307,80 67287	304,53 28354	301,82 73769	304,58 30676	306,25 53856	303,65 58199	306,32 31111
304,84 91505	306,14 83936	307,85 94833	304,60 24505	301,88 13479	304,65 29431	306,17 86054	303,71 24071	306,24 16196
304,59 13503	306,38 4526	307,91 69527	304,67 33081	301,93 52994	304,72 39963	306,10 30881	303,77 08623	306,18 54527
304,06 94112	306,60 83444	307,97 2537	304,74 54188	301,98 93158	304,79 61665	306,02 76194	303,83 1096	306,13 78234
303,77 83568	306,77 90627	308,02 48394	304,81 86701	302,04 33967	304,86 94512	305,96 74145	303,89 2841	306,10 20956
303,84 3594	306,88 3617	308,08 16283	304,89 29899	302,09 7567	304,94 38459	305,92 31654	303,95 58852	306,07 4206
303,89 21875	306,91 72798	308,13 9747	304,96 85375	302,15 19171	305,01 93606	305,88 78427	304,02 01251	306,04 30794
303,94 20217	306,87 17229	308,19 88908	305,04 57083	302,20 65855	305,09 61625	305,85 89811	304,08 53766	306,00 10509
303,99 18737	306,78 6036	308,26 20649	305,12 83563	302,26 1678	305,17 57932	305,83 41676	304,15 1474	305,97 19542
304,06 02633	306,64 2889	308,33 07843	305,23 20066	302,31 69088	305,27 01383	305,82 11522	304,21 83385	305,93 89309
304,13 23632	306,52 18449	308,40 48631	305,32 54275	302,37 24311	305,37 22909	305,80 79554	304,28 5865	305,89 88486
304,22 09628	306,40 89632	308,48 44036	305,40 95363	302,42 84239	305,45 1544	305,78 87458	304,35 39951	305,85 47354
304,31 45738	306,35 38335	308,56 67967	305,49 27009	302,48 50265	305,52 17048	305,78 38098	304,42 28524	305,79 84797
304,39 79726	306,33 23649	308,65 20158	305,56 34062	302,54 23175	305,59 85924	305,77 14485	304,49 25095	305,73 73972
304,46 85495	306,33 5907	308,73 93518	305,63 05937	302,60 02782	305,68 55866	305,73 94935	304,56 29977	305,66 85874

304,541775	306,3612866	308,830791	305,7223934	302,6589548	305,7769812	305,6889616	304,6345311	305,5888122
304,6124978	306,399991	308,9255038	305,8255172	302,7184218	305,8801472	305,6267828	304,7074616	305,4941665
304,7002723	306,4543603	309,0218766	305,9228936	302,7787361	305,9832128	305,5483456	304,7813168	305,3991185
304,7923936	306,5309477	309,1187984	306,0311528	302,8399245	306,0662582	305,4614455	304,8552399	305,3131052
304,8865029	306,6210229	309,2156284	306,144322	302,9019439	306,1586126	305,3812971	304,9271998	305,232371
304,9801614	306,7263815	309,3124597	306,2445174	302,9647529	306,2719605	305,311099	304,9935077	305,1604228
305,0765627	306,84192	309,4082821	306,3744312	303,0280997	306,3935521	305,2639405	305,0458177	305,1198943
305,1789707	306,9720991	309,5044951	306,4997576	303,0920066	306,4939308	305,2387006	305,0690628	305,1079576
305,2863199	307,1200957	309,6042407	306,6051497	303,1565788	306,559525	305,2222708	305,0581394	305,1124595
305,4048444	307,2801603	309,7074793	306,7466569	303,2218374	306,6709006	305,2153819	305,0260007	305,1289336
305,5275781	307,456109	309,8149932	306,8535664	303,2878149	306,7832938	305,2117797	304,9805664	305,1521634
305,6736203	307,6464065	309,9274542	306,9524489	303,3546021	306,8811611	305,207914	304,924273	305,1782884
305,8264715	307,8437103	310,0445809	307,0241307	303,4222541	306,9415466	305,2073169	304,8635596	305,2042867
305,9760705	308,0469773	310,1649519	307,0752819	303,4909074	306,9857495	305,2150842	304,8092747	305,2274442
306,1305928	308,2556211	310,2894943	307,1226498	303,5606345	307,0413122	305,2341482	304,7601939	305,2473181
306,2725844	308,4682767	310,4164721	307,1675376	303,6316104	307,0852262	305,260341	304,714283	305,2655665
306,3904542	308,6847769	310,5448773	307,1947144	303,7038233	307,1189638	305,2860442	304,689294	305,2825108
306,4968206	308,9057532	310,6732825	307,2166222	303,777308	307,1416205	305,3054546	304,6932657	305,301427
306,5872725	309,127989	310,7989295	307,2408743	303,8519945	307,1502191	305,3212009	304,6848661	305,3203676
306,6655321	309,3521266	310,9220362	307,2546259	303,9279177	307,1713579	305,338278	304,6500006	305,3396498
306,7482467	309,5783795	311,0433763	307,2684317	304,0052203	307,1903874	305,3562731	304,6188502	305,3611922
306,8313404	309,8033288	311,1646777	307,2786877	304,0844806	307,1947913	305,3743691	304,5887507	305,3815336
306,9165369	310,0241945	311,2855269	307,2791837	304,1656603	307,1955366	305,3874525	304,5565683	305,3967179

307,0073901	310,2399826	311,4051291	307,279763	304,2488274	307,1883838	305,3965621	304,5271932	305,4076547
307,1174882	310,4504794	311,5277274	307,272158	304,3344463	307,1776277	305,4043498	304,4892529	305,4231459
307,2614583	310,656442	311,6555342	307,262374	304,4244117	307,1775263	305,4193269	304,4166727	305,4423515
307,4833707	310,8592444	311,7870862	307,2531684	304,5204964	307,1729266	305,4363883	304,3172787	305,4572014
307,823953	311,0585327	311,9242299	307,2425578	304,6191286	307,1637602	305,4512608	304,2081495	305,4732142
308,2163676	311,2545195	312,0670751	307,2252115	304,781593	307,1530684	305,4715972	304,1144217	305,4943273
308,6631193	311,4473894	312,2139714	307,2148556	304,9681369	307,1477444	305,4943594	304,02907	305,5121704
309,1777523	311,6339031	312,3674837	307,2228499	305,0692851	307,1527451	305,5196814	303,9568626	305,5291591
309,749104	311,8170152	312,5325845	307,2449324	305,2244581	307,1742162	305,546598	303,9292885	305,5496263
310,3474065	311,9983417	312,7077017	307,2650353	305,3074859	307,2055981	305,5738648	303,9337206	305,5689933
310,9061928	312,1796246	312,8921513	307,2974944	305,4249897	307,2381506	305,5931282	303,9584087	305,5830078
311,3710033	312,3620639	313,0819392	307,2929655	305,5374915	307,2419219	305,5940081	303,9864878	305,5788395
311,7333609	312,5426227	313,2786471	307,256262	305,7036179	307,1967988	305,5496848	304,0229613	305,5343435
312,0595299	312,7259271	313,4826581	307,2306648	305,6117578	307,1790008	305,4949962	304,0572401	305,4852094
312,3501707	312,9138919	313,6886119	307,2294119	305,6264293	307,1782063	305,4601521	304,0740957	305,457329
312,6194494	313,105127	313,8949835	307,2590126	305,6861515	307,206936	305,4364423	304,092226	305,4368517
312,8759306	313,299068	314,1020717	307,3180109	305,7877554	307,2640875	305,4310515	304,1271884	305,429778
313,1235084	313,4954644	314,3097805	307,4027338	305,9175837	307,3488491	305,4462232	304,1785576	305,4463189
313,3645659	313,6940956	314,5180284	307,5086936	306,0655857	307,4555872	305,4769318	304,2424239	305,4802209
313,6009087	313,8947738	314,7268285	307,6316562	306,22537	307,579405	305,5193612	304,3142644	305,5259101
313,8338253	314,0973592	314,9362297	307,768103	306,3927022	307,7167088	305,5710919	304,3912594	305,580503
314,0642202	314,3017476	315,1462813	307,9151075	306,5649848	307,8645472	305,6303716	304,4727984	305,6421463
314,2928471	314,5078384	315,3570293	308,0699561	306,740368	308,0201818	305,6957288	304,5582225	305,7093597

314,520208	314,7155523	315,5685055	308,2307267	306,917805	308,181676	305,7662521	304,6471336	305,7812226
314,7467222	314,9248033	315,7807317	308,395838	307,0966917	308,3474433	305,8415191	304,7390427	305,8572452
314,9725109	315,1355575	315,9937114	308,5648486	307,2768931	308,5170457	305,9216934	304,8339046	305,9375792
315,1978806	315,3477387	316,2074567	308,7366276	307,4580218	308,6893554	306,0068912	304,9315127	306,0223064
315,4231053	315,5612472	316,4219676	308,9102323	307,6397887	308,8634454	306,0963165	305,0315324	306,1110109
315,6482561	315,7760311	316,6372364	309,0854766	307,822178	309,0391373	306,1895917	305,1341233	306,2033645
315,8735366	315,991983	316,8532531	309,2617335	308,0050513	309,2158196	306,2859778	305,2393962	306,2987992
316,0988785	316,209139	317,0700213	309,4392136	308,1884551	309,3936975	306,385723	305,3473141	306,3975058
316,3244234	316,4274036	317,2875222	309,6176419	308,3723733	309,5725038	306,488554	305,4576862	306,4992912
316,5502685	316,6467115	317,5057432	309,79683	308,5567949	309,7520553	306,5942836	305,5703821	306,6040234
316,7763255	316,8671219	317,7246959	309,9769489	308,7417299	309,9325184	306,7030818	305,6855203	306,7118222
317,0027369	317,0884976	317,9443425	310,157767	308,9271769	310,113668	306,814631	305,8029333	306,8224829
317,2295881	317,3107559	318,1646605	310,3391451	309,113135	310,2953691	306,9287405	305,9225207	306,9358825
317,4567968	317,5339764	318,3856716	310,5212172	309,2996051	310,4777516	307,0455939	306,0443793	307,0521394
317,6844318	317,7579247	318,6072682	310,7038534	309,486584	310,6606907	307,1645127	306,1680891	307,1705536
317,9125292	317,9824787	318,8293941	310,8869861	309,67407	310,8441211	307,2851427	306,293431	307,2907596
318,141052	318,2077643	319,0521072	311,070685	309,8620648	311,02811	307,4078488	306,4206308	307,4131341
318,37	318,4337816	319,2754074	311,2549501	310,0505684	311,2126575	307,5326312	306,5496885	307,537677
318,5993733	318,6605305	319,4992949	311,4397814	310,2395809	311,3977634	307,6594896	306,6806041	307,6643882
318,8291719	318,888011	319,7237695	311,625179	310,4291022	311,5834279	307,7884243	306,8133777	307,7932679
319,0593523	319,1159407	319,9486571	311,811084	310,6191141	311,7695956	307,9185662	306,9473083	307,9233519
319,2899124	319,3443071	320,1739502	311,9974939	310,809616	311,9562641	308,0498772	307,082365	308,0545976
319,5208761	319,5732639	320,3997434	312,1844407	311,0006175	312,1434635	308,18283	307,2189295	308,1875298

319,7522433	319,8028113	320,6260368	312,3719244	311,1921189	312,3311937	308,3174249	307,3570016	308,3221487
319,984014	320,0329491	320,8528303	312,5599449	311,38412	312,5194549	308,4536617	307,4965813	308,4584542
320,2161882	320,2636773	321,080124	312,7485023	311,5766208	312,7082469	308,5915405	307,6376688	308,5964463
320,4486712	320,4946783	321,3076993	312,9375579	311,7696231	312,8975359	308,7301612	307,7794786	308,7351573
320,6814691	320,7259729	321,5355704	313,1271141	311,9631267	313,0873241	308,8695834	307,9220627	308,8746514
320,9146261	320,957709	321,7638393	313,3171891	312,1571309	313,2776273	309,0102258	308,0657866	309,0153788
321,1481422	321,1898867	321,992506	313,5077828	312,3516356	313,4684455	309,1520886	308,2106502	309,1573394

Point probe results of heating process on the coordinate (###, 11.5, ###)

Temperature (K), Point: (4, 11.5, 504)	Temperature (K), Point: (254, 11.5, 504)	Temperature (K), Point: (504, 11.5, 504)	Temperature (K), Point: (4, 11.5, 254)	Temperature (K), Point: (254, 11.5, 254)	Temperature (K), Point: (504, 11.5, 254)	Temperature (K), Point: (4, 11.5, 4)	Temperature (K), Point: (254, 11.5, 4)	Temperature (K), Point: (504, 11.5, 4)
			13		15			
583,0469707	531,3185577	686,7090876	186,4860789	392,0805278	188,809546	372,1425403	326,0141301	371,2990186
288,148651	288,1503526	288,1494074	288,150416	288,1494426	288,1504489	288,1501539	288,1503435	288,1495593
288,1377725	288,1159322	288,1049703	288,1129146	288,1534077	288,1089557	288,0949492	288,1138351	288,1133664

288,1421909	288,1837748	288,0986749	288,1807485	288,1539152	288,1761457	288,0907203	288,1816026	288,118246
288,3756726	288,4223917	288,3370823	288,4196625	288,2964027	288,4147556	288,3312301	288,4215937	288,355356
288,6225003	288,6687564	288,5887857	288,6663909	288,4494608	288,6611407	288,5845479	288,6692721	288,6056327
288,9393949	288,9557977	288,910293	288,9541444	288,6580147	288,948346	288,9051085	288,9573091	288,925035
289,268306	289,2501974	289,2431754	289,2492777	288,8831647	289,2429657	289,236942	289,2525236	289,2560567
289,6352689	289,5678989	289,6120789	289,5677809	289,1608692	289,5610647	289,6044731	289,5704666	289,6238727
290,0022319	289,8856005	289,9809823	289,886284	289,4385737	289,8791637	289,9720042	289,8884095	289,9916888
290,3691948	290,203302	290,3498858	290,2047872	289,7162782	290,1972627	290,3395354	290,2063525	290,3595049
290,7085486	290,5037988	290,6913316	290,5058381	289,9861973	290,4980711	290,6808017	290,5069916	290,7004147
291,0064885	290,7784884	290,9915907	290,7807107	290,2444381	290,7729434	290,9826709	290,7816749	291,0009651
291,3044284	291,0531779	291,2918499	291,0555833	290,5026789	291,0478158	291,28454	291,0563581	291,3015155
291,6023683	291,3278675	291,5921091	291,3304559	290,7609197	291,3226882	291,5864091	291,3310413	291,6020659
291,9003083	291,602557	291,8923682	291,6053285	291,0191605	291,5975605	291,8882783	291,6057246	291,9026164
292,102904	291,8276771	292,1353452	291,8305288	291,2328388	291,8228509	292,1328279	291,8308296	292,1460025
292,2804599	292,0397788	292,3632783	292,0426839	291,4348137	292,0351198	292,3623238	292,0429141	292,3743757
292,4580157	292,2518806	292,5912115	292,254839	291,6367886	292,2473887	292,5918198	292,2549986	292,6027489
292,6355716	292,4639823	292,8191446	292,466994	291,8387636	292,4596576	292,8213157	292,4670831	292,8311221
292,8131275	292,6760841	293,0470778	292,6791491	292,0407385	292,6719265	293,0508117	292,6791676	293,0594953
292,9488027	292,868667	293,253206	292,8717143	292,225537	292,8646164	293,2585488	292,871712	293,2660763
293,0082385	293,0257178	293,4196405	293,0286183	292,3790675	293,0216647	293,426676	293,0286858	293,4329868
293,0676744	293,1827687	293,586075	293,1855223	292,5325979	293,1787131	293,5948033	293,1856595	293,5998972
293,1271102	293,3398195	293,7525095	293,3424263	292,6861284	293,3357614	293,7629305	293,3426332	293,7668076
293,186546	293,4968703	293,918944	293,4993303	292,8396589	293,4928097	293,9310578	293,4996069	293,9337181

