# Model 1905 Temperature Controller

## User Manual



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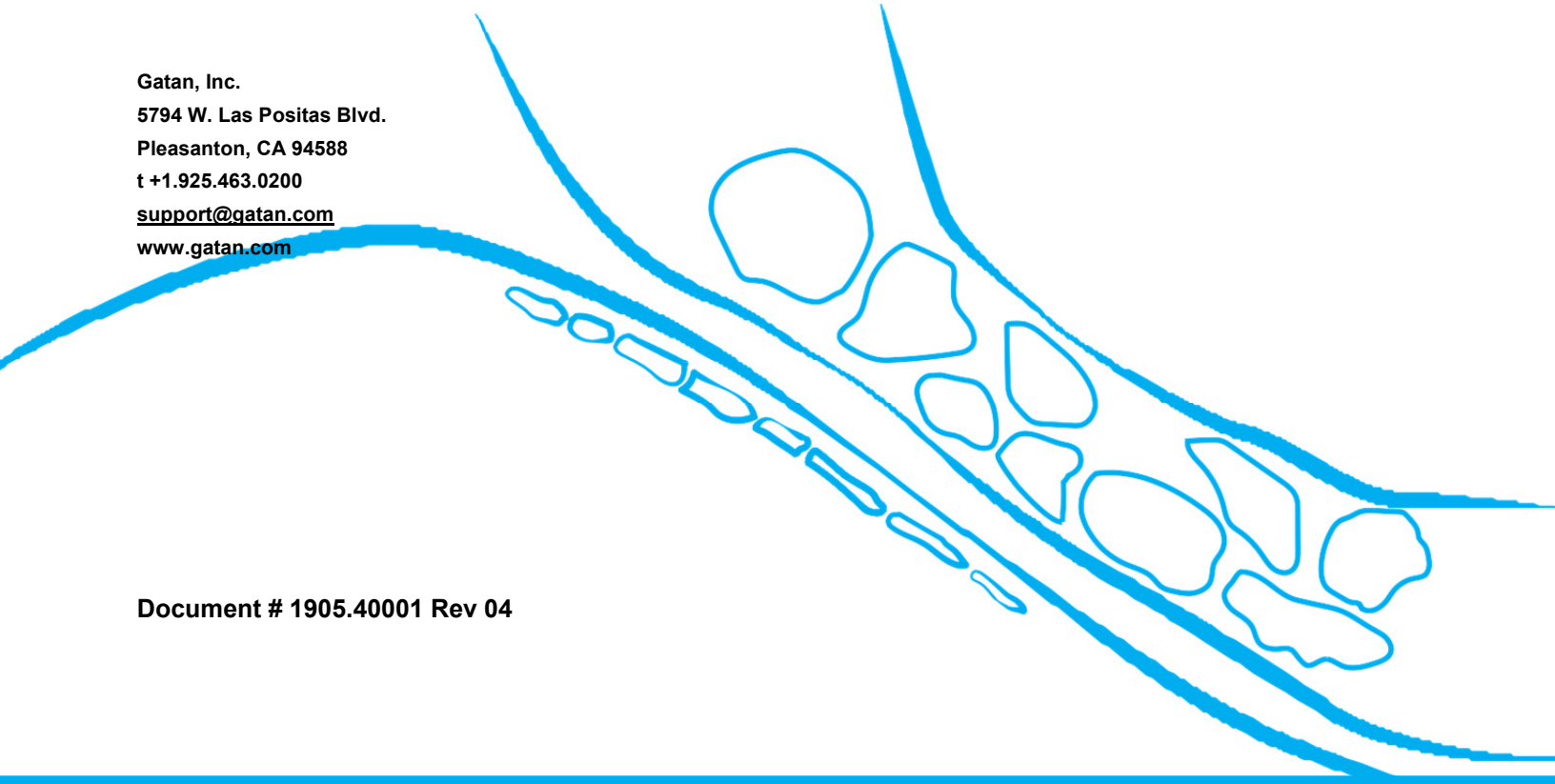

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# 1 Safety considerations

**IMPORTANT**

*Before installing and operating this product, review and read its Regulatory Pamphlet. To avoid risk of injury and potential hazards, read and follow all safety related instruction outlined in the pamphlet.*

*It is your responsibility to ensure your own safety, and that of the people working around you. If this equipment is not used in the manner specified by Gatan, the protection provided by the equipment may be impaired.*

## 1.1 User serviceability

**IMPORTANT**

*Users should not attempt to service the equipment, or perform maintenance tasks beyond those which are described in this manual. Internal access is restricted to trained Gatan or approved engineers. There are no user adjustable parts inside the controller. The controller must be securely closed before any power is applied.*

## 1.2 Applying / disconnecting power

The controller is turned on and off using the capacitive touch logo on the front of the unit. There are no switches on the rear. Power can only be disconnected by physically removing the power supply cord to the mains inlet.

To apply power, insert a suitable rated IEC mains cable plug into the AC mains supply and the IEC inlet to the 1905 controller on the rear panel. Turn the switch ON to apply power and turn OFF to disconnect power to the unit.

### 1.2.1 Positioning of controller equipment

The 1905 controller should be positioned so that it does not form a trip hazard to people in a darkened room. The mains power outlet providing power to the 1905 controller should be freely accessible to the user. If it is not, then an extension cable including a switch (and including an earth) should be included.

Ensure that there is sufficient access at the rear panel for electrical connections.

### 1.2.2 Ventilation of controllers

The 1905 temperature controller includes a fan and opposing ventilation grill on the sides of the unit. The ventilation holes should not be covered or restricted during operation. Do not position the controller in a manner which blocks access to the sides. Air is expelled from the rear of the unit. Ensure that the airflow is directed away from the microscope column to avoid imaging instabilities (drift / resolution issues).

### 1.2.3 Cleaning protocol

There is no explicit cleaning requirement for the enclosure. In the event that cleaning is required, turn the power off and wipe the exterior with a lightly damp cloth. Do not employ solvents that can dissolve paint work.

## 1.3 Wiring schematic

The following diagrams show an overview of the possible wiring configurations of the controller. For some installations the wiring configuration will be simpler than that shown.

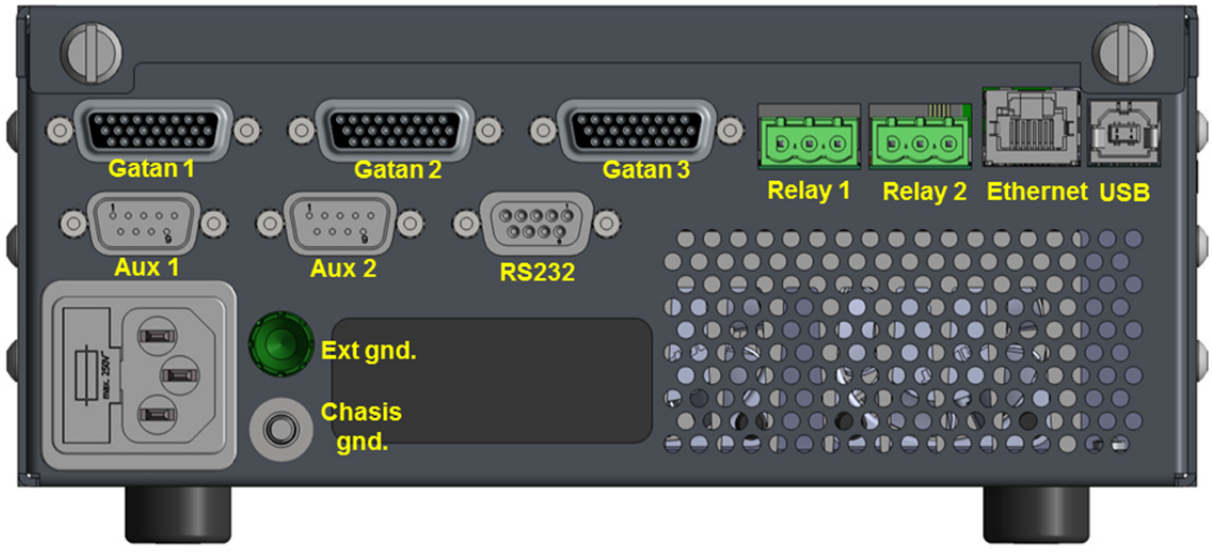


**Figure 1:** ***Rear of 1905 temperature controller.***

## 1.3.1 Gatan transmission electron microscope (TEM) cooling holders

- The supplied holder cable is connected to Gatan 1
- A PC may be optionally connected via the Ethernet port or hub

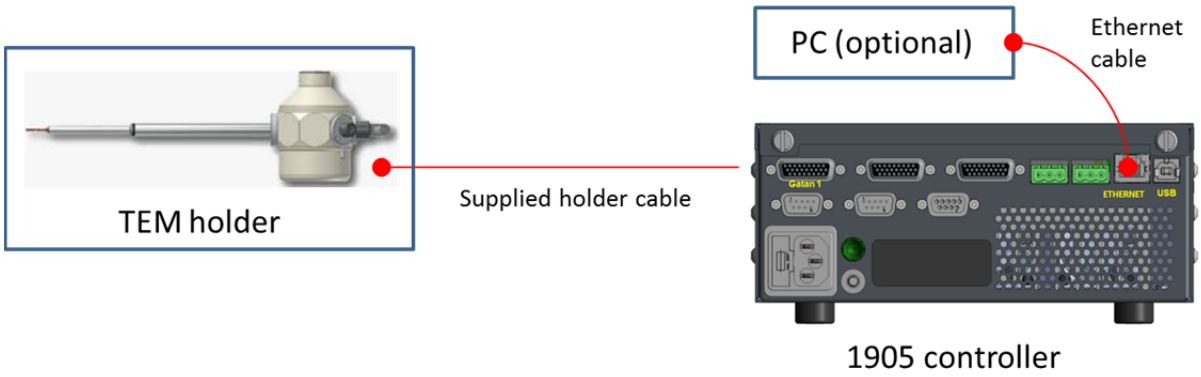


**Figure 2:** ***Gatan TEM cooling holders.***

## 1.3.2 Gatan TEM heating holders

- The holder cable is connected to Gatan 1
- If supplied a water chiller must be connected to Gatan 3
- A PC may be optionally connected to an Ethernet port or hub

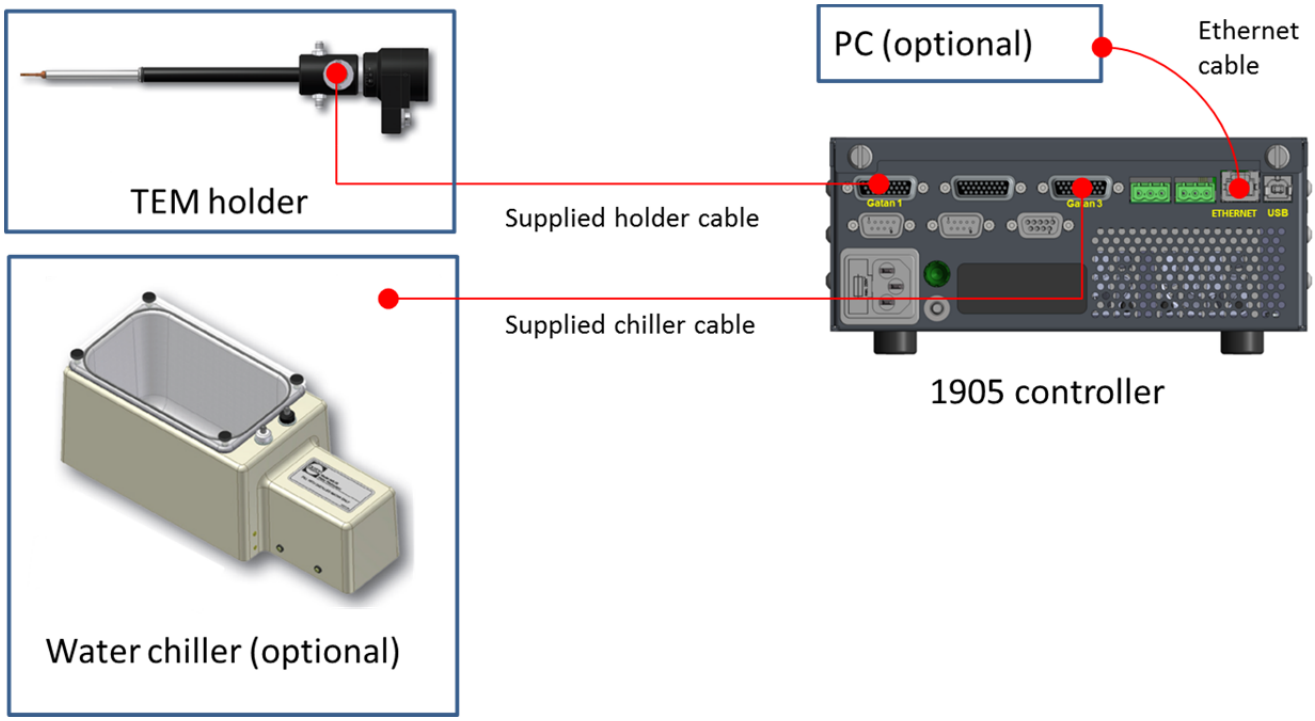


**Figure 3:** ***Gatan TEM heating holders.***

## 1.3.3 Gatan scanning electron microscope (SEM) cooling stages

- The supplied stage cable is connected to Gatan 1
- A PC may be optionally connected to an Ethernet port or hub

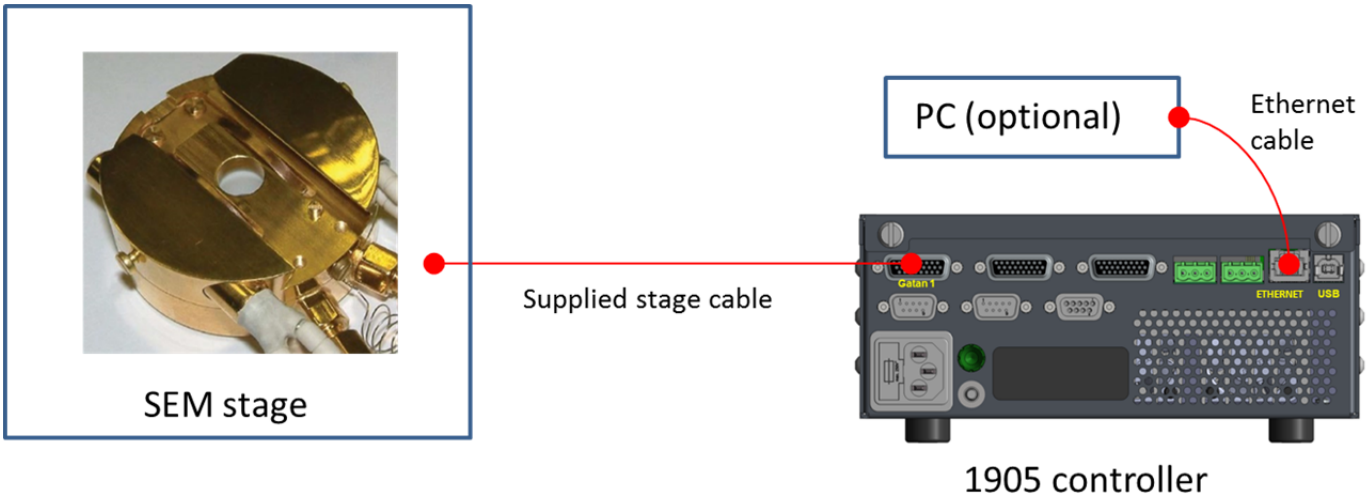


**Figure 4:** ***Gatan SEM cooling stages.***

## 1.3.4 Gatan SEM heating stages

Without an external booster power supply:

- The supplied stage cable is connected to Gatan 1
- If required, a bias power supply is connected to AUX 1
- If required, a chiller interlock is connected to AUX 2
- A PC may be optionally connected to an Ethernet port or hub

