Unistat 825w and Battery Test Cold Plate

Temperature Control
for Power Cell research
and development

Inspired by **temperature**

huber

CASE STUDY RESULTS

Authors

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Introduction

This Case Study demonstrates the Process temperature control abilities of the Unistat 825w when it is connected to a cold plate (the “application”) fabricated from aluminium.

To simulate the heat load from battery cells under test, heating mats of varying power outputs were placed on top of the cold plate and insulated with an “Armorflex” sheet.

Three tests were made:

1.) The minimum achievable temperature

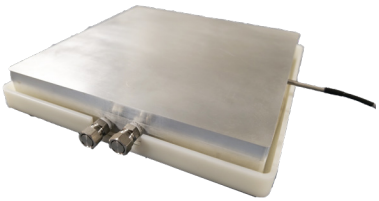
2.) The stability at various set-points

3.) “Recovery” to demonstrate how quickly and accurately a set-point is recovered from a sudden decrease or increase in heat load.The heat pad is disconnected, the system allowed to regain and stabilize at the set point before the heat pad is then reconnected and a heat load applied. This was carried out at various temperature set-points (-60 °C to 120 °C) and wattage inputs.

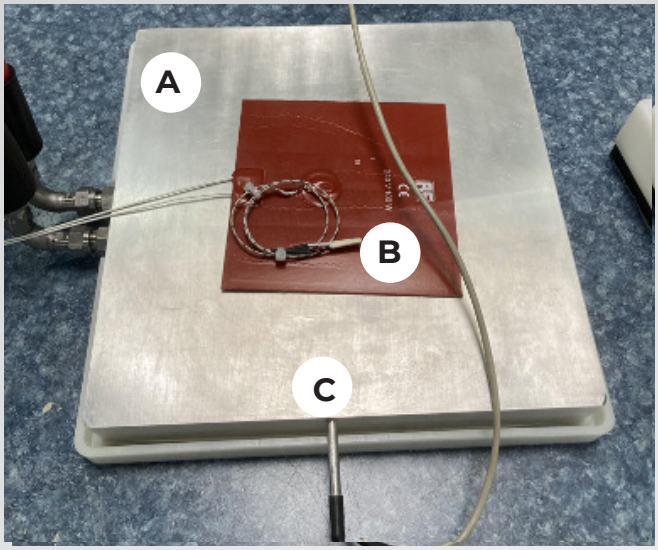
Equipment & Setup

The Cold Plate is connected with the Temperature Control Unit (TCU) using “M16 x 1” insulated metal tubing. A Pt100 is located inside the sleeve and the TCU is configured to control the temperature from this point, see figure 1.

Unistat 825w



Cold plate

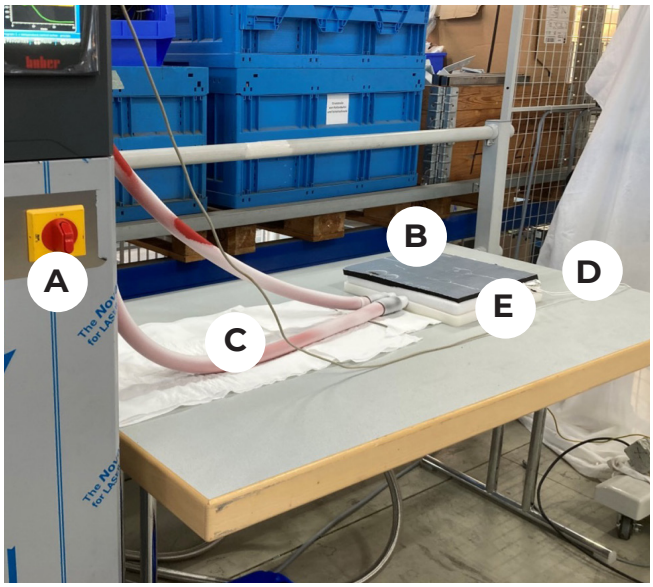


A Cold plate

B Heating mat (temperature sensor not used)

C pt100 temperature sensor connected to TCU

Figure 1: Close-up Image of Cold plate, PT100 Temp Sensor, Heater Mat, Cold plate PTFE Tray, Hosing connections used to carry out this study.



A TCU

B Cold plate with insulation

C Insulated metal hosing

D Cables for heat mat

E pt100 temperature sensor

Figure 2: Image of all equipment used in this study. Unistat 825w (TCU), Insulated metal hosing, cold plate with "Armourflex insulation and PT 100 temperature sensor.

Technical Specifications of Items used

Unit	Unistat 825w						
Catalogue number	1079.0002.01						
Temperature range	-85°C...250°C						
Heating power kW	3						
Cooling power	200	20	0	-20	-40	-60	°C
	2.4	2.4	2.4	2.4	2.4	1.5	kW
Pump data	Flow	Pressure					
	40 l/min	0.9 Bar					
Test conditions							
Tubing	2 x 1-meter M16 metal insulated tubing #6085						
Control	Process						
Heat Transfer Fluid	M90.055/170.02						
Cold Plate							
Dimensions	30cm x 30cm x 10cm						
Material of construction	Aluminum						
Weight	10Kg						

Results

Minimum Achievable Temperature and Stability

Table 1 below shows the minimum achievable application temperatures with increasing heat loads and the stability of control of different set points.

This work shows that the set-point has minimal effect on temperature stability with all set-points giving +/- 0.02 to 0.05 K with the exception of 275 W at -40 °C. Under no heat load a T-min of -79.9 °C is achieved on the cold plate; this indicates an environmental heat gain of ~300 W (Unistat 825w cooling capacity at -80 °C). Under an applied heat load the T-min becomes a function of the applied heat load and the environmental heat gain contributing to a greater cooling requirement.

For example, the 500 W heat load has a T-min of -58.1 °C, this indicates and additional cooling requirement of ~1.0 kW to maintain the T-min is required as the Unistat 825w cooling capacity at -60 °C is 1.5 kW. This data suggests that a greater cooling capacity is required to counter cool a given heat load and the relationship between the applied heat load and cooling capacity is non-linear. Therefore, when specifying a Huber system for temperature control of a cold plate additional capacity at the lowest working set-point should be considered.

The authors of this work hope that Table 1 will serve as a guide, but is by no means extensive and further work to understand your cell heat transfer properties should be carried out

Recovery

The “recovery” is a demonstration of the ability of the Unistat to recover the set-point of the application after a sudden change in heat load achieved by turning the heat source “Off” and after the set-point has been reached and stabilized and then “On” again. The table below shows both the decrease and in the increase from the set-point in the application’s temperature and the approximate time taken for the set-point to be regained.

The overall temperature control curve and close-up of the recovery tests (recovery curve) at the -40 °C set-point for the 275 W heat source is shown below. All temperature control curves can be seen in appendix of this document. The overall curve for the tests listed above and recovery curve described above. In each screen shots below, the following colour codes apply:

