Identifier:	Revision:	Effective Date:
qpod/E-2.22-1.52	**0**	**7/25/17**

Web Page:
http://www.qnw.com/qpod-family-page/

Description:

Temperature-controlled sample compartment for fiber optic spectroscopy

QUANTUM
N·O·R·T·H·W·E·S·T

Quantum Northwest qpod®/E User's Guide

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Peltier-Based Cuvette Holders
and Custom Instrumentation

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CAUTION

A CAUTION notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in damage to the product or loss of important data. Do not proceed beyond a CAUTION notice until the indicated conditions are fully understood and met.

WARNING

A WARNING notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in personal injury or death. Do not proceed beyond a WARNING notice until the indicated conditions are fully understood and met.

Table of Contents

1. General Information

Thank you for purchasing a Quantum Northwest **qpod/E**. We want you to enjoy many years of faithful service from your instrument. If you have any questions, feel free to contact us directly through our website, www.qnw.com/contact-us/, or by email at service@qnw.com.

Your Quantum Northwest cuvette holder and accessories have been carefully designed so that when used properly, you have an accurate, fast, flexible and safe temperature control system.

Information about safety practices appears throughout the documentation provided with your instrument and accessories to help you safely operate the instrument and accessories. Before using the instrument or accessories, you must thoroughly read these safety practices. ALWAYS operate the instrument and accessories in accordance with these safety practices.

1.1. User Documentation

You have been provided with the following documentation to help you set up and operate your Quantum Northwest **qpod/E** cuvette holder:

- This manual, with safety practices and hazards information, instructions for installing and maintaining the components of the **qpod/E**, and troubleshooting information.
- The **T-App** Help file, located on the **T-App** CD (Quantum Northwest>**T-App** Help), if purchased. Elements of the **T-App** Help file are presented in Section 12 of this user guide.

1.2. Modules, Covers and Panels

Customers may insert cuvettes and cuvette accessories into the QNW **qpod/E** while the sample compartment is open. Any other panels or covers that are retained by screws on the cuvette holder and accessories may be opened ONLY by Quantum Northwest service technicians.

1.3. Other Precautions

Do not block any ventilation grills present on the QNW **TC 1** Temperature Controller.

Use of the QNW **qpod/E** system and accessories may involve materials, solvents and solutions that are flammable, corrosive, toxic or otherwise hazardous. Careless, improper, or unskilled use of such materials, solvents and solutions can create explosion hazards, fire hazards, toxicity and other hazards which can result in death, serious personal injury, and damage to equipment and property.

ALWAYS ensure that laboratory safety practices governing the use, handling and disposal of such materials are strictly observed. These safety practices should include the wearing of appropriate safety clothing and safety glasses.

1.4. Warning and Other Symbols

The following is a list of symbols that appear in conjunction with warnings on the QNW cuvette holder and accessories. The hazard they describe is also shown.

A triangular symbol indicates a warning. The meanings of the symbols that may appear alongside warnings in the documentation or on the instrument itself are as follows.

	When used on a warning label, the user is in danger of an electrical shock.
	When used on warning labels attached to the instrument, refer to the relevant operation or service manual for the correct procedure referred to by that warning label.
	When attached to the rear of the instrument, indicates that the product complies with the requirements of one or more EU directives.

1.5. CE Compliance

Your QNW **qpod/E** cuvette holder has been designed to comply with the requirements of the Electromagnetic Compatibility (EMC) Directive and the Low Voltage (electrical safety) Directive (commonly referred to as the LVD) of the European Union. Quantum Northwest has confirmed that each product complies with the relevant Directives by testing a prototype against the prescribed EN (European Norm) standards.

Proof that a product complies with these directives is indicated by:

- the CE Marking appearing on the rear of the product, and
- the following Declaration of Conformity. The Declaration of Conformity is the legal declaration by Quantum Northwest that the product complies with the directives listed above, and shows the EN standards to which the product was tested to demonstrate compliance.

EU Declaration of Conformity

We: Quantum Northwest, Inc.
Of: 22910 E Appleway Ave, Suite 4
Liberty Lake, WA 99019-8606
USA

Hereby declare under our sole responsibility that the following devices:

QNW MODEL (CONTROLLER MODEL)
BATH 10
CD 250™ (TC 1 Controller)
FLASH 300™ (TC 1 Controller)
Luma 40™ (TC 1 Controller)
qCHANGER 6 (TC 1 Controller)
qpod® (TC 1 Controller)
t2 Sport™ (TC 1 Controller)
t2x2 Sport™ (TC 1 Controller)
Turret 4™ (TC 1 Controller)
Turret 6™ (TC 1 Controller)
Versa 20™ (/x2) (TC 1 Controller)

Comply with the essential requirements of the following applicable European Directives:

Electromagnetic Compatibility (EMC) Directive 2004/108/EC,

General Product Safety Directive 2001/95/EC

Low-Voltage Directive 2014/35/EU,

RoHS Directive 2011/65/EU.

Conformity is assessed in accordance to the following standards:

EMC Directive:	Emissions	EN 61326-1 (2013) Group 1 Class A
	Immunity	EN 61326-1 (2013) Group 1 Class A
Low Voltage Directive:	Safety	EN 61010-1 (2011)

I hereby declare that the equipment models named above have been assessed and found to comply with the relevant sections of the above-referenced specifications. The units comply with the relevant requirements of the applicable Legislation, and I am the person authorized to compile the technical documentation.

Signed by: 

Name: Enoch W. Small, Ph.D.
Position: President, Quantum Northwest, Inc.
Date: September 21, 2016
Location: Liberty Lake, Washington, USA

Declaration of Conformity to EU Directive 2011/65/EU (RoHS)

We: Quantum Northwest, Inc.
Of: 22910 E Appleway Ave, Suite 4
Liberty Lake, WA 99019-8606
USA

Declare under our sole responsibility that our products indicated below are in fully compliance with EU Directive 2011/65/EU, with respect to the following substances:

1. Lead (Pb),
2. Mercury (Hg),
3. Cadmium (Cd),
4. Hexavalent chromium (Cr (VI)),
5. Polybrominated biphenyls (PBB),
6. Polybrominated diphenyl ethers (PBDE), Deca-BDE included.

QNW MODEL (CONTROLLER MODEL)
BATH 10
CD 250™ (TC 1 Controller)
FLASH 300™ (TC 1 Controller)
Luma 40™ (TC 1 Controller)
qCHANGER 6 (TC 1 Controller)
qpod® (TC 1 Controller)
qpod® 2e (Integrated Control)
t2 Sport™ (TC 1 Controller)
t2x2 Sport™ (TC 1 Controller)
TLC 50 Legacy (TC 125 Controller)
Turret 4™ (TC 1 Controller)
Turret 400 Legacy (TC 425 Controller)
Turret 6™ (TC 1 Controller)
Versa 20™ (/x2) (TC 1 Controller)

The following statement regarding conformity of our products to the EU Directive 2011/65/EU (RoHS) is based on our actual research and inquiries with our suppliers:

All products sold under the above model numbers previously, currently and in future are/will be fully compliant with EU Directive 2011/65/EU and without exemption.

Signed by: 

Name: Enoch W. Small, Ph.D.
Position: President, Quantum Northwest, Inc.
Date: September 21, 2016
Location: Liberty Lake, Washington, USA

2. Specifications

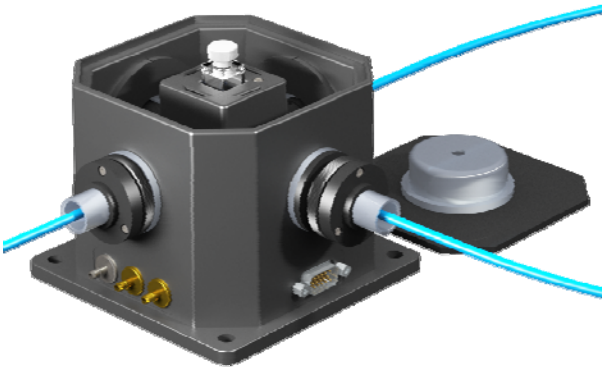


Figure 1. qpod/E Sample Compartment

Figure 2. TC 1 Temperature Controller

2.1. Introduction: QNW qpod/E Sample Compartment with TC 1 Temperature Controller

Intended Use

The QNW **qpod/E** sample compartment contains a temperature-controlled cuvette holder surrounded by optical components of the user's choice. The **qpod/E** comes with the **TC 1** Temperature Controller to control cuvette temperature during optical measurements. Temperature control is achieved using the **TC 1** Temperature Controller alone or along with a computer interfaced to the **TC 1** Temperature Controller box, using the QNW **T-App** software available for purchase. The extended temperature version (**/E**) of the **qpod** extends temperature control to -55 °C to +150 °C. This requires the use of materials that are stable at the high and low temperatures, sensors with extended range, and design details that protect the delicate magnetic stirring motors.

The **qpod/E** optics typically have SMA fiber optic connectors for various light sources and detectors. Kits are available for applications in absorbance (ABSKIT), fluorescence (FLKIT), and multiple applications (MPKIT). Figure 1 shows the **qpod/E** with the MPKIT option.

The **qpod/E** is constructed of a single molded housing. A Peltier-controlled cuvette holder in the center provides temperature control and variable speed magnetic stirring, and holds optical slits for limiting light access to the cuvette as needed. A dry gas purge may be used to minimize condensation when working at low temperatures. SMA fiber optic connections and high-quality fused silica optics may be inserted in different combinations into optical ports in the walls surrounding the cuvette holder. Accessories such as polarizers and filter holders may be inserted in the light paths. Spherical mirrors may be used to enhance excitation or emitted light. All optics provide focusing and position adjustments for maximizing signal throughput.

Specifications

- Temperature range: -55 to +150 °C[1]
- Temperature precision: ±0.02 °C
- Temperature accuracy: ± 0.15 °C from 0 °C to + 80 °C
  ± 0.30 °C from -20 °C to + 110 °C
- Temperature reproducibility: better than ±0.07 °C
- Cuvette size (outside dimensions): 12.5 x 12.5 mm
- Optical port dimensions: 10 mm high x 10 mm wide
- Probes accepted: Series 400 or Series 500
- Cuvette z-height: 8.5 mm

Note: The "z-height" of a cuvette is the distance between the bottom outside surface of the cuvette and the designed position for the optical center line, where the incident beam of light strikes the cuvette. The z-height for a typical microcuvette is shown to the right.

2.2. Measurement Category

The measurement category is IEC 61010:I. Do not to use this equipment for measurements within measurement categories II, III and IV.

2.3. Pollution Degree

The pollution degree is IEC61010:2. Pollution degree "2" applies to a normal indoor atmosphere.

2.4. Overvoltage Category

The overvoltage category (installation category) is CAT II. See IEC 664 & IEC 61010.

2.5. Environmental Conditions

The area should have a dust-free atmosphere with minimal drafts, vibrations, and corrosive fumes. For optimum performance, the ambient air is recommended to be between 20 and 25 °C, but can be from 5 to 40 °C. Relative humidity should be less than 80%. The instrument is designed for operation at 2,000 m elevation or less.