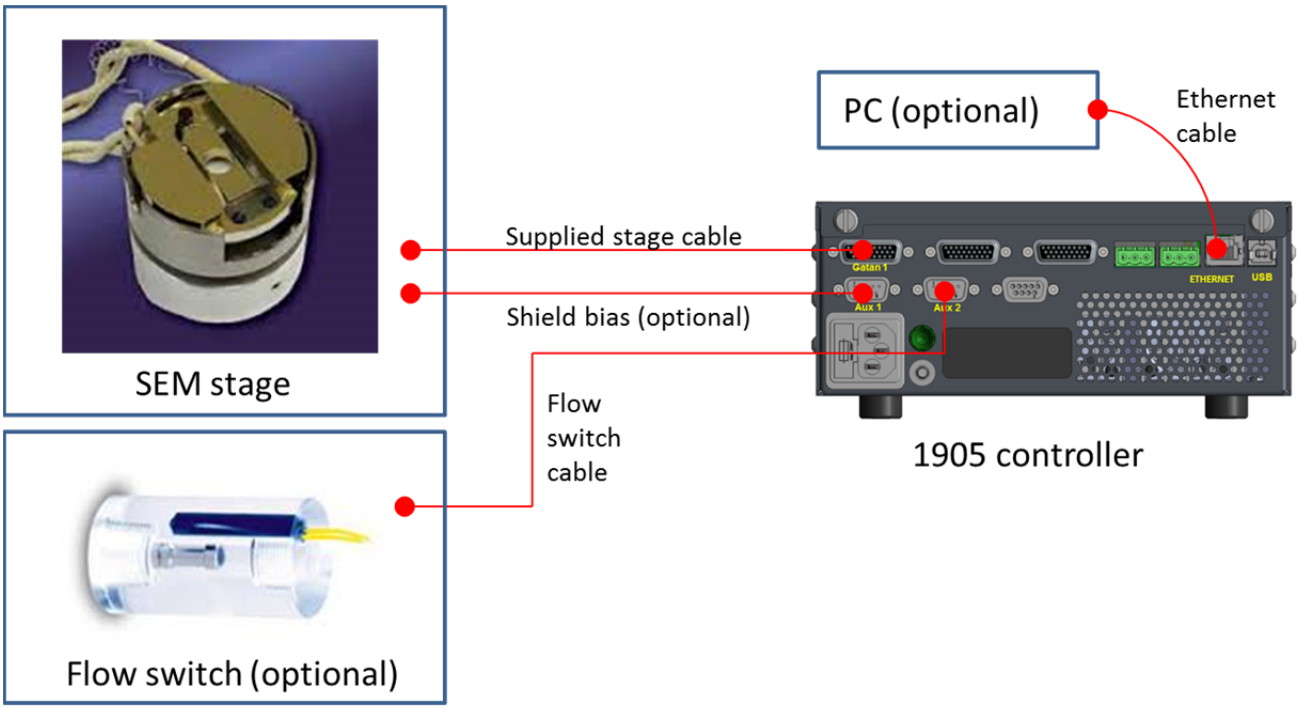


**Figure 5:** ***Gatan SEM heating stages (without external booster).***

## 1.3.5 Gatan SEM heating stages

With an external booster power supply:

- The supplied stage cable is connected to Gatan 1
- An external booster cable is connected to Gatan 2
- If required, a bias power supply is connected to AUX 1
- If required, a chiller interlock is connected to AUX 2
- A PC may be optionally connected to an Ethernet port or hub

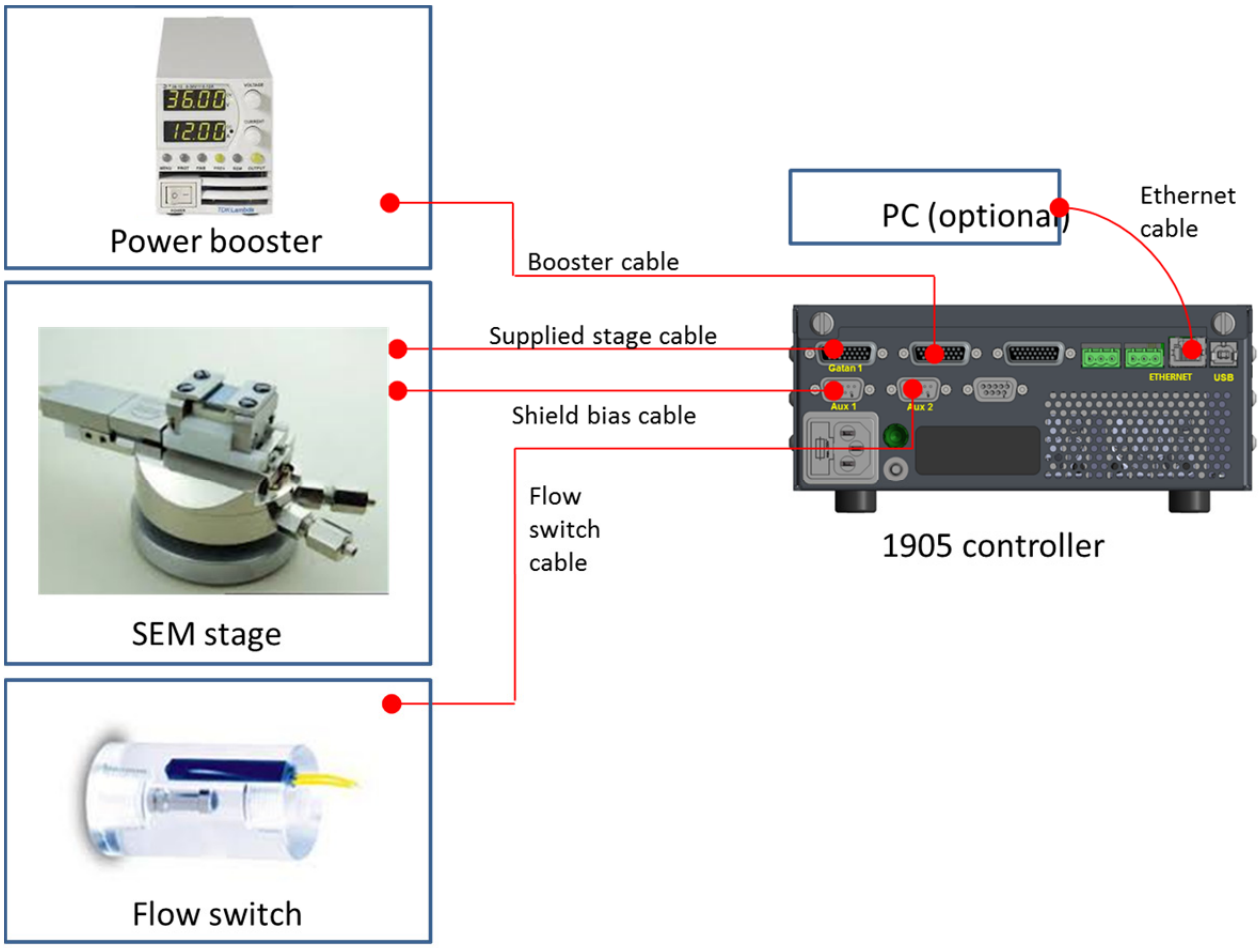


**Figure 6:** ***Gatan SEM heating stages (with external booster power supply).***

# 2 System overview

The 1905 controller is a highly versatile temperature controller capable of measuring and controlling temperatures from 4 – 1800 K and is designed to be used in the laboratory to control Gatan scientific instrumentation. It is not intended to be a generic controller that a user can setup to operate with equipment supplied by other manufacturers. There is no warranty on third party equipment used in this manner.


**Figure 7:** ***System overview.***

## 2.1 Main features

The 1905 temperature controller is contains the following main features:

- On board product Personality Profile library of Gatan products, for easy recognition and 1-step configuration on start-up
- Touch screen LCD user interface

- Temperature measurement from three types of sensor; platinum resistance thermometer (PRT) PT100; silicon diodes (DY-470 and DY-670) and thermocouples (Type T, K and R)
- Built in cold junction compensation for thermocouples
- Universal proportional, integral, derivative (PID) control settings
- Internal slew rate to protect product furnaces
- The ability to measure 2 temperatures simultaneously with a subset of different sensor types
- Maximum single channel heater power of 80 W; (40 V, 2 A, DC)
- Auto detection of cable disconnect, sensor and heater errors
- Safety limits defined per product Personality Profile and auto shut off features
- Pre-set bake out programs with configurable periods and feedback on bake out current drawn
- Simple reconnection protocol allows users to reconnect, or hot swap products without rebooting controller
- Compatibility with automatic product identification (product dependent)
    - For some microscopy products the 1905 controller is designed to be used as a plug and play instrument and is automatically configured on start-up
- Communications through Ethernet using a static IP address
- Interfaces with Gatan Microscopy Suite® (GMS) 3.0 and higher software
- Programs for cryogenic and vacuum applications (bake-out, warm-up and transfer modes)
- Controlled ramp programs

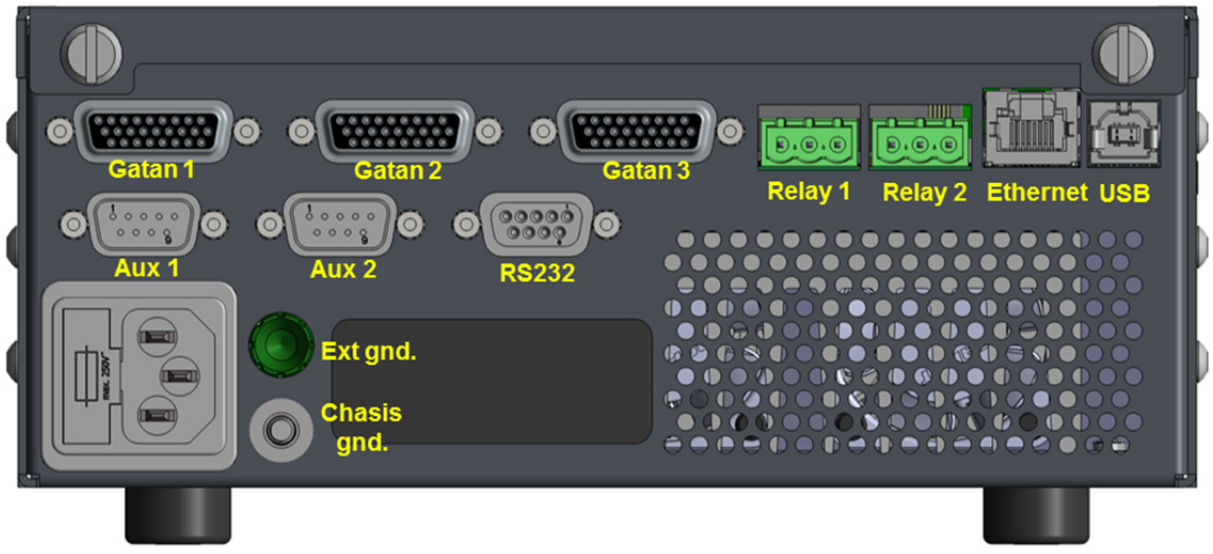


**Figure 8:** ***Connections on rear panel.***

The rear panel shown in Figure 8 has several connectors as described below.

**Gatan 1:** Used primarily for connection to Gatan TEM holders and SEM stages. The heater and sensor signals pass through this connector, in addition to other data lines for product identification and cold junction compensation.

**Gatan 2:** Identical functionality to Gatan 1. However, the 1905 controller does not support the connection of multiple Gatan products simultaneously. In some instances it may be necessary to separate heater and sensor signals across the Gatan 1 and Gatan 2 connectors. If this method of operation is required it will be detailed in the user manual for the specific Gatan product (supplied separately).

**Gatan 3:** Used for sensor only connections to Gatan TEM holders and SEM stages. In addition, this connector supplies the power for water re-circulators used with Gatan heated TEM holders.

**Relay 1 and 2:** Connectors capable of switching up to 30 V, 3 A. These are controlled through the front panel interface, DigitalMicrograph® (DM) user interface or DM script.

**Ethernet:** Used for PC control or access to the controller via a static IP address. For most users the PC will be running GMS 3.0 or higher.

**USB:** This port is currently not intended for use by users. Please do not plug a USB cable into this port.

**Aux 1:** Interface connector which supplies a programmable output voltage in addition to providing digital input/output channels for triggering. The programmable output voltage is used on Gatan SEM heating stages to supply a bias voltage for improved imaging at elevated temperatures.

**Aux 2:** This connector has an identical functionality to Aux 1, but is separately isolated to prevent ground loops or interference between separate auxiliary devices.

**RS232:** Used by Gatan factory engineers. This may also be used by field service engineers.

**External ground:** The controller has a number of grounding options available for the heater output, selectable through the user interface. There are: floating, mains (chassis) ground, external (microscope) ground or buffered goniometer ground. It the output is grounded to an external source, it should be supplied through this connector.

## 2.2 Modes of operation

There are three principal modes of heater output control; Manual, Automatic, and Ramp. For Manual control the heater power output is adjusted by the user as a percentage term of the maximum output voltage for that particular product. For Automatic and Ramp modes the heater power output is automatically controlled using a PID control feedback loop. The control loop calculation is performed with respect to an internal product specific slew rate. The appendix covers the PID theory and tuning methods used to obtain optimum PID values.

The PID values and internal slew rates are pre-configured by the factory with settings specific to the product the controller is intended to be used with. These are stored within the on board product library or personality profile electrically erasable programmable read only memory (EEPROM). As the EEPROM is product and not controller specific, the EEPROM is located in the product's unique type of cable.

PID optimization is often defined as a balance or compromise between temperature stability at a target, the approach rate, and the size and time period of any overshoot or undershoot. The internal slew rate provides additional protection to the performance of furnaces whilst minimizing such compromises.

For the majority of users performing microscopy experiments, slightly over-damped PID values are favored. This is because they promote maximum stability once a temperature is reached over the speed with which a temperature is reached. Such settings slow down the approach rate and minimizes overshoot of temperatures.

The internal slew rate is more important on products with a very small heat capacity, or where there is a large thermal lag between furnace and sensor. The slew rate works in tandem with the PID control loop to ensure that the controller does not strain delicate furnaces, and provides additional control stability over a wide range of operating conditions.

Some Gatan products are intended to work in different regimes with different thermal loads. For example some cryogenic products also operate above ambient when no cryogen is utilized. Also, heating holders will experience more radiative losses at the top end of their working range than the bottom. In order to provide optimum control in these different regimes, the 1905 controller is designed to work with multiple PID zones. Internal hysteresis is applied to ensure that control stability is not compromised at zone boundaries.

## 2.3 On board product Personality Profiles library

The memory inside the 1905 controller contains multiple Personality Profiles specific to different Gatan thermometry products. For example different products have different sensors, furnaces, safe operating ranges and power limits as well as PID settings. Upon start-up, the user is prompted to select a product range from TEM or SEM, and from Heating or Cooling and to identify their product from a list. The default naming convention for the product personality is the Gatan Model Number.

Newer Gatan products support automatic detection. In this case the product cable provides an identification signal when the Detect button on the product selection page is pressed. This allows the controller to be a plug and play instrument without the need for the user to choose the product Personality Profile. See the product user manual for details of whether this feature is supported.

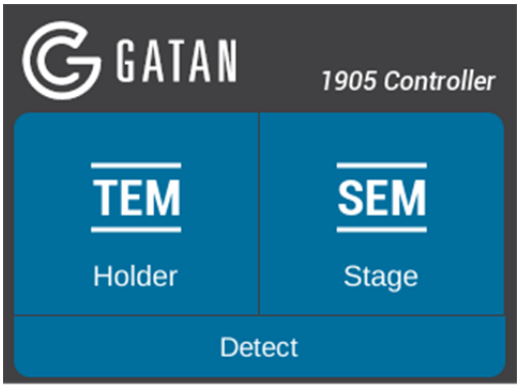


**Figure 9:** ***Product choice screen on power up.***

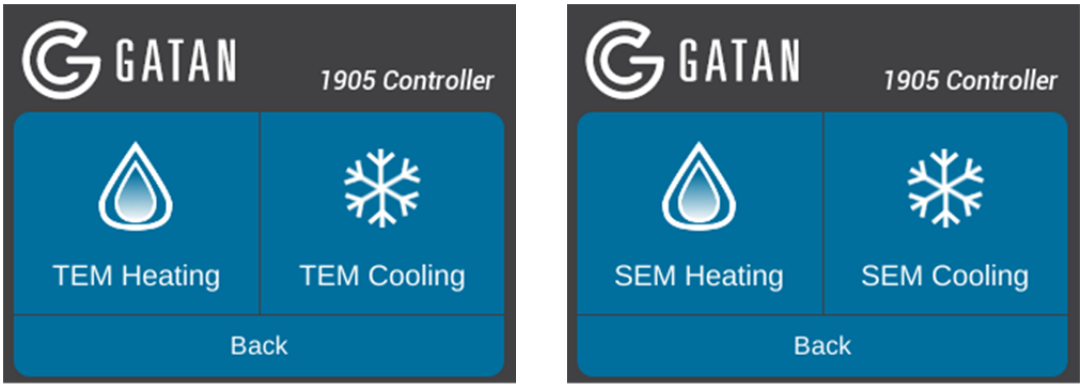


**Figure 10:** ***Product type selection for TEM (left) and SEM (right).***

Where Automatic Detection is not supported on older product, the user needs to select the correct product from sub menus divided into TEM and SEM, and Heating and Cooling sub-menus.