1.) Blue is the Set-point

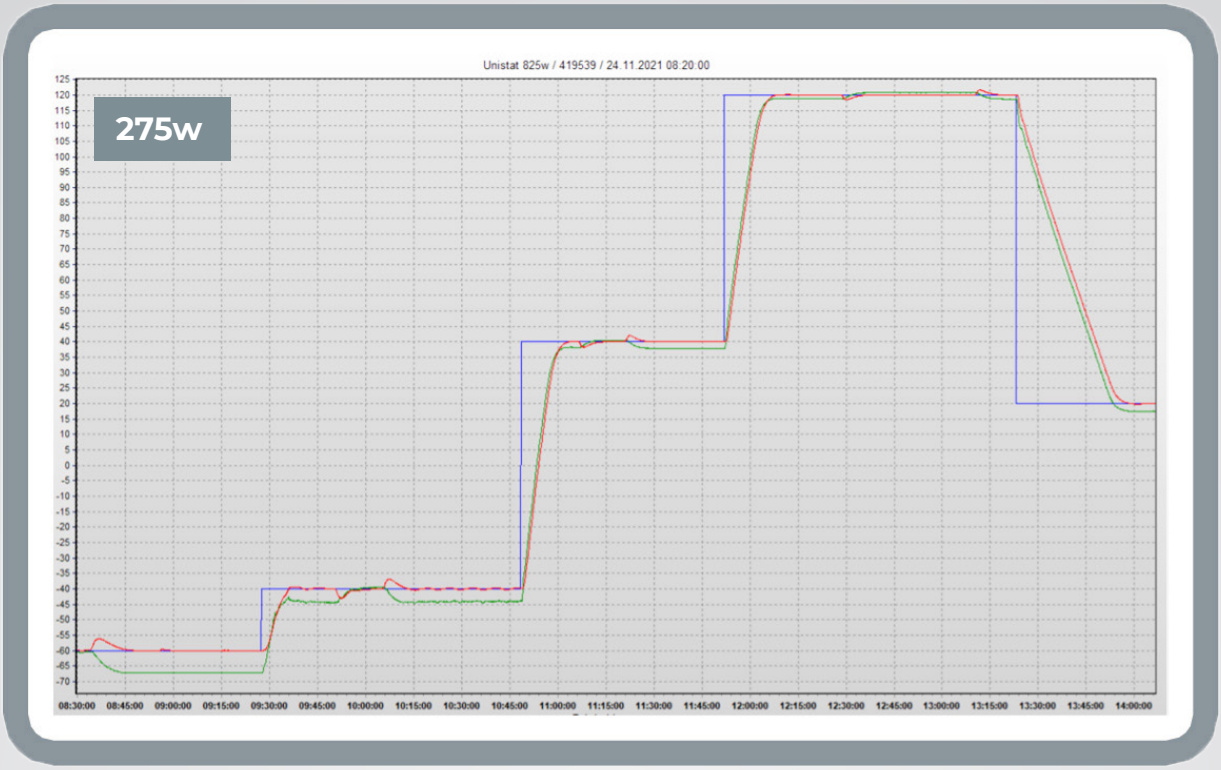
2.) Green is the HTF temperature

3.) Red is the application temperature

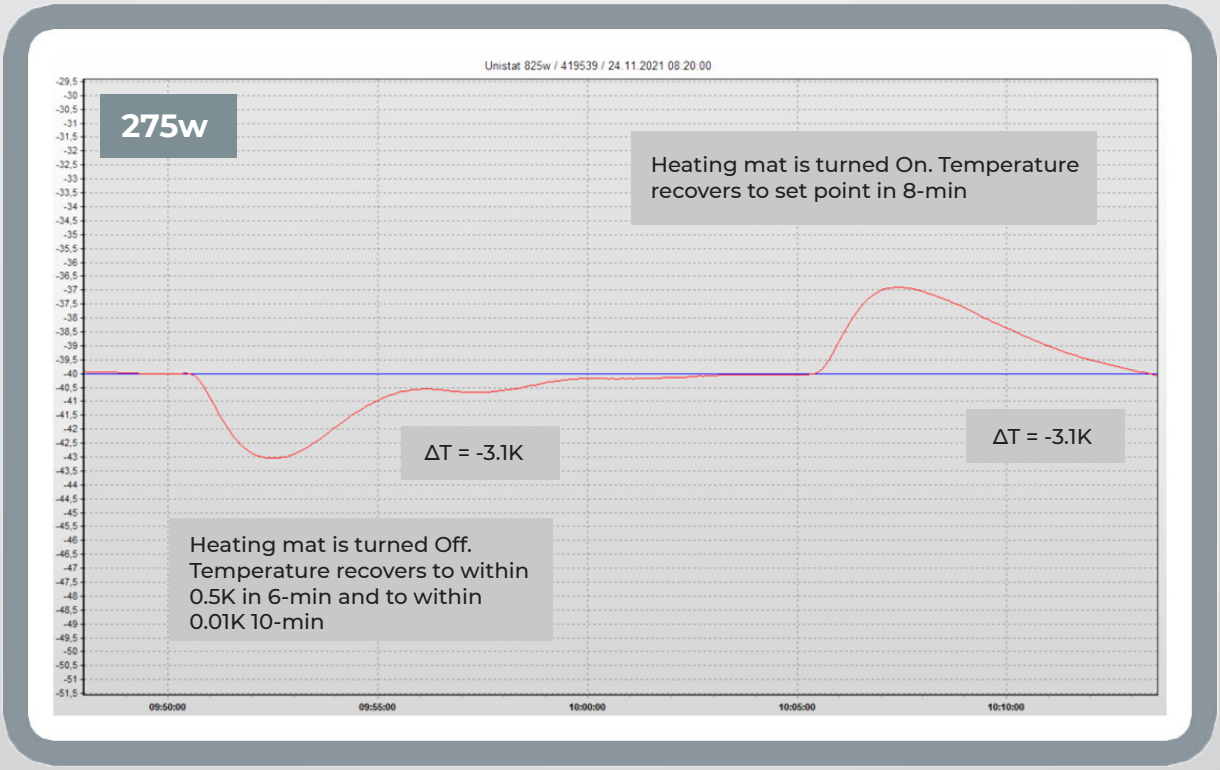
				Stability @ (°C)		
	Heater mat			-40	40	120
	Dimensions	w/cm²	T-min			
Heat Load	cm		°C	+/- K	+/- K	+/- K
0w	***	***	-79.8	0.02	0.02	0.02
275w	25 x 25	0.44	-66.4	0.15	0.02	0.02
396w	30 x 30	0.44	-64.2	0.02	0.02	0.03
500w	25.4 x 25.4	0.78	-58.1	0.03	0.04	0.02
500w + 396w	55.4 x 55.4	0.29	53.5	***	0.04	0.02

Table 1: Summary table of heat load applied to cold plate (heater pad), associated pad dimensions, w/cm2 value per heat pad, lowest achievable working temperature under applied heat load (T-min) and Temperature stability at listed set-points (-40 °C, 40 °C, 120 °C).

275w // Overall view



Recovery // Set point: -40°C



Recovery Rates Summary

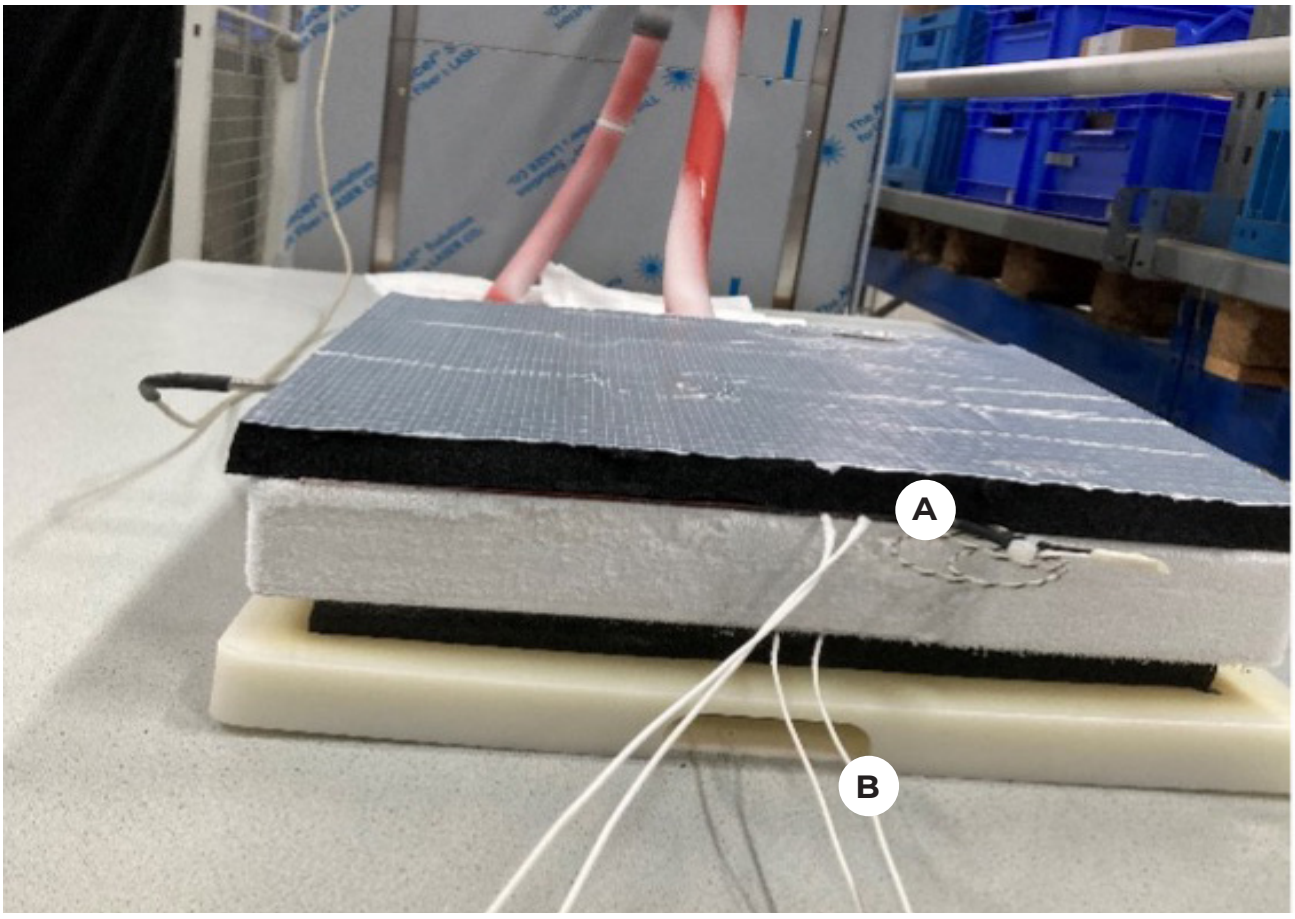
The table below (Table 2) shows both the decrease and the increase from the set-point in the application's temperature after a change in heat-load and the corresponding time taken for the set-point to be regained.