To avoid damage through spillage of solutions and samples being analyzed, the worktops should be covered with a material that is corrosion resistant and impervious to liquids.

[1] See **Section 9** for special considerations needed to work at high and low temperatures.

Allow at least two inches of space on both sides, and six inches at the rear of the **TC 1** temperature controller to permit free air circulation. The power cord and all other connections are located at the rear of the instruments. The power switch is located on the rear panel.

2.6. Electrical Specifications

Mains Supply

A standard power cable is provided based on the user's country requirements (18 AWG/115 V AC US/Canada; 1.0 mm/220 V AC international). The required supply voltage is 100-240 V AC (frequency 50 or 60 Hz). The mains voltage fluctuations must not exceed 10% of the nominal voltage.

The installation of electrical power supplies must comply with the rules and/or regulations imposed by local authorities responsible for the supply of electrical energy to the workplace.

All power supplies for the **TC 1** Temperature Controller must be single-phase, AC voltage, three-wire system (active, neutral, earth) and should be terminated at an appropriate power outlet receptacle that is within reach of the power cord. For safety reasons, a separate power outlet receptacle should be provided for each unit in the system. The use of extension cords or outlet adaptors is not recommended.

WARNING

Shock Hazard - Danger of electrocution. Good electrical grounding is essential to avoid potentially serious shock hazards. A 3-wire outlet with ground connection must be provided for the **qpod/E**. Make certain that power outlets are earth-grounded at the grounding pin.

CAUTION

Caution - Never connect or disconnect any cables while the **qpod/E**/**TC 1** Temperature Controller is switched on. Damage to the printed circuit boards may occur.

2.7. Computer Requirements

A computer is required only if **T-App** software has been purchased.

The **T-App** temperature application software used for external control of Quantum Northwest temperature controllers requires a personal computer using a Microsoft Windows™ operating system (XP, Vista, 7, 8 or 10). The **T-App** software is normally provided on a CD, requiring a CD player be part of the computer. However, **T-App** may also be downloaded *via* the Internet from a link provided by QNW. Contact QNW should you wish to obtain the application by Internet.

3. Installing, Starting and Stopping the QNW qpod/E

3.1. Installing the QNW qpod/E

Unpacking

After accepting delivery, take the equipment to the installation site. Quantum Northwest instruments are inherently robust, and the packaging is designed to prevent internal damage. However, the contents form part of a precision measuring system and all packages should be handled with care. In transit, sharp jolts must be avoided and the packages should not be inverted or tilted unnecessarily. Markings on the shipping cartons generally indicate which side of the package should be kept on top.

Note: You may have purchased one of three **qpod/E** packages. The **qpod/E-ABSKIT** provides collimating optics to pass light straight through for absorbance, transmittance or turbidity measurements. The **qpod/E-FLKIT** provides imaging lens systems for excitation and detection of fluorescence emission at right angles. The **qpod/E-MPKIT** is a multipurpose kit with a combination of optics that may be used for either absorbance or fluorescence measurements.

Unpacking the equipment is your responsibility. As the packages are opened, ensure that you have received everything you ordered. If there are any discrepancies, notify the supplier. If any items are found to be damaged, immediately notify the carrier and supplier.

You should have received:

- 1x **qpod/E** Sample Compartment with lid and cap
- one of three optical kits:

  ABSKIT - optics for absorbance or transmission measurements:

  - 2 QCL-UV collimating lenses

  FLKIT - optics for fluorescence measurements:

  - 2 QIL-UV imaging lenses
  - 2 QMP mirror plugs

  MPKIT - multipurpose kit:

  - 2 QCL-UV collimating lenses
  - 2 QIL-UV imaging lenses
  - 2 QMP mirror plugs
- 1x plastic utility box containing:
  - 5/64-inch hex driver
  - set of optical slits
  - stir bar

- 2 blanks for unused optical ports
- 1x **TC 1** Temperature Controller
- 1x power cable
- 1x DB15 15-pin cable assembly
- 1x submersible pump
- 1x bucket for submersible pump
- 1x $\frac{1}{8}$-inch diameter vinyl tubing to connect water
- 1x $\frac{1}{16}$-inch diameter vinyl tubing to connect gas
- 1x $\frac{1}{8}$-inch-to-$\frac{1}{16}$-inch barbed reducer fitting
- This manual

Note: Any additional accessories ordered (such as polarizers or optical filter holders) are not listed here.

Any differences from the original order should be referred immediately to your Quantum Northwest sales office. Do not discard any packaging components or filler materials.

Installing the QNW T-App Software (if purchased)

CAUTION

Caution - Install **T-App** software before connecting the **TC 1** to your computer. Software installation installs a driver. If the **TC 1** Temperature Controller is connected to the computer with the enclosed USB or RS-232 cable and turned on before software installation, then the computer may automatically load an incorrect driver that may be difficult to remove.

1. Follow the instructions provided with the software to complete the installation. The instructions are found in a text file titled "Instructions.txt" within the **T-App** folder. Those instructions will be similar to the following:

> **Instruction for installation of T-App**
>
> 1. Copy the "T-App" folder to a convenient location on the computer to be used.
>
> 2. Run "CDM v2.12.12 WHQL Certified.exe" to the install drivers needed for serial communications between the QNW TC 1 temperature controller and the T-App application.
>
> 3. Connect the TC 1 to the computer to be used with the USB cable provided with the TC 1 (or any USB cable with the correct plug ends). Turn on the TC 1 power. Installation of the drivers for the USB connection should begin immediately and proceed automatically.
>
> 4. Run "T-App.exe". For further information select the Help>(T-App Help) menu item.

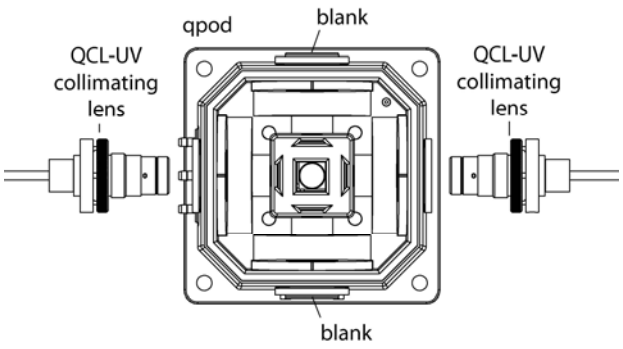


Figure 3. Absorbance configuration

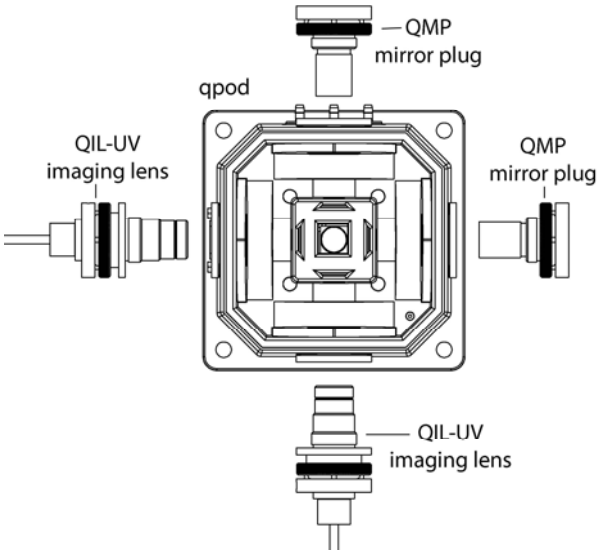


Figure 4. Fluorescence configuration

1. If desired, fasten the **qpod/E** down to a table or optical breadboard. The holes in the corners of the base are located and sized such that it will attach via ¼-20 screws to a table with 1-inch centers or with M-6 screws to a table with 25-mm centers.

Figure 5. Submersible pump, bucket, electrical cable, and vinyl tubing for the **qpod/E**

2. Cut two long lengths of $\frac{1}{8}$-inch tubing (provided) to connect each brass hose barb shown in **Figure 1** to the lowest position of the coolant water bucket (usually at floor level).
3. Connect the DB15 15-pin cable from the **qpod/E** sample holder to the back of the **TC 1** temperature controller.

Note: Be careful not to over-tighten the screws to avoid stripping the threads.

CAUTION

Caution - Never connect or disconnect any cables while the **qpod/E/TC 1** Temperature Controller is switched on. Damage to the printed circuit boards may occur.

4. Check that the **TC 1** power switch in the back is in the off position. Plug the power cable into the back of the **TC 1** Temperature Controller and into a wall socket. (The **TC 1** will accept AC voltages from 100 to 240 at 50 or 60 Hz.) Leave the power off.

Note: Leave the power off at this time.

5. Connect one of the two long lengths of vinyl tubing described in Step 2 to the barb connector on the submersible pump provided. It does not matter which of the two long lengths of vinyl tubing is chosen.
6. Fill the reservoir bucket at least half full of cold distilled or deionized water and set the submersible pump into it. An algaecide may be added to prevent algal growth over time. Position the bucket to within 75 cm (30 in) higher or lower than the spectrophotometer.

CAUTION

Caution – Position the bucket in a location that minimizes the risk of spilling the liquid contents.

7. Position the free end of the other length of tubing described in Step 2 in (or above) the water in the bucket. This piece of tubing serves as the return tubing for water returning to the reservoir.

Note: Secure the two pieces of tubing together with a twist-tie to make it unlikely that the return tubing does not accidently get dragged out of the bucket.

Note: The water in the bucket should be changed frequently (e.g., weekly) to avoid bacterial and algal growth.

8. Connect the power connector from the submersible pump to the matching socket on the back of the **TC 1** Temperature Controller.
9. Turn on the power to the **TC 1** using the switch on the back of the **TC 1** unit. On the **TC 1** front panel, press once on the right-arrow button and once on the SET button. These two steps turn on the pump by turning on the temperature control. (The pump runs only when the temperature control is turned on.[2])
10. Check for leaks in the system.

[2] In fact, the pump will stay on when the temperature control has been turned off if the pump had been turned on using the **T-App** command [F1 PP +].

11. Check that water is flowing from the free tubing end. If it does not, lift the pump off the bottom of the bucket, but not out of the water, and drop it. This usually will get the flow started. If it does not after several tries, lift the pump up close to the water surface and let a small drop of liquid detergent land in the water close to the pump intake. Sometimes a bubble in one of the T-connectors or in one of the short lengths of tubbing next to the cuvette holders will block the water flow, and water will move through only one of the cuvette holders. To prevent this possibility, pinch each of the input lines near the sample holder in turn to force the water to flow through the other and drive residual air out.
12. For now, turn the **TC 1** power off.
13. OPTIONAL - If you plan to work at low temperatures, connect a source of dry gas, typically nitrogen, to the small hose barb labeled "**gas**" on the front of the **qpod/E** (**Figure 1**). Use the length of $\frac{1}{16}$-inch tubing provided (a $\frac{1}{8}$- to $\frac{1}{16}$-inch barbed reducer fitting is also provided). It is very important to use dry gas flow when working at temperatures below the dew point, approximately 5 °C. Not only will the dry gas prevent condensation on the cuvette windows, but it will also prevent condensation in the interior of the **qpod/E** cuvette holders. Set the dry gas flow rate to about 50 cc/min.