293,2459819	293,6539211	294,0853785	293,6562343	292,9931894	293,6498581	294,099185	293,6565806	294,1006285
293,3054177	293,810972	294,251813	293,8131383	293,1467199	293,8069064	294,2673123	293,8135544	294,267539
293,3809976	293,925009	294,3683672	293,9269859	293,2609751	293,9208635	294,3852375	293,9275246	294,3843267
293,4576375	294,0362216	294,481646	294,0380063	293,3726514	294,0319909	294,4998662	294,038671	294,4978231
293,5342775	294,1474341	294,5949247	294,1490267	293,4843277	294,1431183	294,6144948	294,1498174	294,6113195
293,6109174	294,2586467	294,7082035	294,2600471	293,5960039	294,2542457	294,7291235	294,2609638	294,7248159
293,6875574	294,3698593	294,8214822	294,3710675	293,7076802	294,3653731	294,8437521	294,3721102	294,8383123
293,7641973	294,4810718	294,934761	294,4820879	293,8193564	294,4765005	294,9583808	294,4832566	294,9518087
293,8408373	294,5922844	295,0480398	294,5931083	293,9310327	294,5876279	295,0730094	294,594403	295,0653051
293,9149397	294,6911476	295,1502628	294,6918087	294,0286132	294,6864112	295,1762448	294,6931885	295,1677335
293,9846708	294,7687372	295,2334406	294,7692863	294,1019118	294,7639299	295,2598535	294,7706804	295,2510954
294,054402	294,8463269	295,3166184	294,8467639	294,1752104	294,8414487	295,3434622	294,8481723	295,3344574
294,1241331	294,9239165	295,3997963	294,9242415	294,248509	294,9189674	295,427071	294,9256642	295,4178193
294,1938642	295,0015061	295,4829741	295,0017191	294,3218076	294,9964861	295,5106797	295,0031561	295,5011813
294,2635954	295,0790958	295,5661519	295,0791967	294,3951061	295,0740048	295,5942884	295,0806481	295,5845432
294,3333265	295,1566854	295,6493298	295,1566743	294,4684047	295,1515235	295,6778971	295,15814	295,6679052
294,4030576	295,2342751	295,7325076	295,2341519	294,5417033	295,2290422	295,7615059	295,2356319	295,7512671
294,4727888	295,3118647	295,8156854	295,3116295	294,6150019	295,306561	295,8451146	295,3131238	295,8346291
294,538539	295,3813736	295,8926969	295,3810365	294,6802134	295,3760164	295,9224996	295,3825031	295,9115426
294,5990849	295,4403183	295,961647	295,4398927	294,7348524	295,4349306	295,9917482	295,4412764	295,9800259
294,6596308	295,499263	296,0305971	295,4987488	294,7894914	295,4938447	296,0609969	295,5000497	296,0485092
294,7201768	295,5582077	296,0995472	295,5576049	294,8441304	295,5527588	296,1302455	295,558823	296,1169924
294,7807227	295,6171524	296,1684973	295,6164611	294,8987694	295,611673	296,1994941	295,6175962	296,1854757

294,8412686	295,6760971	296,2374474	295,6753172	294,9534084	295,6705871	296,2687427	295,6763695	296,253959
294,9018145	295,7350419	296,3063975	295,7341734	295,0080474	295,7295012	296,3379914	295,7351428	296,3224423
294,9623604	295,7939866	296,3753476	295,7930295	295,0626864	295,7884154	296,40724	295,7939161	296,3909255
295,0229064	295,8529313	296,4442976	295,8518857	295,1173254	295,8473295	296,4764886	295,8526894	296,4594088
295,0834523	295,911876	296,5132477	295,9107418	295,1719643	295,9062436	296,5457372	295,9114627	296,5278921
295,1439982	295,9708207	296,5821978	295,9695979	295,2266033	295,9651578	296,6149859	295,970236	296,5963754
295,1893323	296,0204469	296,6427894	296,0190544	295,2700704	296,0146281	296,6753532	296,0195242	296,6561961
295,2328135	296,0689379	296,7023627	296,0673659	295,3121767	296,062948	296,7346387	296,0676569	296,7149616
295,2762946	296,117429	296,761936	296,1156773	295,3542829	296,111268	296,7939243	296,1157896	296,7737271
295,3197758	296,16592	296,8215094	296,1639888	295,3963891	296,1595879	296,8532098	296,1639223	296,8324927
295,3632569	296,2144111	296,8810827	296,2123002	295,4384953	296,2079078	296,9124953	296,212055	296,8912582
295,4067381	296,2629021	296,9406561	296,2606117	295,4806015	296,2562278	296,9717808	296,2601878	296,9500237
295,4502192	296,3113932	297,0002294	296,3089232	295,5227078	296,3045477	297,0310663	296,3083205	297,0087892
295,4937004	296,3598843	297,0598027	296,3572346	295,564814	296,3528676	297,0903518	296,3564532	297,0675547
295,5371815	296,4083753	297,1193761	296,4055461	295,6069202	296,4011876	297,1496373	296,4045859	297,1263202
295,5806627	296,4568664	297,1789494	296,4538575	295,6490264	296,4495075	297,2089228	296,4527187	297,1850858
295,6241438	296,5053574	297,2385228	296,502169	295,6911326	296,4978274	297,2682083	296,5008514	297,2438513
295,667625	296,5538485	297,2980961	296,5504804	295,7332388	296,5461473	297,3274939	296,5489841	297,3026168
295,7065185	296,6005486	297,3571891	296,5968769	295,7723397	296,5925589	297,3853889	296,5951398	297,3601486
295,739847	296,6450763	297,4156994	296,6409503	295,807795	296,6366554	297,4415973	296,6388973	297,4161838
295,7731755	296,689604	297,4742096	296,6850238	295,8432502	296,680752	297,4978056	296,6826548	297,472219
295,806504	296,7341317	297,5327199	296,7290972	295,8787055	296,7248486	297,554014	296,7264122	297,5282542
295,8398326	296,7786594	297,5912302	296,7731706	295,9141607	296,7689451	297,6102223	296,7701697	297,5842895

295,87 31611	296,82 31871	297,64 97405	296,81 72441	295,94 9616	296,81 30417	297,66 64307	296,81 39272	297,64 03247
295,90 64896	296,86 77148	297,70 82508	296,86 13175	295,98 50713	296,85 71383	297,72 2639	296,85 76847	297,69 63599
295,93 98181	296,91 22425	297,76 6761	296,90 53909	296,02 05265	296,90 12348	297,77 88474	296,90 14422	297,75 23951
295,97 31466	296,95 67702	297,82 52713	296,94 94644	296,05 59818	296,94 53314	297,83 50557	296,94 51997	297,80 84304
296,00 64752	297,00 12979	297,88 37816	296,99 35378	296,09 1437	296,98 9428	297,89 12641	296,98 89571	297,86 44656
296,03 98037	297,04 58256	297,94 22919	297,03 76112	296,12 68923	297,03 35245	297,94 74725	297,03 27146	297,92 05008
296,07 31322	297,09 03532	298,00 08022	297,08 16847	296,16 23475	297,07 76211	298,00 36808	297,07 64721	297,97 6536
296,10 64607	297,13 48809	298,05 93124	297,12 57581	296,19 78028	297,12 17177	298,05 98892	297,12 02296	298,03 25713
296,13 97892	297,17 94086	298,11 78227	297,16 98315	296,23 32581	297,16 58142	298,11 60975	297,16 39871	298,08 86065
296,17 31177	297,22 39363	298,17 6333	297,21 3905	296,26 87133	297,20 99108	298,17 23059	297,20 77445	298,14 46417
296,20 59035	297,26 80092	298,24 42761	297,25 71928	296,30 06414	297,25 3463	298,23 18744	297,25 0242	298,20 42334
296,23 853	297,31 19487	298,31 49861	297,30 02501	296,33 15348	297,29 68556	298,29 24285	297,29 23699	298,26 48683
296,27 11565	297,35 58881	298,38 56961	297,34 33074	296,36 24282	297,34 02481	298,35 29826	297,33 44979	298,32 55032
296,30 3783	297,39 98276	298,45 6406	297,38 63647	296,39 33217	297,38 36406	298,41 35367	297,37 66258	298,38 61381
296,33 64096	297,44 3767	298,52 7116	297,42 9422	296,42 42151	297,42 70332	298,47 40908	297,41 87537	298,44 6773
296,36 90361	297,48 77065	298,59 78259	297,47 24794	296,45 51085	297,47 04257	298,53 46449	297,46 08816	298,50 74079
296,40 16626	297,53 1646	298,66 85359	297,51 55367	296,48 6002	297,51 38183	298,59 5199	297,50 30095	298,56 80428
296,43 42891	297,57 55854	298,73 92458	297,55 8594	296,51 68954	297,55 72108	298,65 57531	297,54 51374	298,62 86777
296,46 69157	297,61 95249	298,80 99558	297,60 16513	296,54 77888	297,60 06033	298,71 63072	297,58 72653	298,68 93126
296,49 95422	297,66 34644	298,88 06658	297,64 47086	296,57 86823	297,64 39959	298,77 68613	297,62 93932	298,74 99475
296,53 21687	297,70 74038	298,95 13757	297,68 77659	296,60 95757	297,68 73884	298,83 74154	297,67 15211	298,81 05824
296,56 47952	297,75 13433	299,02 20857	297,73 08233	296,64 04692	297,73 0781	298,89 79695	297,71 36491	298,87 12173
296,59 74218	297,79 52827	299,09 27956	297,77 38806	296,67 13626	297,77 41735	298,95 85236	297,75 5777	298,93 18521

296,6300483	297,8392222	299,1635056	297,8169379	296,702256	297,817566	299,0190777	297,7979049	298,992487
296,6626748	297,8831617	299,2342156	297,8599952	296,7331495	297,8609586	299,0796318	297,8400328	299,0531219
296,6953013	297,9271011	299,3049255	297,9030525	296,7640429	297,9043511	299,1401859	297,8821607	299,1137568
296,7279278	297,9710406	299,3756355	297,9461099	296,7949363	297,9477437	299,20074	297,9242886	299,1743917
296,7609116	298,015264	299,4469241	297,989467	296,8252806	297,9914364	299,2614401	297,9665659	299,2350427
296,7943278	298,059831	299,5189131	298,0331872	296,85496	298,0354926	299,3223168	298,0090242	299,295713
296,827744	298,1043981	299,5909021	298,0769073	296,8846394	298,0795487	299,3831936	298,0514824	299,3563834
296,8611602	298,1489652	299,6628911	298,1206274	296,9143189	298,1236049	299,4440703	298,0939406	299,4170537
296,8941331	298,1939222	299,7357773	298,1647998	296,9435738	298,1679754	299,5045912	298,1365981	299,4776087
296,9269023	298,2390585	299,8090759	298,20918	296,9726336	298,2124904	299,5649484	298,1793473	299,5381107
296,9596715	298,2841947	299,8823744	298,2535602	297,0016934	298,2570053	299,6253057	298,2220964	299,5986126
296,9924407	298,329331	299,955673	298,2979404	297,0307532	298,3015203	299,685663	298,2648456	299,6591146
297,0225574	298,3738127	300,030948	298,3433284	297,0590014	298,346406	299,7421052	298,3084014	299,716062
297,0524366	298,4182357	300,1064	298,3888067	297,087177	298,391325	299,798197	298,3520295	299,7726911
297,0823159	298,4626588	300,181852	298,4342849	297,1153525	298,436244	299,8542887	298,3956576	299,8293203
297,1119853	298,5071479	300,2573297	298,4798231	297,1435009	298,4811169	299,9102031	298,4392985	299,8857684
297,1399687	298,5521245	300,3331489	298,5258501	297,1714272	298,5255863	299,9645678	298,4829727	299,9406112
297,1651732	298,5964618	300,4102352	298,5729962	297,1989654	298,5688987	300,0162451	298,5259521	299,9920383
297,1859581	298,6386554	300,4890464	298,6217096	297,2261858	298,6104717	300,065903	298,567278	300,0398852
297,165917	298,685142	300,57037	298,6670959	297,2533311	298,65012	300,1123794	298,6053406	300,0856756
297,0141724	298,7348744	300,6527573	298,7047482	297,2804457	298,6884369	300,1574314	298,6371904	300,1330733
296,8327602	298,7851289	300,7353559	298,7410865	297,307512	298,7263264	300,2033241	298,665894	300,1815833
296,7886218	298,8363759	300,8194213	298,7775851	297,3345543	298,7641589	300,2517751	298,6906008	300,23207

296,8012319	298,8894257	300,9054385	298,8143664	297,3616901	298,8022408	300,3027221	298,7126049	300,2843808
296,8224533	298,9430104	300,9919643	298,8511113	297,3888776	298,8403443	300,3541864	298,7340531	300,3371196
296,8583042	298,9984368	301,080148	298,8875248	297,4161954	298,8787014	300,4069036	298,7542167	300,3912261
296,9004769	299,0552409	301,1699733	298,9238718	297,4436022	298,9173386	300,4606789	298,7737965	300,4465619
296,945164	299,1137529	301,2618593	298,9605737	297,4711681	298,9565346	300,5160761	298,7931701	300,5035984
296,9916891	299,1731578	301,3549417	298,9976928	297,4988465	298,9961759	300,5725205	298,8126965	300,5616646
297,0367892	299,233411	301,4492117	299,0352356	297,5266316	299,0362451	300,6295038	298,8324382	300,6198243
297,0822153	299,2947444	301,5448438	299,0733827	297,5546512	299,0768791	300,6871816	298,8526241	300,6787698
297,1246448	299,357544	301,6417834	299,1125222	297,5831254	299,1184082	300,7462576	298,8735883	300,7391503
297,1643275	299,4212228	301,7400066	299,1523476	297,6118571	299,1605408	300,806299	298,8950452	300,8003689
297,2034028	299,4855213	301,8407162	299,1930427	297,6408271	299,2034319	300,8671897	298,9170317	300,8623119
297,2433941	299,55084	301,9465507	299,2347578	297,6700702	299,2472105	300,9291773	298,9396056	300,9253628
297,2918292	299,617399	302,0634864	299,2777118	297,6997006	299,2921622	300,9926131	298,9628551	300,9898938
297,3509712	299,6848479	302,1776988	299,3218002	297,7296681	299,3381212	301,0573219	298,9866251	301,0557661
297,4212938	299,7529829	302,2775307	299,3670377	297,76005	299,3851088	301,1233688	299,0109041	301,1230088
297,5003673	299,8218327	302,3732471	299,4133778	297,7909212	299,4332066	301,1907807	299,0357541	301,1916871
297,5854219	299,8915921	302,4652664	299,4608254	297,8222559	299,4822595	301,2595899	299,0612561	301,2616654
297,6757376	299,9623697	302,5547638	299,5092458	297,854055	299,5321489	301,3298784	299,0874824	301,3328877
297,7727602	300,034532	302,6589882	299,5588772	297,8864773	299,5831891	301,401659	299,1146045	301,4054332
297,8756759	300,1081596	302,7861377	299,6098548	297,9194451	299,6354104	301,4747518	299,1426246	301,4794497
297,9836555	300,1833843	302,9098288	299,6621226	297,9529183	299,6888101	301,5493055	299,1716442	301,555237
298,0989638	300,2601014	303,0358312	299,7154803	297,9868242	299,7432195	301,6254046	299,2016908	301,633139
298,2230437	300,3386507	303,2547869	299,7699597	298,0211939	299,7986613	301,7033049	299,2329818	301,7137615

298,3543955	300,4186659	303,5501453	299,8253593	298,0559901	299,8551178	301,7824533	299,2653936	301,7963539
298,4986279	300,5004481	303,7541165	299,8820754	298,0914308	299,9129341	301,8627001	299,2991359	301,8801299
298,6565089	300,5841035	303,9190331	299,9401202	298,1275828	299,97207	301,9434349	299,3341211	301,9644589
298,8282674	300,6702385	304,0426869	299,9996255	298,1645767	300,0327013	302,0233377	299,3704953	302,0486802
299,0116022	300,7591329	304,1324929	300,0606287	298,2025359	300,0948485	302,1000048	299,4083037	302,1310018
299,2155995	300,8545766	304,2326484	300,1233688	298,2416027	300,1586838	302,1681921	299,4478552	302,2065356
299,4838465	300,9650711	304,3373244	300,1874706	298,2814374	300,2237969	302,2219615	299,4887875	302,2712043
299,8500391	301,0924331	304,4465258	300,2534177	298,3224104	300,2907337	302,2476075	299,5314009	302,3062416
300,2704741	301,2181591	304,5475471	300,3212078	298,3644461	300,3595308	302,2718197	299,575546	302,3254389
300,6934556	301,3671242	304,6373169	300,3908539	298,407503	300,4301171	302,3007173	299,6213155	302,3444395
301,0888171	301,54184	304,708294	300,4624162	298,4515215	300,502701	302,3266247	299,6687579	302,3637949
301,3763232	301,7190222	304,7705726	300,5362167	298,4964566	300,5776167	302,3498392	299,7180771	302,3834342
301,5224496	301,9102324	304,8371534	300,6125623	298,5422633	300,6551129	302,3718326	299,7692548	302,407097
301,5658797	302,1091597	304,9014993	300,6913554	298,5888867	300,7345707	302,3923396	299,8221178	302,4323826
301,6751876	302,2959266	304,9647639	300,7718053	298,6362985	300,8157387	302,4135136	299,8767049	302,4600351
301,9300047	302,4589403	305,0330897	300,854206	298,6844671	300,8991081	302,4364283	299,9329643	302,4894834
302,1602099	302,6210406	305,1013081	300,9390078	298,7333818	300,9851005	302,4609081	299,9908713	302,5178853
302,4693778	302,8136891	305,1692319	301,0267612	298,7831299	301,0740812	302,4863549	300,0503294	302,5404484
302,8037242	302,9854644	305,238533	301,1185163	298,8338367	301,1658022	302,5104021	300,1113017	302,5589547
303,0255084	303,2658773	305,3103667	301,2190981	298,8856141	301,262617	302,5326264	300,1739196	302,5714804
303,1762139	303,4390146	305,3876354	301,3219807	298,9385394	301,367371	302,5515892	300,238288	302,575391
303,2942554	303,5552383	305,4695528	301,4226548	298,9927088	301,4697566	302,5675332	300,3045215	302,5700512
303,3999828	303,6645312	305,5532173	301,5252736	299,0482392	301,5714193	302,5735488	300,372845	302,5541999