Heat Load					
275w	Set Point	Decrease	Recovery time	Increase	Recovery time
	-60°C	***	***	-56.2°C	12 Min
	-40°C	-43.1°C	13 Min	-36.9°C	8 Min
	40°C	38.3°C	7 Min	42°C	9 Min
	120°C	118.4°C	8 Min	121.6°C	8 Min
396w					
	-40°C	***	***	-36.7°C	14 Min
	40°C	38.1°C	10 Min	42°C	9 Min
	120°C	118.4°C	8 Min	121.7°C	9 Min
500w					
	-55°C	-63.5°C	11 Min	-47.9°C	12 Min
	-40°C	-46.2°C	8 Min	-34.2°C	8 Min
	40°C	36.4°C	8 Min	43.7°C	9 Min
896w	120°C	117°C	8 Min	123.1°C	10 Min
	-50°C	-56.1°C	12 Min	-45°C	14 Min
	-20°C	-23.6°C	10 Min	-16.4°C	10 Min
	40°C	37.1°C	9 Min	42.9°C	11 Min
	120°C	117.4°C	10 Min	122.6°C	11 Min

Table 2: Summary table of applied heat load, temperature set-point, decrease in temperature from loss of heat load (Decrease), recovery time (Off) to set-point after heat load loss, increase in temperature from applied heat load (Increase) and recovery time (On) to set-point under applied heat load.

Indication on the Impact of the “w / cm²”

To input 896w of heat energy into the cold plate, the cold plate was sandwiched between the 396w heating pad and the 500w heating pad.



A 500w heating pad connection cables **B** 396w heating pad connection cables

Figure 3: Close-up Image of Cold plate, PT100 Temp Sensor, 2 x Heater Mats, Cold plate PTFE Tray, Hosing connections

Set point °C	Heat input W	w/cm²	Recovery ΔT "Off"	Recovery ΔT "On"
-40°C	275	0.44	-3.1	+3.1
40°C	275	0.44	-1.7	+2.0
120°C	275	0.44	-1.6	-1.6
-40°C	396	0.44	***	+4.3
40°C	396	0.44	-2.1	+2.0
120°C	396	0.44	-1.6	+1.7
-40°C	500	0.78	-6.2	+5.8
40°C	500	0.78	-3.6k	+3.7
120°C	500w	0.78	-3.0k	+3.1
-40°C	896	0.29	***	***
40°C	896w	0.29	-2.9k	+2.9
120°C	896w	0.29	-2.6k	+2.6
Low Temperature comparison				
-55°C	500	0.78	-8.5	+7.1
-50°C	896	0.29	-6.1	+5.0

Table 3: Comparison table of Set-points, applied heat input, watts per cm² of heater pad and associated recovery Temperature delta (ΔT) for each condition. A comparison of low temperature set-points (-55 °C & -50°C) and the impact of the w/cm² on recovery ΔT for 500 W and 896 W is listed respectively

The data presented shows the following trends:

1) The recovery ΔT is greater at lower set-points than higher ones. 2) The recovery ΔT increases in deviation away from the setpoint when the w/cm² has a greater value. 3) The loss of heat input on the cold plate (Switching off) results in a greater deviation away from the set-point than heat input from the pad (Switching On).

This is likely explained by the differences in thermal transfer efficiencies between the circulating HTF and the heater pad, as the loss and input load are the same. Therefore, the highest deviations from set-point occur at lower temperatures with the highest w/cm² ratio.

For the data presented this is the -55°C setpoint with the 500 W heat pad (ΔT -8.5 and +7.1). This suggests that the w/cm2 value is crucial in assessing the recovery ΔT and is a clear demonstration that the larger the surface area of the heat exchanger, the more efficient is the thermal transfer & temperature control.

Conclusion

Specifying the best Unistat for any application with theoretical calculations alone can yield disappointing results.

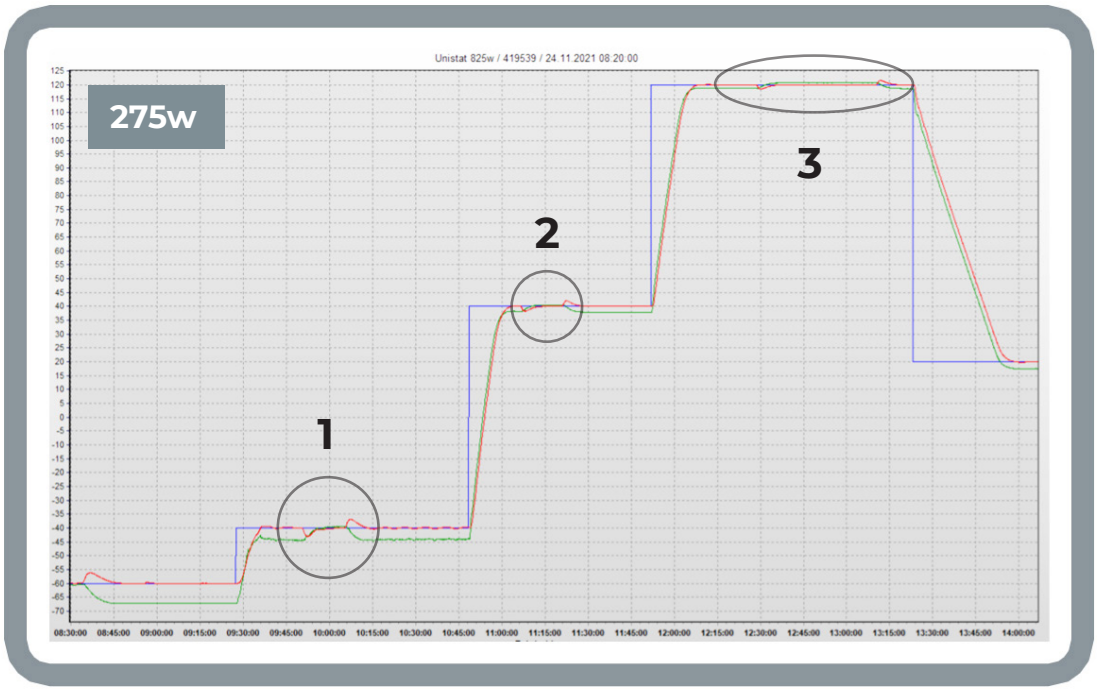
This case study shows empirical data with detailed technical specifications such as the cooling and heating power of the Unistat, the surface area (cm²) of the "component" under test (the heat pad) and the heat (w) that it generates.

Given the technical specifications, the data shows the efficiencies in temperature control when the w/cm² ratio is low. This could result in (perhaps) a less powerful machine being required or a factor to be taken into consideration during the design of the component under test to increase the efficiencies of thermal transfer.

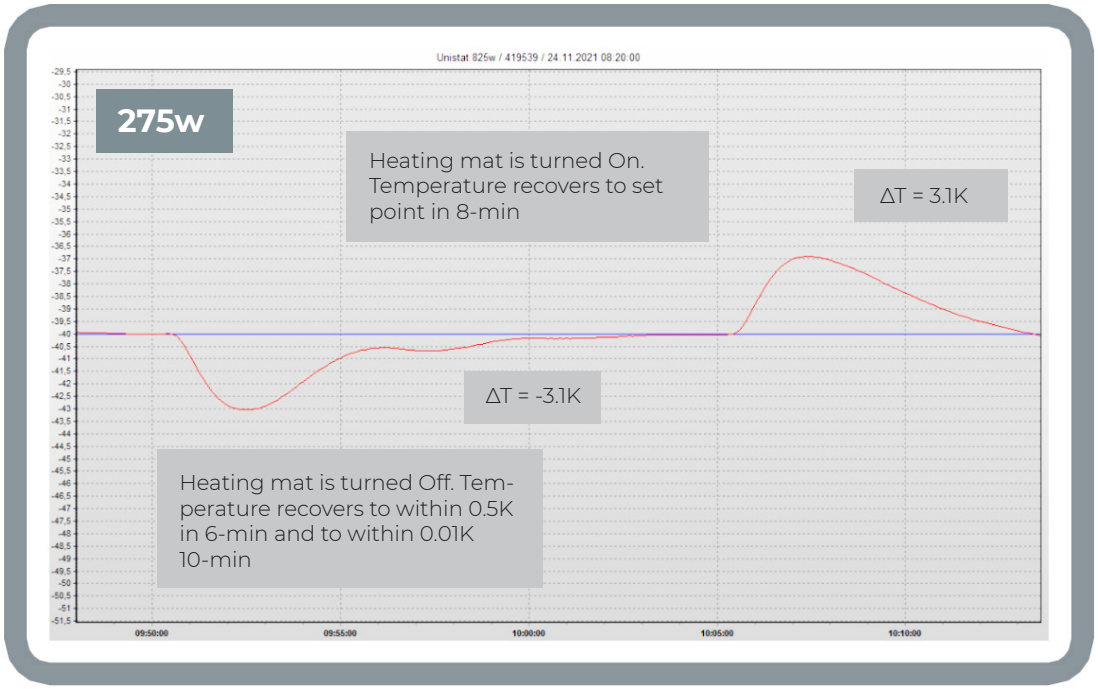
The data also demonstrates the lowest working temperatures under varying heat loads as well as the performance (response times and stability) at different set-points.