CAUTION

Caution – When using dry gas do prevent condensation on the cuvette, ensure that the working area is adequately ventilated. Always secure the gas tank to a solid object. **Never put water through the gas line.**

3.2. Installing Optics

There are two basic optical configurations for the **qpod/E**: one to measure ***absorbance*** and the other to measure ***fluorescence***.

Optics to measure absorption

As shown in **Figure 3**, set up the **qpod/E** for absorbance measurements by inserting a collimating lens on any two opposite sides of the **qpod/E**. Put black plastic blanks from the **qpod/E** accessory kit in the other two optical ports. One lens collimates the output from the source fiber into a beam about 5 mm in diameter. The beam passes through the sample and is then focused on the collection fiber. A collimating lens assembly contains a single 6-mm diameter, 12-mm focal length, broadband AR-coated, fused silica lens whose principal point is located 12 mm from the end of the fiber.

Optics to measure fluorescence

As shown in **Figure 4**, set up the **qpod/E** for fluorescence measurements by insert an imaging lens to focus light from a source fiber into the center of the sample cuvette. Place another imaging lens at 90° to the source lens to image the illuminated volume onto a collection fiber. To enhance collection efficiency, spherical mirrors may be placed on the remaining positions of the **qpod/E**. One spherical mirror opposite the excitation fiber focuses the excitation source back through the sample, and another opposite the collection lens focuses extra emitted light back through the sample to roughly double the amount of emitted light collected.

An imaging lens assembly contains two ½-inch diameter, 30-mm focal length, broadband AR-coated fused silica lenses. The principal point of one lens is located 30 mm from the fiber and the principal point of the second lens is located 30 mm from the center of the cuvette. Thus, the imaging lens pair creates an image of the fiber end, without magnification, in the center of the cuvette, or images the illuminated volume on a collection fiber.

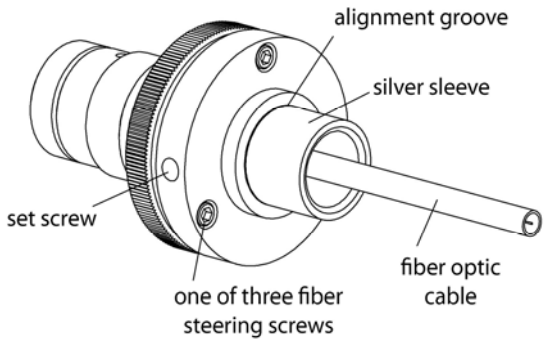


Figure 6. Components of a lens assembly

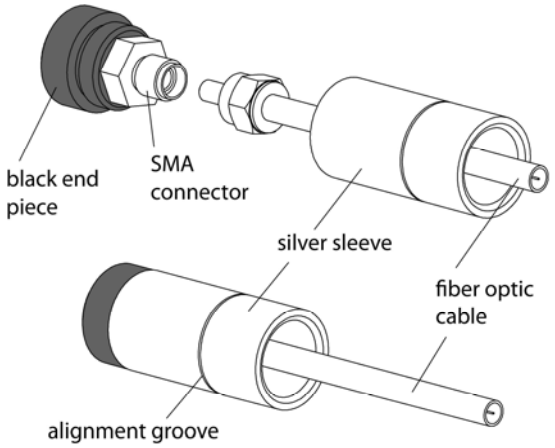


Figure 7. Attaching the fiber optic to the SMA connector

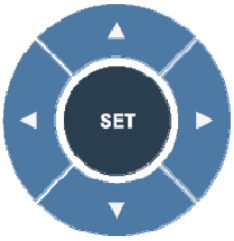
Inserting a lens into the qpod/E

1. Use the 5/64-inch hex screwdriver from the **qpod/E** accessory kit to loosen the set screw (**Figure 6**).
2. Remove the silver sleeve with a black end piece from the lens assembly. Set it aside.
3. Screw the empty optical assembly all the way into the appropriate position in the **qpod/E**. If you are using an accessory component such as a filter holder or polarizer, first place the accessory in the **qpod/E**. As you screw in the empty lens assembly, the accessory will fit over its end and then snap into place.
4. Look for the location of the set screw. If it is in a difficult position to reach, remove the three fiber steering screws, rotate the end of the optical assembly until the set screw is accessible, and reattach the alignment assembly so the screw is more available. The steering screws compress an O-ring, permitting fine alignment of the end of the fiber relative to the lens.
5. Now, unscrew the silver sleeve from the black end piece revealing the SMA connector (**Figure 7**).
6. Slide the silver sleeve over the end of the fiber optic connector and cable, leaving the threaded end toward the end of the cable.
7. Attach the fiber optic cable to the SMA connector.
8. Holding the black end piece, screw the silver sleeve back into place.
9. Insert the SMA connector and silver sleeve into the hole in the optical assembly. For a first adjustment, insert the assembly until the alignment groove is even with the face of the lens assembly. Later, you can optimize the signal intensity by sliding the SMA connector and silver sleeve in deeper.
10. Provide a source of light and a detector. You may maximize the signal by adjustments of the three fiber steering screws, making small movements of the position of the fiber end relative to the lens, and by loosening the set screw to insert the silver sleeve deeper into the lens assembly. Inserting the silver sleeve further into lens assembly moves the end of the fiber closer to the lens, altering the focus of the light. This adjustment is most important at UV wavelengths.

11. Use the optical slits or blanks (provided in the **qpod/E** accessory kit) around the cuvette in a manner that correctly limits the excitation and emission light.

3.3. Starting the QNW qpod/E

1. Place a magnetic stir bar in a standard 1 x 1-cm square cuvette. Insert a liquid sample into the cuvette.
2. Place the cuvette in the **qpod/E** Sample cuvette holder.
3. OPTIONAL - If you wish to monitor the temperature inside the cuvette, plug a standard Series 400 or Series 500 thermistor probe (not provided) into the ¼ - inch phone jack labeled "probe" in the back panel of the **TC 1**. Place the end of the probe in a region of the liquid in the cuvette where it will not occlude the spectrometer light beam.
4. Turn on the **TC 1** controller using the power switch on the back panel.



TC 1 Front panel Menu Control Buttons

5. Use the left, right, up and down arrows on the front panel Menu Control Buttons, shown above, to cycle through the controller options. These options are described in detail in **Section 4.2** below. To simply set a temperature, and turn on magnetic stirring, press the right arrow once to go to the **Set Target Temp.** page and use the up and down arrows to set a target temperature, say 37.0 °C. Press **SET** to initiate temperature control and seek this temperature. The temperature of the cuvette holder will change and stabilize at the new target value. Next, press the right arrow twice to go to the **Set Stirring** page. Use the up and down arrows to set a speed, say 1200 rpm, and press **SET** to start the stirrer(s). For more detailed use of the menu button, including temperature ramping, see **Section 4.2** below.

3.4. Stopping the QNW qpod/E

1. To turn off temperature control, press the right arrow on the **TC 1** Menu Control Buttons once to go to the Set Target Temp. page and press SET again. To turn off stirring, go to the Set Stirring page and press SET again.
2. After measurements are completed, turn off power on the back of the **TC 1** controller. This action will turn off both the **TC 1** and the submersible pump. If you are using a circulator pump other than that provided with the **qpod/E**, remember to turn it off also.

4. Step-by-Step Instructions for Using the QNW qpod/E

4.1. Instrument Overview

The **qpod/E**, shown in **Figure 1**, is a complete sample compartment for fiber optic spectroscopy, including a Peltier-controlled cuvette holder with magnetic stirring, and fused silica lens systems with SMA fiber optic connectors. A heat exchanger mounted to the thermoelectric device uses a flow of water to drain off excess heat. A small electric motor turns a magnet under the cuvette tower for stirring. Dry gas may be directed next to the cuvette windows to minimize condensation when working below the dew point temperature. Two $\frac{1}{8}$-inch hose barbs for water provide access to the heat exchanger. The $\frac{1}{16}$-inch hose barb is used for the dry gas.

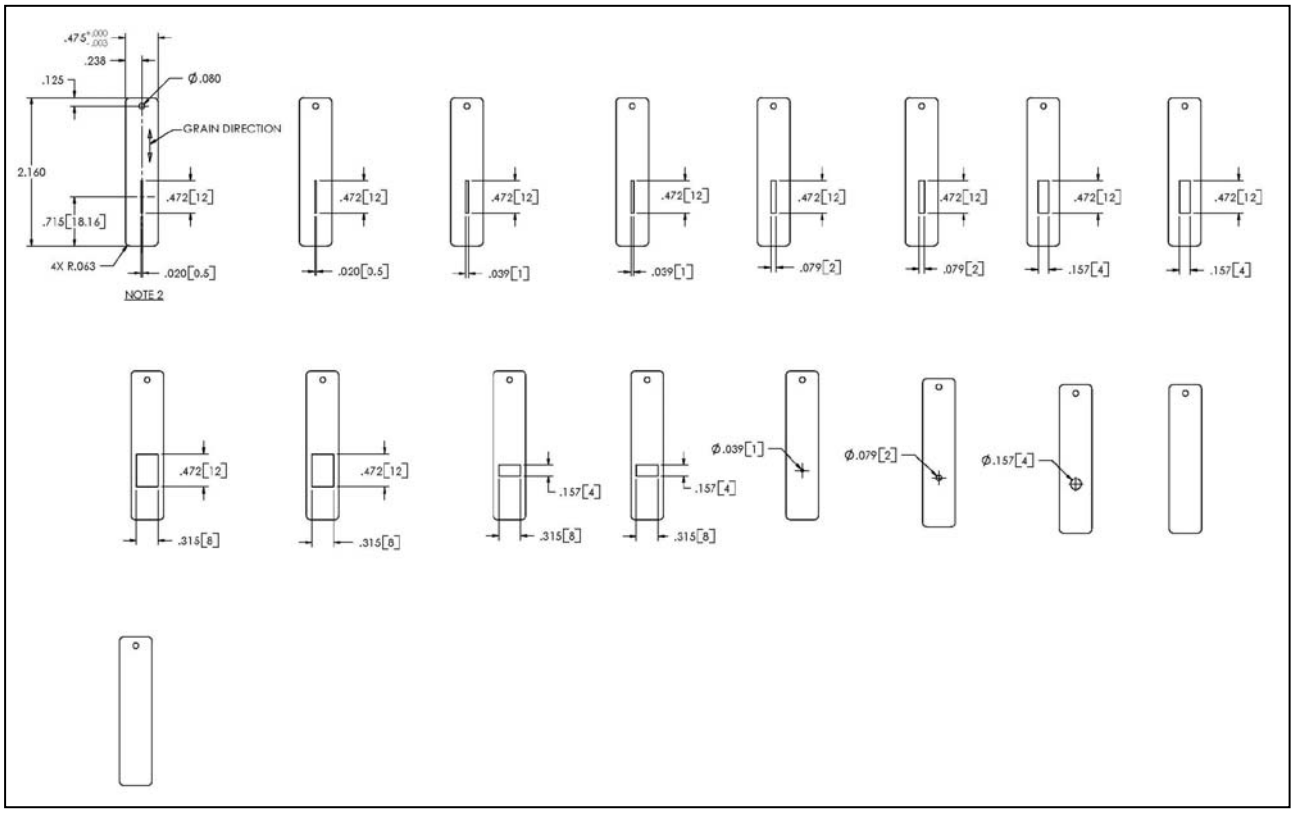


Figure 8. Set of slits provided for the **qpod/E**

Optical slits (**Figure 8**) are placed around the cuvette in a manner that limits the excitation and emission light, when needed.