303,4973855	303,7739255	305,6390745	301,6260839	299,1050952	301,6738228	302,5577734	300,4432238	302,532019
303,5951711	303,9532554	305,7276512	301,7265098	299,1630954	301,7825052	302,5255485	300,5158268	302,5042849
303,6936777	304,1067644	305,8195499	301,8350687	299,2222883	301,8960081	302,4868105	300,5910077	302,4706018
303,7930162	304,2342289	305,9134176	301,9520909	299,2828097	302,0153356	302,452476	300,6691915	302,4352395
303,8852706	304,3483396	306,0087871	302,0708239	299,3447964	302,1402426	302,4248147	300,7495191	302,4040832
303,9751796	304,462805	306,1049453	302,194376	299,4080293	302,2610583	302,4126203	300,8318731	302,3833635
304,0620365	304,5837666	306,1999053	302,3232908	299,4722704	302,383102	302,4117366	300,9161992	302,3758593
304,1447438	304,7076946	306,2937386	302,4523311	299,5378194	302,5172143	302,4214423	301,0014649	302,3821933
304,2275452	304,8304299	306,3872492	302,5966514	299,6046748	302,6562042	302,4396519	301,0853939	302,3957941
304,3070433	304,952037	306,4835341	302,7391722	299,6728432	302,7875111	302,4652358	301,1615679	302,4159755
304,3860859	305,0921732	306,5844871	302,8669639	299,7419334	302,8699055	302,4906916	301,2266915	302,4415446
304,4646646	305,2446498	306,6904041	303,0013317	299,8120444	303,0075038	302,5191712	301,2846089	302,4707705
304,5450234	305,414785	306,8025644	303,1396759	299,8835794	303,1463576	302,5475991	301,3390832	302,500383
304,6254305	305,5993508	306,9185642	303,2870447	299,956816	303,2790395	302,572157	301,3915247	302,5276972
304,709954	305,7934744	307,0384785	303,4020505	300,0322462	303,3786004	302,5922961	301,4430274	302,5510535
304,8037654	305,9973456	307,1630376	303,48388	300,1101968	303,4441202	302,6119597	301,4967903	302,5711867
304,9053537	306,2079073	307,2902045	303,5520544	300,1905809	303,5409366	302,6345193	301,5537145	302,5893726
305,0175853	306,4236633	307,4198927	303,6763576	300,2726148	303,6529157	302,6569758	301,6127828	302,6062019
305,1365772	306,6434504	307,5513248	303,7670128	300,3560846	303,7403281	302,6726592	301,6751111	302,6226009
305,2620324	306,8693281	307,6824776	303,8403839	300,4409184	303,810309	302,6783234	301,7438663	302,6418229
305,3878128	307,0971861	307,8114677	303,8997733	300,5265324	303,8458417	302,6829077	301,8147117	302,66056
305,517532	307,3258412	307,9394615	303,9428069	300,6145912	303,8831251	302,6940799	301,879446	302,6783149
305,6573494	307,5553925	308,068207	303,9831098	300,704988	303,9472293	302,7108286	301,9410171	302,6958036

305,80 72083	307,78 30112	308,19 89557	304,00 54958	300,79 89851	303,99 10463	302,72 81974	302,00 05577	302,70 92199
305,97 38078	308,00 54682	308,33 08958	304,02 92925	300,89 82491	304,01 39978	302,73 81629	302,05 55963	302,71 70499
306,15 58449	308,22 2311	308,46 62859	304,04 63296	301,00 37408	304,02 82225	302,74 13118	302,10 14168	302,72 27629
306,35 38226	308,43 43027	308,60 77138	304,05 47648	301,11 58956	304,02 16325	302,74 66217	302,13 05891	302,73 71323
306,56 87554	308,64 15222	308,75 38128	304,06 56179	301,23 58249	304,03 60594	302,76 1289	302,13 50735	302,75 63307
306,77 72323	308,84 55294	308,90 4637	304,07 78022	301,36 53769	304,05 07292	302,77 73748	302,11 84314	302,77 16038
306,96 23177	309,04 63146	309,06 1208	304,09 04512	301,50 71151	304,05 91789	302,79 43045	302,09 34207	302,78 97746
307,15 15871	309,24 42384	309,22 17613	304,08 17017	301,68 42317	304,06 8079	302,81 58296	302,06 88017	302,81 24759
307,36 15605	309,43 89722	309,38 76171	304,09 43709	301,90 76223	304,06 67757	302,84 0299	302,04 98739	302,83 16837
307,61 21762	309,62 69397	309,56 24453	304,11 59391	302,07 31982	304,07 45227	302,86 70298	302,05 23093	302,85 14537
307,90 90502	309,81 15942	309,74 58202	304,13 488	302,26 80582	304,10 61101	302,89 532	302,07 59539	302,87 4002
308,25 75877	309,99 47178	309,93 61285	304,17 01429	302,39 66249	304,13 33192	302,92 03892	302,10 66353	302,89 44481
308,63 77535	310,17 81569	310,13 15702	304,19 77187	302,58 72155	304,16 29677	302,93 50265	302,14 53356	302,90 72849
309,00 61488	310,36 3112	310,33 08136	304,18 23577	302,82 10913	304,17 15663	302,92 12094	302,18 37643	302,89 3679
309,33 76147	310,54 55803	310,53 6474	304,15 05523	303,18 59629	304,15 83674	302,85 9539	302,22 51314	302,83 47787
309,63 82948	310,73 14598	310,74 54169	304,14 3288	303,19 21387	304,14 64558	302,79 85563	302,26 69199	302,78 08671
309,91 60292	310,92 29147	310,95 43134	304,19 13492	303,53 20701	304,18 19783	302,76 68825	302,28 7957	302,75 53723
310,17 85032	311,11 74682	311,16 38137	304,27 32441	303,76 56441	304,25 91761	302,75 60576	302,30 94458	302,74 20772
310,43 14407	311,31 45777	311,37 41366	304,38 03869	303,96 77174	304,36 33626	302,76 69181	302,35 05952	302,74 70887
310,67 76648	311,51 40737	311,58 52403	304,51 25549	304,16 45997	304,49 15619	302,79 64796	302,40 86295	302,77 61976
310,91 88833	311,71 57975	311,79 70785	304,66 33091	304,35 95311	304,64 04286	302,83 81939	302,47 91048	302,82 03987
311,15 63843	311,91 95932	312,00 96407	304,82 6009	304,55 37567	304,80 25858	302,88 79909	302,55 7227	302,87 31587
311,39 11192	312,12 5335	312,22 29413	304,99 6514	304,74 69775	304,97 29754	302,94 40372	302,63 98656	302,93 17045

311,6237803	312,3329242	312,4370044	305,172371	304,9393696	305,1488856	303,0055244	302,7259124	302,9951011
311,8549727	312,5422624	312,6518572	305,3517887	305,1312635	305,3284244	303,071971	302,8150678	303,0629892
312,085117	312,7532703	312,8675209	305,5337006	305,3228938	305,5104847	303,1431328	302,9072661	303,1352206
312,3145736	312,9658588	313,0840115	305,71736	305,5144233	305,6942998	303,2189208	303,0023591	303,2117005
312,5434514	313,1799926	313,3013318	305,9025835	305,7059019	305,8796812	303,2992354	303,1002623	303,2923147
312,7720209	313,3955922	313,5194906	306,0888722	305,8974538	306,0661164	303,3838955	303,2008054	303,37686
313,0005345	313,612553	313,7384877	306,2758866	306,0892017	306,2532598	303,472661	303,3036772	303,4651066
313,2290649	313,8308209	313,9583169	306,4635935	306,2811739	306,4410805	303,5652904	303,4087559	303,556962
313,4578092	314,0502836	314,1789704	306,6518062	306,4734552	306,6293918	303,6613626	303,5157693	303,6522141
313,6867013	314,2709787	314,4004507	306,8405873	306,6660171	306,8182564	303,761019	303,6248089	303,7509342
313,9158693	314,4928121	314,6227435	307,0298695	306,8588881	307,0076115	303,8640596	303,7359522	303,8529798
314,1454013	314,7157191	314,8458388	307,2196068	307,0520879	307,1974138	303,9703473	303,8492527	303,9582535
314,3752174	314,9397584	315,0697456	307,409841	307,2455987	307,3877025	304,0800066	303,9646619	304,0668438
314,6054545	315,1647917	315,2944222	307,6005179	307,4394413	307,5784288	304,1925944	304,082326	304,1784266
314,836195	315,3907359	315,5198438	307,7916052	307,6336285	307,7695631	304,3078448	304,2023329	304,292807
315,0673596	315,617671	315,7460343	307,983134	307,828148	307,9611338	304,426014	304,324598	304,4101726
315,298989	315,8453513	315,9728517	308,1750843	308,0230218	308,153125	304,5462521	304,4486615	304,5296898
315,5311044	316,0736485	316,200222	308,3674456	308,2182615	308,3455285	304,6681159	304,5742833	304,6509236
315,763684	316,3026948	316,4282214	308,5602286	308,4138551	308,5383528	304,7920622	304,7017109	304,7743222
315,9967277	316,5324901	316,65685	308,7534334	308,6098027	308,731598	304,918091	304,8309441	304,8998857
316,2302355	316,7630345	316,8861078	308,94706	308,8061043	308,9252639	305,0462024	304,9619831	305,027614
316,4642075	316,9943281	317,1159948	309,1411084	309,0027599	309,1193507	305,1763964	305,0948277	305,1575072
316,6985519	317,2260717	317,346299	309,3355891	309,1998106	309,3138719	305,307794	305,2288156	305,2886242

316,93 32646	317,45 82523	317,57 7011	309,53 05025	309,39 72583	309,50 88282	305,44 03562	305,36 39174	305,42 09233
317,16 83956	317,69 10326	317,80 82462	309,72 5843	309,59 50804	309,70 42122	305,57 45618	305,50 04939	305,55 4917
317,40 3945	317,92 44126	318,04 00048	309,92 16104	309,79 32772	309,90 00238	305,71 04106	305,63 8545	305,69 06052
317,63 99126	318,15 83923	318,27 22865	310,11 78049	309,99 18484	310,09 6263	305,84 79028	305,77 80707	305,82 79879
317,87 62985	318,39 29717	318,50 50915	310,31 44265	310,19 07942	310,29 29299	305,98 70382	305,91 9071	305,96 70652
318,11 2967	318,62 78213	318,73 81746	310,51 15181	310,39 01898	310,49 00695	306,12 69486	306,06 08839	306,10 69061
318,34 9927	318,86 29629	318,97 15522	310,70 90768	310,59 00302	310,68 76788	306,26 76916	306,20 3553	306,24 75724
318,58 72417	319,09 85499	319,20 53381	310,90 70827	310,79 02804	310,88 57368	306,40 9671	306,34 73866	306,38 94971
318,82 49111	319,33 45822	319,43 95325	311,10 55358	310,99 09404	311,08 42436	306,55 28869	306,49 23847	306,53 26802

Point probe results of heating process on the coordinate (###, 19, ###).

Temperature (K), Point: (4, 19, 504)	Temperature (K), Point: (254, 19, 504)	Temperature (K), Point: (504, 19, 504)	Temperature (K), Point: (4, 19, 254)	Temperature (K), Point: (254, 19, 254)	Temperature (K), Point: (504, 19, 254)	Temperature (K), Point: (4, 19, 4)	Temperature (K), Point: (254, 19, 4)	Temperature (K), Point: (504, 19, 4)
			22		24			
505,14 33156	542,66 76462	559,11 52972	296,15 29335	498,22 6225	295,53 48147	318,48 54403	469,11 00589	319,74 5032
288,15 03648	288,14 9083	288,15 05453	288,14 91295	288,14 77251	288,14 91281	288,15 01491	288,14 91248	288,14 97293
288,25 64879	288,26 14842	288,26 0189	288,25 99903	288,23 37176	288,25 85677	288,26 16362	288,25 91986	288,24 82218
288,47 63259	288,46 44596	288,47 20282	288,46 33416	288,39 93368	288,46 19901	288,47 92681	288,46 34953	288,46 93816

288,67 66166	288,63 81371	288,66 5576	288,63 77587	288,53 09192	288,63 59798	288,67 87328	288,63 76488	288,66 89819
288,87 72242	288,81 19906	288,85 9714	288,81 23015	288,66 38472	288,81 00736	288,87 86401	288,81 19009	288,86 89049
289,07 94953	288,98 67682	289,05 69513	288,98 75046	288,80 38393	288,98 47135	289,08 08708	288,98 66709	289,07 05214
289,29 42442	289,17 36892	289,26 7499	289,17 48316	288,95 71986	289,17 14983	289,29 56744	289,17 35524	289,28 48376
289,54 85056	289,39 90641	289,52 01965	289,40 05508	289,15 28872	289,39 67417	289,55 02917	289,39 8787	289,53 93696
289,80 2767	289,62 44391	289,77 2894	289,62 62701	289,34 85758	289,62 19851	289,80 49091	289,62 40215	289,79 39015
290,05 70284	289,84 98141	290,02 55915	289,85 19894	289,54 42644	289,84 72285	290,05 95264	289,84 92561	290,04 84335
290,31 35671	290,08 31557	290,28 11732	290,08 55382	289,75 64515	290,08 04755	290,31 61575	290,08 24955	290,30 51804
290,57 35215	290,32 84471	290,54 10812	290,33 08312	289,99 33865	290,32 57281	290,57 58093	290,32 77423	290,56 52497
290,83 34759	290,57 37386	290,80 09892	290,57 61242	290,23 03214	290,57 09807	290,83 54611	290,57 2989	290,82 53189
291,09 34303	290,81 903	291,06 08972	290,82 14173	290,46 72564	290,81 62333	291,09 51129	290,81 82358	291,08 53882
291,35 33847	291,06 43215	291,32 08052	291,06 67103	290,70 41913	291,06 14859	291,35 47646	291,06 34825	291,34 54575
291,57 50049	291,28 09661	291,55 15241	291,28 33426	290,91 1054	291,27 81356	291,58 4887	291,28 01337	291,57 60904
291,78 65576	291,49 00873	291,77 45772	291,49 24477	291,11 0019	291,48 72736	291,80 72542	291,48 9275	291,79 89925
291,99 81102	291,69 92085	291,99 76302	291,70 15529	291,30 89839	291,69 64115	292,02 96214	291,69 84163	292,02 18946
292,20 96629	291,90 83297	292,22 06833	291,91 0658	291,50 79489	291,90 55494	292,25 19886	291,90 75575	292,24 47967
292,42 12155	292,11 74509	292,44 37364	292,11 97631	291,70 69138	292,11 46874	292,47 43558	292,11 66988	292,46 76988
292,61 04203	292,31 14107	292,65 10999	292,31 37169	291,89 13026	292,30 86853	292,68 10431	292,31 06831	292,67 49049
292,75 89431	292,47 77707	292,82 99024	292,48 00892	292,04 91571	292,47 51225	292,85 91869	292,47 70756	292,85 35379
292,90 7466	292,64 41307	293,00 87049	292,64 64614	292,20 70115	292,64 15597	293,03 73307	292,64 34682	293,03 21709
293,05 59888	292,81 04906	293,18 75074	292,81 28337	292,36 4866	292,80 79969	293,21 54744	292,80 98607	293,21 0804
293,20 45117	292,97 68506	293,36 63099	292,97 92059	292,52 27205	292,97 4434	293,39 36182	292,97 62532	293,38 9437
293,35 30345	293,14 32106	293,54 51124	293,14 55782	292,68 05749	293,14 08712	293,57 17619	293,14 26458	293,56 807