For some Gatan products the internal temperature sensor has changed during the life of the product. In particular the silicon diode (Type 5 [DY-470]) utilized on many cryogenic products became obsolete and Gatan replaced this with a similar specification diode (Type 6 [DY-670]). The difference between a Type 5 and a Type 6 sensor is the algorithm required to provide a calibrated temperature. In order to help the user choose the correct personality, the personality contains and extension number ".5" or ".6" and this is highlighted on the accompanying cable. The diode obsolescence took place between 2015 and 2016.

Please note that if you choose the wrong personality sensor type 5 or 6 for your product, then this will be evident through an incorrect temperature reading at ambient. For example if a Type 5 sensor is in the product and a type 6 personality is chosen, then instead of reading 22C at ambient, the temperature will show approximately 39C. Choosing the wrong sensor type will not damage the sensor, it will only result in an offset to the calibration.

The personality extension label ".T" is used to identify where a Type T thermocouple is the temperature sensor. This is only used where the sensor type has changed during the lifespan of the product. Again the cable will be labelled to show where a Type T thermocouple is used.

## 2.4 Temperature measurement

The 1905 controller temperature measurement is configured for three types of sensor; platinum resistance thermometer (PRT) PT100; silicon diodes (Type 5 / DY-470 and Type 6 /DY-670) and thermocouples (Type T, K and R). On start up the sensor will be automatically selected according to the product Personality Profile. Unlike some other controllers, the 1905 controller will self-calibrate on start-up and no further procedures are required to start reading temperatures. Users should not need to be concerned over which temperature sensor is employed as long as the correct product Personality Profile is selected.

*Note: For thermocouples, the temperature measurement accuracy is slightly dependent on the thermal stability in the room, and in particular the area to the rear of the controller where the cold junction compensation is housed. Please allow clear ventilation access at the rear of the controller.*

## 2.4.1 Dual temperature measurement

The 1905 controller can be configured to have 2 separate measurement inputs. As inputs are shared on the multiple connectors, it is possible to have these 2 channels on only one of the connectors, or spread across 2 of the connectors. There is no direct mapping of Sensor 1 to Gatan 1 connector and Sensor 2 to Gatan 2 connector. It is not possible to have the same type of sensor on each channel. The majority of products from Gatan contain only a single sensor. The configuration of which channel contains which sensor is configured in the Personality Profile of that product.

Details of second sensors will be provided in the appropriate product manual.

| Sensor 1 | Sensor 2 |
|---|---|
| PRT | Thermocouple (T,K, or R) |
| Silicon diode (5 / DY-470 or 5 / DY-670) | Thermocouple (T, K or R) |
| Thermocouple (T,K, or R) | PRT |
| Thermocouple (T, K or R) | Silicon diode (5/ DY-470 or 6 / DY-670) |

It is important to understand that sensor 2 is a supplementary measurement only channel. Where 2 sensors are present, the second sensor is always shown in the GUI as a smaller font. In Figure 11 below, the second sensor is reading 83.7 °C as shown in the top right hand part of the screen. Please note the heater output will always be with reference to Sensor 1 which is always shown centrally as the larger font.

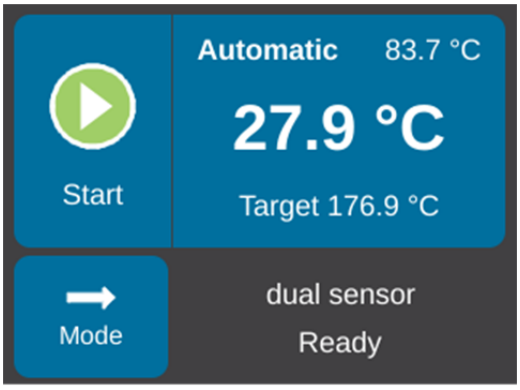


**Figure 11:** ***Home screen for a dual sensor configuration.***

Where 2 sensors are present, these are detailed in the Sensor information screen. An example is shown in Figure 12. It is not possible for the user to re-program the unit to switch these functions as they are configured specific to a pre-defined product type.

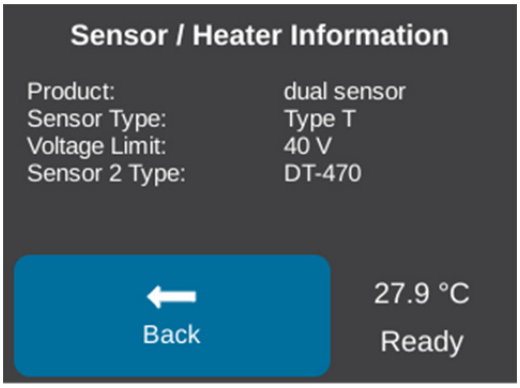


**Figure 12:** ***Sensor / Heater Information screen for dual sensor configuration.***

Temperatures recorded from Sensors 1 and 2 if present can be utilized for *in-situ* experiments through DM software.

## 2.4.2 Powered heater output

The maximum output voltage (Vmax) forms part of the product Personality Profile and is set to match the power rating of the product's furnace. The absolute maximum power rating of the 1905 controller is 80 W at 40 V.

The maximum voltage, current or power output is limited at the factory according to the product Personality Profile. When the unit is set to manual mode then the user can control the power output as a percentage of the pre-set Vmax. For precise control, the user can specify heater output voltages in steps with resolution 0.01%.

## 2.4.3 Unpowered heater output

The 1905 controller can be used to control a furnace via a combination of an unpowered heater output signal and an external power supply, normally intended for delivering power in excess of 2 A or 80 W. The external power supply and cables for Gatan 1 and Gatan 2 will be provided as part of the product package. Gatan 1 will provide the temperature measurement but no heater output if the Slave configuration is used. In some literature the power booster may also be termed a 'slave'.

For products requiring the booster output for temperature control, the 1905 controller will have pre-set PID values to control only the external power supply. It is not recommended to use an alternative supply to that supplied as the temperature control parameters (PID values) will vary with output power used, and the product may not be safe.

# 3 Getting started

## 3.1 Installing the 1905 controller

For some products where installation is ordered, the 1905 controller will be provided as part of the wider installation. For other simpler products, the user may connect the controller to the mains, to the product, and optionally to a computer for software control. If the user is installing the product, then please refer to the safety information in the compliance pamphlet which accompanies this manual.

Connect the 1905 temperature controller to the product using the cables provided. Ensure the 1905 is placed in appropriate location to ensure the cables can reach both the product and 1905 controller. Attach the cable to the product and to 1905 controller according to the wiring diagrams in Section 1.3. Ensure the connectors are secure by tightening the screw-locks. Do not over-tighten these locks.

## 3.2 Turning the controller on and off

If the unit is connected to powered main at the rear mains inlet, then the Gatan logo will illuminate blue at low intensity and the intensity varies over a few seconds. To turn the controller on or off, then the user needs to touch the Gatan logo button for approximately 2 s. The power change sequence will be evident. When powered, the blue logo is brighter and doesn't change in intensity. The unit can be powered down from any state without harm, (other than to the outcome of an experiment).

The controller takes some time to boot up the processor during which time GATAN should be highlighted as text on the LCD touch screen. The initial illumination intensity is reduced. The touch screen only becomes active once the boot up sequence has completed. Once the controller is powered up, choose the correct product personality according to the description in section 2.3.

## 3.3 Introduction to the user interface

Each screen of the user interface contains distinct touch areas which behave as specific buttons. The home screen of the user interface is displayed upon start-up after the Gatan product has been chosen or detected. In its default state, the measured temperature is displayed along with a target temperature. If the unit is powered down, the last used target temperature is not recalled, rather the target temperature is simply a pre-set in the product Personality Profile definition file.

In this initial state, nothing is active apart from the measurement. The heater is set to OFF with 0% output power and no control loop running. The temperature units are preset as part of the product Personality Profile. In this example the controller is connected to Gatan heating holder model number 652 and the Ready statement indicates there are no errors detected. The Start button is an action button that will perform the program mode as identified on the home screen. In the case shown below, pressing Start will activate the PID temperature control to reach the stated target temperature of 330 K.

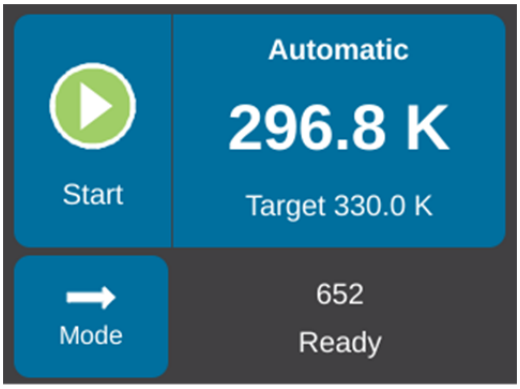


**Figure 13:** ***A home screen for a 652 Gatan holder.***

Pressing the bottom left Mode arrow button opens a new screen shown in Figure 14.

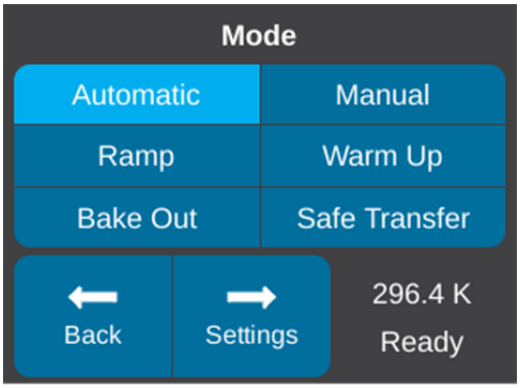


**Figure 14:** ***Mode screen.***

The mode screen is used to choose the mode of operation which will start once the Start or Resume button is pressed on returning to the Home screen. It is not possible to change modes whilst a program is active unless the Hold button has been pressed. The Hold button is common to many screens and is presented as a choice between Stop and Hold once Start has been pressed. Pressing Hold always sets a new target temperature to the currently measured temperature and Holds at that temperature until another action is requested. The only exclusion to this rule of allowing change when Hold is pressed is associated with Manual mode. It is not possible to switch to and from Manual mode when any program is active. The user must press stop to allow this change. This is programmed as a safety feature.

To simplify the choice for the user, the listed modes presented are controlled by the product Personality Profiles, so only choices pertinent to that product should be shown.

Pressing the Settings arrow button opens a new screen shown in Figure 15.

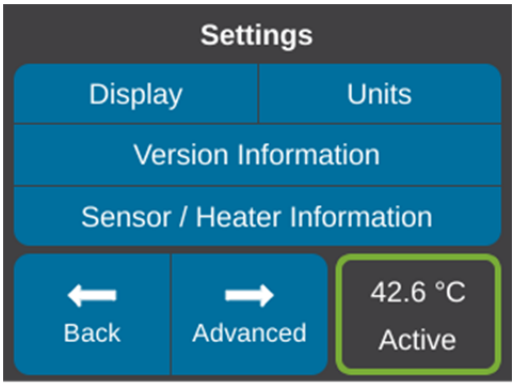


**Figure 15:** ***Settings screen.***

The user can choose new screens or go back. Multiple back presses are required to reach the home screen again which is the primary user interface for starting, pausing, resuming and stopping specific actions.

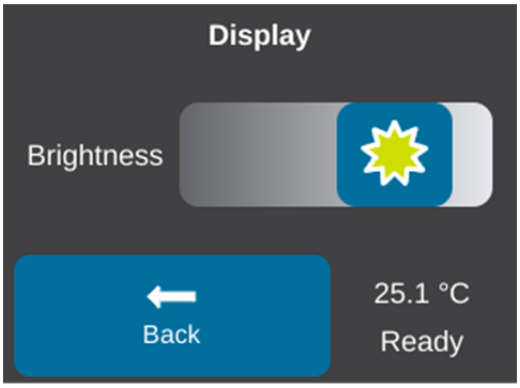


**Figure 16:** ***Display settings screen.***

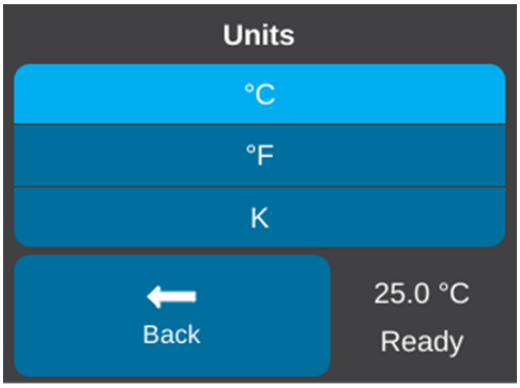


**Figure 17:** ***Temperature Units screen.***

If a choice is made on different units, then these are applied universally across all the screens.

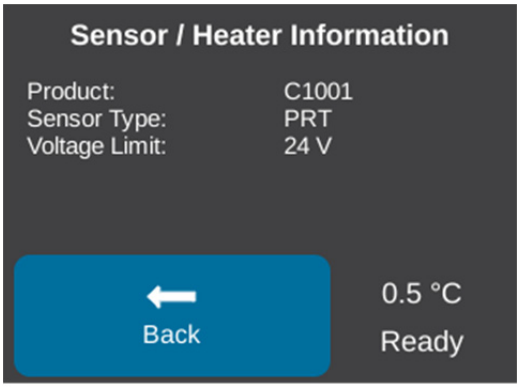


**Figure 18:** ***Sensor / Heater information screen for single sensor configuration.***

The Sensor / Heater information screen shows the sensor type, and maximum voltage that can be applied for that specific product alongside the temperature and status of the controller.

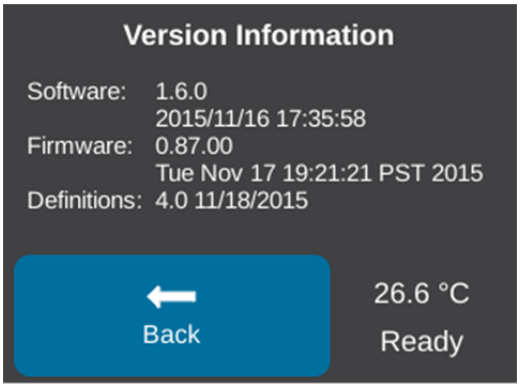


**Figure 19:** ***Version Information.***

The Version Information screen provides details of three sets of files. These are the Software and Firmware versions together with the product personality profile definitions. This information may be useful to the factory, field service, or to aid diagnostics.

# 3.4 Main program modes

## 3.4.1 Automatic

Automatic means PID temperature control to achieve a target static temperature as displayed. The default condition is for there to be a single set of PID terms to cover the product over the entire temperature range. The target set point is chosen by the user within the limits of the product defined in the product Personality Profile. To enter a new target temperature, press the Target part of the screen to open a new dialogue. Press on the number to allow a new number to be entered. The software does not allow a temperature which is out of range for the product connected.

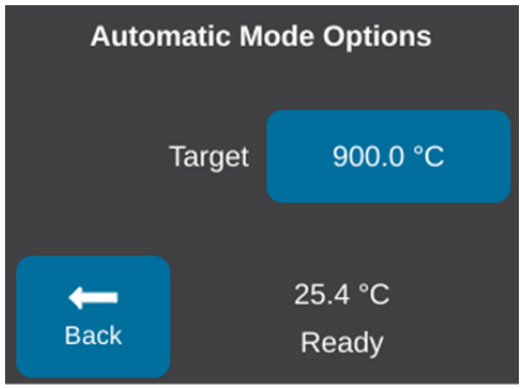


**Figure 20:** ***Enter a new target temperature.***

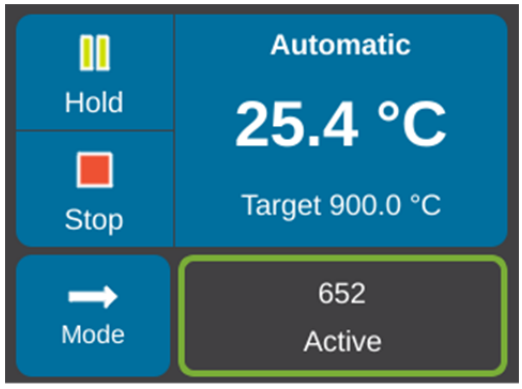


**Figure 21:** ***Options to Hold or Stop.***

Once Start has been pressed, then the lower right area is shown highlighted in green as being Active. Furthermore the actions buttons presented to the user are now either Hold or Stop.