Appendix

Heater source input of 275w // Overall Temperature Control Curve



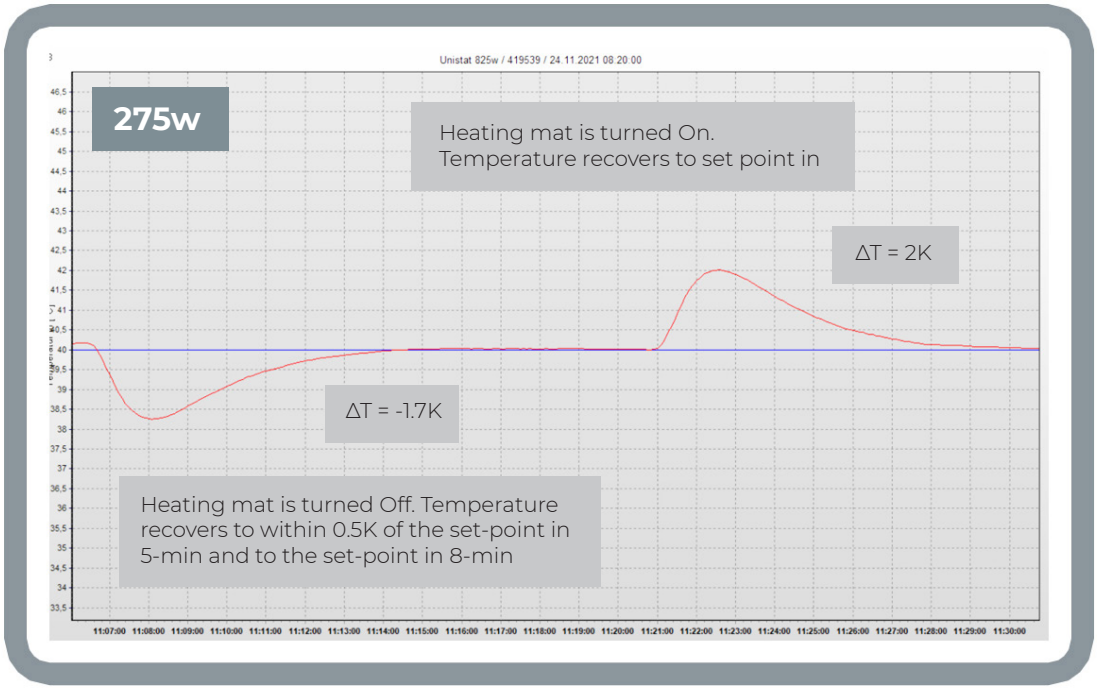
1 Recovery Curves // Set point: -40°C



Appendix

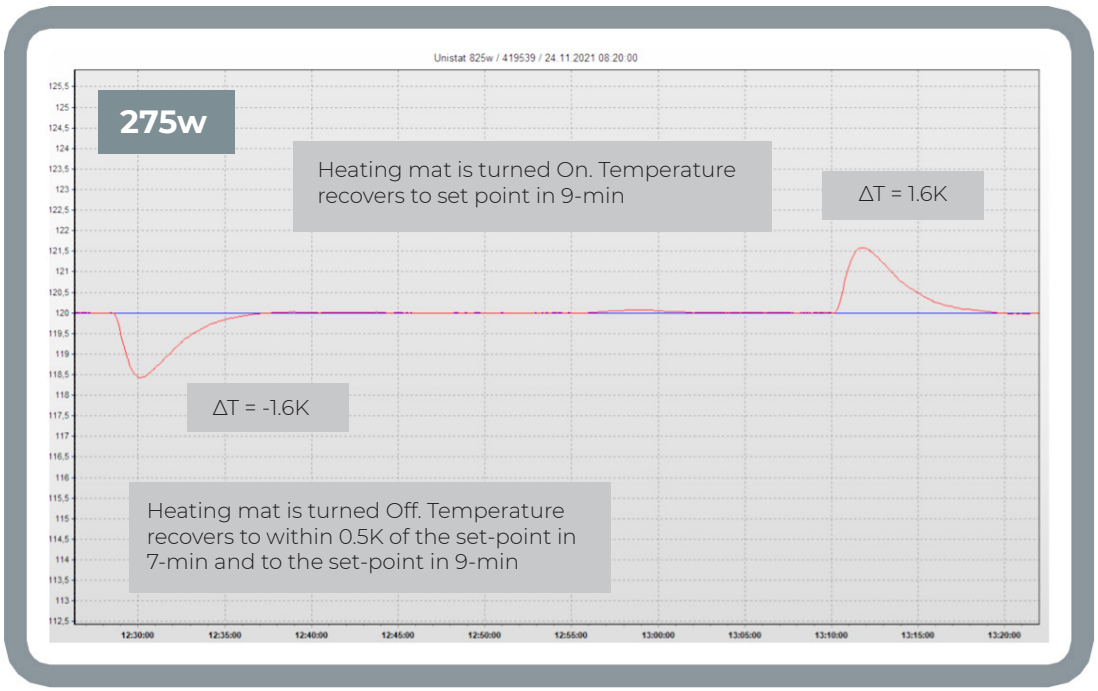
2

Set point: 40°C



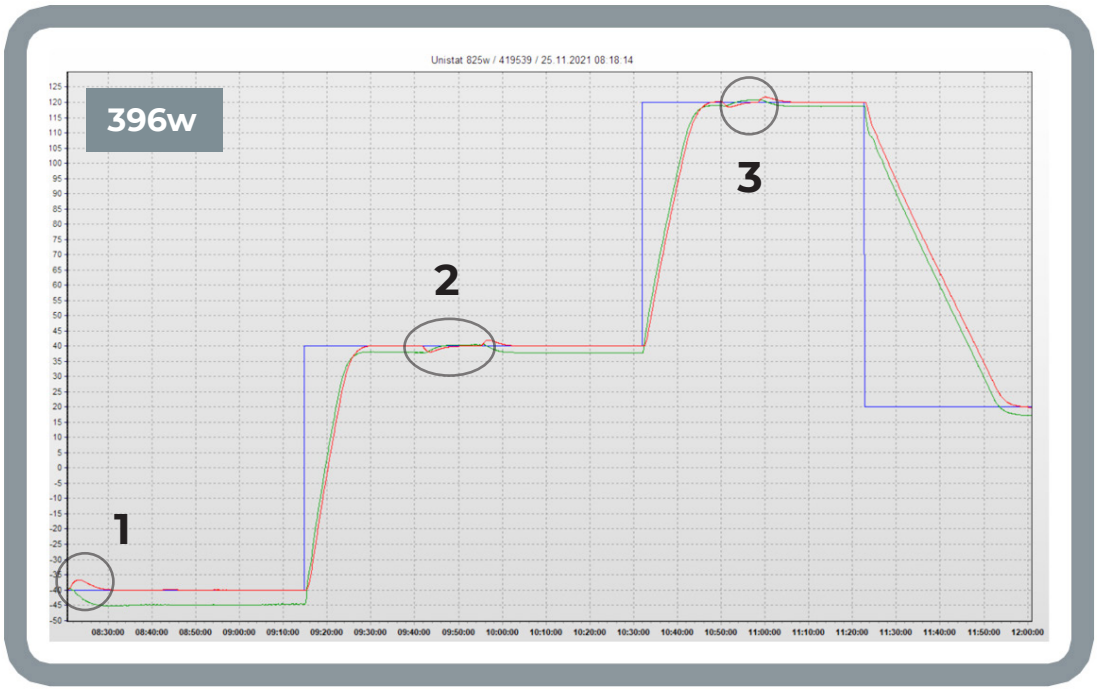
3

Set point: 120°C