293,5015573	293,3095706	293,7239149	293,3119504	292,8384294	293,3073084	293,7499057	293,3090383	293,746703
293,6127359	293,4348382	293,849018	293,4370816	292,9632391	293,4325732	293,8744301	293,4342987	293,8714464
293,7214621	293,5574074	293,9705949	293,5595048	293,0858788	293,5551344	293,9954337	293,556858	293,992651
293,8301884	293,6799766	294,0921718	293,6819279	293,2085186	293,6776956	294,1164372	293,6794173	294,1138556
293,9389147	293,8025459	294,2137488	293,804351	293,3311584	293,8002569	294,2374408	293,8019767	294,2350603
294,0476409	293,9251151	294,3353257	293,9267741	293,4537982	293,9228181	294,3584443	293,924536	294,3562649
294,1563672	294,0476843	294,4569026	294,0491973	293,576438	294,0453793	294,4794478	294,0470954	294,4774696
294,2650935	294,1702535	294,5784795	294,1716204	293,6990777	294,1679405	294,6004514	294,1696547	294,5986742
294,3611815	294,2769517	294,6858888	294,2782117	293,8057168	294,2746356	294,7073904	294,2763377	294,7057763
294,4354984	294,3563096	294,7688921	294,3575304	293,8847922	294,3539988	294,7901014	294,3556712	294,7885846
294,5098153	294,4356674	294,8518954	294,436849	293,9638676	294,433362	294,8728123	294,4350048	294,8713929
294,5841323	294,5150253	294,9348987	294,5161677	294,0429431	294,5127252	294,9555232	294,5143383	294,9542012
294,6584492	294,5943832	295,017902	294,5954863	294,1220185	294,5920883	295,0382342	294,5936718	295,0370095
294,7327661	294,6737411	295,1009053	294,674805	294,2010939	294,6714515	295,1209451	294,6730054	295,1198178
294,807083	294,753099	295,1839086	294,7541236	294,2801693	294,7508147	295,203656	294,7523389	295,2026261
294,8813999	294,8324569	295,2669119	294,8334423	294,3592447	294,8301779	295,2863669	294,8316725	295,2854345
294,9557168	294,9118147	295,3499152	294,9127609	294,4383202	294,9095411	295,3690779	294,911006	295,3682428
295,020214	294,9811461	295,4234188	294,9820412	294,5074048	294,9788614	295,4423725	294,9802985	295,441586
295,0718736	295,0373694	295,4845031	295,0381981	294,5634283	295,0350521	295,5033569	295,0364639	295,5025551
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295,2785121	295,2622626	295,7288405	295,2628257	294,7875223	295,2598152	295,7472944	295,2611258	295,7464317

295,3301718	295,3184859	295,7899249	295,3189826	294,8435458	295,316006	295,8082788	295,3172913	295,8074008
295,3818314	295,3747092	295,8510092	295,3751396	294,8995693	295,3721968	295,8692632	295,3734568	295,86837
295,433491	295,4309325	295,9120935	295,4312965	294,9555928	295,4283876	295,9302476	295,4296222	295,9293391
295,4851506	295,4871558	295,9731779	295,4874534	295,0116163	295,4845783	295,991232	295,4857877	295,9903083
295,5368102	295,5433791	296,0342622	295,5436103	295,0676398	295,5407691	296,0522164	295,5419532	296,0512774
295,5764226	295,5878473	296,0866034	295,5880021	295,1091085	295,5851847	296,1043322	295,5862835	296,1033504
295,6145675	295,6308834	296,1378796	295,6309608	295,1488043	295,6281658	296,1553676	295,6291721	296,1543397
295,6527123	295,6739196	296,1891558	295,6739195	295,1885001	295,671147	296,2064031	295,6720608	296,2053291
295,6908572	295,7169558	296,240432	295,7168782	295,2281959	295,7141282	296,2574386	295,7149494	296,2563184
295,729002	295,759992	296,2917082	295,7598369	295,2678917	295,7571093	296,308474	295,757838	296,3073077
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296,39 08644	296,52 35317	297,17 39447	296,52 08769	295,93 73085	296,51 90917	297,18 32598	296,51 65313	297,18 08952
296,42 35176	296,56 18396	297,21 71863	296,55 90176	295,96 95991	296,55 72998	297,22 60094	296,55 45133	297,22 35706
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296,54 57267	296,70 65298	297,38 2882	296,70 26725	296,09 35646	296,70 13074	297,38 51546	296,69 74663	297,38 21492
296,57 36407	296,74 00208	297,42 20233	296,73 57896	296,12 29245	296,73 45387	297,42 12195	296,73 03869	297,41 79878
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296,71 32106	296,90 74757	297,61 77297	296,90 1375	296,26 97235	296,90 0695	297,60 15439	296,89 49901	297,59 71808
296,74 11246	296,94 09667	297,65 6871	296,93 44921	296,29 90833	296,93 39262	297,63 76088	296,92 79107	297,63 30194
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296,88 06945	297,10 84216	297,85 25774	297,10 00775	296,44 58824	297,10 00825	297,81 79332	297,09 25139	297,81 22124

296,90 86085	297,14 19126	297,89 17186	297,13 31946	296,47 52422	297,13 33138	297,85 39981	297,12 54345	297,84 8051
296,93 65224	297,17 54036	297,93 08599	297,16 63117	296,50 4602	297,16 6545	297,89 0063	297,15 83551	297,88 38897
296,96 44364	297,20 88946	297,97 00012	297,19 94288	296,53 39618	297,19 97763	297,92 61279	297,19 12757	297,91 97283
296,99 17603	297,24 14006	298,01 03275	297,23 15428	296,56 30886	297,23 20034	297,96 26883	297,22 31734	297,95 60426
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297,32 65074	297,62 67174	298,65 02755	297,61 07815	296,92 89605	297,61 25174	298,49 2295	297,59 8226	298,48 28221
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305,8179466	306,9224125	307,3210133	303,1266958	299,0845404	303,1536232	302,8122259	301,1572534	302,8136964
305,949152	307,1463529	307,4525549	303,2222011	299,1839905	303,2508259	302,8330283	301,2737034	302,8332663

306,08578	307,367519	307,5855673	303,300488	299,2941219	303,3290272	302,851331	301,3889916	302,8492574
306,2278835	307,5849523	307,7214645	303,3678753	299,4186488	303,3901622	302,8625784	301,5030045	302,862153
306,3746123	307,7983786	307,8622182	303,4252402	299,5639401	303,4328569	302,8707843	301,6138383	302,8759766
306,5282781	308,0071296	308,007278	303,4652727	299,7412475	303,4690067	302,8840594	301,7179414	302,8953956
306,6910582	308,2116288	308,1562995	303,5052843	299,967845	303,5080435	302,9017814	301,8127468	302,9144592
306,8622661	308,4129599	308,3103945	303,5370264	300,2018553	303,5447985	302,9184934	301,8972994	302,9317453
307,0390954	308,6113059	308,4682736	303,5507638	300,4271654	303,5831077	302,9382417	301,9721283	302,9530282
307,2208766	308,8069299	308,6302243	303,560479	300,6517841	303,6094945	302,9604887	302,0387566	302,975093
307,4123617	308,9976322	308,7982232	303,5907763	300,8840312	303,6192333	302,9848879	302,0997547	302,9953317
307,6177656	309,1840555	308,972854	303,6181833	301,1168948	303,6361273	303,0111495	302,1602353	303,0175185
307,8395686	309,3679242	309,1532901	303,6509157	301,3566372	303,6609416	303,0386765	302,2140559	303,0403824
308,0847521	309,5501394	309,3393099	303,6775019	301,5988613	303,6834428	303,0636932	302,2697549	303,0614755
308,3513768	309,7328352	309,5292271	303,6952721	301,8508036	303,7048584	303,0814889	302,3237266	303,0765618
308,631476	309,914077	309,7249053	303,716439	302,1136586	303,7307023	303,0698717	302,3762094	303,0672168
308,9092503	310,0954574	309,9248256	303,7350664	302,3619187	303,7546244	303,0322962	302,4303209	303,0377312
309,1787967	310,2805989	310,1263673	303,7668048	302,9199777	303,7822934	303,0000696	302,4747709	303,0134307
309,4400951	310,4686633	310,3296392	303,8214808	303,3532193	303,8268181	302,9761189	302,5057907	302,9935076
309,6938639	310,659415	310,5342591	303,9011002	303,6818389	303,8981461	302,9631761	302,5380102	302,9770771
309,9410867	310,8527532	310,7398558	304,0101978	303,9559818	304,0023988	302,9654401	302,5782514	302,9752273
310,1828004	311,048541	310,9462757	304,1460205	304,1990127	304,1373567	302,9809329	302,6294621	302,9884554
310,4200402	311,2466269	311,153464	304,3009802	304,4238015	304,2931118	303,0070525	302,6909177	303,0137952
310,6537135	311,4468776	311,3614144	304,4684349	304,6366769	304,4616369	303,0421593	302,7601715	303,0488743
310,8845637	311,6491827	311,5701447	304,6441358	304,8415804	304,6383107	303,085229	302,8353115	303,0922329

311,1132982	311,8534329	311,779688	304,824932	305,0415557	304,8198874	303,1353749	302,915106	303,1428434
311,3404445	312,0595422	311,9900768	305,008942	305,2384404	305,0044968	303,1919616	302,9988977	303,2000226
311,5664829	312,2674207	312,2013488	305,1949256	305,43345	305,1909447	303,2545349	303,0862174	303,2631422
311,7915668	312,4770355	312,4135179	305,3825989	305,626875	305,3789615	303,3229473	303,1769172	303,3319671
312,0160684	312,6883105	312,626616	305,5711627	305,819517	305,5677825	303,3968394	303,2706332	303,4059576
312,2403596	312,9011568	312,8406837	305,7601381	306,0119139	305,7569606	303,4756921	303,3669846	303,4844698
312,4645697	313,115555	313,0557628	305,9495188	306,2041228	305,9464972	303,5591246	303,4658262	303,5672164
312,6890174	313,3314458	313,2719263	306,1390887	306,3964477	306,1361987	303,6464267	303,5668155	303,6535669
312,9135957	313,5488492	313,4891498	306,3289205	306,5887866	306,3261302	303,7378368	303,6700674	303,7437329
313,1385595	313,7675513	313,7073563	306,5189902	306,7812463	306,5162794	303,8328503	303,7754949	303,8373803
313,3640833	313,9874055	313,9264931	306,7092812	306,9738997	306,7066382	303,9311216	303,8830383	303,93428
313,5900087	314,2085449	314,146608	306,8998087	307,1666805	306,8972141	304,0329645	303,9927518	304,03464
313,8164061	314,4306722	314,3674861	307,090579	307,3596787	307,0880246	304,1379365	304,1047463	304,1382031
314,0433179	314,653609	314,588998	307,2815961	307,5529482	307,2790806	304,2457715	304,2190885	304,2448148
314,2707033	314,877527	314,8112681	307,4728563	307,746437	307,4703716	304,3567258	304,3357141	304,3546238
314,498406	315,1021023	315,0340295	307,6644112	307,940213	307,6619568	304,4699182	304,4542293	304,4667892
314,7263446	315,3271655	315,2571427	307,8562879	308,1343116	307,8538668	304,5848893	304,5744285	304,5808721
314,954603	315,5528911	315,4807513	308,0484585	308,3286964	308,0460701	304,7021126	304,6965235	304,6973248
315,1831812	315,779279	315,7048553	308,240923	308,5233672	308,2385664	304,8215882	304,8205143	304,8161472
315,4120793	316,0063293	315,9294548	308,4336815	308,7183242	308,431356	304,9433162	304,9464011	304,9373394
315,6412972	316,2340419	316,1545497	308,6267339	308,9135673	308,6244387	305,0672964	305,0741836	305,0609014
315,8707208	316,4621572	316,3799649	308,8201722	309,1091824	308,8179095	305,1925506	305,2031919	305,1857698
316,1003451	316,6906637	316,6056924	309,0140004	309,3051734	309,0117727	305,3190356	305,3333961	305,3118974

316,3302321	316,9197028	316,8318277	309,2081684	309,5014934	309,2059765	305,447284	305,4651614	305,4398633
316,5603819	317,1492745	317,0583709	309,4026764	309,6981425	309,4005209	305,5772957	305,5984875	305,5696676
316,7907945	317,3793788	317,285322	309,5975242	309,8951207	309,5954059	305,7090709	305,7333746	305,7013101
317,0214699	317,6100156	317,5126809	309,7927119	310,0924279	309,7906316	305,8426094	305,8698225	305,834791
317,2523357	317,8408916	317,7402641	309,9883761	310,2901946	309,9863357	305,9769276	306,0071027	305,9690365
317,4833968	318,0720262	317,9680838	310,1845079	310,4884123	310,1825092	306,1120907	306,1452634	306,1041178
317,7146867	318,3035558	318,1962253	310,3810436	310,6870201	310,3790878	306,2485563	306,2846435	306,2405344
317,9462055	318,5354805	318,4246887	310,5779832	310,8860181	310,5760717	306,3863244	306,4252432	306,3782863

Domain probe results of the cooling process.

Time (s)	Temperature (K), Domain Probe 1
7200	303,1505282
7800	302,1482469
8400	301,137417
9000	300,4028418
9600	299,8665118
10200	299,5465252
10800	299,3139815
11400	299,1189951
12000	298,9535003
12600	298,8145829
13200	298,684341
13800	298,5772931
14400	298,4702452
15000	298,3631973
15600	298,2670137
16200	298,176711
16800	298,0864082
17400	297,9961797
18000	297,9088009
18600	297,821422
19200	297,7340432

19800	297,6448906
20400	297,551562
21000	297,4560409
21600	297,3583273
22200	297,2584213
22800	297,1537782
23400	297,0440066
24000	296,9304775
24600	296,813191
25200	296,692147
25800	296,5624368
26400	296,4311425
27000	296,2998482
27600	296,1685539
28200	296,037231
28800	295,8913901
29400	295,7455492
30000	295,5997083
30600	295,4538673
31200	295,2951083
31800	295,0853062
32400	294,8755041
33000	294,665702
33600	294,4558999
34200	294,2354007
34800	293,9918149
35400	293,7379977
36000	293,473949

Point probe results of cooling process (###, 4, ###).

Time (s)	Temperature (K), Point: (4, 4, 504)	Temperature (K), Point: (254, 4, 504)	Temperature (K), Point: (504, 4, 504)	Temperature (K), Point: (4, 4, 254)	Temperature (K), Point: (254, 4, 254)	Temperature (K), Point: (504, 4, 254)	Temperature (K), Point: (4, 4, 4)	Temperature (K), Point: (254, 4, 4)	Temperature (K), Point: (504, 4, 4)
7200	303,1481354	303,1525893	303,1492513	303,1525046	303,1558806	303,1522833	303,1517812	303,1524775	303,1494012
7228,8	303,0967944	303,1400132	303,0942804	303,1416695	303,2008509	303,1379256	303,1368404	303,1436915	303,0965642
7257,6	303,0153487	303,0386849	303,0040735	303,0415681	303,1032149	303,0384172	303,0407723	303,044193	303,0057442
7315,2	302,769424	302,7476318	302,7499674	302,7489088	302,79832	302,7507302	302,7414193	302,7490654	302,7451573
7384,32	302,4598957	302,468282	302,4193685	302,4474367	302,5627	302,4523662	302,3803129	302,4310539	302,3911664
7465,882	302,1344293	302,3004693	302,15783	302,2307732	302,4367713	302,233672	302,0799581	302,1829184	302,0747331
7562,124	301,8664148	302,1541125	301,9324703	302,0122417	302,287367	302,0120474	301,7699333	301,9186051	301,7556291
7675,691	301,6211096	301,976978	301,5282247	301,7636467	302,082103	301,7660574	301,4409263	301,6282571	301,4197628
7774,493	300,6958736	301,6702591	301,1952414	301,5494734	301,8955491	301,5520904	301,1980299	301,4113124	301,1833603
7780,669	300,6754111	301,6582658	301,1775466	301,5359864	301,8829374	301,538647	301,1834143	301,3975578	301,1699253