If Hold is pressed, then the current measured temperature becomes a new temporary target temperature, and the Automatic PID control loop is not interrupted.

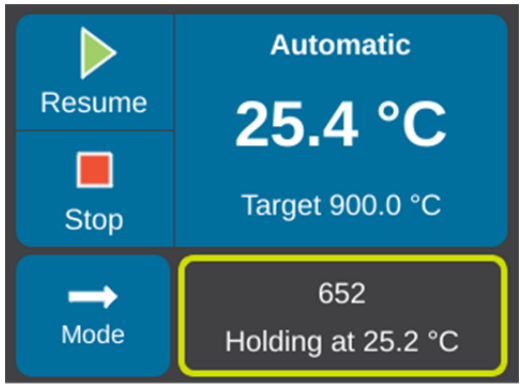


**Figure 22:** ***Options to Resume or Stop from Holding Mode.***

If Hold has been pressed, then the display keeps the original target temperature, (for example 900 °C), but also shows the temperature the system is being held at. Pressing Resume removes the temporary target temperature and continues with the PID control to the original target temperature. Whilst in Hold mode, the

user can navigate to other modes and edit configurable parameters without interfering with the temperature control loop.  This mode of operation allows the maximum flexibility. Pressing Stop terminates the PID control loop and removes heater power.

## 3.4.2 Manual mode

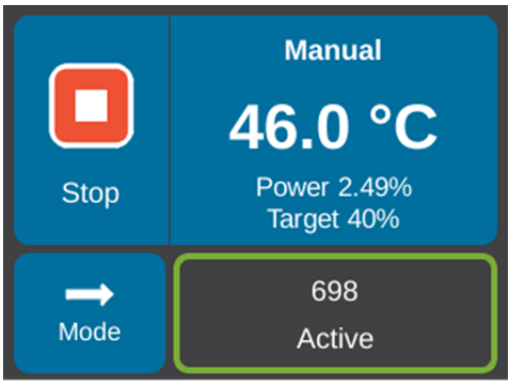


**Figure 23:** ***Manual mode.***

When Manual mode is chosen, the user can specify a target constant power output. This may allow users to achieve the maximum image stability once equilibrium conditions are met. In order to protect fragile furnaces, manual power is applied incrementally until the target power is reached. The ramp rate for the manual power increment is part of the product personality. If a lower power setting is requested this is applied immediately. Gradual changes in power are only applied for increases.

Depending on the furnace impedance applying a high or maximum power may trigger an alert condition where the maximum temperature or maximum safe current for the furnace is exceeded. Please see section 3.6 for more information on error conditions. If an error is triggered then simply reduce the power and re-apply a lower target.

To configure the power, press the large button showing the temperature and then select a value on the power configuration screen as shown below and press apply. If power is already on, it is possible to adjust the power without pressing stop. A new power target is active once the Apply button is pressed. If power is not already on, then pressing Apply chooses that setting.

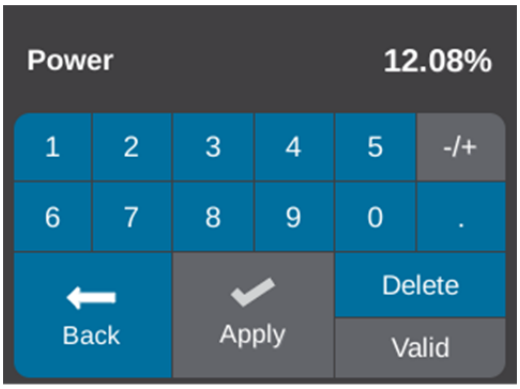


**Figure 24:** ***Entry dialogue for manual power***

It is not possible to enter more than 100% power. For fine control, power can be requested in steps of 0.01%. If an incorrect entry is made, then the Valid button is shown as de-activated. Note, the percent target and reported power is really a percentage of the maximum voltage that can be applied to the product and not a true map of the resistive heating power which is a non-linear relationship with voltage.

Once target power is configured, press the Back arrow to go to the Home screen because power is only applied once the Start button is pressed.

*Note: Once the Start button is pressed the mode cannot be changed until the Stop button is pressed.*

### 3.4.3 Ramp mode

A ramp can either increase or decrease in temperature. Temperature control is a balanced between heater power and cooling power or thermal losses. Sometime cooling power is configurable (manually) and sometime not. Gatan does not currently supply products where the cooling power is controlled in tandem with heating power as controlled by the 1905 controller. This means that some ramp rates up or down may not be achievable and users will need to understand the limits of their thermal apparatus.

A ramp is effectively a moving target temperature with the PID control loop turned on. A slow ramp may be employed for example with products with a large thermal lag where the user wishes to avoid any overshoot.

The Ramp Mode Options screen is found by pressing on the measured temperature. It is possible to edit all values when a Ramp has not started, or else when in Hold mode. Once Start has been pressed, then it is no longer possible to edit the Ramp duration or the Start Temperature. To edit these, the user must either be in Hold mode, or have stopped the Ramp.

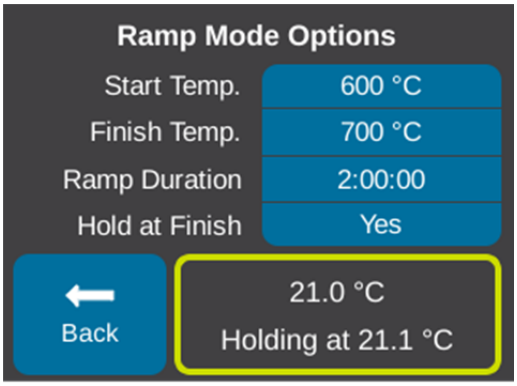


**Figure 25:** ***Ramp mode options.***

When the user presses Start from a ramp screen, the system will show a screen saying Attaining Ramp Start until the measured temperature is within 1degree of the start of the ramp temperature. Whilst in this mode, the Ramping has not started. Once the target temperature has been reached to within 1degree, then the screen will display Ramp in Progress and the ramp time remaining is shown as a live count-down clock.

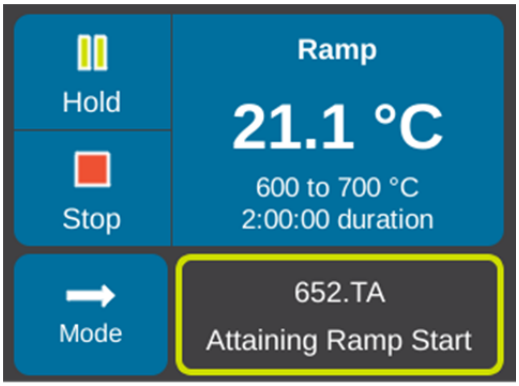


**Figure 26:** ***Attaining Ramp Start***

Please be aware that since the controller does not actively control cooling, then the system may wait in initialization mode for a considerable time if the start ramp temperature is lower than the currently measured temperature. Likewise if the ramp start temperature is slightly more than 1degree above the measured temperature. If this condition is hindering experimental progress, then press Hold to allow the Ramp Start Temperature to be edited to one which is achievable more quickly.

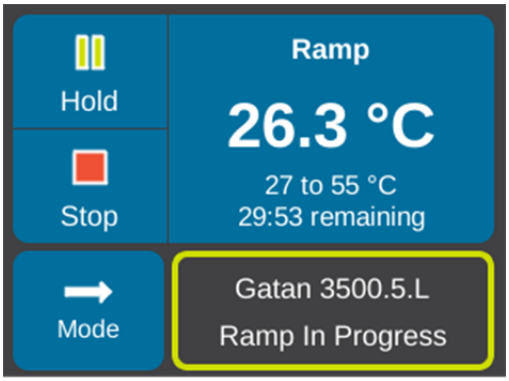


**Figure 27:** ***Ramp in Progress.***

Once Start has been pressed, the system is either going to be in the initialization mode of Attaining Ramp Start or Ramp in Progress. In either mode it is possible to press the Hold button. As in other modes, when Hold is pressed, the currently measured temperature becomes a new temporary target temperature and the clock and Ramping is therefore paused. When in this mode it is possible to edit only the Finish Temperature and the Hold at Finish option.

Once Resume is pressed, then the same or new Ramp parameters are utilized and the clock restarts the countdown. Also, the resumed target temperature will be that from the resumed Ramp program, and not the measured temperature when Hold was pressed. This is normally posed no problem whilst the measured temperature is close to the target ramp temperature.

When the Hold at Finish option is Yes, then the PID loop remains on and the target temperature for the end of the ramp remains the target temperature. When Hold at Finish is No, then the program terminates and the PID control loop and heater power is turned off.

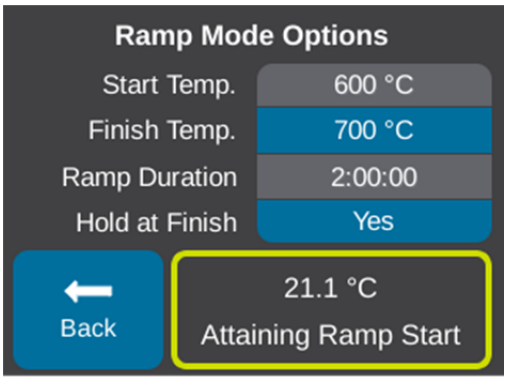


**Figure 28:** ***Editing Ramp Mode Options whilst Ramp is active.***

If more complex ramp and holder options are required, users are encouraged to use the recipes tool communicating with the controller through Gatan DigitalMicrograph software.

## 3.4.4 Bake Out mode

Bake Out mode is made available by the Personality Profile. Bake out is a common term in vacuum science whereby a product is held at a predefined elevated temperature whilst under vacuum. A Bake Out should only be performed when the vacuum status of the equipment is correctly configured. For TEM holders, the bake out program is specifically designed to recharge the sorb in order to achieve a suitable quality vacuum in the dewar space. This vacuum space is independent of the microscope vacuum. Bake Out is therefore normally performed on TEM holders when the dewar vacuum is connected to a suitable high vacuum pumping station. For TEM holders do not attempt a Bake Out until you have established a suitable vacuum pumping system for both the rod and the dewar. The controller has no intelligence of the vacuum conditions so this is entirely the user's responsibility.

For other products, the Bake Out may simply raise the temperature of the whole product, and therefore the user is responsible for ensuring the vacuum space is appropriate. Bake Out mode applies a higher set point for a timed period which is configurable by the user. In all cases the Bake Out clock only starts counting down once the Bake Out temperature has been reached to within 1 °C.

For certain TEM holders from Gatan, the dewar heater is an additional heater to the rod / tip heater and both are activated during bake out. Irrespective of the number of heaters the controller automatically applies appropriate power to reach a pre-configured temperature. The time period for the program is configurable. This is achieved by pressing the Bake Out button, entering a new duration.

To activate Bake Out, press start and the screen will shows that the system is initializing. Initialization is complete and the Bake Out clock starts only when the Bake Out temperature is reached. The current drawn in the Bake Out process is displayed live and for some sorbs this provides a useful indication of the progress and quality of the Bake Out and the associated surrounding vacuum. As the sorb re-generates and the surrounding vacuum increases in quality, the current required to achieve the preset temperature drops.

When Bake Out is active, other functions are disabled. If the user stops or pauses the Bake Out, then power is removed. Resume re-applies power and the count down once the temperature is reached.

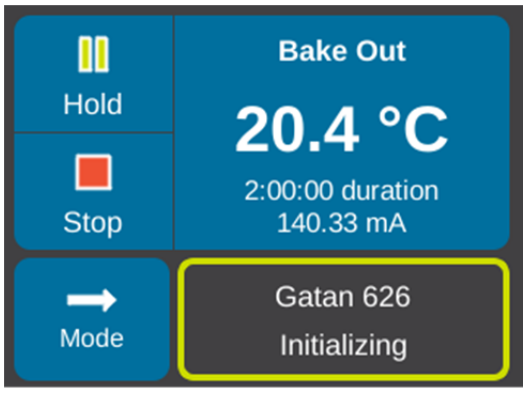


**Figure 29:** ***Bake Out Initializing.***

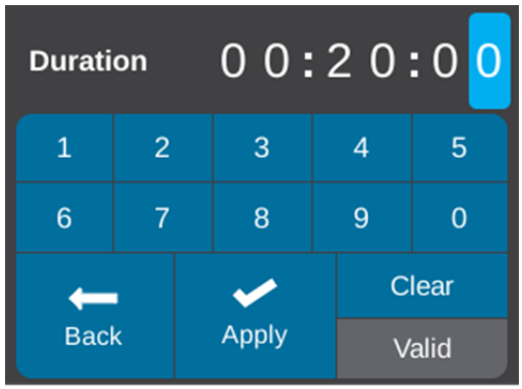


**Figure 30:** ***Configuring Bake Out Duration.***

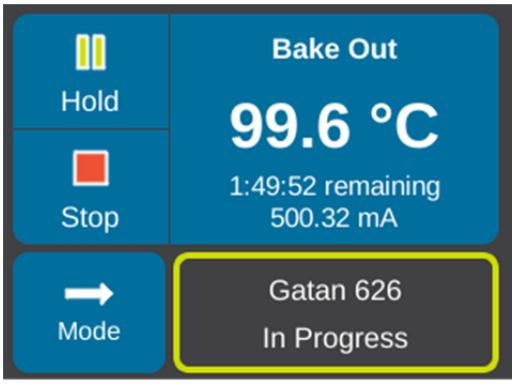


**Figure 31:** ***Bake Out In Progress.***

## 3.4.5 Cryogenics: Warm Up mode

Warm Up mode will normally only be present for devices which are cooled to operate. Warm Up mode is a configurable timed ramp designed to raise the temperature to ambient. When start is pressed, the count-down clock starts and the remaining time is displayed. Like Bake Out mode, the user is entirely responsible for the vacuum environment and any safety precautions associated with this. When cryogenic devices are held cold for a considerable period they act as cryo-pumps especially when they are the coldest object in the

vacuum space. When they warm up, considerable outgassing can take place which may harm certain vacuum environments if precautions are not taken.

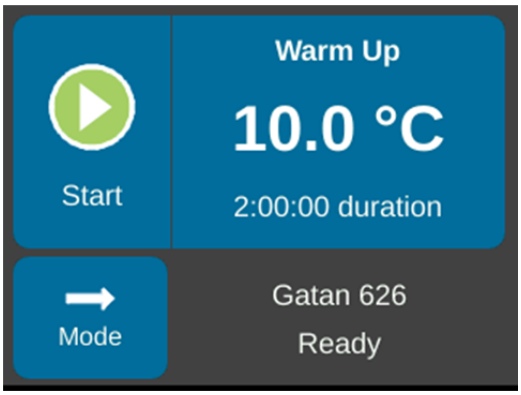


**Figure 32:** ***Warm Up mode.***

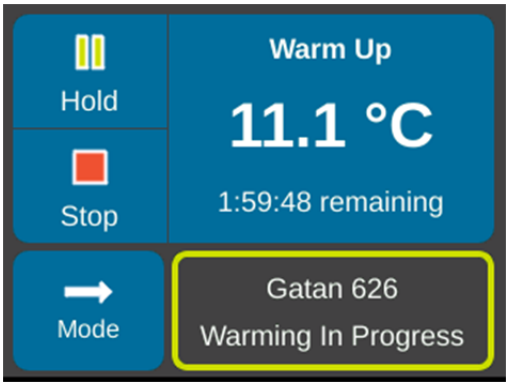


**Figure 33:** ***Warming In Progress.***

## 3.4.6 Safe transfer mode

### Cryo-transfer mode

Safe cryo-transfer mode is only present as a mode for cryo-transfer devices. When Safe Transfer is selected and Start is pressed, the user is presented with a screen message Wait to Load whilst the measured temperature is higher than predefined target temperature. This message changes to OK to Load once the measured temperature is lower than the target temperature.

As the controller does not instigate cooling or active temperature control in this mode, it is the user's responsibility to remember to perform the required steps for safe cryo-transfer. The controller program simply acts as an aid to the process, and the safety aspect refers to the act of keeping the specimen in a suitable amorphous, frost-free state optimized for electron microscopy. There is no time out for this mode of operation. Rather the user should change modes if they wish to start controlling temperature.