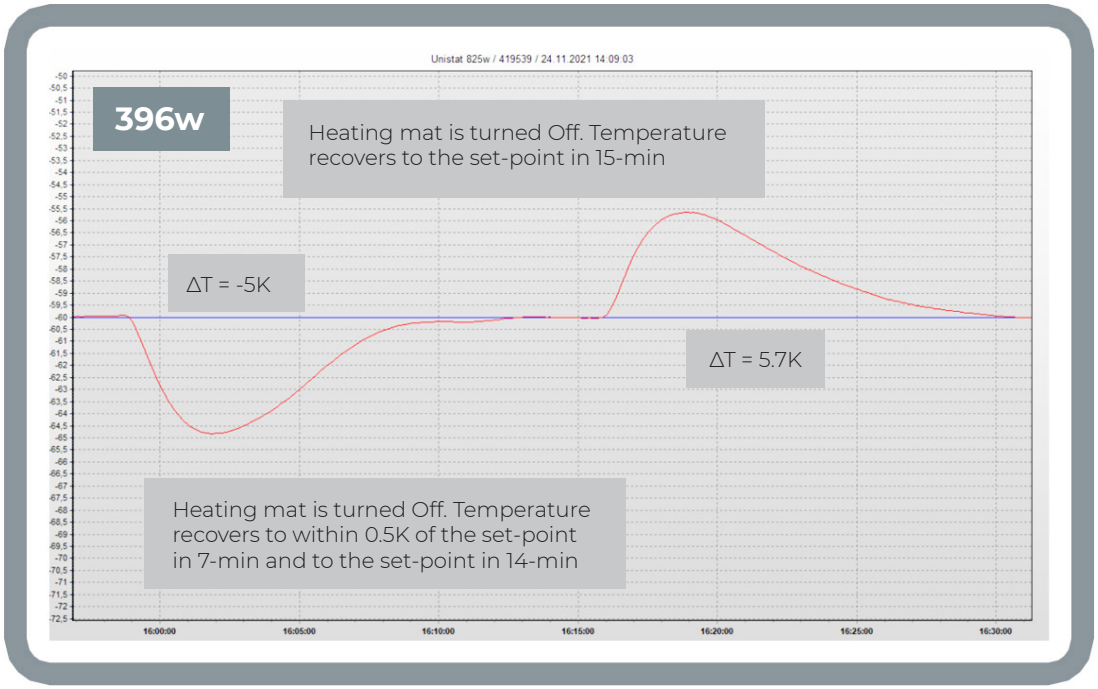


Appendix

Heater Source Input of 396w // Overall Temperature Control Curve



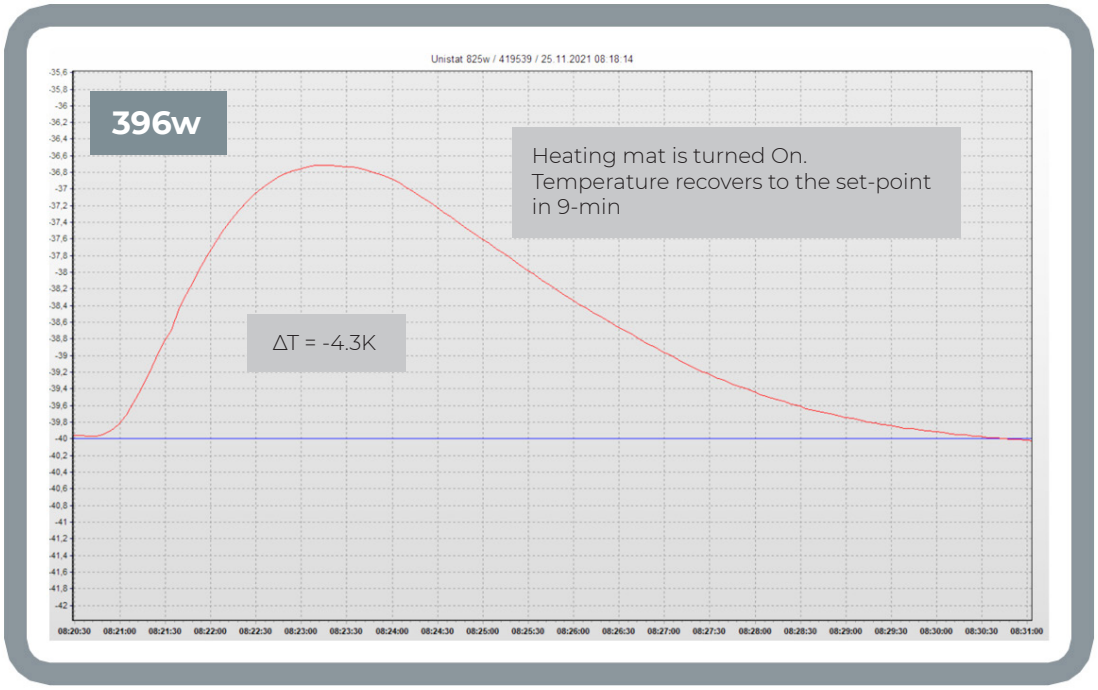
Recover Curves // Set point: -60°C



Appendix

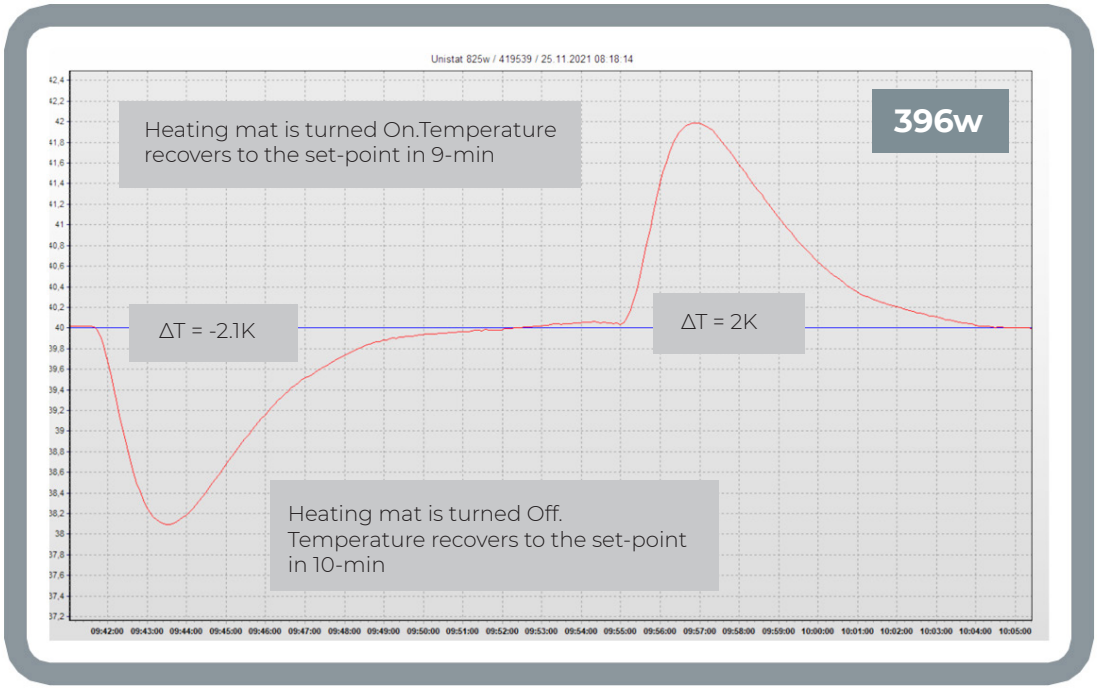
1

Set point: -40°C



2

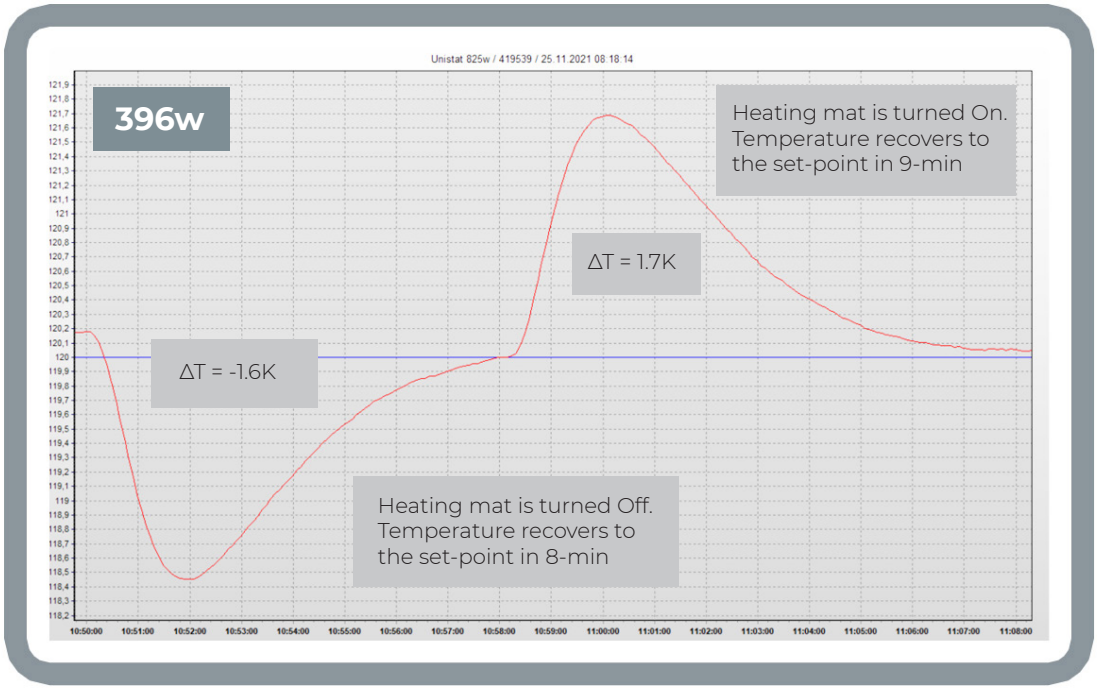