7793,019	300,9525169	301,640786	298,8368624	301,5094803	301,8592077	301,5121763	301,1548441	301,3708954	301,143832
7793,061	300,9530189	301,640733	298,606584	301,5093903	301,859128	301,5120864	301,1547474	301,370805	301,1437437
7793,103	300,9534546	301,6406798	298,6563482	301,5093003	301,8590481	301,5119965	301,1546507	301,3707147	301,1436554
7793,105	300,9534884	301,640682	298,6563767	301,5092921	301,8590453	301,511991	301,1546446	301,3707088	301,1436502
7793,108	300,9535166	301,6406786	298,6562552	301,5092861	301,8590399	301,5119853	301,1546386	301,3707031	301,1436447
7793,111	300,953547	301,6406746	298,6561433	301,5092803	301,8590347	301,5119798	301,1546326	301,3706975	301,1436392
7793,113	300,9535781	301,6406709	298,6560321	301,5092747	301,8590295	301,5119742	301,1546266	301,3706918	301,1436336
7793,116	300,9536092	301,6406672	298,6559211	301,509269	301,8590243	301,5119686	301,1546205	301,3706861	301,1436281
7793,119	300,9536403	301,6406637	298,6558103	301,5092634	301,859019	301,5119631	301,1546145	301,3706804	301,1436226
7793,121	300,9536713	301,6406604	298,6556995	301,5092577	301,8590138	301,5119575	301,1546084	301,3706747	301,143617
7793,124	300,9537022	301,640657	298,6555888	301,509252	301,8590085	301,511952	301,1546024	301,370669	301,1436115
7793,126	300,9537329	301,6406538	298,6554782	301,5092464	301,8590033	301,5119465	301,1545964	301,3706634	301,143606
7793,132	300,9537934	301,6406472	298,6552571	301,509235	301,858993	301,5119354	301,1545843	301,3706522	301,1435949
7793,142	300,9539116	301,6406341	298,654816	301,5092123	301,8589725	301,5119131	301,1545601	301,37063	301,1435727
7793,163	300,954138	301,6406076	298,6539385	301,509167	301,8589324	301,5118684	301,1545118	301,3705855	301,1435284
7793,205	300,9545663	301,6405551	298,6522032	301,5090769	301,8588532	301,5117788	301,1544151	301,3704961	301,1434402
7793,289	300,9553856	301,640451	298,648813	301,5088975	301,8586954	301,511599	301,1542217	301,3703157	301,1432641
7793,457	300,9569833	301,6402424	298,6424846	301,5085379	301,8583775	301,5112399	301,1538351	301,3699548	301,1429114
7793,603	300,9583307	301,6400607	298,6373134	301,5082247	301,8581005	301,5109277	301,1534988	301,3696408	301,1426043
7793,64	300,9586536	301,6400153	298,6360619	301,5081464	301,8580314	301,5108496	301,1534148	301,3695624	301,1425276
7793,713	300,9592482	301,6399245	298,6336742	301,5079898	301,8578931	301,5106936	301,1532466	301,3694055	301,1423741
7793,859	300,9603449	301,6397417	298,6293106	301,507677	301,8576172	301,5103815	301,1529104	301,3690918	301,1420672
7793,867	300,9604018	301,6397316	298,6290784	301,50766	301,8576022	301,5103646	301,1528921	301,3690747	301,1420505

7793,875	300,9604579	301,6397218	298,6288489	301,5076429	301,8575872	301,5103476	301,1528738	301,3690576	301,1420338
7793,882	300,9605138	301,639712	298,6286214	301,5076259	301,8575722	301,5103307	301,1528556	301,3690406	301,1420171
7793,89	300,96057	301,6397022	298,6283952	301,5076089	301,8575571	301,5103137	301,1528373	301,3690235	301,1420005
7793,898	300,9606264	301,6396925	298,6281703	301,5075919	301,8575421	301,5102967	301,152819	301,3690065	301,1419838
7793,906	300,9606832	301,6396827	298,6279465	301,5075749	301,8575271	301,5102798	301,1528007	301,3689894	301,1419671
7793,914	300,9607401	301,6396729	298,627724	301,5075579	301,857512	301,5102628	301,1527824	301,3689723	301,1419504
7793,922	300,9607971	301,6396631	298,6275027	301,5075409	301,857497	301,5102459	301,1527642	301,3689553	301,1419337
7793,93	300,960854	301,6396533	298,6272828	301,5075238	301,857482	301,5102289	301,1527459	301,3689382	301,141917
7793,938	300,9609109	301,6396435	298,6270642	301,5075068	301,857467	301,510212	301,1527276	301,3689212	301,1419003
7793,946	300,9609675	301,6396337	298,6268468	301,5074898	301,8574519	301,510195	301,1527093	301,3689041	301,1418836
7793,962	300,96108	301,639614	298,6264168	301,5074558	301,8574219	301,5101611	301,1526728	301,36887	301,1418503
7793,994	300,9613022	301,6395746	298,6255753	301,5073878	301,8573617	301,5100933	301,1525996	301,3688018	301,1417835
7794,057	300,9617353	301,6394958	298,6239666	301,5072517	301,8572416	301,5099576	301,1524534	301,3686654	301,14165
7794,184	300,9625588	301,639338	298,6210583	301,5069797	301,8570014	301,5096862	301,152161	301,3683926	301,141383
7794,438	300,9640474	301,6390227	298,6164254	301,506436	301,8565215	301,5091433	301,1515763	301,3678474	301,140849
7794,947	300,9664715	301,6383925	298,6112198	301,5053495	301,8555637	301,508058	301,1504074	301,3667581	301,1397812
7795,963	300,9696077	301,637131	298,6132292	301,5031792	301,853654	301,5058895	301,1480712	301,3645841	301,1376457
7797,997	300,9717312	301,6345853	298,6455168	301,4988491	301,8498546	301,5015613	301,1434054	301,3602532	301,1333728
7802,063	300,9696756	301,6293247	298,7594019	301,490228	301,842313	301,4929368	301,1340971	301,3516484	301,1248098
7806,943	300,9649981	301,6226955	298,9410207	301,4799378	301,8333261	301,482631	301,1229593	301,3413971	301,1144984
7812,701	300,9614999	301,6143999	299,1564951	301,467864	301,8227744	301,4705218	301,1098561	301,3293879	301,1022734
7813,014	300,961289	301,6139423	299,1669781	301,4672085	301,8222018	301,4698641	301,1091442	301,3287362	301,101608
7813,327	300,9611067	301,6134816	299,1772764	301,4665533	301,8216295	301,4692066	301,1084326	301,328085	301,1009422

7813,346	300,9610952	301,6134528	299,1779178	301,4665124	301,8215938	301,4691655	301,1083881	301,3280444	301,1009006
7813,366	300,9610836	301,6134239	299,1785591	301,4664715	301,821558	301,4691245	301,1083436	301,3280037	301,100859
7813,385	300,9610721	301,6133951	299,1792008	301,4664305	301,8215223	301,4690834	301,1082991	301,327963	301,1008174
7813,405	300,9610607	301,6133662	299,179843	301,4663896	301,8214865	301,4690423	301,1082547	301,3279223	301,1007758
7813,425	300,9610494	301,6133373	299,1804858	301,4663487	301,8214508	301,4690012	301,1082102	301,3278816	301,1007342
7813,444	300,9610383	301,6133085	299,1811291	301,4663077	301,821415	301,4689601	301,1081657	301,3278409	301,1006925
7813,464	300,9610273	301,6132796	299,1817729	301,4662668	301,8213793	301,468919	301,1081212	301,3278002	301,1006509
7813,483	300,9610165	301,6132507	299,1824173	301,4662259	301,8213435	301,4688779	301,1080768	301,3277596	301,1006093
7813,503	300,9610058	301,6132217	299,1830622	301,4661849	301,8213078	301,4688369	301,1080323	301,3277189	301,1005677
7813,542	300,9609849	301,6131639	299,1843539	301,4661031	301,8212363	301,4687547	301,1079433	301,3276375	301,1004844
7813,62	300,9609447	301,6130481	299,1869449	301,4659394	301,8210933	301,4685904	301,1077655	301,3274748	301,1003179
7813,777	300,9608709	301,6128162	299,1921561	301,465612	301,8208073	301,4682618	301,1074097	301,3271494	301,0999849
7814,09	300,9607483	301,6123509	299,2026889	301,4649574	301,8202355	301,4676047	301,1066983	301,3264989	301,0993187
7814,716	300,9605936	301,611415	299,2241494	301,463649	301,8190922	301,4662912	301,105276	301,3251986	301,0979854
7815,968	300,9605882	301,6095219	299,2682667	301,4610348	301,8168069	301,4636661	301,1024327	301,322601	301,0953163
7818,473	300,9614309	301,6056551	299,3583623	301,4558164	301,8122404	301,4584237	301,0967518	301,3174176	301,0899673
7823,483	300,9647873	301,5976328	299,5335556	301,4454153	301,8031189	301,4479693	301,0854116	301,3070935	301,0792316
7829,494	300,9694584	301,5875398	299,7224557	301,4329915	301,7921886	301,4354769	301,071841	301,2947775	301,0662908
7829,87	300,9697658	301,5869056	299,7341191	301,4322154	301,7915055	301,4346965	301,0709931	301,2940083	301,0654816
7830,32	300,970133	301,5861424	299,7479551	301,4312844	301,7906859	301,4337603	301,0699758	301,2930856	301,0645102
7830,433	300,9702244	301,5859514	299,7514052	301,4310517	301,790481	301,4335263	301,0697215	301,2928549	301,0642674
7830,659	300,9704062	301,585569	299,7582673	301,4305863	301,7900713	301,4330583	301,0692129	301,2923937	301,0637816
7830,884	300,9705872	301,5851862	299,7650968	301,4301209	301,7896615	301,4325903	301,0687044	301,2919325	301,0632958

7831,335	300,9709445	301,5844181	299,7785884	301,4291905	301,788842	301,4316547	301,0676875	301,2910106	301,0623239
7832,237	300,9716418	301,5828752	299,8050403	301,4273304	301,7872032	301,4297842	301,0656543	301,2891678	301,0603792
7834,04	300,9729397	301,5797609	299,8555136	301,4236137	301,7839262	301,4260467	301,0615906	301,2854871	301,0564867
7836,204	300,9742802	301,5759738	299,9113847	301,4191598	301,7799949	301,4215682	301,0567189	301,2810789	301,0518103
7838,758	300,9754957	301,5714492	299,9716635	301,4139113	301,7753575	301,4162911	301,0509763	301,2758879	301,0462863
7840,979	300,9761888	301,567473	300,0198822	301,4093504	301,7713245	301,4117058	301,0459846	301,2713798	301,0414767
7843,201	300,9764121	301,5634582	300,063777	301,4047947	301,7672933	301,4071265	301,0409977	301,26688	301,0366636
7845,423	300,9761429	301,5594107	300,1037441	301,4002436	301,7632639	301,4025527	301,036015	301,2623878	301,0318479
7847,644	300,9753319	301,555331	300,139646	301,3956973	301,7592364	301,3979846	301,0310369	301,2579036	301,0270299
7849,866	300,9739693	301,5512212	300,1715669	301,3911557	301,755211	301,3934223	301,0260635	301,2534274	301,02221
7852,087	300,9721607	301,5470879	300,2003281	301,386618	301,7511876	301,3888648	301,0210938	301,2489577	301,0173888
7854,309	300,9698582	301,5429285	300,2255611	301,3820847	301,7471663	301,384313	301,0161288	301,2444959	301,0125664
7856,531	300,9671353	301,5387468	300,2477499	301,3775555	301,7431469	301,379766	301,0111677	301,2400409	301,0077431
7858,752	300,964007	301,5345426	300,2669292	301,3730304	301,7391298	301,3752242	301,006211	301,2355932	301,0029193
7860,974	300,9604956	301,5303157	300,2831498	301,3685097	301,7351151	301,3706875	301,0012591	301,2311534	300,9980952
7863,196	300,956639	301,5260672	300,2965674	301,3639931	301,7311027	301,3661557	300,996312	301,2267216	300,9932713
7865,417	300,9524783	301,5217983	300,3073629	301,3594804	301,7270926	301,3616286	300,9913698	301,2222977	300,9884477
7869,861	300,9434288	301,5132066	300,3220891	301,3504669	301,7190791	301,352589	300,9815006	301,2134739	300,9788036
7874,304	300,9332488	301,5045253	300,3256253	301,3414758	301,7110776	301,3435773	300,9716613	301,2046955	300,9691683
7878,747	300,9224753	301,4957914	300,3230785	301,3325008	301,7030839	301,3345857	300,9618443	301,195949	300,9595423
7883,19	300,9112300	301,4870146	300,3157483	301,3235416	301,6950971	301,3256133	300,9520492	301,1872322	300,9499269
7887,634	300,899571	301,4781988	300,304285	301,3145987	301,6871166	301,3166607	300,9422768	301,1785451	300,9403236
7892,077	300,8875524	301,469348	300,289296	301,3056726	301,6791419	301,307728	300,9325276	301,1698873	300,9307337

7900,964	300,8623365	301,451526	300,2488185	301,2878963	301,6632265	301,2899468	300,9131266	301,1526866	300,9116171
7909,85	300,8360913	301,4336059	300,2012157	301,2702003	301,6473532	301,272251	300,8938247	301,1355975	300,89257
7918,737	300,8089257	301,4156085	300,1496595	301,2525878	301,6315309	301,2546407	300,8746238	301,1186174	300,8735978
7927,623	300,7809552	301,3975549	300,0958608	301,2350601	301,6157627	301,2371162	300,8555249	301,1017443	300,8547047
7936,51	300,7522586	301,3794676	300,0406889	301,217618	301,6000496	301,219678	300,8365291	301,0849769	300,835894
7945,397	300,7229193	301,3613663	299,9858691	301,2002618	301,5843917	301,2023265	300,8176371	301,0683136	300,8171684
7954,283	300,6930072	301,3432639	299,9319546	301,1829922	301,5687889	301,1850623	300,7988492	301,0517531	300,79853
7963,17	300,6625769	301,3251735	299,8787574	301,1658098	301,5532419	301,1678857	300,7801655	301,0352938	300,7799805
7972,056	300,6316755	301,3071048	299,8264546	301,1487149	301,5377516	301,150797	300,7615862	301,0189343	300,7615212
7980,943	300,600346	301,2890669	299,7752853	301,1317078	301,5223188	301,1337966	300,743111	301,0026732	300,7431532
7989,829	300,5686293	301,2710681	299,7252422	301,1147887	301,5069439	301,1168848	300,7247397	300,9865091	300,7248772
7998,716	300,5365676	301,253116	299,6763163	301,0979579	301,4916272	301,1000618	300,706472	300,9704404	300,7066939
8007,603	300,5042209	301,2352153	299,628436	301,0812117	301,4763671	301,0833239	300,6883029	300,9544618	300,6885996
8016,489	300,4716248	301,2173737	299,5816251	301,0645538	301,4611677	301,0666745	300,6702364	300,9385758	300,6705985
8025,376	300,4388303	301,1995969	299,5358648	301,0479842	301,4460312	301,0501139	300,6522719	300,9227812	300,652691
8034,262	300,4058923	301,1818896	299,4911245	301,0315029	301,4309595	301,0336416	300,634409	300,9070767	300,6348769
8043,149	300,3728677	301,1642561	299,4474041	301,0151097	301,4159545	301,0172575	300,616647	300,891461	300,6171565
8052,035	300,3398127	301,1467	299,4047268	300,9988041	301,4010178	301,0009611	300,5989852	300,8759329	300,5995295
8069,809	300,2738362	301,1119275	299,323502	300,9665501	301,371433	300,968725	300,5640672	300,8452263	300,5646574
8087,582	300,2083306	301,0775011	299,2460325	300,9346398	301,3421342	300,936832	300,5295382	300,8148512	300,5301548
8105,355	300,1434873	301,0434301	299,1721311	300,9030688	301,3131229	300,9052774	300,4953922	300,7847989	300,4960183
8123,128	300,0793055	301,00972	299,1017103	300,8718318	301,2843987	300,8740557	300,4616224	300,7550613	300,4622439
8140,901	300,0155881	300,9763733	299,0344657	300,8409233	301,2559595	300,8431616	300,4282223	300,7256305	300,4288271

8158,674	299,9519746	300,9433773	298,9701183	300,8103259	301,227792	300,8125775	300,3951721	300,6964881	300,3957503
8176,447	299,8880753	300,9107438	298,9087421	300,7800458	301,1999028	300,7823096	300,3624784	300,6676383	300,3630213
8194,221	299,824258	300,8784709	298,8501065	300,7500776	301,1722882	300,7523526	300,3301353	300,6390746	300,3306355
8229,767	299,7041326	300,8153649	298,7425818	300,691367	301,1181429	300,6936607	300,2668259	300,5830638	300,2672193
8300,859	299,4050981	300,6945034	298,5573893	300,5784458	301,0138445	300,5807665	300,1452591	300,4751168	300,1453967
8443,045	299,0445415	300,4713295	298,2591972	300,3682469	300,8191246	300,3706033	299,9196931	300,2733912	299,9192925
8613,667	298,8323584	300,2257544	297,9678228	300,1350395	300,602272	300,137435	299,6785467	300,0486702	299,6774692
8815,001	298,5208455	299,960326	297,6740788	299,8809773	300,3650994	299,8833418	299,4446981	299,8079714	299,4411227
9052,575	298,4612954	299,6974597	297,3882045	299,6374585	300,1084546	299,6398145	299,2220823	299,5794616	299,215975
9332,913	298,396322	299,4556276	297,1220222	299,4099903	299,8453094	299,4124819	299,0037726	299,3636446	298,9966217
9613,251	298,2468653	299,2591957	296,9139016	299,2229451	299,6401311	299,2256116	298,8200817	299,1850424	298,8125014
9893,588	298,0277755	299,0944603	296,7503977	299,064673	299,4744826	299,0674362	298,6623724	299,0327336	298,6546559
10224,39	297,4771387	298,9329348	296,6067752	298,9081274	299,3182311	298,9109449	298,504981	298,8809105	298,4970432
10555,19	296,7020703	298,794071	296,4948687	298,7730027	299,1857225	298,775829	298,3674808	298,7495046	298,359385
10945,53	295,8100845	298,6530605	296,3922085	298,6350689	299,0512327	298,6379246	298,2257335	298,6146332	298,2175104
11406,13	294,6015952	298,5089987	296,2969049	298,4935622	298,9135269	298,4964652	298,0792959	298,4757402	298,0710883
11949,64	293,6004115	298,3612363	296,2057515	298,3479508	298,7726094	298,3509265	297,9279318	298,3323758	297,9198473
13036,67	292,2044071	298,1207161	296,0573764	298,1100753	298,5440849	298,1131974	297,6747268	298,097385	297,6666015
15210,72	290,6350339	297,7536505	295,7851229	297,744869	298,2021809	297,7484852	297,2426862	297,7345645	297,2369733
17384,77	289,7734163	297,4161971	295,4998623	297,4076625	297,9235062	297,4119913	296,8167743	297,3981958	296,8124218
19558,82	289,2423022	297,0650087	295,1861994	297,0557291	297,6587802	297,0615771	296,3719346	297,0470152	296,3678572
22438,82	288,7458003	296,5564273	294,7218109	296,5459067	297,2821723	296,5547742	295,7880728	296,5395062	295,7841397
25318,82	288,4527842	296,0184057	294,1713599	296,0067832	296,8278774	296,0193837	295,1773616	296,003738	295,1741039

28198,82	288,3452249	295,4184763	293,4271929	295,4041468	296,2928332	295,423238	294,4296695	295,4065726	294,4268576
31078,82	288,2958598	294,6277622	292,606341	294,6038847	295,7185294	294,6425221	293,4415606	294,6224352	293,4390159
33958,82	288,3095109	293,433269	291,7623837	293,3986486	294,8920153	293,4716523	292,401581	293,4513971	292,3995982
36838,82	288,3497174	292,2683695	290,9444338	292,2244174	293,6941761	292,3322367	291,3854932	292,3126865	291,384166

Point probe results of cooling process (###, 11.5, ###).