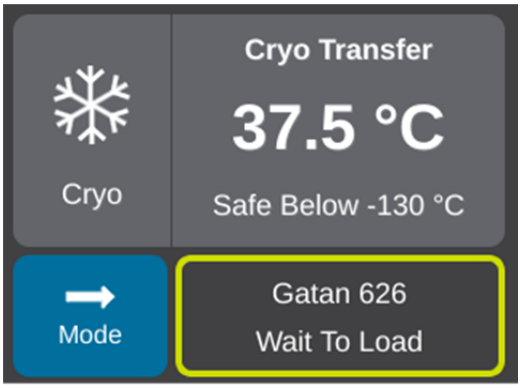


**Figure 34:** ***Safe cryo-transfer screen.***

### Heated transfer mode

Safe transfer mode is designed for select products which operate above ambient. It is normally safer practice and a better method to protect delicate specimens by restricting removal from the vacuum environment till a safe temperature close to ambient is reached. When Safe Transfer is selected and Start is pressed, the user is presented with a screen message Safe to Remove only once the pre-defined safe target temperature is reached. There is no time out for this mode of operation. Rather the user should change modes.

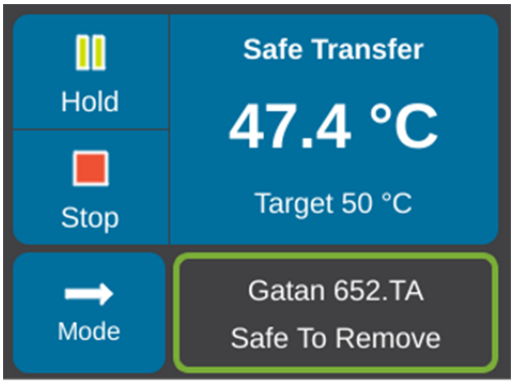


**Figure 35:** ***Safe transfer to heated product.***

# 3.5 Alerts

The 1905 temperature controller contains several safety features which are designed to protect the specimen, the product, and provide a limited amount of diagnosis to potential error conditions.

## 3.5.1 Cable or product disconnect status

Once a product type is selected on start-up, the controller expects that specific product and cable to be connected. If the cable is not connected then an alert is shown which allows the user to simply select Continue to reconnect to the same product and clear the alert. An alternative button Select Holder allows the user to connect to a different product. When this button is pressed, the user is presented with the original home screen which prompts the user to select the product they are connecting to.

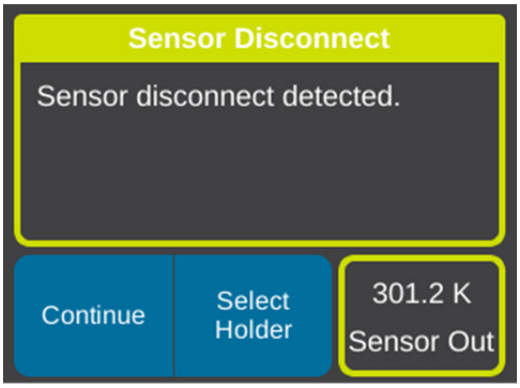


**Figure 36:** ***Sensor disconnect alert.***

# 3.6 Warnings

## 3.6.1 High temperature alert

If the measured temperature is higher than the maximum allowed temperature for that holder, then a Hot Alarm is triggered and heater power is terminated to protect the product. The user should only dismiss the error once a safe operating temperature has been reached. Users should be cautious about restoring power without diagnosing the cause of the error.

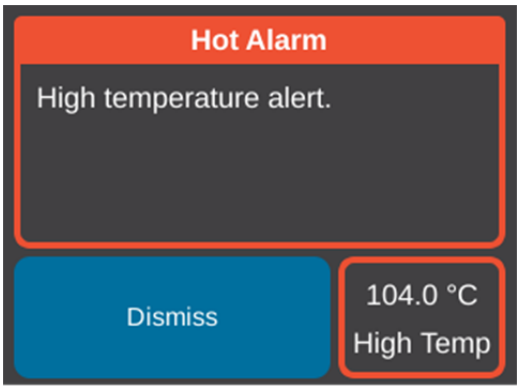


**Figure 37:** ***Hot Alarm.***

## 3.6.2 Control Loss

The temperature controller may show a Control Loss error in case the target temperature is not achieved within a timeframe expected by the controller once Automatic control is underway. When a Control Loss error is shown, the error indicates the measured temperature at which the error condition occurred, and heater power is disabled. To re-enable control, dismiss the Error and press Start once more. Control Loss does not necessarily indicate a failure of the controller. Rather it could indicate problems associated with different aspects of the experimental hardware. The Control Loss error status and thresholds which trigger this event are part of the Personality Profile.

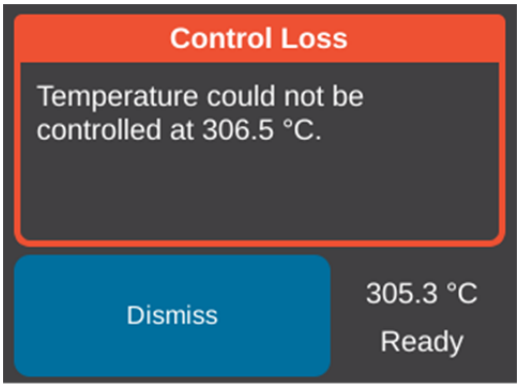


**Figure 38:** ***Control Loss.***

## 3.6.3 Heater Short

The resistance of the heater is a defined characteristic of the product. If this resistance falls too low, then the controller will disable heater power and show a red warning message of a potential heater short (circuit). Heater shorts can occur if wires become damaged, for example by getting trapped. Users should investigate the potential cause of such problems and contact Gatan field service in case help is required.

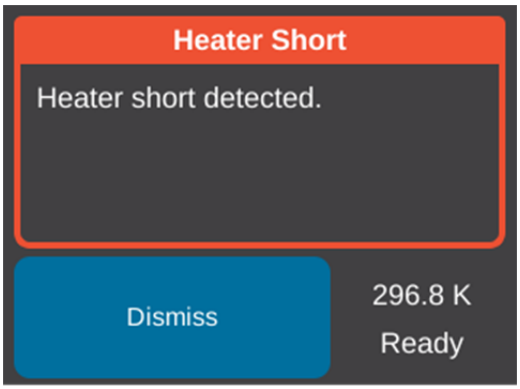


**Figure 39:** ***Heater Short error condition.***

## 3.6.4 Heater Disconnect

Like the Heater Short error, if the heater resistance is too high, then the controller provides a red warning message and disables heater power. Users should investigate the potential cause of such problems and contact Gatan field service in case help is required. The product will not function correctly if the heater or cabling is damaged and the controller is programmed to disable the heater in this condition.

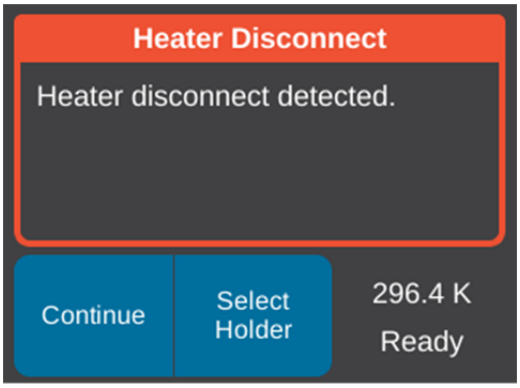


**Figure 40:** ***Heater Disconnect error condition.***

## 3.6.5 Sensor short and sensor disconnect

For some sensor types, the controller will detect a sensor short or sensor disconnect. In all conditions the heater power (including bake out heater) is disabled. The controller is unable to distinguish between a sensor problem and the user intentionally removing the cable. Hence if the system reports a sensor issue and the cable and product remain connected, this provides some diagnosis as to a potential problem with the system. The controller cannot differentiate between an issue with the cable and the product. The alerts are designed for Sensor 1 only, and not for an optional second sensor channel.

## 3.6.6 Current Limit

If the defined Current Limit for the product heater is exceeded then the controller presents a red Current Limit warning message and the heater output is disabled. This status will only be triggered if a threshold current is exceeded when heater power is being applied (i.e., in manual, automatic, warm up or bake out modes). The user should investigate the cause of this error prior to resuming the experiment. This alert can be cleared if the problem with the product or cable is resolved.

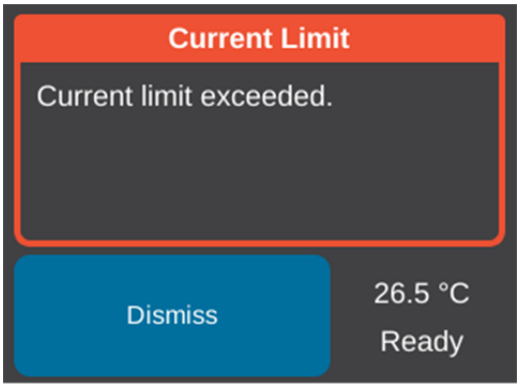


**Figure 41:** ***Current Limit alert.***

## 3.6.7 Coolant Flow Monitor

If the personality of the product is set to monitor coolant flow, then when this error condition arises, the system will show this error and will disable power in all modes. When coolant flow is re-established then the user is informed about this change in status. The user must manually re-apply power. Once triggered, the user cannot dismiss the error condition to re-apply power unless coolant flow has been detected.

The 1905 controller monitors coolant flow using the Digital Output line and Digital Input line on AUX2 as a source and monitor, with the signal normally being routed through a flow switch. When the personality is set to monitor coolant flow, the AUX2 Digital Output is set by default to High, and cannot be adjusted by the user. Coolant flow error will be true whilst Digital 2 is read as Low.

Please note, coolant flow monitor is not always defined on as personality when re-circulators are present. It is normally only present when coolant flow switches are integral to the safety protection of the product.

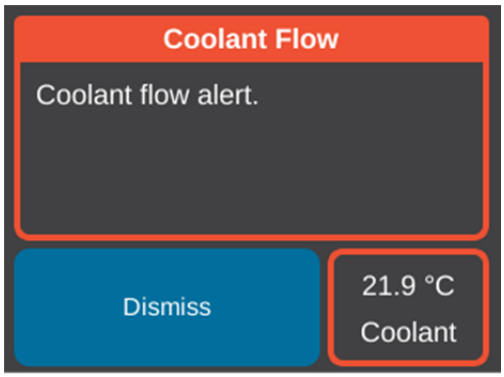


**Figure 42:** ***Coolant flow alert.***

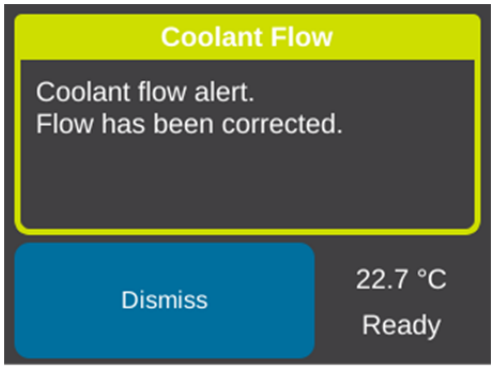


**Figure 43:** ***Coolant Flow has been corrected.***

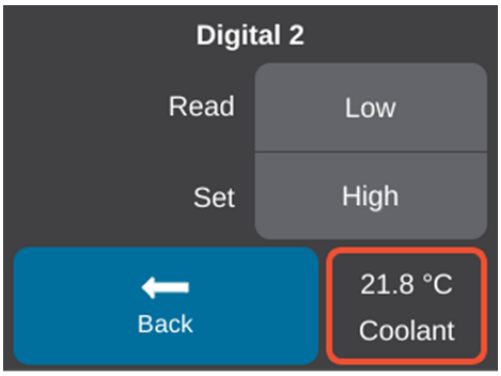


**Figure 44:** ***AUX Digital 2 Read and Set dedicated to coolant flow.***

# 3.7 Severe warning: Controller failure

## 3.7.1 Heater Over Current

This status indicates a major problem with the internals of the controller and is different to the current limit alert described in Section 3.5.5. This message indicates a fault with the unit and in this condition power is disabled. If this error message is shown, then please contact Gatan field service as the unit will normally require a factory repair. This condition can be triggered if the internal temperature exceeds 65 °C, and this would normally open happen if the internal fans are broken and the unit has been used to supply heater power for some time.

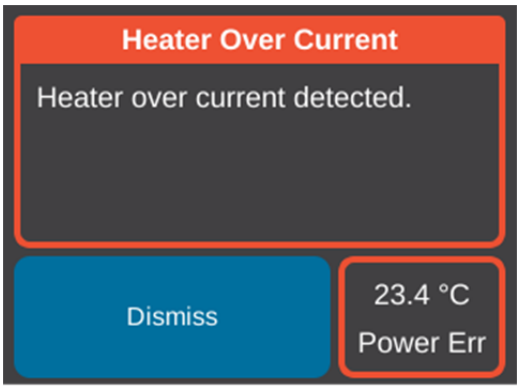


**Figure 45:** ***Heater Over Current warning.***

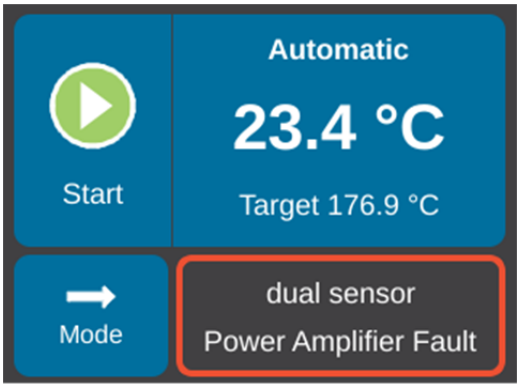


**Figure 46:** ***Power Amplifier Fault.***

If the user dismisses the Heater Over Current message, then a Power Amplifier Fault message remains on the screen. Do not confuse the Heater Over Current message with a current limit alert since the two conditions are very different. The Heater Over Current message is a fault in the power amplifier as shown in a follow up screen message.

# 4 Advanced settings

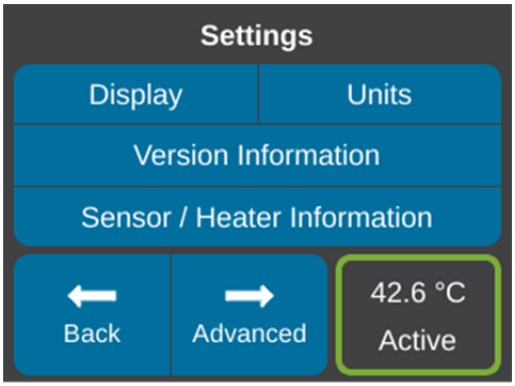


**Figure 47:** ***Settings screen.***

The settings screen contains an Advanced button which takes the user to an Advanced Settings screen described below.

## 4.1 Change Connected Product

Choose this button to choose another product. When pressed the system shows that it is disconnecting. Once disconnected you have a choice of re-connecting, or choosing another product. If this latter option is chosen then you are taken back to the product personality choice / detect screen.

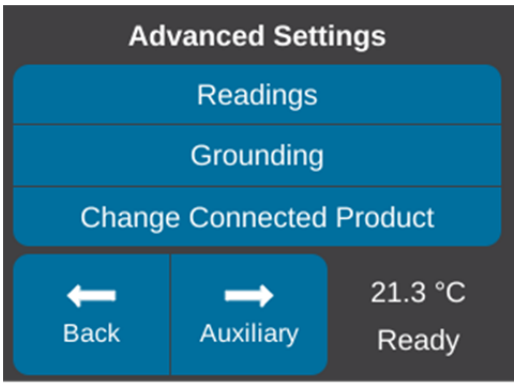


**Figure 48:** ***Advanced Settings screen.***

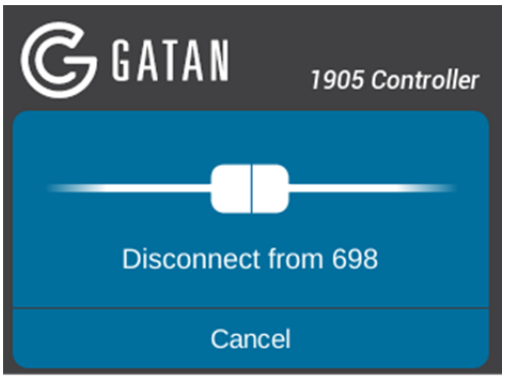


**Figure 49:** ***Disconnect screen.***

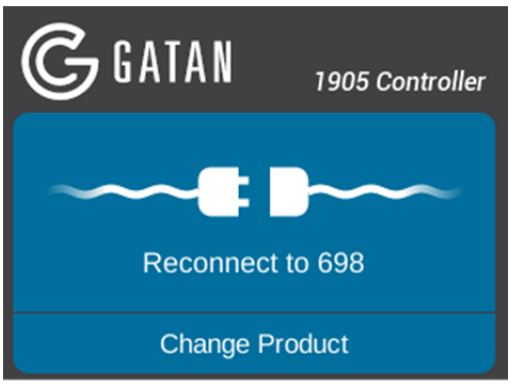


**Figure 50:** ***Reconnect screen.***

## 4.2 Readings

The Readings screen shows the Sensor temperature together with a live display of the applied Voltage and Current being drawn across the heater. If heater power is being applied, then a green box is highlighted as active. The Readings screen is a useful check on the health of the system.