Each cuvette holder holds a standard 10 x 10 mm cuvette with outside dimensions of 12.5 x 12.5 mm. Metal clips are used to push the cuvettes into corners for reproducible positioning and to favor temperature transfer.

T-App is a computer program (purchased separately) that permits external computer control of the **TC 1** Temperature Controller. The temperature of the cuvette holders and a temperature sensed by an external probe may be plotted vs time. Simple text scripts may be used to automate multiple-step operations. **T-App** may be used with a USB cable to connect your computer to the **TC 1**. Full instructions for using **T-App** may be found in the associated Help file, sections of which are provided in **Section 12**. Examples of scripts are found in **Section 13**.

4.2. Detailed Instructions

Using the front panel Menu Control Buttons

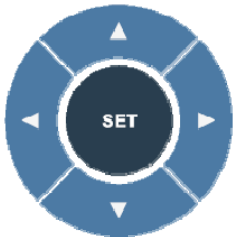


Figure 9. The Menu Control Buttons (**SET**, **left arrow**, **right arrow**, **up arrow**, and **down arrow**) on the front panel of the **TC 1** controller allow full functionality without an external control program.

Refer to **Figure 9** for the appearance of the **TC 1** Menu button. Use the right and left arrows to cycle through four pages:

– Display – Set Target Temperature – Set Stirring – Set Ramping –

Display

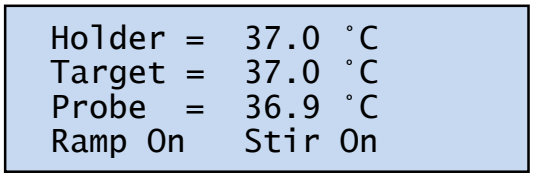


Figure 10. Example **TC 1** Display page for a single cuvette holder and external probe, with temperature ramping and stirring set to "On"

Display: This main page shows the actual cuvette *Holder* temperature, the *Target* temperature and a *Probe* temperature (if a probe is present). The page also shows whether the *Ramp* and *Stir* functions are on or off. After a few seconds of inactivity, all other pages will revert back to the **Display** page.

When seeking a temperature, the green LED on the front panel will flash slowly. When the cuvette holder has locked onto a new target temperature, the green LED will remain lit. A rapidly flashing red LED usually means a loose electrical cable or inadequate water flow for the Peltier unit.

Note: Pressing the **SET** button while the **Display** page is active results in no action. To start or stop controller functions, access the four other pages, **Set Target Temperature – Set Stirring – Set Ramping – Set Position.**

Set Target Temperature

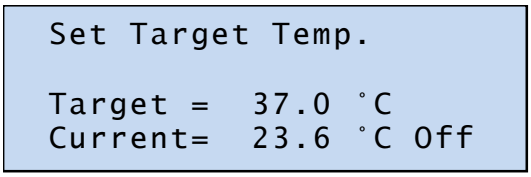


Figure 11. **TC 1** Set Target Temperature page

Set Target Temperature: To set the *Target* temperature, use the up and down arrows. Press **SET** to retain this new *Target* and initiate temperature control. The green LED light will begin flashing slowly as the device seeks the targeted temperature, and the page window will show the *Current* to be *ON*.

Discontinue Temperature Control: Press **SET** while the green LED light is lit or slowly flashing to discontinue temperature control. The LED light will turn off completely, and the page window will show the *Current* to be *Off*.

Set Stirring

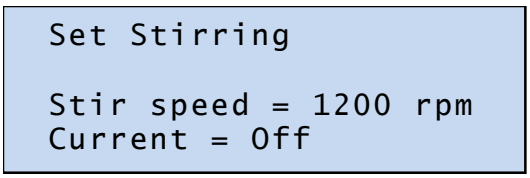


Figure 12. **TC 1** Set Stirring page

Set Stirring: To turn on magnetic *Stirring*, use the up and down arrows to choose an approximate stirring speed between 200 and 2000 rpm. Press **SET** to set the speed and initiate stirring. The page will update to show the *Current* value to be the same as *Stir speed*.

Discontinue Stirring: Press **SET** while the *Stirring* is on (shown by nonzero *Current* rpm) to turn the stirrer off. The page will update to show the *Current* speed to be *Off*.

Set Ramping

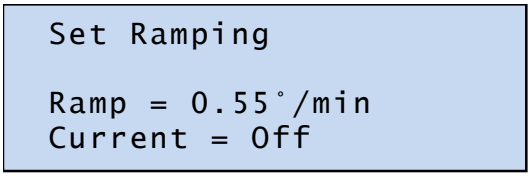


Figure 13. **TC 1** Set Ramping page

Set Ramping: To perform a temperature ramp, set the *Ramp* rate using the up and down arrows, and press **SET**. The page will update to show the *Current* rate in °/min to be the same as the *Ramp* rate. With ramping set, turning on temperature control will generate a linear ramp to the target temperature. When the sample holder reaches the target temperature, no further temperature change occurs, although the *Current* rate will remain as set.

The fastest possible ramp is determined by how fast the cuvette holder is able to reach the target temperature without ramping. Attempting to ramp too quickly, especially at high and low temperature extremes, will result in a nonlinear ramp. The slowest ramp that may be set on this page is 0.09 °C/minute. (If needed, much slower ramps may be set through software commands.)

Discontinue Ramping: Press **SET** while the *Ramp* is on (shown by nonzero *Current* °/min) to turn the *Ramp* off. The page will update to show the *Current* rate to be *Off*.

4.3. Cooling Water for the Peltier

The Peltier element (or "thermoelectric cooler") is a heat pump. When cooling, it transfers heat from the cuvette tower to the heat exchanger; when heating, electrical polarity is reversed and it transfers heat from the heat exchanger to the tower. When cooling, it is particularly important to transfer this heat away from the Peltier unit. This is accomplished with flowing water through the heat exchanger.

A source of water (or other cooling fluid) must be connected to the $\frac{1}{8}$-inch hose barbs on the side of the **qpod/E**. The QNW **BATH 10** includes a submersible pump, the appropriate fittings for connecting tubing, and a plastic bucket. Connect the pump to the **qpod/E**, place it in the bucket with water, and run a return tube to the bucket. A more robust pump is available as the **BATH 100**, although the larger pump has a higher wattage and tends to heat the water when used for extended periods of time. An enclosed circulation system, the **KOOL 440** is also available. Details are available on qnw.com.

Cooling water may also be provided from another source, such as a refrigerated cooling bath (or even a tap, for brief use only).

The Peltier unit requires a flow of 100 to 300 mL/min. This flow should require a pressure of about 3 - 5 psi (0.2 - 0.3 bar).

CAUTION

Caution - Do not exceed an input water pressure of 25 psi (1.7 bar), as damage may occur inside the **qpod/E**.

Note: The heat exchanger and hose barbs are brass, and the tubing inside the **qpod/E** is vinyl. Be sure that any circulating fluid used, other than water, will not corrode these materials.

The temperature of the heat exchanger in the **qpod/E** is monitored using a thermistor. If the temperature exceeds 60 °C, then temperature control is shut down to prevent damage to the Peltier element and the warning, "check coolant flow," displayed on the **TC 1** temperature controller. This will happen if the circulating fluid gets too warm and/or is restricted in flow. The heat exchanger temperature may be accessed by computer through the RS 232 or USB connections on the back of the **TC 1** Temperature Controller.

Temperature increases will be faster when room temperature water is used in the circulator. Temperature decreases will be faster when ice water is used. Only water should be circulated using the **BATH 10**. When using a refrigerated bath, circulating pre-cooled fluids (such as 30% methanol or diluted ethylene glycol) at below 0 °C will permit measurements below the specified temperature range.

4.4. Dry Gas to Minimize Condensation

Dry gas flows into the **qpod/E** via the small $\frac{1}{16}$-inch hose barb in the base of the unit. It passes up through holes below the optical ports in the cuvette tower to fill the space between the cuvette and the optical mask, preventing condensation on the surface of the cuvette.

Note: A flow of dry gas is necessary any time the **qpod/E** is controlled below the dew point temperature present on the inside of the sample compartment of the spectrometer. For ambient air, this would typically be about 5 °C.

4.5. External Temperature Probe

A $\frac{1}{4}$-inch phone jack labeled "Probe" can be found on the back panel of **TC 1** Temperature Controller. This jack will accept the plug on a standard Series 400 or Series 500 thermistor probe. (For a Series 400 probe, consider the YSI 423 semi-flexible thermistor probe.) When a probe is plugged into the jack, the probe temperature is presented on the display of the **TC 1**. Place the probe in the sample to measure the actual temperature of the sample, which will lag in time from the temperature of the cuvette tower.

Excellent Series 500 probes may be obtained with diameters less than 1 mm, providing access to small sample volumes. A disadvantage of these probes is that they are not pre-calibrated. Note that a probe may be easily calibrated using the calibration hole found in the upper surface of any Quantum Northwest cuvette holder (**Section 4.6**).

4.6. Calibration/Support Hole

Each cuvette holder made by Quantum Northwest has a **calibration/support hole** drilled in the upper surface next to the cuvette position. The **calibration/support hole** is used for the NIST-traceable calibration of the device before it is shipped.

The top of the **calibration/support hole** is tapped with an M4 metric thread, which is plugged with a stainless-steel set screw. For access to the hole, remove the screw. To calibrate a Series 400 or Series 500 temperature probe, insert the probe and set temperatures over the range of interest, recording holder and probe temperatures as reported by the **TC 1** Temperature Controller. To use the **calibration/support hole** to affix any device to the top of the cuvette holder, attach it using an M4 screw. Thus, for example, one might attach a post or other device to be used to support tubing or electrical wires that must access the cuvettes.

4.7. External Computer Control

All functions may be accessed either through a Serial (RS 232) or a USB located on the back of **TC 1** Temperature Controller. These functions are described in **Section 10**, *Terms Used in Serial Communications with the TC 1*, and **Section 11**, *Serial Communications for the TC 1 Temperature Controller.* You may write your own program or purchase the QNW application **T-App**. **T-App** will plot temperatures of the probe, cuvette tower, and even the Peltier element heat exchanger *vs* time. It will also permit you to set up temperature ramps. These functions are described in **Section 12**, *Elements of the T-App Software Help File*, and **Section 13**, *Example Controller Scripts for T-App Software*.