Temperature (K), Point: (4, 11.5, 504)	Temperature (K), Point: (254, 11.5, 504)	Temperature (K), Point: (504, 11.5, 504)	Temperature (K), Point: (4, 11.5, 254)	Temperature (K), Point: (254, 11.5, 254)	Temperature (K), Point: (504, 11.5, 254)	Temperature (K), Point: (4, 11.5, 4)	Temperature (K), Point: (254, 11.5, 4)	Temperature (K), Point: (504, 11.5, 4)
303,1511	303,149649	303,1507258	303,1496116	303,1505272	303,1495953	303,1498224	303,1496509	303,1501245
303,1640819	303,1502018	303,1636467	303,1502172	303,1553774	303,150472	303,1554473	303,1505801	303,159144
303,1658855	303,1552387	303,1683568	303,1556609	303,1535029	303,1566165	303,1703301	303,15587	303,1706229
303,15644	303,1484763	303,1637318	303,1449513	303,1456611	303,1474868	303,1879094	303,1419605	303,1774638
303,1183161	303,0854589	303,1151651	303,0583314	303,1185609	303,0621065	303,1203196	303,038645	303,105981
302,9589647	302,9616665	302,9686599	302,8905723	303,0141236	302,8938568	302,9071181	302,8334174	302,8952709
302,7351605	302,8044551	302,7632085	302,6702438	302,8441375	302,6708333	302,5981506	302,5562715	302,5874275
302,4502495	302,6133882	302,3956703	302,4092086	302,6230898	302,4110944	302,2455085	302,2430981	302,2351783
301,8526932	302,3907206	302,1510164	302,1826412	302,4279963	302,1841707	301,9851665	302,0069603	301,9896655

301,812802	302,3766649	302,1243213	302,1687286	302,4156614	302,1702772	301,9693594	301,9937038	301,9744153
302,1749926	302,3487217	303,3138875	302,1408289	302,3912992	302,1422398	301,9378573	301,9678792	301,9436927
302,1735592	302,348626	304,3982078	302,1407343	302,3912153	302,1421444	301,9377499	301,9677918	301,9435876
302,1760068	302,3485308	304,6639774	302,1406395	302,3911323	302,142049	301,9376424	301,9677044	301,9434824
302,1759285	302,3485238	304,6638155	302,1406303	302,391156	302,142043	301,9376358	301,9676948	301,9434746
302,175872	302,3485169	304,6628364	302,1406238	302,3911579	302,1420368	301,937629	301,9676899	301,9434681
302,1758148	302,3485102	304,6618657	302,1406177	302,3911547	302,1420309	301,9376223	301,9676851	301,9434616
302,1757555	302,3485036	304,660896	302,1406117	302,3911504	302,1420249	301,9376156	301,9676801	301,9434552
302,1756947	302,3484972	304,6599266	302,1406056	302,391146	302,1420189	301,9376089	301,967675	301,9434487
302,1756329	302,3484909	304,6589575	302,1405996	302,3911415	302,1420128	301,9376021	301,9676697	301,9434422
302,17557	302,3484847	304,6579885	302,1405936	302,391137	302,1420068	301,9375954	301,9676644	301,9434357
302,1755062	302,3484785	304,6570197	302,1405876	302,3911324	302,1420007	301,9375887	301,967659	301,9434292
302,1754417	302,3484725	304,6560511	302,1405817	302,3911279	302,1419947	301,937582	301,9676536	301,9434226
302,1753104	302,3484606	304,6541146	302,1405698	302,3911187	302,1419826	301,9375686	301,9676427	301,9434095
302,1750406	302,3484372	304,6502443	302,1405463	302,3911002	302,1419586	301,9375417	301,9676207	301,9433833
302,1744812	302,3483905	304,6425156	302,1404994	302,3910625	302,1419107	301,9374879	301,9675765	301,9433307
302,173325	302,3482958	304,6271092	302,1404052	302,3909852	302,1418153	301,9373804	301,9674887	301,9432255
302,1711245	302,3481031	304,5965137	302,1402155	302,3908272	302,141625	301,9371655	301,9673142	301,9430152
302,1675802	302,3477205	304,5364202	302,1398357	302,3905058	302,1412434	301,9367357	301,9669653	301,9425949
302,1653331	302,3473888	304,4847549	302,139505	302,3902242	302,1409113	301,9363618	301,9666617	301,9422293
302,1643974	302,3473059	304,4719235	302,1394224	302,3901531	302,1408283	301,9362683	301,9665857	301,9421379
302,1624118	302,3471398	304,4464551	302,1392573	302,3900103	302,1406622	301,9360814	301,9664339	301,9419551
302,1585846	302,346809	304,3962632	302,1389273	302,389719	302,1403301	301,9357076	301,9661302	301,9415895

302,1583603	302,3467911	304,393544	302,1389093	302,3897029	302,140312	301,9356873	301,9661137	301,9415697
302,1581381	302,3467731	304,3908295	302,1388914	302,3896871	302,1402939	301,935667	301,9660971	301,9415498
302,1579251	302,346755	304,3881185	302,1388734	302,3896715	302,1402759	301,9356467	301,9660806	301,9415299
302,1577182	302,346737	304,3854102	302,1388554	302,389656	302,1402578	301,9356264	301,9660641	301,94151
302,1575157	302,3467188	304,3827044	302,1388375	302,3896405	302,1402398	301,935606	301,9660476	301,9414902
302,1573157	302,3467007	304,3800012	302,1388195	302,389625	302,1402217	301,9355857	301,9660311	301,9414703
302,1571173	302,3466826	304,3773005	302,1388015	302,3896095	302,1402037	301,9355654	301,9660146	301,9414504
302,1569199	302,3466645	304,3746025	302,1387835	302,389594	302,1401856	301,9355451	301,9659981	301,9414305
302,1567231	302,3466464	304,3719072	302,1387656	302,3895785	302,1401676	301,9355247	301,9659816	301,9414107
302,1565268	302,3466283	304,3692144	302,1387476	302,389563	302,1401495	301,9355044	301,9659651	301,9413908
302,1563308	302,3466102	304,3665243	302,1387296	302,3895475	302,1401314	301,9354841	301,9659486	301,9413709
302,1559398	302,346574	304,3611535	302,1386937	302,3895165	302,1400953	301,9354434	301,9659156	301,9413312
302,1551621	302,3465015	304,3504495	302,1386218	302,3894545	302,1400231	301,9353622	301,9658495	301,9412517
302,1536249	302,3463563	304,3291944	302,138478	302,3893305	302,1398785	301,9351996	301,9657175	301,9410927
302,1506247	302,3460657	304,2873152	302,1381905	302,3890825	302,1395894	301,9348745	301,9654534	301,9407747
302,1449134	302,3454844	304,2059945	302,1376152	302,3885863	302,1390111	301,9342245	301,9649254	301,9401389
302,1345318	302,3443225	304,052247	302,1364644	302,387593	302,1378541	301,9329254	301,9638699	301,938868
302,1170938	302,3420008	303,7759927	302,1341624	302,3856046	302,1355387	301,9303303	301,961761	301,9363294
302,0910892	302,3373634	303,3261296	302,1295576	302,3816233	302,1309039	301,9251539	301,9575498	301,9312639
302,0569354	302,3280946	302,7418098	302,1203475	302,3736568	302,121625	301,9148549	301,9491478	301,9211722
302,0298847	302,3169586	302,344791	302,1092979	302,36408	302,1104862	301,9025721	301,9390906	301,9091109
302,0051854	302,3038308	301,9527758	302,0962658	302,3529244	302,097351	301,888173	301,9272533	301,8949306
302,0040831	302,303117	301,957224	302,0955574	302,3523161	302,0966367	301,8873915	301,9266101	301,8941603

302,00 29896	302,30 24039	301,96 64528	302,09 4849	302,35 17062	302,09 59224	301,88 66104	301,92 59669	301,89 33904
302,00 29228	302,30 23593	301,96 70923	302,09 48047	302,35 1668	302,09 58778	301,88 65616	301,92 59268	301,89 33423
302,00 28567	302,30 23147	301,96 77406	302,09 47605	302,35 16299	302,09 58332	301,88 65128	301,92 58866	301,89 32941
302,00 27907	302,30 22702	301,96 8387	302,09 47162	302,35 15917	302,09 57885	301,88 6464	301,92 58464	301,89 3246
302,00 27247	302,30 22256	301,96 90294	302,09 46719	302,35 15535	302,09 57439	301,88 64152	301,92 58062	301,89 31979
302,00 26585	302,30 21811	301,96 96673	302,09 46277	302,35 15153	302,09 56992	301,88 63664	301,92 5766	301,89 31498
302,00 25922	302,30 21365	301,97 03008	302,09 45834	302,35 1477	302,09 56546	301,88 63176	301,92 57258	301,89 31017
302,00 25257	302,30 20919	301,97 09298	302,09 45391	302,35 14388	302,09 561	301,88 62688	301,92 56856	301,89 30536
302,00 24592	302,30 20474	301,97 15542	302,09 44949	302,35 14005	302,09 55653	301,88 622	301,92 56454	301,89 30055
302,00 23926	302,30 20028	301,97 21741	302,09 44506	302,35 13622	302,09 55207	301,88 61712	301,92 56052	301,89 29573
302,00 22592	302,30 19138	301,97 33977	302,09 43621	302,35 12856	302,09 54314	301,88 60736	301,92 55248	301,89 28611
302,00 19914	302,30 17356	301,97 57816	302,09 4185	302,35 11323	302,09 52528	301,88 58784	301,92 53641	301,89 26687
302,00 14527	302,30 13792	301,98 03029	302,09 38309	302,35 08254	302,09 48957	301,88 54882	301,92 50426	301,89 22838
302,00 03638	302,30 06664	301,98 83876	302,09 31227	302,35 02113	302,09 41815	301,88 47078	301,92 43996	301,89 15142
301,99 81451	302,29 924	302,00 1068	302,09 17064	302,34 89825	302,09 27534	301,88 31481	301,92 31141	301,88 99753
301,99 35792	302,29 63837	302,01 52365	302,08 88741	302,34 65248	302,08 98978	301,88 00322	301,92 05441	301,88 68992
301,98 41153	302,29 06562	302,01 20628	302,08 32113	302,34 16091	302,08 41908	301,87 38137	301,91 54088	301,88 07529
301,96 47202	302,27 9136	301,94 09138	302,07 18982	302,33 17759	302,07 28015	301,86 14245	301,90 51586	301,86 84833
301,94 13821	302,26 51888	301,79 17047	302,05 83482	302,31 99578	302,05 91866	301,84 66379	301,89 28977	301,85 38029
301,93 99266	302,26 43161	301,78 18912	302,05 75015	302,31 92197	302,05 8336	301,84 57143	301,89 21316	301,85 28857
301,93 81824	302,26 32682	301,77 00265	302,05 64857	302,31 83344	302,05 73157	301,84 46064	301,89 12126	301,85 17853
301,93 77461	302,26 30062	301,76 70564	302,05 62317	302,31 81131	302,05 70606	301,84 43295	301,89 09828	301,85 15102
301,93 68741	302,26 2482	301,76 11011	302,05 57238	302,31 76705	302,05 65505	301,84 37757	301,89 05234	301,85 096

301,9360027	302,2619577	301,7551334	302,0552159	302,317228	302,0560405	301,8432219	301,890064	301,8504099
301,9342631	302,2609086	301,7431421	302,0542003	302,3163428	302,0550207	301,8421149	301,8891455	301,8493099
301,9307962	302,2588084	301,7190439	302,0521694	302,3145723	302,052982	301,839902	301,887309	301,8471107
301,9239217	302,2546002	301,6708286	302,0481094	302,3110303	302,0489086	301,8354814	301,8836392	301,8427155
301,9157899	302,2495358	301,6136916	302,0432403	302,3067787	302,0440279	301,8301864	301,8792411	301,8374474
301,9063384	302,2435428	301,5473582	302,0374987	302,30176	302,0382778	301,8239497	301,8740588	301,8312388
301,8982146	302,2383163	301,4907671	302,0325064	302,2973925	302,0332823	301,8185325	301,8695559	301,8258436
301,8901807	302,2330773	301,4359659	302,0275173	302,2930241	302,0282942	301,8131244	301,865059	301,820455
301,8822183	302,2278273	301,382801	302,0225311	302,2886547	302,0233129	301,8077245	301,8605678	301,8150727
301,8743218	302,2225662	301,3313279	302,0175485	302,284284	302,0183388	301,8023332	301,8560824	301,809697
301,8664803	302,2172944	301,2812367	302,0125698	302,279912	302,013372	301,7969506	301,8516031	301,8043282
301,8586754	302,2120135	301,232197	302,0075948	302,275539	302,0084115	301,7915752	301,8471288	301,7989652
301,8509066	302,206722	301,1843479	302,0026242	302,2711654	302,0034583	301,7862082	301,8426603	301,7936092
301,8431671	302,2014211	301,1375033	301,9976576	302,2667913	301,9985115	301,7808487	301,838197	301,7882593
301,8354483	302,19611	301,0916498	301,9926961	302,2624173	301,993572	301,7754972	301,8337393	301,7829164
301,8277424	302,1907882	301,0468226	301,9877417	302,2580438	301,9886409	301,7701542	301,8292874	301,7775809
301,8200401	302,1854561	301,0030932	301,9827965	302,2536712	301,9837207	301,7648201	301,8248416	301,7722531
301,8123317	302,1801141	300,9607006	301,9778614	302,2492993	301,9788118	301,7594947	301,8204017	301,7669332
301,7968603	302,1694042	300,88025	301,9680207	302,2405578	301,9690263	301,7488707	301,81154	301,7563181
301,7812402	302,1586552	300,8071208	301,9582363	302,2318211	301,9592994	301,7382981	301,8027125	301,7457512
301,7655068	302,1478877	300,7380526	301,9484923	302,2230887	301,9496135	301,7277628	301,7939095	301,73522
301,7496788	302,1371083	300,6721967	301,938786	302,2143608	301,939965	301,7172631	301,7851295	301,724723
301,7337769	302,1263217	300,609404	301,9291174	302,2056376	301,9303539	301,7067995	301,7763729	301,7142613