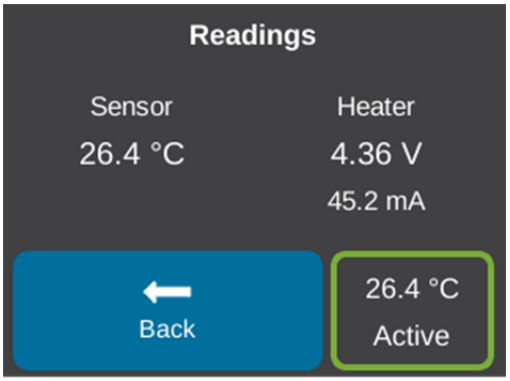


**Figure 51:** ***Readings screen shows live update of temperature, voltage and current.***

## 4.3 Grounding

The 1905 controller must remain grounded to mains earth through the mains inlet at all times. This is a safety requirement.

The 1905 controller has 4 different grounding schemes for the holder or stage being connected. A default choice is predefined in the factory. However, an alternative choice can be saved by the user, for example if there is a requirement to be compatible with a microscope stage touch alarm. Normally one grounding scheme will be optimum such that the user does not need to alter this setting regularly.

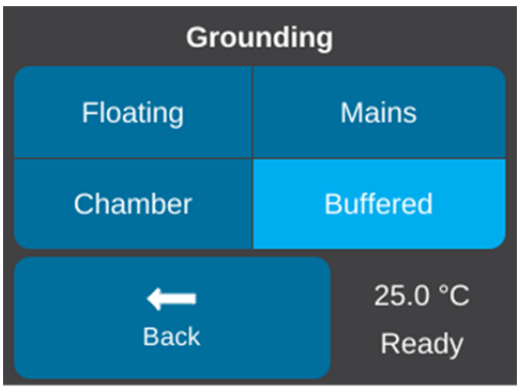


**Figure 52:** ***Choice of Grounding configurations.***

## 4.4 Local Limits

The 1905 controller has local limits preconfigured by the Personality Profile for each Gatan product. The local limits define the maximum temperature of the product which can be measured prior to a warning being presented and the heater power being disabled.

Vmax is the maximum operating voltage that can be applied to the product heater (not the bake out heater). The Imax is the threshold current which can flow before an alarm status is triggered which disables heater power. Imax is therefore not an operating ceiling, but a safety threshold.

These limits are pre-determined for a product personality and are only accessible through the front panel interface if the controller is set into engineering mode. These limits are normally only adjusted by editing or creation of a new profile.

## 4.5 PID Settings

PID refers to the algorithm in the controller which determines the heater output required to stabilize the temperature at the target temperature. There is a section on Advanced PID Theory in the appendix. The 1905 controller operates either with a single set of PID values (fixed PID), or a range of up to 10 PID values which apply to specific temperature spans (PID zones). The product personality profile defines which is used, the number of zones, and the PID values for each zone.

For most products there is some thermal lag due to heat capacity and a degree of insulation between the furnace location and the sensor location. The PID values are a compromise between speed of approach to the target temperature, minimizing overshoot, and achieving a stable temperature. For some products the ability of the PIDs to achieve these attributes will depend on cooling power which is under manual control.

The PID values, like the limits are pre-determined for a product personality and are only accessible through the front panel interface if the controller is set into engineering mode. These limits are normally only adjusted by editing or creation of a new profile and are not expected to be adjusted by users.

## 4.6 Auxiliary settings

The Auxiliary Interface is selected through the Advanced Settings screen. The Auxiliary interface is employed on a select number of products where the actions may be pre-configured. Alternatively some of the actions may be achieved by scripting commands from the DM software, or through this user interface itself.

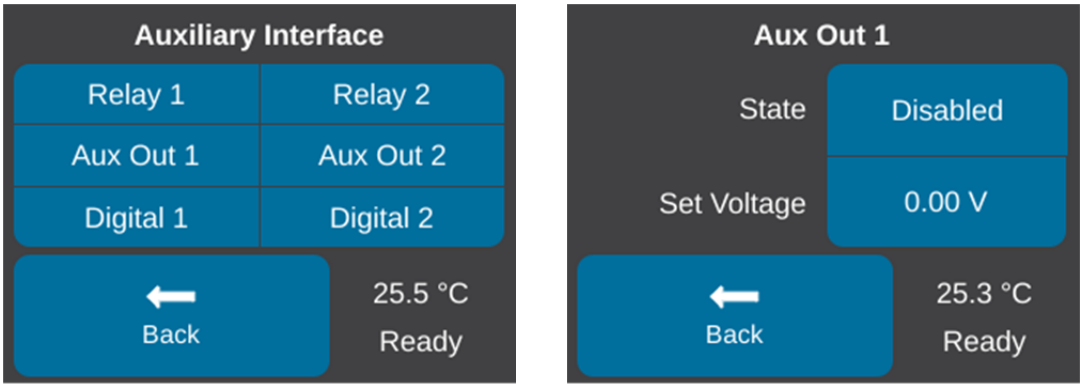


**Figure 53:** ***Auxiliary Interface (right) & Aux Out (left).***

Aux Out 1 and Aux Out 2 can be configured to provide an analogue voltage output on their respective connectors.

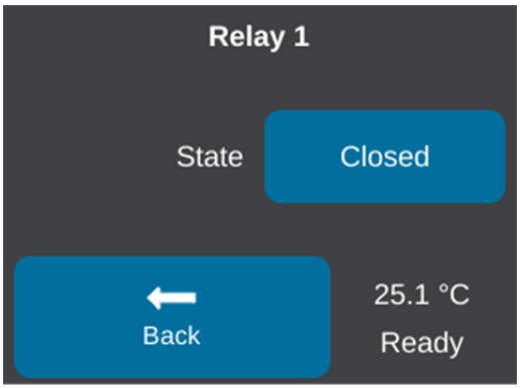


**Figure 54:** ***Relay Configuration.***

Relay 1 and Relay 2 can be configured as Open or Closed.

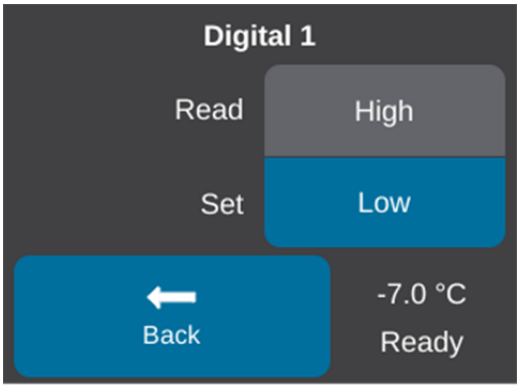


**Figure 55:** ***Digital Read and Set.***

The Digital Outputs on Digital 1 and Digital 2 can be Set Low or High, and the Digital Inputs can be Read as Low or High.

# 5 PC communication

## 5.1 Ethernet

The Ethernet port is the default method of communication with the controller via the DM software platform. The controller requires GMS 3.0 or later, which is supported on a 64-bit Windows platform.

Communication is only allowed with one 1905 controller at a time. This requires an online GMS license which includes a holder and an acquisition device such as a camera or DigiScan™. An Ethernet cable is supplied with each controller.

### 5.1.1 Setting up the PC Ethernet connection

The1905 temperature controller is designed to use a static Ethernet connection. The Ethernet port on the PC must be configured correctly in order for the PC to communicate with the 1905 controller. The steps necessary are:

1 Open the Windows Network and Sharing Center configuration page. From the Windows Start Menu, select **Control Panel**, then Network and Internet. From here, select the **Network and Sharing Center Page**.

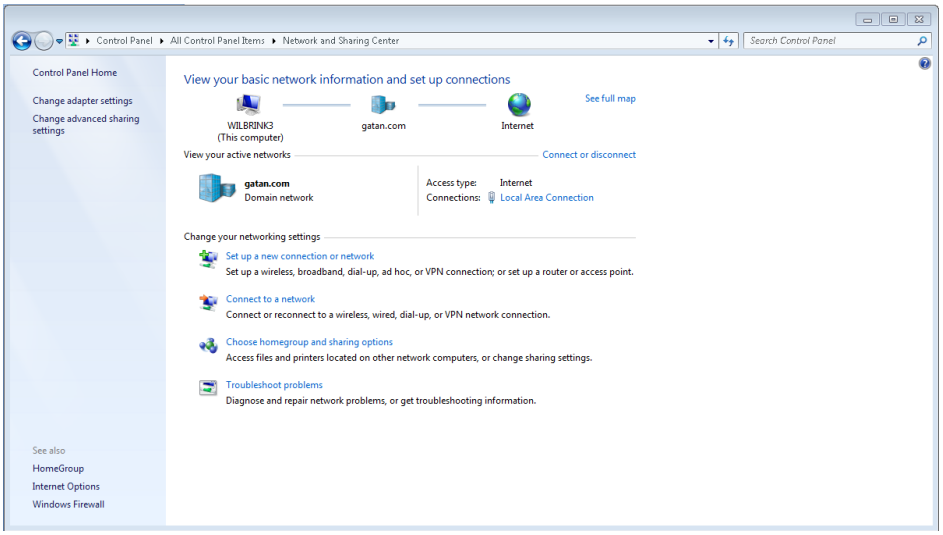


**Figure 56:** ***Network and Sharing Center Page.***

2 Select the connection you want to modify, e.g., **Local Area Connection**, and click on it. This will display the Local Area Connection Status window.

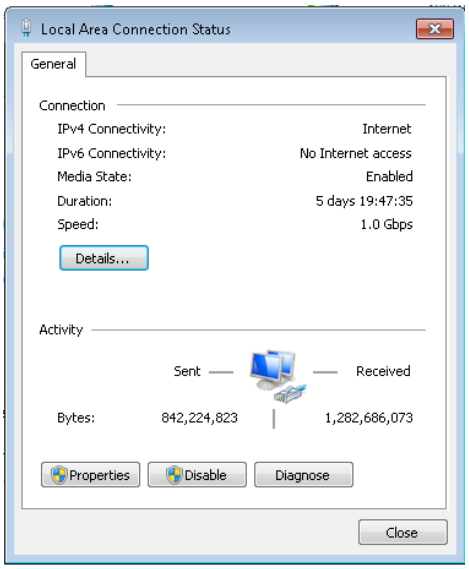


**Figure 57:** ***Local Area Connection Status.***

3 Click the **Properties** button. This will display the Local Area Connection Properties window.

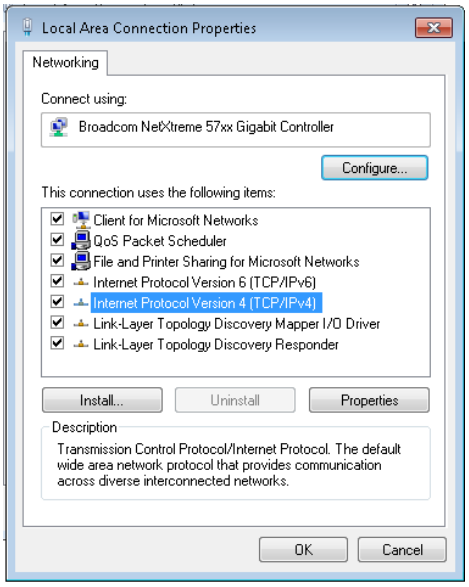


**Figure 58:** ***Local Area Connection Properties.***

4 Click on **Internet Connection Protocol Version 4** and click on the **Properties** button. This will display the Internet Protocol Version 4 Properties window.

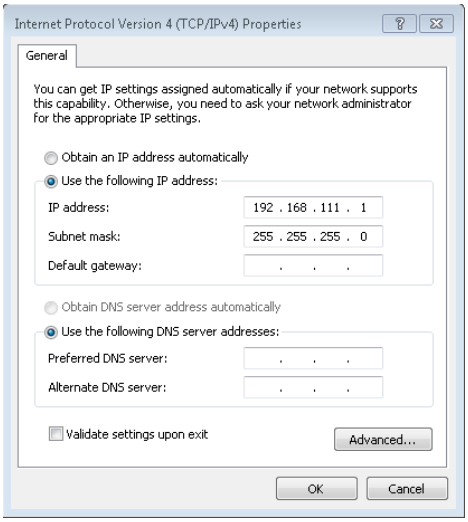


**Figure 59:** ***Internet Protocol Version 4 (TCP/IPv4) Properties.***

5 Select **Use the following IP address**

6 Type in the IP address: **192.168.111.1** and the Subnet Mask **255.255.255.0** as shown above

7 Click **OK** to save the configuration

## 5.1.2 Configuration of DM software

DM software must be configured with the correct Ethernet address setting to communicate with the 1905 controller:

1 From DM's *Microscope* menu, select **Setup**. Then select the **Holder tab** to display the Holder setup page.

2 Select the **Gatan 1905** from the Controller Type dropdown list

3 Enter the Ethernet address of the holder. This defaults to **192.168.111.61**. You do not need to specify a port.

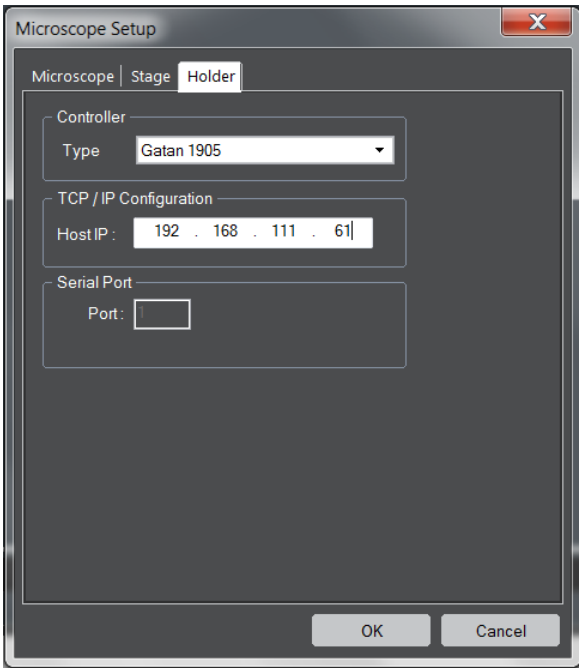


**Figure 60:** ***TCP/IP Configuration in Holder Microscope Setup***

4 Click **OK**. You will need to restart DigitalMicrograph for these changes to take effect.

## 5.2 *In-situ* software functionality

Once communication with the controller is established then *in-situ* software functionality can take place, for example automatic tagging of Gatan Digital Camera and DigiScan images with temperature data.

## 5.3 GMS User Interface

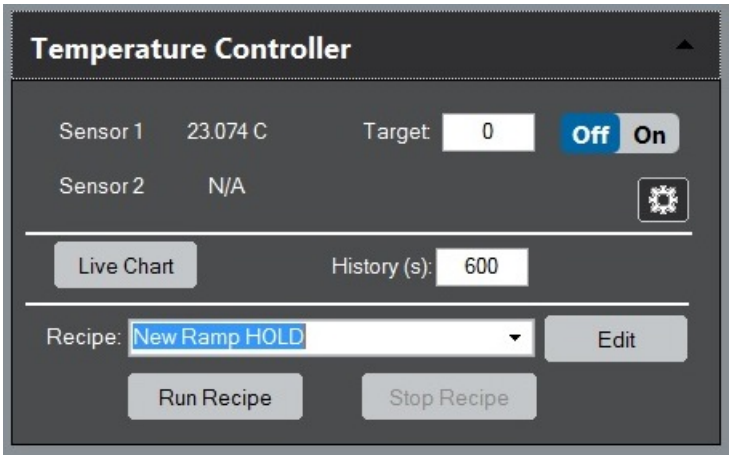


**Figure 61:** ***DigitalMicrograph Temperature Controller window***

Once communication is established a live temperature reading is shown in **Sensor 1**. If communication is not established, this shows a static temperature of 20C. Sensor is shown either as N/A or as a live reading depending on whether it is configured as part of the product personality profile. The temperature reading and charting functions work with the controller in any mode. However, setting the **Target** temperature, toggling the **On** / **Off** status and running recipes should only be attempted with the controller set to Automatic mode. Please do not attempt to use this with the unit set in Manual, Bake out, Warm up, Single Ramp program, or Transfer modes.