4.8. Working at Extended Temperatures

Section 8, *Temperature and Stirring Speed Ranges for Cuvette Holders*, summarizes the temperature ranges accessible for cuvette holders that use the QNW **TC 1** Temperature Controller. If working at high or low temperatures, consult **Section 9**, *Working at High and Low Sample Temperatures at the Laboratory Bench*, for detailed advice on how to achieve cuvette temperatures far removed from room temperature.

5. Troubleshooting and Maintenance

5.1. Troubleshooting

If the submersible pump has operated without being immersed in water, it may not prime properly. If this occurs, place one drop of detergent on the pump intake and try again.

If the **TC 1** display indicates that there is inadequate coolant (see **Section 5.2**, error message 8), it may be that the circulating water is too warm. Add ice to the water to cool it down.

If a microcuvette is used requiring a z-height of other than 8.5 mm, spectroscopic measurements may be erratic and erroneous as the spectrometer's light beam may be partially blocked by the masking on the cuvette. Set the spectrometer to a visible wavelength (e.g., 550 nm), darken the room, and use a white card to help trace the pathway of the light beam into the cuvette. If the cuvette interferes with the light beam, use a different cuvette. For a discussion of cuvette z-height, see **Section 2.1**.

If a cuvette is difficult to remove, it may be shorter than the minimum 30-mm height required for cuvettes in the **qpod/E**. Use a taller cuvette instead.

For an explanation of notations on the display screen of the **TC 1** Temperature Controller, see **Section 6**, *Glossary of Terms Appearing on the **TC 1** Front Panel Display Screen*.

For an explanation of the LED lights on the display screen of the **TC 1** Temperature Controller, see **Section 7**, *LED Status Indicators on the **TC 1** Front Panel*.

5.2. Error Messages

When errors occur, the line 1 of the **TC 1** Temperature Controller display presents an error code. Line 3 of the display identifies the error and line 4 of the display presents possible solutions. The most common events that cause errors to be displayed are loose cables or inadequate coolant flow. For errors not easily solved, contact QNW at www.qnw.com/contact-us/ or service@qnw.com.

Specific error messages include the following.

---

5 – cell out of range

warnings: loose cable, sensor failure

The temperature controller is not receiving a reasonable response from the sensor on the cuvette tower. Either the sensor has failed or a cable is not making a good connection.

---

6 – cell out of range

warnings: loose cable, check cable

The temperature controller is not receiving reasonable responses from either the cell tower or heat exchanger sensors. Since it is very unlikely for both to fail, probably a cable is loose.

7 – heat exchanger error

warnings: loose cable, sensor failure

The temperature controller is not receiving a reasonable response from the sensor on the heat exchanger. Either the sensor has failed or a cable is not making a good connection.

8 – inadequate coolant

warnings: inadequate coolant, water temperature

The sensor on the heat exchanger is reading a temperature above 60 °C. Temperature control has been shut down to prevent damage to the Peltier element. Either the water was too warm or the rate of flow was inadequate to draw sufficient heat from the heat exchanger.

9 – Invalid command

The controller has been sent an invalid text command.

5.3. Maintenance

The **qpod/E** and **TC 1** Temperature Controller require very little routine maintenance on the part of the user. For routine cleaning of exposed surfaces, use only a cloth dampened with water or diluted detergent. Do not use organic or abrasive solvents.

CAUTION

Caution – Any action which makes it necessary to open the **qpod/E** or **TC 1** Temperature Controller units must be executed only by QNW technicians or authorized personnel.

The water hoses and their attachments to the **qpod/E**, **TC 1** Temperature Controller, and submersible pump should be inspected prior to each usage to ensure that they are intact. Replace the nylon tubing when it becomes discolored or cracked. Periodically replace the water stored in the bucket to minimize the growth of microorganisms. When not in use, the pump, bucket, and tubing may be stored dry.

5.4. Spare Parts

Vinyl tubing and magnetic stir bars may be obtained from a variety of commercial vendors. For electrical cables to be used with **qpod/E** and **TC 1** Temperature Controller and submersible pumps, please contact QNW at service@qnw.com.

6. Glossary of Terms Appearing on the TC 1 Front Panel Display Screen

Term	Meaning
Holder	The temperature measured inside the Peltier-controlled cuvette holder, expressed in degrees Celsius (°C)
ID=n	The type of device being controlled by the TC 1 controller; ID=14 for SINGLE cuvette holder; ID=24 for DUAL; ID=34 for MULTI; ID=00 for specialty device
LKK	The control of the Reference and Sample cuvettes is linked so that control parameters of the Reference cuvette are identical to those of the Sample cuvette, and the TC 1 controller is under the command of an external computer control program (DUAL only)
LNK	The control of the Reference and Sample cuvettes is linked so that control parameters of the Reference cuvette are identical to those of the Sample cuvette, and change is possible only through the Sample cuvette settings (DUAL only)
LOK	The TC 1 controller is under the command of an external computer control program, and that program has locked the front panel to prevent the manual changing of settings
Off	For Ramping or Stirring, the function is not running either by default, or because the SET button was pressed while the function was running
On	For Ramping or Stirring, a valid parameter has been entered, and the SET button has been pressed
POS	The Position number (1, 2, 3, …) of the cuvette currently in the light beam of the spectrometer (MULTI only)
Probe	The temperature measured by an external probe, positioned by the user, expressed in degrees Celsius (°C)
Ramp	A setting of a rate of linear temperature change of the Peltier-controlled cuvette holder, expressed in degrees Celsius per minute, leading to the desired target temperature (°C /min)
REF	The Reference cuvette of a Reference/Sample cuvette pair (DUAL only)
RElink	The command to link the control of the Reference and Sample cuvettes such that the Reference cuvette receives control identical to that of the Sample cuvette (DUAL only)

SAM	The Sample cuvette of a Reference/Sample cuvette pair (DUAL only)
Stir	A setting of stirring of a magnetic stirrer under a cuvette, expressed in revolutions per minute (rpm)
Target	The value of the temperature being targeted for the Peltier-controlled cuvette holder, expressed in degrees Celsius (°C)
TT	The target temperature set for the Peltier-controlled cuvette holder, expressed in degrees Celsius (°C)
UNlink	The command to unlink the control of the Reference and Sample cuvettes such that the Reference and Sample cuvettes may be controlled independently of each other (DUAL only)
Version	The version number of the firmware used in the TC 1 controller
wTT	The Ramp condition of waiting for a new target temperature to be set, following the setting and activation of a ramp rate

7. LED Status Indicators on the TC 1 Front Panel

Light Status	Indication
Off	No active temperature control
Flashing Green	Seeking target temperature
Solid Green	Maintaining target temperature
Flashing Red	An error has occurred - see error messages in **Section 5.2**

8. Temperature and Stirring Speed Ranges for Cuvette Holders

Cuvette Holder Class	Cuvette Holder Type	Stirring Motor Type	Effective Minimum/ Maximum Stirring Speed, rpm	Factory Set Minimum/ Maximum Temperature, °C	Reasonable Laboratory Minimum/ Maximum Temperature, °C
Single	t2 Sport	Direct Current	200 to 1800	-40 to +110	-15 to +110
Single	Versa 20	Direct Current	900 to 1800	-40 to +105	-15 to +105
Single	Versa 20/E Extended Temperature	Direct Current	900 to 1800	-55 to +150	-50 to +150
Single	CD 250	Direct Current	900 to 1800	-40 to +105	-15 to +105
Single	CD 250/E Extended Temperature	Direct Current	900 to 1800	-55 to +150	depends on cuvette
Single	Luma 40	Direct Current	900 to 1800	-40 to +105	-15 to +105
Single	Luma 40/E Extended Temperature	Direct Current	900 to 1800	-55 to +150	-50 to +150
Dual	t2x2 Sport	Direct Current	200 to 1800	-40 to +110	-15 to +110
Multi	Turret 4	Stepper	60 to 1800	-40 to +110	-15 to +110
Multi	Turret 6	Stepper	60 to 1800	-40 to +110	-25 to +110
Multi	qCHANGER 6	Stepper	60 to 1800	-40 to +110	-15 to +110

CAUTION

Caution - See **Section 9** for a complete discussion of what minimum and maximum temperatures are achievable with Quantum Northwest products under standard laboratory conditions. Attempting to reach the factory set limits may damage the instrument if care is not taken.

9. Working at High and Low Sample Temperatures at the Laboratory Bench

9.1. Thermostatting a Liquid Sample in a Cuvette at Temperatures Other Than Room Temperature

A standard spectrophotometer for UV-Vis-NIR absorbance or fluorescence comes with a cuvette holder for the liquid sample and often a second one for the reference sample. The cuvette holders are housed in the sample compartment of the spectrometer on a lab bench. "Room temperature" is often cited when specifying the temperature at which a sample was held when a spectrum was measured. For many situations, this is adequate. For sensitive measurements – either because the sample is chemically different at different temperatures, or its spectra are different at different temperatures – it is necessary to control the temperature of the sample to a precisely set value.

One way of altering the sample temperature of a cuvette holder uses a temperature-controlled circulating water bath (containing water or a mixture of water and another solvent), and a cuvette or cuvette holder that allows the flowing water to directly cool or heat the cuvette. Using such a system, the sample temperature often does not match the temperature of the circulating fluid. Alternatively, a Peltier cuvette holder can be used. A Peltier unit uses thermoelectric cooling/heating to alter the sample temperature. Such control typically occurs much more rapidly and precisely over a wider range of temperatures. With a Peltier cuvette holder, the circulating water bath is used to remove heat from the Peltier's heat exchanger rather than directly influencing the temperature of the sample in the cuvette. Air-cooled Peltier units use air rather than liquid for removing heat from the heat exchanger, and have more limited temperature ranges available to them.

Problems arise at both hot and cold temperatures. As a sample in a cuvette gets warmer, bubbles are likely to form in the cuvette. Left in place, they scatter incident light and create artifacts in spectra. Cold samples are problematic at or below the dew point of the ambient air, as condensation forms on the surface of the cuvette. This condensation also scatters incident light, creating artifacts in spectra. As the temperature is lowered, the condensed water may freeze, causing issues with icing on the cuvette holder and potential damage to the cuvette holder or the spectrometer when the ice melts.

9.2. Successfully Working at High and Low Temperatures

Work at any temperature benefits from having the sample in the cuvette stirred using a magnetic stirrer built into the cuvette holder and a stir bar placed in the cuvette. This eliminates temperature gradients in the sample and facilitates more rapid equilibration to the set temperature. For high sample temperatures, up to +150 °C, magnetic stirring also helps dislodge bubbles that may form inside the cuvette as dissolved gases become less soluble with increasing temperature, although degassing samples before measurements is a more reliable means of preventing the artifacts that they cause.

Low temperature work must address the condensation of water on cuvette surfaces that are exposed to the atmosphere. The condensation can be limited by the application of a flow of dry gas (dried air, nitrogen, or argon, for example) to the surface of the cuvette while the sample is chilled. For cuvette holders used inside the sample chamber of a spectrometer, the whole sample compartment can be purged with dry gas.