301,7178282	302,1155328	300,5494721	301,9194868	302,1969198	301,9207798	301,6963721	301,7676394	301,7038348
301,6859557	302,0939751	300,4396165	301,9003834	302,179526	301,9017819	301,6756633	301,7502657	301,6831265
301,6542521	302,0724826	300,3379346	301,881436	302,1622087	301,8829314	301,6550982	301,7329839	301,6625615
301,6227918	302,0510954	300,243345	301,8626414	302,1449778	301,8642256	301,6346751	301,7157932	301,6421389
301,5916014	302,0298329	300,1564651	301,8439957	302,1278237	301,8456613	301,614392	301,6986932	301,6218575
301,5606759	302,0087122	300,0760982	301,8254943	302,1107292	301,8272354	301,5942473	301,6816835	301,6017158
301,529991	301,9877622	300,0019131	301,8071331	302,0936849	301,8089445	301,5742388	301,6647635	301,5817119
301,4995129	301,9670272	299,934036	301,7889079	302,0767065	301,7907851	301,5543645	301,6479327	301,561844
301,4691988	301,9465045	299,8710479	301,7708148	302,0597981	301,7727541	301,5346225	301,6311905	301,5421099
301,4389988	301,926186	299,8122402	301,7528503	302,043001	301,7548484	301,5150104	301,6145362	301,5225074
301,4088579	301,9060686	299,757093	301,7350111	302,0263354	301,7370652	301,4955264	301,5979692	301,5030344
301,3787179	301,8861472	299,7051312	301,7172942	302,0098402	301,7194017	301,4761684	301,5814887	301,4836887
301,3485224	301,8664157	299,65597	301,6996967	301,9935077	301,7018553	301,4569342	301,565094	301,464468
301,3182233	301,8468598	299,6091918	301,6822111	301,9773232	301,6844184	301,4378168	301,5487806	301,445365
301,2877716	301,8274816	299,564646	301,6648397	301,9612846	301,6670935	301,4188192	301,5325513	301,4263827
301,2571243	301,8082755	299,5221711	301,6475804	301,9453837	301,6498784	301,3999399	301,5164055	301,4075194
301,2262457	301,789236	299,481584	301,6304309	301,9296128	301,6327709	301,3811771	301,5003425	301,3887729
301,1951085	301,7703576	299,4427134	301,613389	301,913965	301,6157688	301,3625288	301,4843614	301,3701414
301,1636938	301,7516354	299,4054085	301,5964526	301,8984344	301,5988703	301,3439936	301,4684615	301,3516231
301,0996746	301,7147963	299,3363364	301,5629976	301,8678157	301,5654833	301,3073734	301,4369891	301,3150369
301,034565	301,6785145	299,27188	301,5299355	301,8375968	301,5324824	301,2711799	301,4058296	301,2788764
300,9685162	301,6427623	299,2114173	301,4972535	301,8077535	301,4998556	301,2354017	301,374977	301,2431299
300,901729	301,6075142	299,1546461	301,4649395	301,7782652	301,4675912	301,2000282	301,3444256	301,2077859

300,8344184	301,5727478	299,1011655	301,4329824	301,7491145	301,4356789	301,165049	301,3141693	301,1728342
300,7667929	301,5384257	299,0504561	301,4013593	301,7202748	301,4040962	301,1304406	301,2841919	301,1382508
300,6989712	301,5045474	299,0023447	301,3700735	301,6917454	301,3728468	301,0962083	301,2544985	301,1040408
300,6310046	301,4710965	298,9567257	301,3391164	301,6635151	301,3419224	301,0623438	301,2250839	301,0701959
300,4953969	301,4058253	298,8737164	301,2784789	301,6082018	301,2813381	300,9960509	301,1673516	301,0039323
300,2177131	301,2810423	298,7314969	301,1618331	301,5016787	301,1647654	300,8687035	301,0559311	300,8766113
299,7888228	301,0506796	298,5077446	300,9444908	301,3026166	300,9475023	300,6321597	300,8473059	300,6400427
299,3917282	300,7968523	298,2924077	300,7029958	301,0805298	300,706066	300,3716103	300,6144597	300,3792603
298,9107914	300,5219606	298,0782652	300,4395409	300,8371416	300,4426721	300,100801	300,3607297	300,107958
298,6030311	300,2344502	297,8597622	300,1661763	300,5732189	300,1693785	299,8564878	300,1010286	299,863694
298,4742623	299,9627214	297,6421078	299,9155558	300,2919689	299,9184695	299,6330042	299,8696802	299,640917
298,3616914	299,7632789	297,4609234	299,7265035	300,0571501	299,7292237	299,4477914	299,689684	299,4561596
298,1985947	299,5989467	297,3095509	299,5687913	299,8884254	299,5713766	299,2874165	299,5376994	299,2960347
297,804651	299,4379384	297,1664378	299,4126165	299,7366998	299,4151325	299,1251973	299,385819	299,1339473
297,1705901	299,2977438	297,0499623	299,2758488	299,6068241	299,2783521	298,9826526	299,2522184	298,9914299
296,3298019	299,1532225	296,9404093	299,1342668	299,4734015	299,1367897	298,8359934	299,1134595	298,8448024
295,1604524	299,0043527	296,8367628	298,9879869	299,3349834	298,990555	298,6845906	298,9698273	298,6934314
294,0457133	298,852266	296,7363933	298,838207	299,1907776	298,840831	298,5277703	298,8223884	298,5366165
292,5060285	298,6048069	296,5726586	298,5934701	298,9555038	298,5962385	298,2678911	298,5805368	298,2767266
290,8208717	298,2294005	296,2764263	298,2203853	298,6054762	298,2235417	297,8348694	298,2102475	297,843815
289,8999522	297,8931989	295,9704485	297,8841912	298,3204032	297,888274	297,3858009	297,8743157	297,3939925
289,3270684	297,5273109	295,6350158	297,5171483	298,0623035	297,5233279	296,9016376	297,5081695	296,9087931
288,7887683	296,9843773	295,137777	296,972164	297,6776619	296,982346	296,2725436	296,9660057	296,2788905

288,4732119	296,4139801	294,5470006	296,4004858	297,1998485	296,4146578	295,6222649	296,3982665	295,6278077
288,3591226	295,783642	293,7477148	295,7673002	296,631487	295,788334	294,8204889	295,7708988	294,8245925
288,3081022	294,9473989	292,8709029	294,9205836	296,0332063	294,9626695	293,7592683	294,9414057	293,7613818
288,3228795	293,6814821	291,9711533	293,6435298	295,1679191	293,72137	292,6496191	293,7000182	292,650713
288,3610168	292,4559942	291,1009835	292,4086761	293,9034813	292,5223149	291,5680347	292,5017198	291,5684398

Point probe results of cooling process (###, 19, ###).

Temperature (K), Point: (4, 19, 504)	Temperature (K), Point: (254, 19, 504)	Temperature (K), Point: (504, 19, 504)	Temperature (K), Point: (4, 19, 254)	Temperature (K), Point: (254, 19, 254)	Temperature (K), Point: (504, 19, 254)	Temperature (K), Point: (4, 19, 4)	Temperature (K), Point: (254, 19, 4)	Temperature (K), Point: (504, 19, 4)	Temperature (K), Point: (254, 11.5, 254)
303,1495254	303,1525115	303,1487694	303,1524096	303,1557725	303,1523691	303,1497322	303,1524082	303,1510623	303,1505272
303,1076833	303,138456	303,0879458	303,1400357	303,2035565	303,1405656	303,1025677	303,1430603	303,1275672	303,1553774
303,0180642	303,0370365	303,0032206	303,0400117	303,1103327	303,0416447	303,0116713	303,0441261	303,0363297	303,1535029
302,7683395	302,7475551	302,7682279	302,7478636	302,8097564	302,7511926	302,7480735	302,7502594	302,7518298	303,1456611
302,449588	302,4699872	302,4468082	302,4440769	302,5691887	302,4481585	302,3967037	302,4319792	302,3916709	303,1185609
302,1790624	302,3022449	302,1822862	302,2255531	302,4394565	302,2300525	302,0847731	302,1830916	302,0887936	303,0141236
301,9376499	302,1560802	301,9541959	302,0066711	302,2878317	302,011077	301,7679388	301,9179575	301,779027	302,8441375
301,6042792	301,9793792	301,4574362	301,7556081	302,0819235	301,7585786	301,4364899	301,6284562	301,4478064	302,6230898
301,3550106	301,7008917	301,1619805	301,5437086	301,8970232	301,5450524	301,1959831	301,4110071	301,2078197	302,4279963
301,328525	301,687894	301,1632735	301,5304469	301,8845189	301,5316969	301,1820056	301,3972614	301,1935428	302,4156614

301,35 18898	301,66 61386	274,95 48969	301,50 45352	301,86 08754	301,50 56096	301,15 48287	301,37 06235	301,16 64962	302,39 12992
301,35 14424	301,66 60685	275,12 91214	301,50 44473	301,86 07957	301,50 55211	301,15 47368	301,37 05332	301,16 64054	302,39 12153
301,35 13677	301,66 59984	275,73 70126	301,50 43595	301,86 0716	301,50 54326	301,15 46448	301,37 04429	301,16 63148	302,39 11323
301,35 13445	301,66 59951	275,74 1085	301,50 43519	301,86 07202	301,50 54274	301,15 46399	301,37 04377	301,16 63094	302,39 1156
301,35 13318	301,66 59911	275,74 40777	301,50 43469	301,86 07148	301,50 54218	301,15 4634	301,37 0432	301,16 63039	302,39 11579
301,35 13169	301,66 59868	275,74 71025	301,50 43418	301,86 071	301,50 54163	301,15 46282	301,37 04263	301,16 62981	302,39 11547
301,35 13011	301,66 59824	275,75 01296	301,50 43365	301,86 07055	301,50 54108	301,15 46224	301,37 04206	301,16 62923	302,39 11504
301,35 12847	301,66 5978	275,75 31572	301,50 43311	301,86 07008	301,50 54054	301,15 46167	301,37 04148	301,16 62865	302,39 1146
301,35 12682	301,66 59735	275,75 61849	301,50 43257	301,86 06961	301,50 53999	301,15 46109	301,37 04091	301,16 62807	302,39 11415
301,35 12516	301,66 59691	275,75 92125	301,50 43202	301,86 06913	301,50 53944	301,15 46051	301,37 04034	301,16 62749	302,39 1137
301,35 12349	301,66 59647	275,76 224	301,50 43147	301,86 06865	301,50 5389	301,15 45994	301,37 03976	301,16 62692	302,39 11324
301,35 12183	301,66 59603	275,76 52674	301,50 43093	301,86 06816	301,50 53835	301,15 45936	301,37 03919	301,16 62635	302,39 11279
301,35 11854	301,66 59515	275,77 13218	301,50 42982	301,86 06718	301,50 53726	301,15 45821	301,37 03805	301,16 62521	302,39 11187
301,35 11217	301,66 59339	275,78 34295	301,50 42762	301,86 0652	301,50 53507	301,15 45591	301,37 03578	301,16 62294	302,39 11002
301,35 10014	301,66 58987	275,80 76422	301,50 42321	301,86 06122	301,50 53068	301,15 45131	301,37 03127	301,16 61842	302,39 10625
301,35 07789	301,66 58289	275,85 60578	301,50 41444	301,86 05323	301,50 52186	301,15 44212	301,37 02227	301,16 60938	302,39 09852
301,35 03697	301,66 56904	275,95 28367	301,50 39696	301,86 03724	301,50 50418	301,15 42376	301,37 00425	301,16 59125	302,39 08272
301,34 96016	301,66 54127	276,14 59859	301,50 36192	301,86 00541	301,50 46882	301,15 38703	301,36 96816	301,16 55498	302,39 05058
301,34 90153	301,66 5171	276,31 35928	301,50 33139	301,85 9778	301,50 43806	301,15 35507	301,36 93677	301,16 52344	302,39 02242
301,34 88344	301,66 51106	276,35 54298	301,50 32375	301,85 97091	301,50 43037	301,15 34708	301,36 92893	301,16 51556	302,39 01531
301,34 84659	301,66 49897	276,43 89624	301,50 30849	301,85 95713	301,50 415	301,15 3311	301,36 91324	301,16 49979	302,39 00103
301,34 77426	301,66 4748	276,60 5398	301,50 27797	301,85 92957	301,50 38424	301,15 29915	301,36 88188	301,16 46827	302,38 9719
301,34 7702	301,66 47348	276,61 4439	301,50 27631	301,85 92807	301,50 38257	301,15 29741	301,36 88018	301,16 46655	302,38 97029

301,3476615	301,6647217	276,6234783	301,5027465	301,8592657	301,5038089	301,1529568	301,3687847	301,1646484	302,3896871
301,3476218	301,6647086	276,6325162	301,5027299	301,8592508	301,5037922	301,1529394	301,3687677	301,1646312	302,3896715
301,3475827	301,6646956	276,6415521	301,5027133	301,8592358	301,5037755	301,152922	301,3687506	301,1646141	302,389656
301,347544	301,6646825	276,6505855	301,5026967	301,8592208	301,5037588	301,1529046	301,3687336	301,1645969	302,3896405
301,3475055	301,6646695	276,6596165	301,5026801	301,8592059	301,5037421	301,1528873	301,3687166	301,1645798	302,389625
301,3474671	301,6646565	276,6686452	301,5026635	301,8591909	301,5037254	301,1528699	301,3686995	301,1645627	302,3896095
301,3474286	301,6646434	276,6776716	301,5026469	301,8591759	301,5037087	301,1528525	301,3686825	301,1645455	302,389594
301,3473902	301,6646303	276,6866957	301,5026303	301,8591609	301,503692	301,1528352	301,3686654	301,1645284	302,3895785
301,3473518	301,6646172	276,6957177	301,5026137	301,859146	301,5036753	301,1528178	301,3686484	301,1645112	302,389563
301,3473134	301,6646041	276,7047374	301,5025972	301,859131	301,5036586	301,1528004	301,3686314	301,1644941	302,3895475
301,3472366	301,6645779	276,7227686	301,502564	301,859101	301,5036252	301,1527657	301,3685973	301,1644598	302,3895165
301,3470828	301,6645254	276,7587993	301,5024976	301,8590411	301,5035584	301,1526962	301,3685291	301,1643913	302,3894545
301,3467748	301,6644206	276,8307012	301,5023648	301,8589213	301,5034248	301,1525573	301,3683929	301,1642542	302,3893305
301,3461565	301,6642109	276,9737143	301,5020993	301,8586817	301,5031576	301,1522794	301,3681204	301,16398	302,3890825
301,3449101	301,6637921	277,2563488	301,5015686	301,8582029	301,5026234	301,1517239	301,3675758	301,1634318	302,3885863
301,3423658	301,6629556	277,8074587	301,500508	301,8572467	301,501556	301,1506135	301,3664878	301,1623362	302,387593
301,337015	301,6612864	278,8543052	301,4983898	301,8553397	301,4994246	301,1483946	301,3643168	301,1601477	302,3856046
301,3252323	301,6579499	280,7627516	301,4941646	301,8515451	301,4951742	301,1439632	301,3599928	301,1557803	302,3816233
301,2986626	301,6512259	283,9320532	301,485751	301,8440125	301,4867156	301,1351132	301,3514066	301,1470714	302,3736568
301,264831	301,6430262	286,7888525	301,4757017	301,8350367	301,4766203	301,124498	301,3411849	301,1366432	302,36408
301,2260874	301,633115	289,5540091	301,4638976	301,8245003	301,4647739	301,1119615	301,3292197	301,1243456	302,3529244
301,2239423	301,6325733	289,6515248	301,4632566	301,8239284	301,4641307	301,1112799	301,3285705	301,1236773	302,3523161
301,2217992	301,6320303	289,7375455	301,4626158	301,8233569	301,4634878	301,1105982	301,3279219	301,123009	302,3517062

301,2216651	301,6319964	289,7427704	301,4625758	301,8233212	301,4634476	301,1105556	301,3278814	301,1229672	302,351668
301,2215311	301,6319624	289,7479611	301,4625357	301,8232855	301,4634074	301,110513	301,3278409	301,1229255	302,3516299
301,2213971	301,6319285	289,7531403	301,4624957	301,8232498	301,4633673	301,1104704	301,3278003	301,1228837	302,3515917
301,2212631	301,6318945	289,7583125	301,4624557	301,8232141	301,4633271	301,1104278	301,3277598	301,1228419	302,3515535
301,2211293	301,6318605	289,7634785	301,4624156	301,8231784	301,4632869	301,1103851	301,3277193	301,1228002	302,3515153
301,2209956	301,6318265	289,7686385	301,4623756	301,8231426	301,4632467	301,1103425	301,3276788	301,1227584	302,351477
301,2208619	301,6317926	289,7737924	301,4623355	301,8231069	301,4632065	301,1102999	301,3276382	301,1227166	302,3514388
301,2207284	301,6317586	289,7789404	301,4622955	301,8230712	301,4631664	301,1102573	301,3275977	301,1226749	302,3514005
301,2205949	301,6317246	289,7840824	301,4622555	301,8230355	301,4631262	301,1102147	301,3275572	301,1226331	302,3513622
301,2203283	301,6316566	289,794345	301,4621754	301,8229641	301,4630458	301,1101295	301,3274762	301,1225496	302,3512856
301,219796	301,6315206	289,8147855	301,4620152	301,8228212	301,4628851	301,109959	301,3273141	301,1223825	302,3511323
301,2187357	301,6312483	289,8553303	301,461695	301,8225356	301,4625637	301,1096181	301,32699	301,1220483	302,3508254
301,2166306	301,6307031	289,9351089	301,4610546	301,8219644	301,4619211	301,1089363	301,3263421	301,12138	302,3502113
301,2124822	301,6296094	290,0888935	301,4597742	301,8208223	301,4606365	301,1075722	301,3250472	301,1200432	302,3489825
301,2044306	301,6274098	290,373283	301,4572154	301,8185396	301,4580694	301,1048431	301,3224607	301,1173688	302,3465248
301,1892373	301,6229627	290,8677258	301,4521049	301,8139791	301,4529431	301,0993798	301,3173006	301,1120161	302,3416091
301,1620461	301,6138914	291,6570017	301,4419109	301,8048715	301,4427198	301,0884339	301,3070276	301,1012914	302,3317759
301,1339143	301,6027141	292,3429536	301,4297213	301,79396	301,4304992	301,0752666	301,2947791	301,0883849	302,3199578
301,1321878	301,6020134	292,3835387	301,4289598	301,7932782	301,4297357	301,0744434	301,2940142	301,087578	302,3192197
301,1301361	301,601171	292,4311995	301,4280462	301,79246	301,4288199	301,0734554	301,2930966	301,0866095	302,3183344
301,1296242	301,6009603	292,4430635	301,4278178	301,7922555	301,4285909	301,0732084	301,2928672	301,0863674	302,3181131
301,1286049	301,6005386	292,4665732	301,427361	301,7918465	301,4281331	301,0727144	301,2924086	301,0858831	302,3176705
301,1275893	301,6001167	292,4898995	301,4269043	301,7914374	301,4276753	301,0722203	301,29195	301,0853987	302,317228