Set point: 40°C



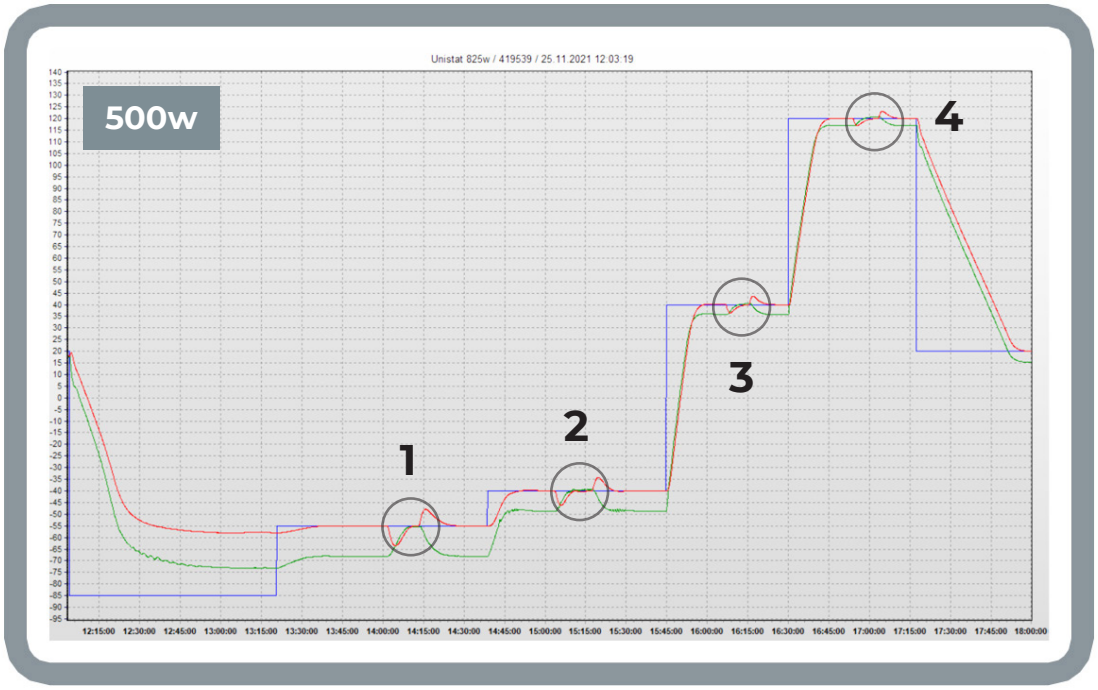
Appendix

3

Set point: 120°C

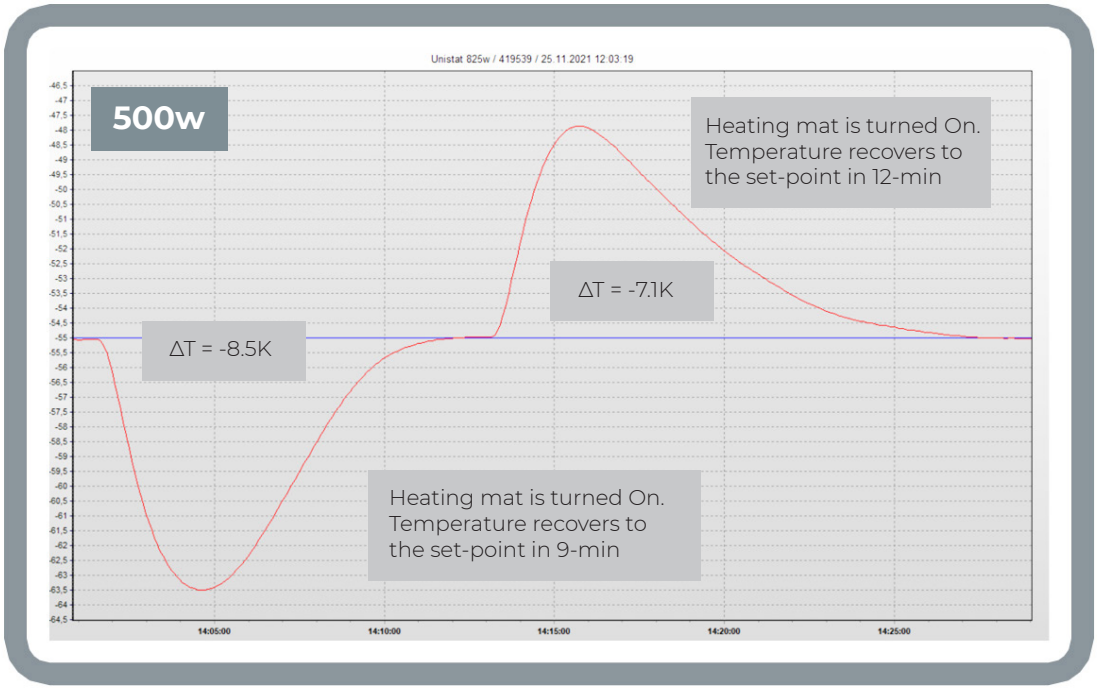


Input Heater Source of 500w // Overall Temperature Control Curve

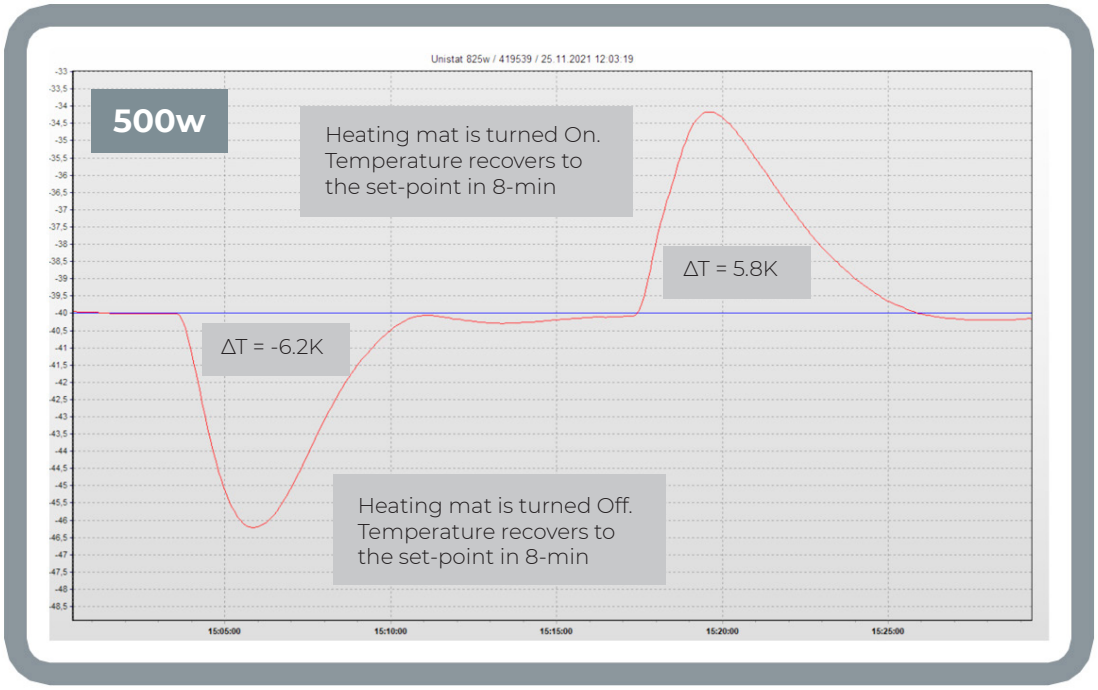


Appendix

1 Recovery Curves // Set point: -55°C