It is possible to enter a new **Target** temperature in this window. A freshly entered Target Temperature will also be updated as the Target Temperature shown on the controller in Automatic mode. Toggling **On** / **Off** is identical to toggling **Start** / **Stop** in the GUI and this is also updated in parallel.

## 5.3.1 Live charts

Enter the history as a configurable entry in seconds and press the **Live Chart** to display a line profile of the temperature. Sensor 1 and Sensor 2 are plotted only if Sensor 2 is active according to the product personality. It is possible to edit the history button whilst a chart is live and the chart will be updated with a newly created X axis. The chart axis Auto-scales by default as the plot progresses. The live data point is always entered at Time = 0 (seconds) with past history shown as a negative number. The chart can be manipulated, saved or exported similar to any other DigitalMicrograph file.

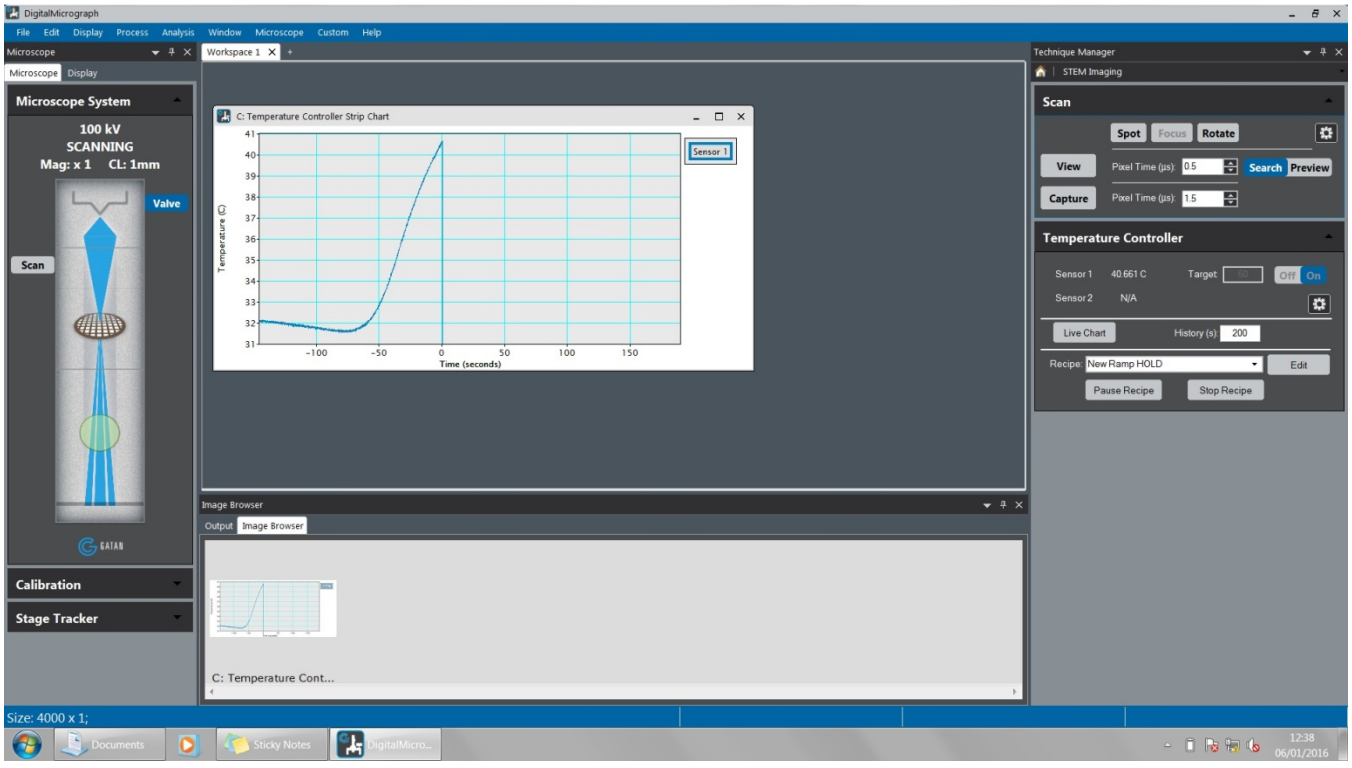


**Figure 62:** ***Temperature Controller Strip Chart***

## 5.3.2 Temperature Controller Recipes

Recipes are intended to offer more complex series of set-points, and ramp and hold actions than is possible through the single ramp program accessible from the controller. When using Recipes, remember that the controller should be Automatic mode and not Ramp mode since the ramping is effectively controlled live through communications with DigitalMicrograph. Please note the default units are Centigrade irrespective of which units are chosen on the controller.

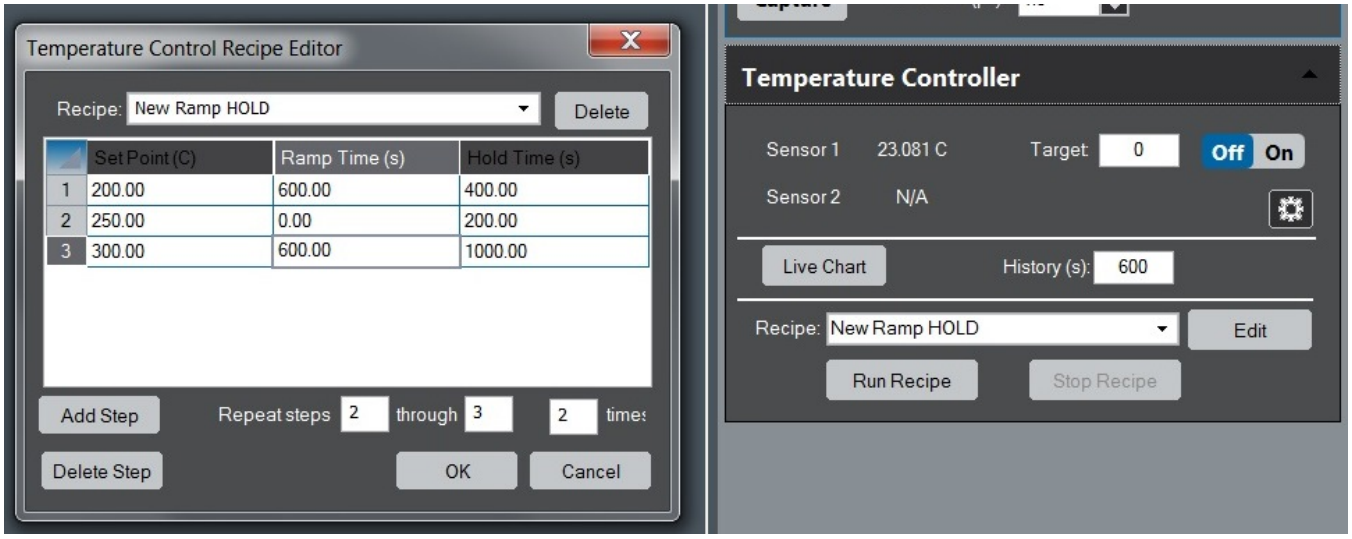


**Figure 63:** ***Temperature Control Recipe Editor***

To create a new recipe or edit an existing recipe, click on **Edit** and choose the **Recipe** or name a new Recipe from the drop down menu. The Ramp Time and Hold Time are entered in seconds. If 0 is entered as a ramp time this is equivalent to creating a new target temperature with immediate effect. The Recipe is built up by adding multiple steps, and it is also possible to cycle through certain steps as shown in the Recipe Editor.

Once a recipe is defined, then you can **Run**, **Pause** and **Stop** the Recipe. If a non-zero ramp period is entered then the target temperature is applied as a step function.

Pausing a Recipe allows it to be resumed. Pausing simply holds the current action. Starting a Recipe automatically toggles the Off / On button. Stopping a recipe does not turn active heating off. If the user wishes to stop a recipe and kill active heating, then manually toggle the control to **Off** or press **Stop** on the controller. The same applies to when a Recipe is fully completed.

For certain experiments, it may be useful to define a target temperature and hold at that temperature for example to fine tune the microscope settings or configure other equipment. The Pause and Resume function in this mode is useful for this task.

# 6 Controller compatibility

The 1905 controller has been designed to work with multiple sensor types and furnace types. For the controller to be compatible it is necessary to have a both a suitable cable to connect the product and it is necessary to have the product personality profile loaded into the controller. The majority of legacy products are already contained in the product personality archive. However in certain cases depending on the vintage of the product in question, it may be necessary for Gatan to supply a new profile with the new cable. The controller does not support Liquid Nitrogen based cryogenic holders manufactured prior to 1998.

In order for Gatan to understand which cable is required, please contact your local sales representative explaining your requirements. This includes the serial number of the holder / stage you wish to use. Where a serial number is not obvious, please provide your local sales representative information to allow Gatan to trace the original design information. As certain products have utilized different designs regarding the heater and sensor configurations, the cable supplied will be labelled specific to the legacy product type being supported, and this will identify the associated personality profile to use.

Updating the product personality archive on the controller requires establishing an Ethernet connection to the controller and running GMS software version 3.0 or later. Please contact Gatan field service in case this is required and where help is required in performing this specific task.

# A Appendix

## A.1 Connector pin-outs

Please note the pin-outs refer to functionality of the controller and may not be employed in different products or cabling. This manual has made no reference to the internal pre-amplifier which is present in the controller which is reserved for future use.

### A.1.1 Gatan connector 1

| Pin # | Function |
|---|---|
| 10 | Bake-out heater connection |
| 1 | Ground for heaters |
| 19 | Power to holder heater |
| 11 | High-impedance input for buffered ground |
| 2 | Power to EEPROM module |
| 20 | Control line A to pre-amp |
| 12 | Control line B to pre-amp |
| 3 | Data from EEPROM module |
| 21 | Control line C to pre-amp |
| 13 | Signal from pre-amp (positive leg of pair) |
| 4 | EEPROM and external CJC ground |
| 22 | Signal from pre-amp (negative leg of pair) |
| 14 | Ground for pre-amp |
| 5 | Signal from external cold-junction temperature sensor |
| 23 | +12 V supply to pre-amp |
| 15 | -12 V supply to pre-amp |
| 6 | Power to external cold-junction temperature sensor |
| 24 | Screen for all DRTD_* signals |
| 16 | Current force to diode/RTD (positive leg of pair) |
| 7 | Voltage sense from diode/RTD (positive leg of pair) |
| 25 | Current force to diode/RTD (negative leg of pair) |
| 17 | Voltage sense from diode/RTD (negative leg of pair) |
| 8 | Signal from thermocouple (negative leg) |
| 26 | Signal from thermocouple (positive leg) |
| 18 | Screen for both TC_* signals |
| 9 | Spare |

### A.1.2 Gatan connector 2

| Pin # | Function |
|---|---|
| 10 | Bake-out heater connection |
| 1 | Ground for heaters |
| 19 | Power to holder heater |
| 11 | High-impedance input for buffered ground |
| 2 | Power to EEPROM module |
| 20 | Control line A to pre-amp |
| 12 | Control line B to pre-amp |
| 3 | Data from EEPROM module |
| 21 | Control line C to pre-amp |

| | |
|---|---|
| 13 | Signal from pre-amp (positive leg of pair) |
| 4 | EEPROM and external CJC ground |
| 22 | Signal from pre-amp (negative leg of pair) |
| 14 | Ground for pre-amp |
| 5 | Signal from external cold-junction temperature sensor |
| 23 | +12 V supply to pre-amp |
| 15 | -12 V supply to pre-amp |
| 6 | Power to external cold-junction temperature sensor |
| 24 | Screen for all DRTD_* signals |
| 16 | Current force to diode/RTD (positive leg of pair) |
| 7 | Voltage sense from diode/RTD (positive leg of pair) |
| 25 | Current force to diode/RTD (negative leg of pair) |
| 17 | Voltage sense from diode/RTD (negative leg of pair) |
| 8 | Signal from thermocouple (negative leg) |
| 26 | Signal from thermocouple (positive leg) |
| 18 | Screen for both TC_* signals |
| 9 | Spare |

## A.1.3 Gatan connector 3

| Pin # | Function |
|---|---|
| 10 | Spare |
| 1 | Ground for chiller |
| 19 | 6 V power to chiller |
| 11 | High-impedance input for buffered ground |
| 2 | Power to EEPROM module |
| 20 | Control line A to pre-amp |
| 12 | Control line B to pre-amp |
| 3 | Data from EEPROM module |
| 21 | Control line C to pre-amp |
| 13 | Signal from pre-amp (positive leg of balanced pair) |
| 4 | EEPROM and external CJC ground |
| 22 | Signal from pre-amp (negative leg of balanced pair) |
| 14 | Ground for pre-amp |
| 5 | Signal from external cold-junction temperature sensor |
| 23 | +12 V supply to pre-amp |
| 15 | -12 V supply to pre-amp |
| 6 | Power to external cold-junction temperature sensor |
| 24 | Caliente screen |
| 16 | Caliente I+ |
| 7 | Caliente I- |
| 25 | Caliente V+ |
| 17 | Caliente V- |
| 8 | Signal from thermocouple (negative leg) |
| 26 | Signal from thermocouple (positive leg) |
| 18 | Screen for both TC_* signals |
| 9 | Spare |

## A.1.4 Aux / RS485

For additional inputs / outputs and interlock facilities. Two separate d-sub connectors are described below.

**Aux 1 / RS485**

| Type: Male (plug) 9 pin connector (DB9) | |
|---|---|
| 1 | AUX_ANA_OUT_1 |
| 2 | AUX_ANA_GND_1 |

| | |
|---|---|
| 3 | AUX_DIG_IN_1 |
| 4 | AUX_DIG_GND_1 |
| 5 | AUX_DIG_OUT_1 |
| 6 | AUX_RS485_A |
| 7 | AUX_RS485_B |
| 8 | AUX_RS485_GND |
| 9 | AUX_SCREEN (mains earth, aka chassis) |

**Aux 2 / RS485**

| Type: Male (plug) 15 pin connector (VGA) | |
|---|---|
| 1 | AUX_ANA_OUT_2 |
| 2 | AUX_ANA_GND_2 |
| 3 | AUX_DIG_IN_2 |
| 4 | AUX_DIG_GND_2 |
| 5 | AUX_DIG_OUT_2 |
| 6 + 11 | AUX_RS485_A |
| 7 + 12 | AUX_RS485_B |
| 8 + 13 | AUX_RS485_GND |
| 9 + 14 | AUX_SCREEN (mains earth, aka chassis) |
| 10 | SPARE |
| 15 | SPARE |

## A.1.5 Recommended standard RS232 connectors

| Type: Female (socket) 9 pin connector (DB9) | |
|---|---|
| 1 | Spare |
| 2 | RXDATA |
| 3 | TXDATA |
| 4 | Spare |
| 5 | GND |
| 6 | Spare |
| 7 | RTS |
| 8 | CTS |
| 9 | Spare |

## A.1.6 Relays

The relays are rated to 30 V, 3 A.

**Relay 1**

| Type: Phoenix contact MSMSTBA 2,5/ 3-G-5,08-LR | |
|---|---|
| 1 | Relay 1 + |
| 2 | Relay 1 GND |
| 3 | Spare |

**Relay 2**

| Type: Phoenix contact MSMSTBA 2,5/ 3-G-5,08-LR | |
|---|---|
| 1 | Relay 2 + |
| 2 | Relay 2 GND |
| 3 | Spare |

# B Appendix

## B.1 Updating software / firmware

In the unlikely event that a controller software and or firmware upgrade is required, the process is achievable through DM software using the Ethernet connection. Please do not confuse this with the upgrade process for the personality files which is described in section B1. Like the process described in B2, DM requires a software license which includes *in-situ* imaging capabilities (includes a DigiScan license).

A software file and a firmware file are two separate files. Both are normally updated together and this must be performed in the correct sequence with the firmware being upgraded first and the Software second after a controller reboot as described below. The firmware and software files must be resident on the hard disk of the PC. The process will not function in case there is more than one controller to connect to the PC, or if there are more than one communication connection between the controller and the PC (e.g., RS232 and Ethernet). If the latter is true, the RS232 connection must be removed.