301,1255767	301,5992712	292,5356434	301,4259911	301,7906194	301,42676	301,071232	301,2910333	301,0844298	302,3163428
301,1216059	301,597576	292,6244829	301,4241654	301,7889836	301,42493	301,0692549	301,2892011	301,0824913	302,3145723
301,113883	301,5941674	292,79111	301,4205164	301,7857126	301,4212729	301,0652988	301,2855417	301,0786116	302,3110303
301,1049923	301,5900452	292,9723761	301,4161421	301,7817884	301,4168895	301,0605482	301,2811597	301,0739512	302,3067787
301,0949004	301,5851452	293,1673657	301,4109855	301,7771589	301,4117229	301,0549394	301,2760002	301,0684463	302,30176
301,0863978	301,5808566	293,3243428	301,4065028	301,773132	301,4072322	301,0500575	301,2715197	301,0636533	302,2973925
301,0781626	301,5765432	293,4686718	301,4020237	301,7691064	301,4027458	301,0451738	301,2670479	301,0588564	302,2930241
301,0701531	301,5722088	293,6032633	301,3975478	301,7650821	301,3982631	301,0402889	301,2625837	301,0540565	302,2886547
301,0623666	301,5678536	293,7290346	301,3930751	301,7610595	301,393784	301,035403	301,2581276	301,0492537	302,284284
301,05479	301,5634788	293,8470887	301,3886055	301,7570385	301,3893085	301,0305166	301,2536794	301,0444482	302,279912
301,0473787	301,5590885	293,9593835	301,3841384	301,7530189	301,3848358	301,0256299	301,2492377	301,0396409	302,275539
301,0401513	301,554681	294,0653036	301,3796742	301,749001	301,3803664	301,0207433	301,2448035	301,0348317	302,2711654
301,0330829	301,5502585	294,1657516	301,3752125	301,7449844	301,3758997	301,0158569	301,240376	301,0300209	302,2667913
301,0261754	301,5458209	294,2608948	301,3707533	301,7409695	301,3714359	301,010971	301,2359555	301,0252089	302,2624173
301,0194297	301,5413682	294,350905	301,3662964	301,7369562	301,3669749	301,006086	301,2315425	301,0203958	302,2580438
301,0128398	301,536901	294,4360974	301,3618416	301,7329447	301,3625164	301,0012022	301,227137	301,015582	302,2536712
301,0063975	301,53242	294,5167687	301,3573889	301,728935	301,3580603	300,99632	301,222739	301,0107677	302,2492993
300,9939041	301,523422	294,6663982	301,3484911	301,7209211	301,3491564	300,9865614	301,2139655	301,0011398	302,2405578
300,9820312	301,5143654	294,7966587	301,3396094	301,7129186	301,3402696	300,9768174	301,2052342	300,9915161	302,2318211
300,9704833	301,505274	294,9156029	301,3307406	301,7049244	301,3313967	300,9670864	301,1965329	300,9818985	302,2230887
300,9591742	301,4961534	295,0252187	301,3218846	301,696938	301,322538	300,9573696	301,1878598	300,9722888	302,2143608
300,9480631	301,4870063	295,1263984	301,3130422	301,6889589	301,3136945	300,9476683	301,1792148	300,9626885	302,2056376
300,9371209	301,4778362	295,2200845	301,3042138	301,6809869	301,3048667	300,9379837	301,1705979	300,9530991	302,1969198

300,91 58248	301,45 94294	295,38 29289	301,28 66168	301,66 50737	301,28 72792	300,91 86903	301,15 34753	300,93 39746	302,17 9526
300,89 50804	301,44 09833	295,52 61143	301,26 90838	301,64 9196	301,26 97637	300,89 94781	301,13 64615	300,91 49123	302,16 22087
300,87 4876	301,42 25231	295,65 34219	301,25 162	301,63 33571	301,25 23236	300,88 03519	301,11 95543	300,89 59188	302,14 49778
300,85 51992	301,40 40664	295,76 69211	301,23 42297	301,61 75632	301,23 49612	300,86 13154	301,10 27521	300,87 69993	302,12 78237
300,83 60256	301,38 56236	295,86 84724	301,21 69158	301,60 182	301,21 76778	300,84 23718	301,08 60534	300,85 81582	302,11 07292
300,81 73237	301,36 72017	295,95 99088	301,19 96801	301,58 61304	301,20 04741	300,82 35234	301,06 94568	300,83 93991	302,09 36849
300,79 90541	301,34 88045	296,04 27194	301,18 25238	301,57 04952	301,18 33506	300,80 47719	301,05 29607	300,82 07247	302,07 67065
300,78 11712	301,33 04392	296,11 82809	301,16 54479	301,55 49158	301,16 63079	300,78 61189	301,03 65636	300,80 21375	302,05 97981
300,76 36285	301,31 2115	296,18 76028	301,14 84531	301,53 93929	301,14 93468	300,76 75651	301,02 02642	300,78 36394	302,04 3001
300,74 63783	301,29 38399	296,25 14796	301,13 154	301,52 39274	301,13 24681	300,74 91114	301,00 40609	300,76 52316	302,02 63354
300,72 93749	301,27 56211	296,31 05903	301,11 47091	301,50 85206	301,11 56724	300,73 0758	300,98 79524	300,74 69155	302,00 98402
300,71 25776	301,25 74645	296,36 55035	301,09 79609	301,49 31728	301,09 89601	300,71 25053	300,97 19371	300,72 86919	301,99 35077
300,69 59427	301,23 93729	296,41 68343	301,08 12924	301,47 78827	301,08 23279	300,69 43489	300,95 601	300,71 05575	301,97 73232
300,67 94468	301,22 13537	296,46 47863	301,06 47072	301,46 26544	301,06 57794	300,67 62929	300,94 01734	300,69 25164	301,96 12846
300,66 30587	301,20 34115	296,50 9662	301,04 82058	301,44 749	301,04 93148	300,65 83373	300,92 44263	300,67 45692	301,94 53837
300,64 67479	301,18 55502	296,55 17121	301,03 17883	301,43 23914	301,03 2934	300,64 04817	300,90 87673	300,65 67161	301,92 96128
300,63 04847	301,16 77731	296,59 1208	301,01 54548	301,41 73605	301,01 66369	300,62 27258	300,89 31954	300,63 89571	301,91 3965
300,61 42396	301,15 00832	296,62 83571	300,99 92052	301,40 23987	301,00 04235	300,60 50692	300,87 77092	300,62 12922	301,89 84344
300,58 15657	301,11 50775	296,69 43665	300,96 70494	301,37 2767	300,96 83378	300,57 0159	300,84 70797	300,58 63472	301,86 78157
300,54 84865	301,08 04473	296,75 33609	300,93 5226	301,34 34243	300,93 65816	300,53 56364	300,81 67757	300,55 17747	301,83 75968
300,51 48025	301,04 61983	296,80 62007	300,90 37317	301,31 43718	300,90 51516	300,50 1496	300,78 6789	300,51 75712	301,80 77535
300,48 03177	301,01 23328	296,85 35714	300,87 25627	301,28 56088	300,87 40435	300,46 77316	300,75 71118	300,48 37327	301,77 82652
300,44 48409	300,97 88509	296,89 60692	300,84 17146	301,25 7133	300,84 32528	300,43 43372	300,72 77366	300,45 02545	301,74 91145

300,4082385	300,9457367	296,9343657	300,8111711	301,228931	300,8127635	300,401293	300,6986458	300,4171188	301,7202748
300,3703294	300,9130008	296,968702	300,7809391	301,2010093	300,7825822	300,3686062	300,6698434	300,3843335	301,6917454
300,3309949	300,8806393	296,9994077	300,7510136	301,173364	300,7527041	300,3362707	300,6413235	300,3518936	301,6635151
300,2463733	300,8174005	297,0486496	300,6923719	301,1191637	300,6941448	300,272981	300,5853873	300,2883785	301,6082018
300,0579091	300,6963839	297,1126246	300,5795447	301,0147752	300,5814436	300,1514711	300,4775514	300,1663879	301,5016787
299,7202352	300,4730975	297,1613007	300,3694418	300,819925	300,3715023	299,9260604	300,2759558	299,9400229	301,3026166
299,3757834	300,2274938	297,1580598	300,136282	300,6029597	300,1384737	299,6851291	300,0513154	299,6969243	301,0805298
299,0084741	299,9620715	297,1132832	299,882119	300,3656889	299,8844165	299,4523609	299,810233	299,4627598	300,8371416
298,6358087	299,699002	297,0312819	299,6385832	300,1089605	299,6408236	299,2310541	299,5815523	299,2407536	300,5732189
298,3181157	299,4568482	296,9244613	299,4111625	299,8458611	299,4133915	299,013708	299,3656247	299,0224872	300,2919689
298,1121357	299,2603799	296,8188742	299,2241268	299,6405851	299,2263855	298,8306723	299,1869252	298,8385953	300,0571501
297,9599815	299,0956521	296,719748	299,0658887	299,4747923	299,0681562	298,6733507	299,0345997	298,6804545	299,8884254
297,7584388	298,9341419	296,6156402	298,9093729	299,3184076	298,9116641	298,5162988	298,8827983	298,5227889	299,7366998
297,3692142	298,7952696	296,5237374	298,7742418	299,1858078	298,7765557	298,379018	298,7513795	298,3850517	299,6068241
296,6585875	298,6542639	296,4303729	298,6363075	299,0512467	298,638676	298,2374373	298,6165202	298,2431022	299,4734015
295,6072577	298,5101925	296,3366921	298,4947927	298,9134789	298,49724	298,0911041	298,4776373	298,0964142	299,3349834
294,276074	298,3624497	296,2425719	298,3491603	298,7725326	298,3517065	297,9397924	298,3342943	297,9447431	299,1907776
292,5611327	298,1219712	296,0860404	298,1112425	298,5439617	298,1139713	297,6868583	298,0993505	297,6916595	298,9555038
290,8271585	297,7550762	295,8039438	297,7460126	298,2020015	297,749288	297,2541769	297,7367634	297,2578672	298,6054762
289,9112935	297,4179238	295,5140135	297,4087673	297,9233201	297,412924	296,8269544	297,4007918	296,829993	298,3204032
289,3398338	297,0668186	295,1980627	297,0566496	297,6585154	297,0625464	296,3806811	297,0497332	296,3835989	298,0623035
288,7981746	296,5580548	294,7318701	296,5465168	297,2818895	296,5555791	295,7957121	296,5419303	295,7986759	297,6776619
288,4779688	296,0199873	294,1803067	296,007281	296,8276094	296,0199847	295,1838979	296,0059877	295,186643	297,1998485

288,3627508	295,420039	293,4348187	295,4046132	296,2926283	295,4238043	294,434604	295,4087416	294,4371286	296,631487
288,3109995	294,6291822	292,6127354	294,604162	295,7183523	294,6429631	293,4446419	294,6243295	293,4469447	296,0332063
288,3204173	293,4344055	291,7674652	293,3988596	294,8919541	293,4719651	292,40362	293,4528443	292,4056409	295,1679191
288,3508607	292,2692529	290,9482836	292,2245606	293,6943432	292,3325084	291,3866111	292,3137759	291,3884021	293,9034813

Code to retrieve data sheets and load it up to Unity.

```
using SimpleJSON;
using System.Collections;
using System.Collections.Generic;
using UnityEngine;
using UnityEngine.UI;
using UnityEngine.Networking;

public class TileDecider : MonoBehaviour
{
    public Text outputArea;
    // Start is called before the first frame update

    //public AudioClip[] Tilesaudio;
    //public AudioSource speaker;
    public int[] order_of_tiles;
    //public TextAsset CSVfile;
    string[] notes;
    public Text display;
    //string[] row;
    int i = 0;
    //int starter = -1;
    int levelno = 1;
    //AudioClip[] temp=new AudioClip[12];

    //public Animator levelcompanim;

    string rowsjson="";
    string[] lines;
    List<string> eachrow;
    public GameObject networkerror;

    void Start()
    {
        /*row = CSVfile.text.Split(new char[] { '\n' });
        if (!PlayerPrefs.HasKey("levelno"))
        {
            PlayerPrefs.SetInt("levelno", 1);
```

```
            levelno = PlayerPrefs.GetInt("levelno");
        }
        else
        {
            levelno = PlayerPrefs.GetInt("levelno");
        }
        aim.speed = 0.5f + (levelno*0.01f);
        takefromCSV();
        */

        takefromCSV();
        StartCoroutine(UpdateOutputRoutine());

    }

    IEnumerator UpdateOutputRoutine()
    {
        while (true)
        {
            yield return new WaitForSeconds(30f);

            takefromCSV();
        }
    }
    // Update is called once per frame
    void Update()
    {
        if (i < 10)
        {
            //takefromCSV();
        }
        /*
        if (starter == 11)
        {
            levelno++;
            if (levelno > PlayerPrefs.GetInt("levelopened"))
            {
                PlayerPrefs.SetInt("levelopened", levelno);
            }
            takefromCSV();
            starter = -1;
            gamecontroller.levelwon(levelno-1);
            Debug.Log("levelno: " + levelno);
        }*/
    }
    public void takefromCSV()
    {
        StartCoroutine(ObtainSheetData());
```

```
    }
    IEnumerator ObtainSheetData()
    {
        UnityWebRequest www =
UnityWebRequest.Get("https://sheets.googleapis.com/v4/spreadsheets/1T2Dvc2RCI2
XgYbSR-
QjqNqSXYNWSbd1xaI3bN5cepFQ/values/Blad1?key=AIzaSyBsJa4uuQdp0yfZg3w2kWLYr9CuBR
1MTck");
        yield return www.SendWebRequest();
        /*if (www.isNetworkError || www.isHttpError || www.timeout>2)
        {
            Debug.Log("error" + www.error);
            //networkerror.SetActive(true);
            //takerandomvalues();
            Debug.Log("Offline");
        }*/

        if (www.result == UnityWebRequest.Result.ConnectionError ||
www.responseCode != 200)
        {
            Debug.Log("error" + www.error);
            //networkerror.SetActive(true);
            //takerandomvalues();
            Debug.Log("Offline");
        }
        else
        {
            //networkerror.SetActive(false);
            string updateText = "";
            string json = www.downloadHandler.text;
            var o = JSON.Parse(json);

            JSONArray valuesArray = o["values"].AsArray;
            JSONNode lastElement = valuesArray[valuesArray.Count - 1];

            string outputString = lastElement.ToString();

            outputString = outputString.Trim('"', '[', ']');

            string output = outputString;

            output = "T=" + output + "K";

            Debug.Log(output);
            display.text = output;

            Debug.Log(output);
            display.text = output;
```

```
            /*foreach (var item in o["values"])
            {
                var itemo = JSON.Parse(item.ToString());
                eachrow = itemo[0].AsStringList;
                foreach (var bro in eachrow)
                {
                    rowsjson += bro+",";
                }
                rowsjson += "\n";



            }
            lines = rowsjson.Split(new char[] { '\n' });
            notes = lines[levelno].Split(new char[] { ',' });
            for (i = 1; i < notes.Length-1; i++)
            {
                display.text += ", " + notes[i];
                //temp[i - 1] = Tilesaudio[i - 1];
            }*/
            /*
            for (i = 1; i < notes.Length-1; i++)
            {
                //Tilesaudio[i - 1] = temp[int.Parse(notes[i]) - 1];
                Tilesaudio[int.Parse(notes[i]) - 1] = temp[i - 1];
            }*/
            //outputArea.text = updateText;
            //Debug.Log(json);
        }
    }

}
```