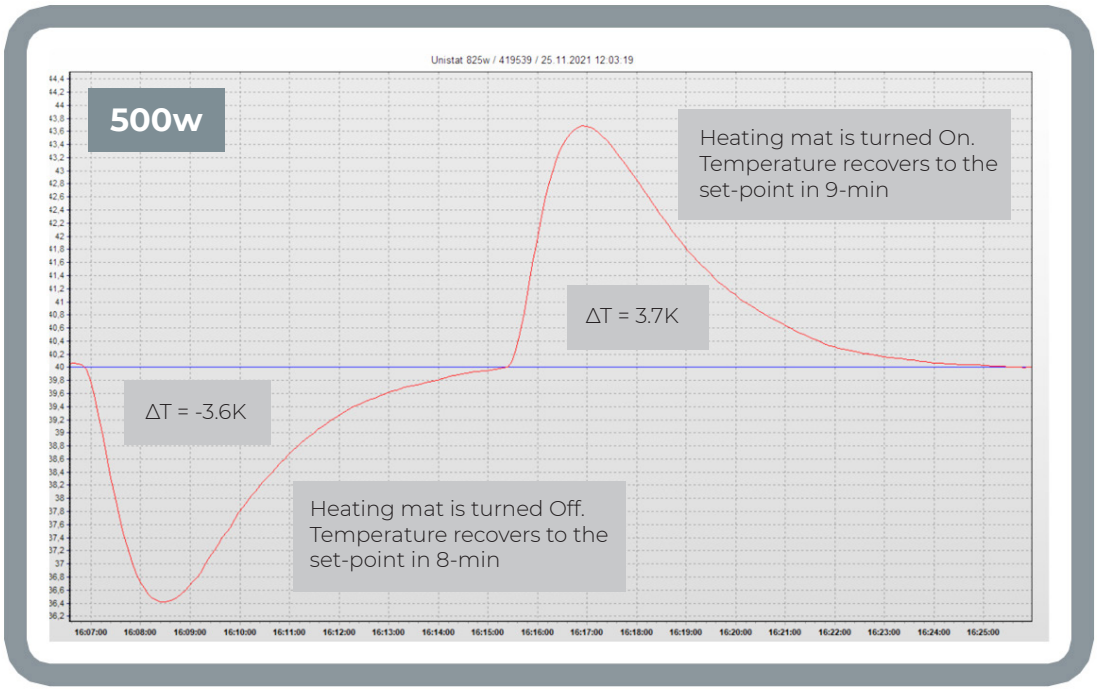
2 Set point: -40°C



Appendix

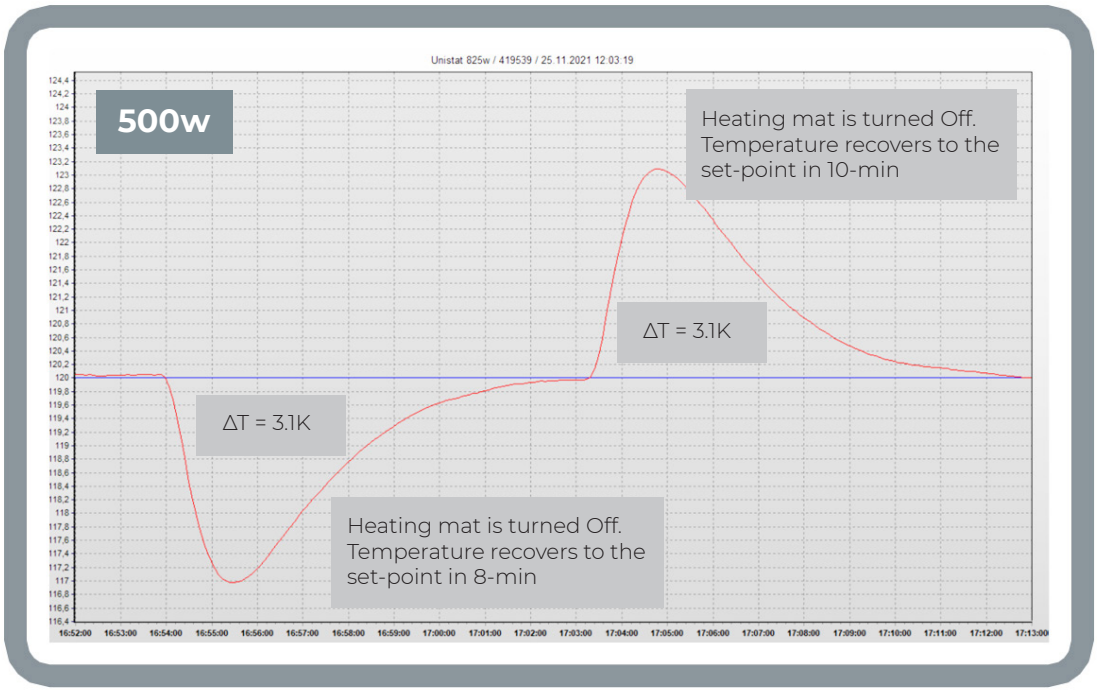
3

Set point: 40°C



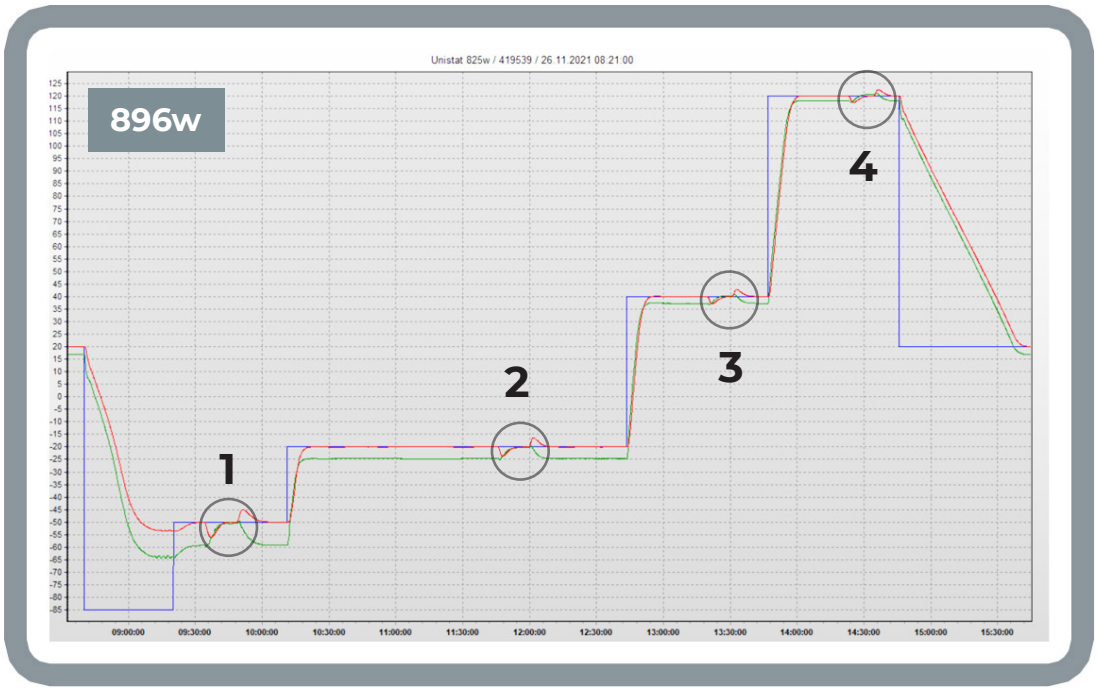
4

Set point: 120°C

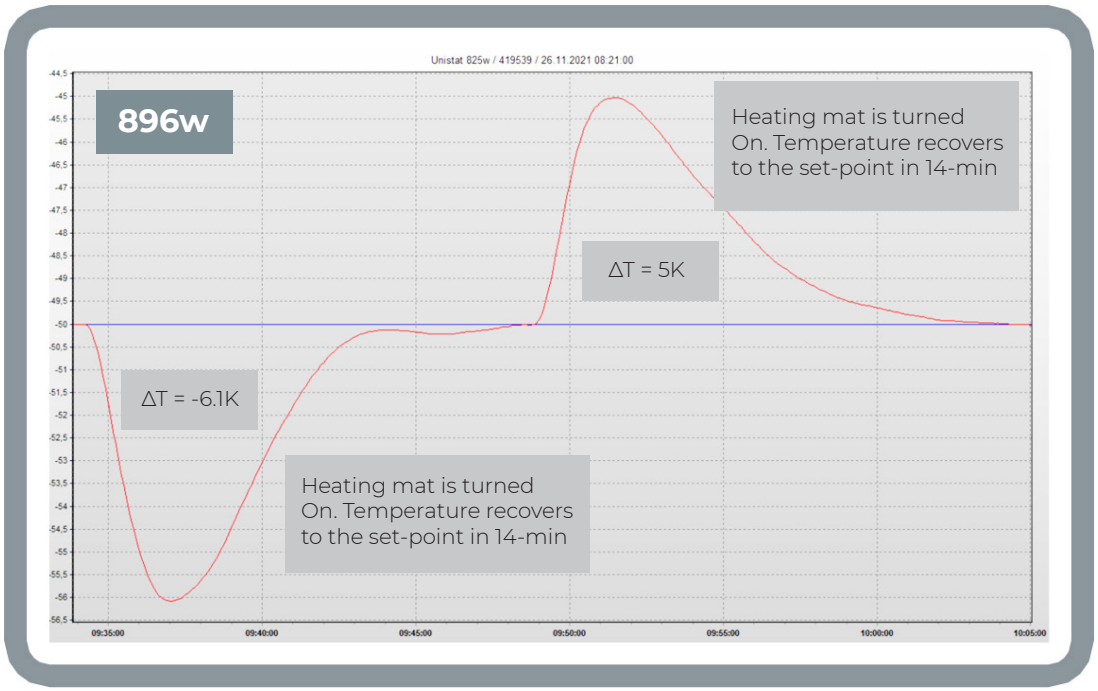


Appendix

Heater Input Source of 896w // Overall Temperature Control Curve