How low can you go? For low-temperature spectroscopy with a benchtop spectrometer, many factors come into play. With Peltier cuvette holders, achieving low temperatures can be aided by the circulation of precooled liquid through the Peltier heat exchanger. For example, when using ice water at 0.0 °C, Peltier

cuvette holders will easily approach -25 °C or so. To go lower, circulation of precooled fluids below 0.0 °C is required. The use of 30% methanol-water as the circulating liquid is recommended, since it has ample heat capacity and low viscosity, permitting adequate flow through the heat exchanger. It should be possible to achieve a sample holder temperature about 25 °C lower than that of the circulating fluid.

The final consideration for achieving high and low extended temperatures with a benchtop spectrometer is the amount of insulation that can be positioned around the cuvette holder without obstructing the light beam in and out of the cuvette, and while maintaining normal operation of the spectrometer itself. Typically, spectrometer manufacturers do not provide either the insulation or the guidance on how to craft a well-insulated sample chamber for their products. This is left to the operator, and is often the final factor on whether or not an extended temperature can be reached. Creativity is required in using foam packing material or other foam products, often with tape and rubber bands, to provide the insulation required for the temperature desired.

9.3. Strategies for Working with Quantum Northwest Products at Extreme Temperatures

Quantum Northwest's Peltier cuvette holders provide not only temperature control, but also stirring and dry gas purging.

Extended temperature spectroscopy ranges are available for UV-Vis-NIR absorbance, fluorescence, fiber optic, flash photolysis, photoacoustic and circular dichroism applications:

- Versa 20/E family of products for UV-Vis-NIR spectrophotometry
- Luma 40/E and TLC 50 Legacy/E families of products for fluorescence spectroscopy
- qpod/E cuvette holder for fiber optic spectrometers
- Flash 300/E stand-alone device for laser flash photolysis and pulsed-laser photoacoustics
- CD 250/E cuvette holder for circular dichroism spectrometers

These cuvette holders can be specially built to extend their temperature ranges from their normal range of -40 to +105 °C. Choosing the extended temperature option – denoted by /E – extends this control range to -55 °C to +150 °C. This requires the use of materials that are stable at the high and low temperatures, sensors with extended range, and design details that protect the delicate magnetic stirring motors. The Versa 20, Luma 40 and Flash 300 can be provided with windowed jackets to trap dry gas around the cuvette holder to eliminate condensation and frosting.

The lowest measured temperature reached to date at Quantum Northwest's manufacturing facility in Liberty Lake, WA, USA, was -52.7 °C with an extended temperature Flash 300/E, considerable added insulation, and circulating fluid of -20 °C. This is short of the -55 °C claimed for the extended temperature (/E) products. Why is this?

In short, with an extended temperature product, the user can send a control command to the unit to go to -55 °C; but, whether the unit will actually go to -55 °C depends on whether cold circulating fluid is used, and how well insulated the sample holder is. This situation is analogous to trying to chill a room to 15 °C with a powerful air condition unit, but if the user keeps the windows open on a hot summer day, the room will not likely get to 15 °C. The scientist's ability to customize and maximize the foam insulation around the cuvette holder is usually the key determinant to achieving low temperature spectroscopy without specialty cryogenic devices.

9.4. Summary

Sample temperatures approaching -55 °C and up to +150 °C are possible in a standard benchtop spectrometer. Magnetic stirring is required for extended temperature work. The temperature of the circulating water bath needs to be controlled, and it may be necessary to blend the water with another solvent such as methanol to reach the required temperatures. For cold temperature work, dry gas must flow onto the surface of the cuvette to reduce condensation and ice build-up, and additional insulation must be added to surround the cuvette holder without obstructing the light beam.

For Quantum Northwest Peltier products that operate at extended temperatures, the following temperatures are achievable under the approximate conditions:

5 °C – lowest temperature in the open air (with typical humidity), no dry gas flow;

-10 °C – lowest temperature in an exposed environment but with dry gas flow;

-25 °C – lowest temperature in an enclosed, dry environment, with 0 °C circulating fluid;

-40 °C – lowest temperature with a windowed jacket surrounding the cuvette holder, -15 °C circulating fluid, some added insulation;

-55 °C – lowest possible temperature with a windowed jacket surrounding the cuvette holder, -30 °C circulating fluid, and maximum added insulation.

10. Terms Used in Serial Communications with the TC 1

Section 11 describes in detail the commands used for serial control of the **TC 1** Temperature Controller. The table below summarizes the main commands and their definitions.

Command	Definition
+	On
-	Off
CT	Current temperature of the cuvette holder, degrees Celsius (°C)
ER	Error
FP	Front panel input
HL	High temperature limit of the heat exchanger of the cuvette holder, degrees Celsius (°C)
HT	Current temperature of the heat exchanger of the cuvette holder, degrees Celsius (°C)
ID	Identification of cuvette holder type (Single, Dual, Multi, or specialty device)
IS	Instrument status
LK	Link the reference cuvette settings to those of the sample cuvette
LO	Lock out the front panel from user input through the control buttons
LS	Lowest stirrer speed, revolutions per minute (rpm)
LT	Lowest target temperature allowed, degrees Celsius (°C)
MS	Maximum stirrer speed, revolutions per minute (rpm)
MT	Maximum target temperature allowed, degrees Celsius (°C)
PA	Automatic reporting of probe temperature
PR	External probe connected
PS	External probe status
PT	Probe temperature, degrees Celsius (°C)
PX	Probe temperature precision
R	Automatic reporting (of SS, for example)
RR	Ramp rate, degrees Celsius per minute (°C/min)
SS	Stirrer speed, revolutions per minute (rpm)
TC	Temperature control
TT	Target temperature, degrees Celsius (°C)
VN	Version number of the TC 1 controller firmware
W	Ramp mode is waiting for target temperature input

11. Serial Communications for the TC 1 Temperature Controller

7/19/2016

Note: This document provides the serial communications protocols for version 2.22 of the firmware on the TC 1 family of controllers.

TC 1/Single – for single cuvette holders such as the t2 Sport, Versa 20, Luma 40, CD 250 and Flash 300;

TC 1/Dual – for dual independent control for sample and reference cuvettes of the t2x2 Sport and qpod;

TC 1/Multi – for multi-position sample changers such as the qCHANGER 6 and the Turret 6.

The version number and the ID (see below) are shown briefly on the display when the temperature controller is turned on. This initial display can be repeated by pressing the down arrow on the front panel of the controller.

All functions of the temperature controller can be managed from a computer, using the command set described below. If you purchased your unit as a component of a spectrometer from certain manufacturers, this feature may be implemented through traditional RS232 serial connectors on the computer, or the spectrometer and on the controller. In this case, they will be connected by a standard 15-pin serial extension cable (male connector on one end and female on the other). No driver installation should be needed. Otherwise the serial linkage will be established through a USB connection between the computer and the controller. In this case the controller includes electronics which convert the USB connection to a serial communications port. However, for the port to be available to programs on the computer, it will be necessary to load driver software.

CAUTION

Caution - It is important that the driver software be loaded before connecting a USB cable between the controller and the computer. Contact Quantum Northwest for further information.

Quantum Northwest offers the **T-App** control program written specifically for control of all functions of the temperature controller and to track temperature as a function of time. The resulting data can be saved to a text file (two columns, time and temperature, tab delimited) or copied and pasted directly into another program (such as Microsoft Excel). If you expect to create software or firmware that communicates with a **TC 1** controller, **T-App** may prove extremely useful for preliminary testing of controller commands.

In programming for the **TC 1** controller, one must adhere to the conventional notation: 8/N/1.

Baud:	19200
Data Bits:	8
Parity:	None
Stop Bit:	1
Flow Control:	None

For many of the commands listed below, the controller returns information in response to the command. All commands and responses are delineated by left and right square brackets ([ ]). Any text sent to the

controller not enclosed within brackets will be ignored. In this document, an ellipsis (…) is used to distinguish responses from commands.

Note: The format of the commands is shown below.

`[command]`	Purpose of the command (sent to the controller).
`...[response]`	Meaning of the response (received from the controller).

11.1. Sample Holder ID Number

`[F1 ID ?]`	What is the ID number of the sample holder being controlled?
`...[F1 ID 14]`	ID is 14.

Assigned Identities:

ID = 00 **specialty sample holder**
14 **single**
24 **dual**
34 **turret or linear multi-sample holder**

11.2. Controller Firmware Version

`[F1 VN ?]`	What is the **V**ersion **N**umber of the controller firmware?
`...[F1 VN 2.22]`	The controller firmware version number is 2.22.

11.3. Stirrer

`[F1 MS ?]`	What is the **M**aximum stirrer **S**peed?
`...[F1 MS 2500]`	The maximum stirrer speed permitted is 2500 rpm.
`[F1 LS ?]`	What is the **L**owest stirrer **S**peed?
`...[F1 MS 300]`	The lowest stirrer speed permitted is 300 rpm.
`[F1 SS S 1000]`	Set **S**tirrer **S**peed to 1000 rpm and turn stirring on.
`[F1 SS S 0]`	Turn stirrer off (does not change the speed setting).
`[F1 SS +]`	Turn stirrer on and set it to the most recent non-zero stirrer speed setting.
`[F1 SS -]`	Turn stirrer off (this does not change the speed setting)..
`[F1 SS ?]`	What is the current stirrer speed setting? Depending on the R+/R- state as specified below, the stirrer status ('+'/on or '-'/off) may also be reported.
`...[F1 SS 1000]`	Stirrer speed setting is 1000 rpm.
`...[F1 SS -]`	Stirrer status is off.

[F1 SS R-]	Turn off automatic **R**eporting of the stirrer speed and status when changed by a command.
[F1 SS R+]	Turn on automatic reporting of stirrer changes. The power on default setting is to not report the speed or the status when changed. If you then send [F1 SS R+], only the stirring speed will be reported when changed. If you then send [F1 SS R+], both the speed and the status will be reported when changed. If you then send [F1 SS R-], neither the speed nor the status will be reported when changed (back to the power on default setting). Note that the [F1 SS ?] will always result in a stirring speed response. The status response will also be sent if it has been enabled as described above.

11.4. Temperature Control

[F1 TC +]	Turn **T**emperature **C**ontrol on.
[F1 TC -]	Turn temperature control off.
[F1 TC ?]	What is the current status of temperature control?
...[F1 TC -]	Temperature control status is '-'/off.
[F1 TC R+]	**R**eport temperature control status when changed by a command.
[F1 TC R-]	Do not report temperature control status when changed.

11.5. Target Temperature

[F1 MT ?]	What is the **M**aximum **T**arget temperature setting allowed for this holder?
...[F1 MT 105]	The maximum target temperature allowed is 105 ºC.
[F1 LT ?]	What is the **L**owest **T**arget temperature setting allowed for this holder?
...[F1 LT -30]	The lowest target temperature allowed is -30 ºC
[F1 TT S 23.10]	Set the **T**arget **T**emperature to 23.10 ºC. Note: The TC 1 does not turn temperature control on when TT is received (as it does when the front panel controls are used to set the TT).
[F1 TT ?]	What is the current target temperature?
...[F1 TT 71.32]	Target temperature is 71.32 ºC.
[F1 TT +] or [F1 TT R+]	Turn on automatic reporting of the target temperature when changed by a command.
[F1 TT -] or [F1 TT R-]	Turn off automatic reporting of target temperature changes.