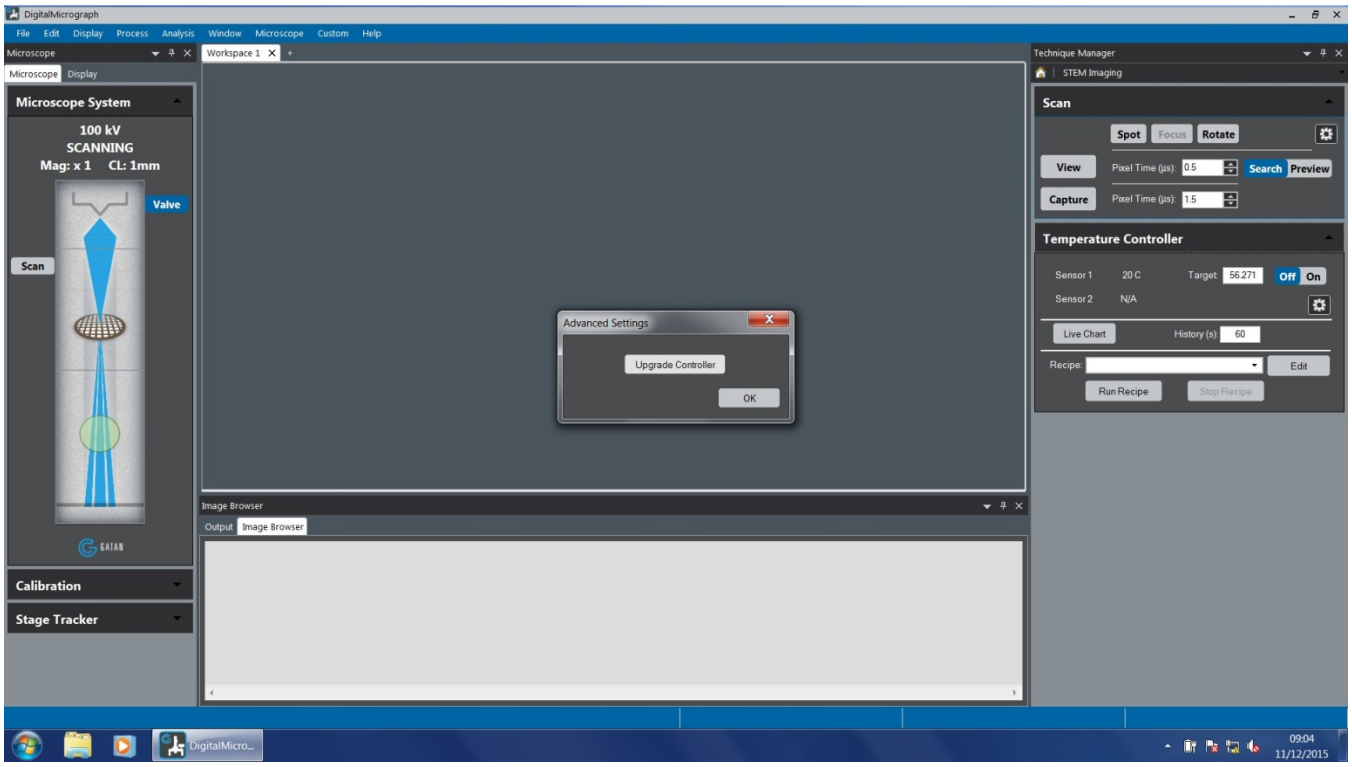


**Figure 64:** ***Upgrading firmware and software using DM.***

DM software needs to be configured as power user mode. This is achieved from the Help drop down menu and configuring User mode. If DigiScan is licensed but not powered or connected, start DigiScan in faux mode by holding down the CONTROL / ALT and SHIFT keys on the PC keyboard simultaneously after starting DM software.

The controller must be showing the Home screen only and not actively controlling a temperature.

1 Click on the scanning (S)TEM imaging icon and expand the temperature controller menu. Once in power user mode, click on the wheel icon to open the Advanced Settings window.

   The controller must not be actively controlling a temperature, i.e., it should show the home screen for the upgrade process to function. With the home screen showing, click the **Upgrade Controller** button and locate the appropriate **firmware file** (*.fwimg) on the PC. Do not click the OK button. Wait for the system to acknowledge a successful upgrade before clicking the OK button which closes this window.

2 Close DigitalMicrograph software

   Power cycle the controller using the front logo button. It is best to wait 10 s after power off to ensure it has fully depowered before powering on again.

   a. Restart software in faux mode again.
   b. Click on the wheel icon and **Upgrade Controller** button again in Advanced Settings and select the appropriate software file (*.swimg) from the hard disk location. Do not click the OK button.

*Note: The time required for acknowledgement can be several seconds as the file being transferred is significant in size. Once acknowledged, click the OK button.*

3 Close DigitalMicrograph software and power cycle the controller

*Note: the version information will have changes in the Versions / Settings screen as shown in Figure 20.*

## B.2 Upgrading the Personality Profile archive.

The product personality archive file consists of a zipped folder of multiple product files. This archive is revision controlled and has the nomenclature *.pdefs. The revision of this archive is displayed as the product definition on the version information screen.

The method for upgrading the personality archive is identical to that described above for the Firmware or Software update process. Please copy the *.pdefs file to the hard disk of the PC connected to the controller running DigitalMicrograph. Click upgrade in the advanced settings window and choose the *.pdefs file. The controller requires powering down and restarting for these to be selectable as new choices. It is the user's responsibility to choose the correct product which is attached. Please refer to the product cable as this will normally indicate the sensor type if there is uncertainty.

## B.3 USB

The USB port on the controller is not active and not supported. Please do not plug a USB cable into this socket.

# C Appendix

## C.1 DM scripting commands

The scripting interface can be used to communicate with the controller. These functions are provided to allow users to develop their own procedures for controlling the holder.

The basic script routines for communicating with attached Gatan 1905 controllers are:

1. `Gatan1905_GetTemperature(long iSensor)` – returns the measured temperature from the attached holder sensor. Each holder can have up to 2 temperatures, indexed from 0 to 1.
2. `Gatan1905_GetTemperatureSetpoint(long iSensor)`– returns the temperature setpoint for the sensor iSensor.
3. `Gatan1905_SetTemperature(long iSensor, double temperature)`– sets the temperature setpoint for the sensor iSensor.

# D Appendix

## D.1 Local limits interface in engineering mode

Engineering mode is intended for use in the factory to aid development or refinement of product personality files. This manual does not detail the protocol to enter engineering mode. The personality file defines safe limits for the product including slew rates. Alteration of limits is not anticipated to be required by field service.

In engineering mode the Tmax, Vmax, Imax and Pmax values can be enabled or disabled and configured as shown below.

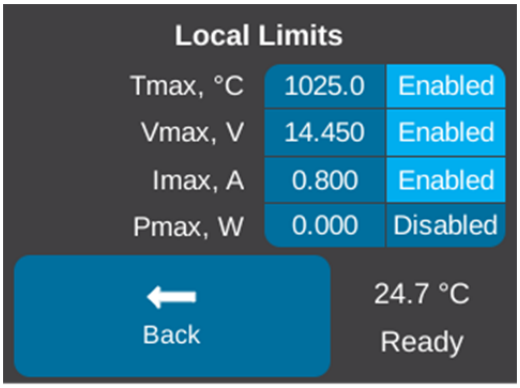


**Figure 65:** ***Local Limits configuration screen.***

## D.2 PID control theory

A PID system uses a control loop feedback mechanism, where the heater output power is adjusted to allow the process temperature to converge on a desired target temperature.

The PID controller algorithm involves three separate constant parameters which can be interpreted in terms of time:

Term1: depends on the present difference between measured and target temperature
Term2: depends on past differences in measured and target temperature
Term3: depends on future errors, based on the current derivative (rate of change)

These weighting of each of these terms are predetermined for each Gatan product specific to a temperature zone. These are loaded in via the Personality Profile EEPROM. The PID control equation, shown below is used to calculate the power which should be applied to the heating element.

$$P = K_p e + \frac{K_p}{T_i}\int_0^t e\,dt - K_p T_d \frac{d(PV)}{dt}$$

Where it is assumed:

P = Heating power going into system
This lies within the range of 0 – 100% where 100% is specific to that product.
PV = Process value
The present temperature of the system.
e = Error
Difference between the internal target value (SV) and Process value (PV). The internal target value accommodates the product specific slew rate, or user specified ramp rate.
$K_p$ = Proportional value.
$T_{i=}$ Integral time value.
$T_d$ = Derivative value.

With the 1905 controller, the integral is continuously updated whilst in Automatic or Ramping mode. Pressing pause or resume and changing the set point does not reset this value. Entering manual mode resets the integral calculation. The contribution of each of the three terms is explained and demonstrated below.

## D.2.1 Proportional (P) only control

If proportional only control is used, the control equation becomes:

$$P = K_p e$$

The applied power depends only on the error between the target and process temperature. Figure 63 shows an example of proportional control with different values of Kp. As Kp is increased, the steady-state temperature reached moves closer to the target, but the temperature also becomes more unstable. Although, for example, $K_p$ = 3 results in a smooth increase to a stable temperature of around 55 ˚C, $K_p$ = 10 results in an initial overshoot before the temperature settles to around 57 ˚C. Very large values of $K_p$ (for example, greater than 1000) simulate on/off control, since the power changes rapidly from 0% to 100% as the temperature crosses the target.

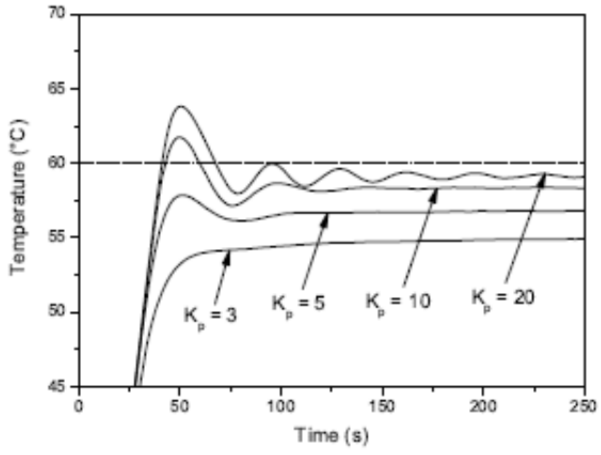


**Figure 66:** ***Effect of varying Kp.***

## D.2.2 Proportional + integral (PI) control

With proportional and integral action, the equation becomes:

$$P = K_p e + \frac{K_p}{T_i}\int_0^t e\,dt$$

By integrating the error over time, the integral term gradually compensates for the drop caused by the proportional term. It attempts to eliminate the droop within a time roughly equal to $T_i$. Smaller values of $T_i$ will result in more severe (faster) integral action. Figure 64 shows an example of proportional + integral control for three different values of $T_i$.

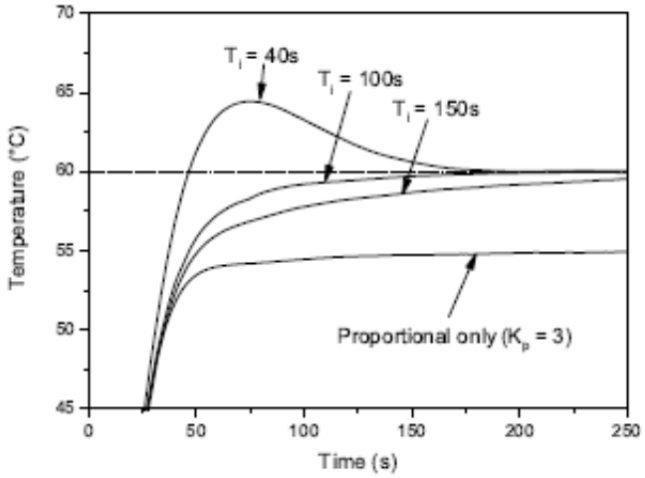


**Figure 67:** ***Varying the Integral contribution.***

For most temperature control systems, proportional + integral control is sufficient, since it results (theoretically) in a temperature equal to the target temperature. However a faster response can sometimes be achieved by adding the derivative term.

## D.2.3 Proportional + integral + derivative (PID control)

With all three terms included, the equation becomes:

$$P = K_p e + \frac{K_p}{T_i}\int_0^t e\,dt - K_p T_d \frac{d(PV)}{dt}$$

The addition of the derivative term slows the rate of change of heater power. For example, if the temperature is below the target and increasing rapidly, the derivative term is negative and results in a decrease in the applied power, which in time helps to slow the temperature rise. The derivative term can be used to correct overshoot or oscillations caused by the integral term, as shown in the Figure 65. Because this allows the use of a smaller value of $T_i$, addition of the integral term can result in a faster system response. However,

because the derivative term is based on the process temperature, it can be sensitive to noise and should only be used with care. A non-zero D term will often introduce noise into the system.

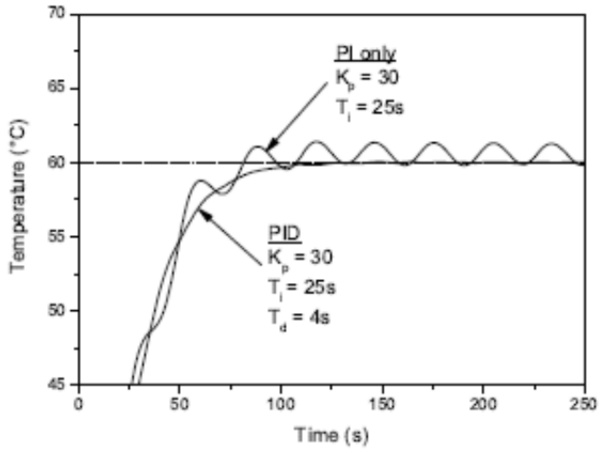


**Figure 68:** ***Applying a non-zero D term.***

## D.2.4 PID interface in engineering mode.

Engineering mode is intended for use in the factory to aid development or refinement of product personality files. This manual does not detail the protocol to enter engineering mode. The personality file defines whether to use a Fixed PID or PID zones as well as configures the PID values and zones. Note the PID values are also dependent on the Vmax settings as well as product specific slew rates.

Alteration of PID values is not anticipated to be required by field service. Incorrect PID settings can cause erratic behavior which may lead to potential damage to specimens and unpredictable outgassing into the microscope vacuum.

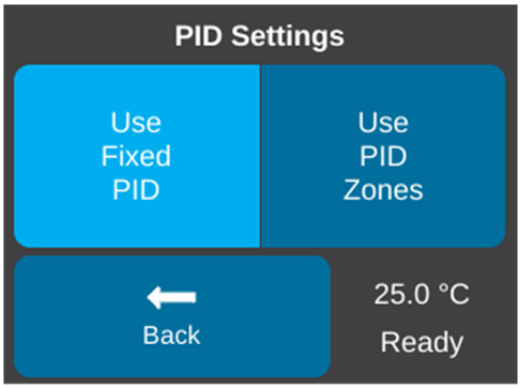


**Figure 69:** ***PID Settings screen.***

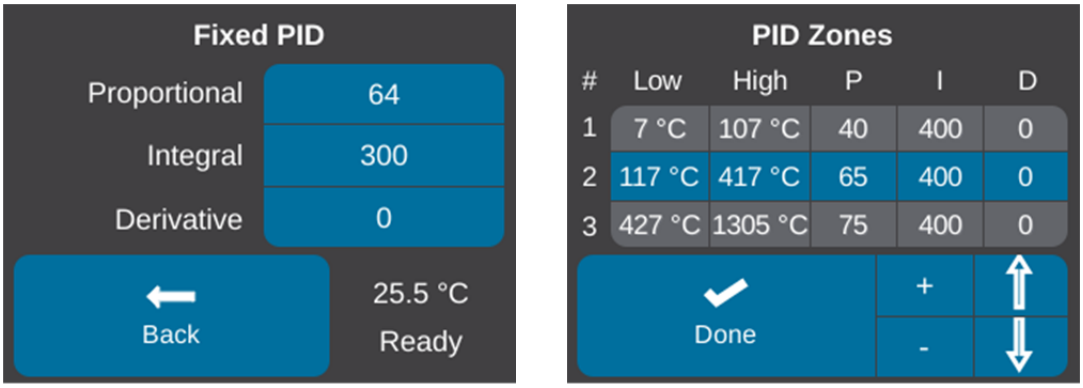


**Figure 70:** ***Fixed PID values (right) and PID Zones (left).***

When using the PID zones screen, use the Up and Down arrow keys to highlight the zone of interest to see or modify. The controller automatically avoids instabilities at zone transition temperatures by applying hysteresis.