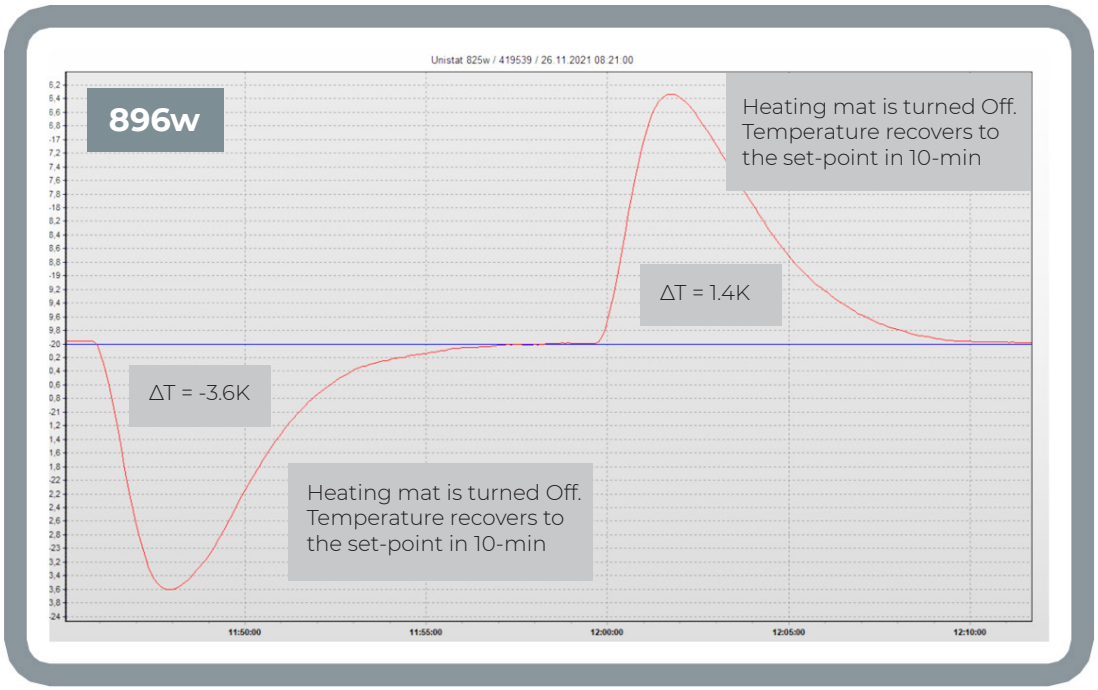
1 Recovery Curves // Set point: -50°C



Appendix

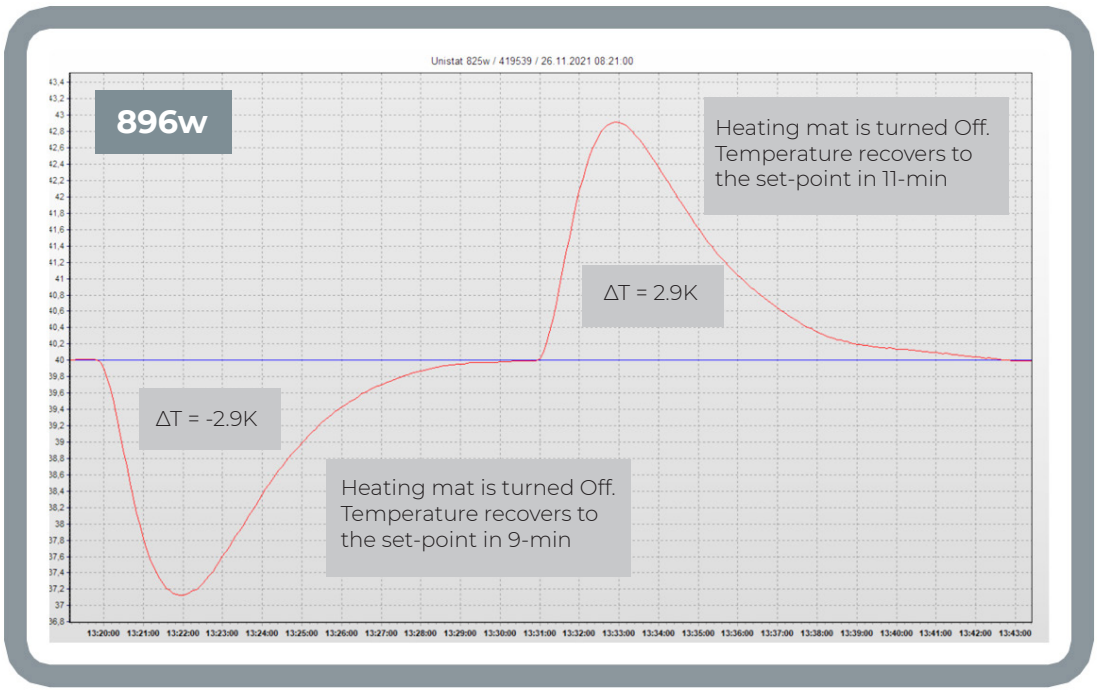
2

Set point: -20°C



3

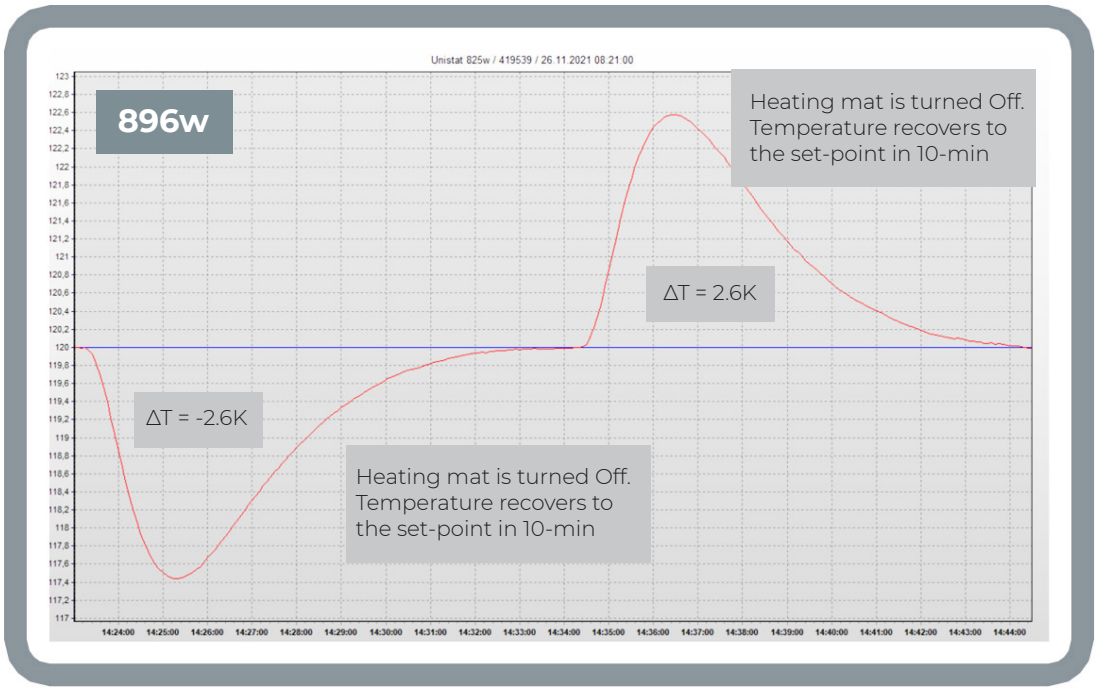
Set point: 40°C



Appendix

4

Set point: 120°C



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