11.6. Instrument Status

[F1 IS ?]	What is the current **I**nstrument **S**tatus?
...[F1 IS 0-+S]	Response is four parameters (or five, see below): number of unreported errors is 0 (0 or 1); stirrer is off (+ is on, - is off); temperature control is on (+ is on, - is off); current sample holder temperature is stable (S is stable, C is changing).
[F1 IS +] or [F1 IS R+]	Automatically report instrument status whenever it changes (e.g., when the sample holder temperature goes from changing to stable).
[F1 IS -] or [F1 IS R-]	Stop automatic reports of instrument status when it changes (the power-on default).
[F1 IS E+]	Include the ramp status as a fifth parameter in the instrument status response.
...[F1 IS 0-+SW]	The ramp status will be one of three states represented by the characters '-' ('minus', ramping off), '+' ('plus', ramping on) or 'W'(waiting for TT). See subsection 11.10 for details.
[F1 IS E-]	Stop including the ramp status in the instrument status response (power-on default).

11.7. Current Sample Holder Temperature

[F1 CT ?]	What is the **C**urrent **T**emperature of the sample holder?
...[F1 CT 22.84]	The current temperature is 22.84 ºC.
[F1 CT +3]	Periodically report current temperature every 3 seconds.
[F1 CT -]	Stop periodic current temperature reports.
[F1 CT +]	Restart periodic probe temperature reports using the current interval (the power-on default is a 3-second interval).
[F1 CT R+]	**R**eport status of the sample holder temperature when it changes.
...[F1 CT C]	The status of CT is changing.
...[F1 CT S]	The status of CT is stable (CT has stayed within +/-0.05 °C of the target temperature for at least 1 minute.
[F1 CT R-]	Stop reporting changes in the status of CT (power-on default).

11.8. Error Reporting

[F1 ER ?]	Report the current error (**ER**ror).
...[F1 ER -1]	No current error.
...[F1 ER 05]	Cell T out of range (Loose cable? Sensor failure?).
...[F1 ER 06]	Both cell and heat exchanger T out of range (Loose cable?).
...[F1 ER 07]	Heat exchanger T out of range (Loose cable? Sensor failure?).

...[F1 ER 08]	Inadequate coolant (check flow). Temperature control has shut down.
...[F1 ER 09<<bad command>>]	Syntax error on a preceding command where "bad command" is the text of the command that caused the syntax error response.
[F1 ER +]	Automatically report errors when they occur.
[F1 ER -]	Stop automatic error reports (this setting has no effect on ER 9 responses).

11.9. Probe Status and Temperature

[F1 PS ?]	What is the **S**tatus of the TC 1 external **P**robe connector?
...[F1 PR +]	A series 400 thermistor probe is connected.
...[F1 PR -]	No probe is connected.
[F1 PS +] or [F1 PS R+]	Enable probe status to be **R**eported automatically when a probe is installed or removed.
[F1 PS -] or [F1 PS R-]	Disable automatic sending of probe status (power-on default).
[F1 PT ?]	What is the current **P**robe **T**emperature?
[F1 PT +3]	Periodically report the probe temperature every 3 seconds (integers only, the '+' is required).
...[F1 PT 22.37]	The current probe temperature is 22.37 °C.
...[F1 PT NA]	Probe temperature is not available.
[F1 PT -]	Stop periodic probe temperature reports. The interval is retained.
[F1 PT +]	Restart periodic probe temperature reports using the current interval (the power-on default is 3 seconds).
[F1 PA S 0.5]	Set the temperature interval for **A**utomatic reporting of the **P**robe temperature to 0.5 °C during a ramp. (Increment must be positive, without sign in tenths between 0.1 and 9.9 °C, and will work for ramps going up or down.) Note: this command does not start automatic reporting, it just sets the interval to be used when it is turned on.
[F1 PA ?]	What is the current temperature interval for automatic reporting?
...[F1 PA 0.5]	The interval is 0.5 °C.
[F1 PA +]	Start automatic reporting of probe temperature at temperature intervals (set by the command above).
[F1 PA -]	Stop automatic reporting of probe temperature every temperature increment.
[F1 PX +]	Change probe temperature returned to a precision of 0.01 °C.
[F1 PX -]	Change probe temperature returned to a precision of 0.1 °C.

Note: Since probe temperatures are always reported to 0.01 °C by the TC 1 controller, these last two commands have no effect. They are included to maintain compatibility with customer software /

firmware based on the older TC 125, TC 225 and TC 425 temperature controllers (i.e., they will not cause an [F1 ER 9 <<….>>] report – see subsection 11.8).

Note: Except for [F1 PS ?] and [F1 PS R(+/-)], any probe related command issued when a probe is not connected to the TC 1 will result in the warning response [F1 NOPROBE].

11.10. Temperature Ramping

`[F1 RR S 0.50]` Sets the ramp rate to 0.50 °C/minute. This command also sets the ramp status to `'W'`/ waiting mode (see below). With the exception of 0 the ramp rate must be in the range 0.01 to 10; otherwise an ER 9 reply will be returned by the controller, the ramp rate will be set to the nearest allowed value, and the controller will send a second response specifying the ramp rate that was set.

`[F1 RR S 0]`
`or [F1 RR -]` Sets ramp status to `'-'`/off (but does not change the current ramp rate setting). If either command is sent during a temperature ramp, the controller will then drive at maximum to the last set target temperature.

`[F1 RR +]` Set ramp status to `'W'`/ waiting mode.
In waiting mode the TC 1 is waiting for a new target temperature to be set (see subsection 11.5). When the TT command is received, if temperature control is on (see subsection 11.4) the controller begins ramping the temperature from the current value to the new TT at the previously specified ramp rate. If temperature control was off when the TT command is received, the ramping process does not begin until it is turned on. In either case the ramping state is `'+'`/on until the ramp is completed or cancelled.

If this command is sent while a ramp is in progress, the ramp status will change to `'W'`/ waiting and the controller will drive at maximum to the last target temperature set.

`[F1 RR ?]` What is the current ramp rate setting? Depending on the R+/R- state as specified below, the ramp status (`'W'`/waiting, `'+'`/on or `'-'`/off) may also be reported.

`...[F1 RR 1.00]` Current ramp rate is 1.00 °C/minute.

`...[F1 RR W]` Ramp status is waiting.

`[F1 RR R-]` Turn off automatic reporting of the rate and ramp status when changed by command or by use of the front panel.

`[F1 RR R+]` Turn on automatic reporting of ramp changes. Automatic reports will be sent by the controller when the ramp rate or status is changed by command.

The power on default setting is to not report the ramp rate or the ramp state when changed.
If you then send [F1 RR R+], only the ramp rate will be reported when changed.
If you then send [F1 RR R+], both the rate and the state will be reported when changed.
If you then send [F1 RR R-], neither the rate nor the state will be reported when changed (back to the power on default setting).
Note that the [F1 RR ?] will always result in a ramp rate response. The ramp status response will also be sent if it has been enabled as described above.

The following seven commands, are accepted by and work with the TC 1. They are provided mainly to maintain compatibility with control software/firmware developed for use with the older TC 125/225/425 family of temperature controllers.

There are no corresponding reference commands (see subsection 11.13) for the TL commands.

`[F1 TL +]` Ramp the sample and reference identically.

`[F1 TL -]` or.

`[F1 TL 0]` Ramp the sample and reference independently (the power on default).

[F1 RS S #], [F1 RS ?] Set or query the RS parameter (# is a positive integer).

[F1 RS S #], [F1 RS ?] Set or query the RT parameter (# is a positive integer).

RS and RT provide an alternate method of setting the ramp rate.

If the last set command for RS or RT results in both set to positive values (even if the actual setting is not changed by the command), they are used to calculate RR for actual use by the firmware and the ramp status is set to 'W'/waiting.

If ramp status is 'W'/waiting or '+'/ramping, setting both RS and RT to 0 will change the status to '-'/off (but will not change the ramp rate setting).

To Ramp the temperature:

1. equilibrate at the starting temperature;
2. set the ramp rate;
3. set a new target temperature (subsection 11.5).

The target temperature may be above or below the current temperature; as soon as it is set, the ramp will begin, up or down, to that new target.

After reaching the target, the controller will hold at that temperature. At any time, a new ramp rate and target temperature can be set to start a new ramp.

Once the ramp is completed, if you want to start another ramp (even using the same ramp rate) you must send the ramp rate set command. Otherwise, setting a new target temperature will cause the controller to drive at maximum to the new target.

Note: The following details aid in running T-App.

3. The minimum settable ramp rate (using the [F1 RR S #] command) is 0.01 °C/minute. The maximum is 10 °C/min.
4. For higher ramp settings, the observed rate may be lower than that specified or it may be nonlinear over part of the temperature range because the maximum possible rate of heating or cooling is limited (and dependent on the ramp direction as well as on the temperature).
5. For compatibility with the TC 125/225/425 family of controllers, when the ramping process is completed the controller will send an [F1 TT #] response, where # will be the target temperature used to start the ramp. Depending on automatic reply settings, an [F1 RR -] and/or [F1 IS 0++C-] response may also be sent by the TC 1.
6. When the ramp status is '+'/On, sending a [F1 TT S #] command or a [F1 TC -] command will change the ramp status to '-'/Off.

11.11. Heat Exchanger Temperature

`[F1 HT ?]` What is the current temperature of the heat exchanger?

`[F1 HT +3]` Start periodic heat exchanger temperature reports every 3 seconds.

`...[F1 HT 39.23]` The current heat exchanger temperature is 39.23 ºC.

[F1 HT -]	Stop periodic heat exchanger temperature reports.
[F1 HL ?]	What is the high temperature limit for the heat exchanger?
...[F1 HL 60]	The heat exchanger high temperature limit is 60 ºC.
	In operation with temperature control on, if the HT parameter exceeds HL, the TC 1 will turn temperature control off. It will also send [F1 ER 8], [F1 TC -] and/or [F1 IS …] (with parameter 3 = '-'/minus) depending on the current auto-reply settings (see below).

11.12. Cell Changing

Note: These commands are valid only for a sample holder with multiple cuvette positions.

[F2 DI]	Device initialize: move to home position, then back to the current position setting.
[F2 PI]	Device initialize: move to home position, then back to the current position setting and reply when done.
...[F2 DL 1]	Device is finished moving. (Original reply was OK rather than DL 1)
[F2 DL 3]	Device locate: move to position 3. (Device should be initialized prior to using this command for the first time.)
[F2 DL ?] or	
[F2 PL ?]	What is the current position?
...[F2 DL 1]	Device is in position 1.
[F2 PL 4]	Device locate: move to position 4 and reply when done. (Device should be initialized prior to using this command for the first time.)
...[F2 DL 4]	Device is now in position 4.
[F2 ?]	What is the current motor status?
...[F2 OK]	Most recent move is complete.
...[F2 BUSY]	Most recent move is still in progress.

11.13. Reference Cuvette

Note: These commands are valid only for systems with two independently-controlled sample holders. Otherwise, they will cause an ER 9 response.

[R1 ...]

To control and monitor the temperature and status of the reference cuvette using a Dual Temperature Controller, use any commands in subsections 11.1-11.8, 11.10 and 11.11, substituting R1 for F1. There are no corresponding [R1 …] commands for subsections 11.9 and 11.12.

11.14. Front Panel Controls

Note: The TC 1 can be controlled manually using the buttons and the display on the front. Once a control program has connected to the TC 1, the controller will automatically send reports to the program whenever a manual change has been made. The commands in this section allow the program to control access to front panel (FP) settings and determine if and how such front panel changes are reported.

[F1 LO (+/-)] **L**ock**O**ut (+) or do not lockout (-) the front panel. When lockout is on (+) the front panel will display "LOK" or "LLK" in the upper right corner of the display (not shown in the MAIN display for a multiposition system). The user will be able to use the left-arrow and right-arrow buttons to move between the settings displays (as if no control program were connected) but the up-arrow, down-arrow and SET buttons will not allow changes in the settings. The up-arrow and down-arrow buttons will work to move between the MAIN SAM, MAIN REF, and version/ID displays.

[F1 LO ?] Query the current lockout state.

. . . [F1 LO +] or ...[F1 LO -]

[F1 LK (+/-)] **L**in**K** (+) or unlink (-) the reference to/from the sample. This command is only available for a dual sample holder system. When link is on (+) the front panel will display "LNK" or "LKK" in the upper right corner of the display. The user will be unable to change any of the REF settings (they will be locked as described above). When the user changes a "SAM" setting using the front panel controls (such as temperature control On/Off, stirrer speed, ramp rate) the identical change will automatically be made for "REF'.

[F1 LK ?] Query the current link state.

. . . [F1 LK +] or ...[F1 LK -]

T-App uses this command to turn linking off in the temperature controller and handles linking of the reference settings to the sample settings in the program (see link reference to sample).

"LKK" in the upper right corner of the display indicates that both lockout and link have been turned on by the control program.

[F1 FP (+/-)] Report (+) or do not report (-) changes made by use of the **F**ront **P**anel controls on the TC 1. The power-on default is to report FP changes.

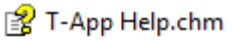
Setting changes are reported by [F1 TT #], [F1 SS #] and [F1 RR #] replies.

The power-on default for status changes is to report by [F1 TC (+/)], [F1 SS (+/)] or [F1 RR (+/)] replies, even if the control program has not turned on these status change replies. The control program cannot turn these responses off (except as described below).

If the control program has sent [F1 IS +] or [F1 IS R+] commands to turn automatic instrument status reports on, status changes resulting from use of the front panel controls will be reported only by the instrument status reply, [F1 IS ….].

There is no query command for the FP state.

12. Elements of the T-App Software Help File



The program T-App comes with a complete Help File. This file may be explored in detail by locating the file T-App Help.chm and clicking on it to open it. Below are elements from the Help file that are useful for getting started with T-App, if purchased.

12.1. Application Startup Window

This Startup Window is displayed while the program searches for a **Temperature Controller** by checking each active COM port on the computer, beginning with the highest.

When a **Controller** is found, this startup window is replaced by the Application Control Window.

If a **Controller** is not found, the startup window changes to that below. Click on the areas where the pointer changes to a hand for further information on the Application Menus and buttons,

This may result if the **Controller** is not connected to power, or if the Bluetooth or USB link between the **Controller** and the computer is not available.

Click the Try Again button (or use the File>Restart menu item) once you have corrected the problem. Click the Exit button (or use the File>Exit menu item) to terminate the program.

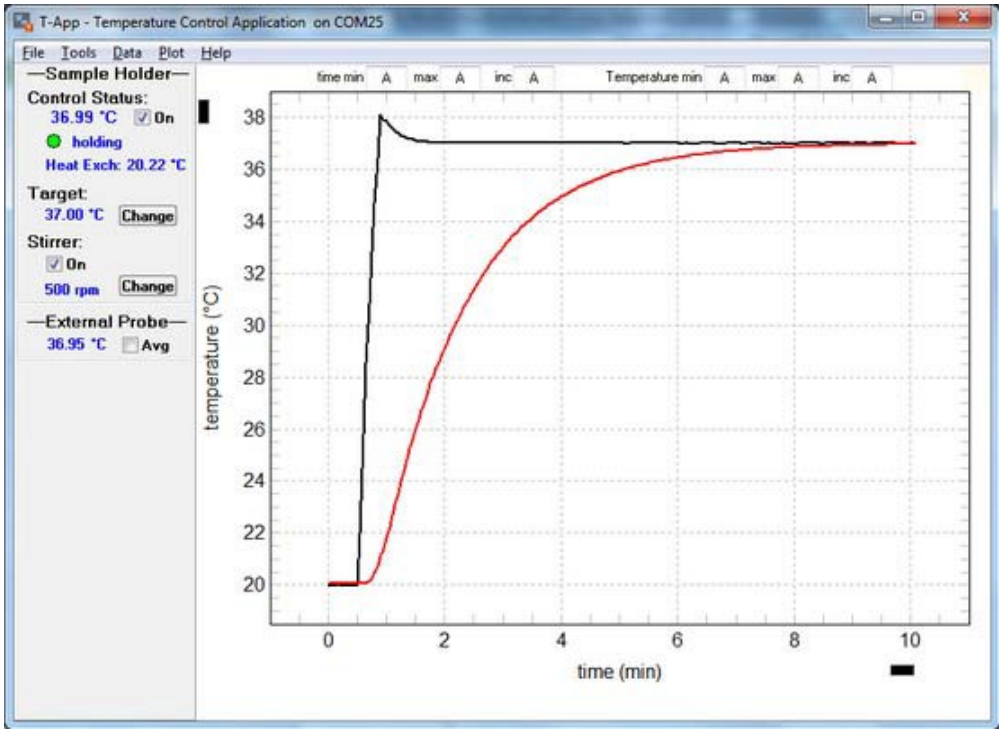
You may also use the File>(Work Offline) menu item to use the program without connecting to a sample holder in order to plot previously saved time/temperature data without being connected to a **Controller**.

12.2. Application Control Window

Immediately after **T-App** connects to a T**emperature Controller**, a banner with blinking text appears across the top of the application window as shown below. This banner persists while **T-App** is communicating (coordinating) with the **Controller**. At the end of the coordinating process, **T-App** causes the C**ontroller** to begin automatically sending temperatures every 3 seconds.

The figure below shows the Application Control Window as it would appear if the user changed the sample holder Target Temperature from 20 to 37 C while temperature control was on. The black trace is the sample holder temperature and the red trace is the external thermistor probe temperature.

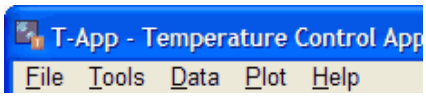
Click on the areas where the pointer changes to a hand for further information on the Application Menus, the Temperature Plot or the Status Panel.



The image above shows the T-App Application window as it would appear using a **TC 1 Temperature Controller** with a Series 400 thermistor probe attached (with the thermistor tip in the stirred sample).

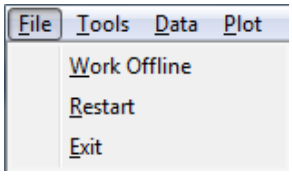
12.3. Application Menus

Click on the individual menu bar items (where the pointer changes to a hand) for further information on that menu.



12.4. File Menu

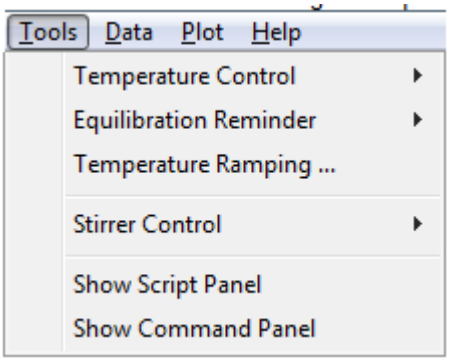
Click on the individual menu item (where the pointer changes to a hand) for further information on that menu item.



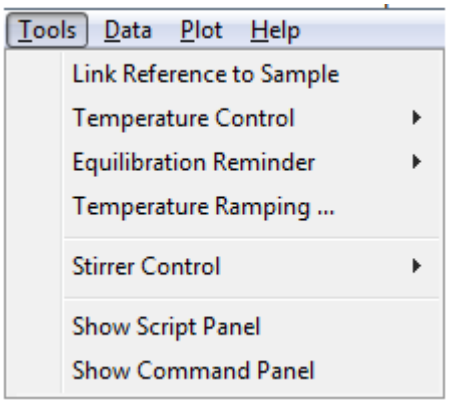
12.5. Tools Menu

Click on the individual menu item (where the pointer changes to a hand) for further information on that menu item.

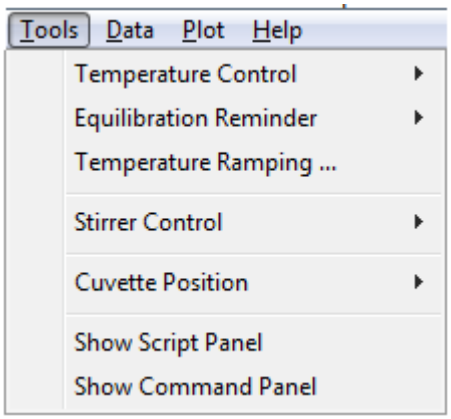
Tools menu items for a single sample holder system.



Tools menu items for a dual sample holder system.

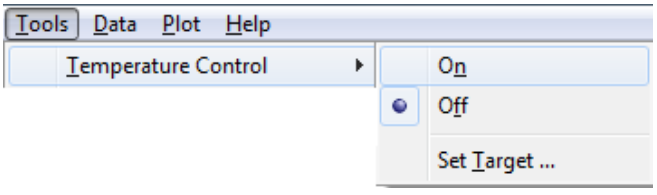


Tools menu items for a multi-position sample holder system.

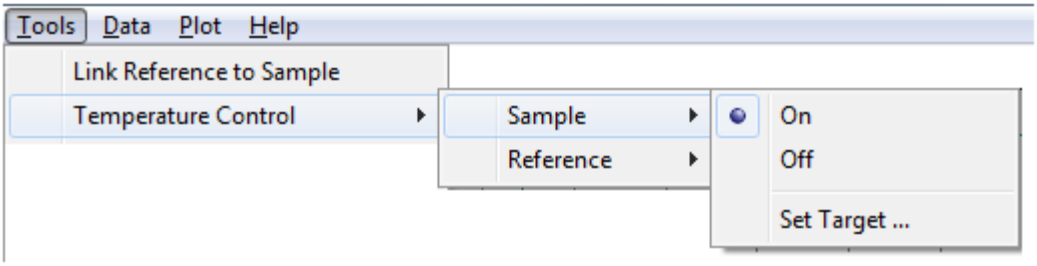


12.6. Temperature Control

Tools>(Temperature Control) menu for a single controller, including multi-position controllers.



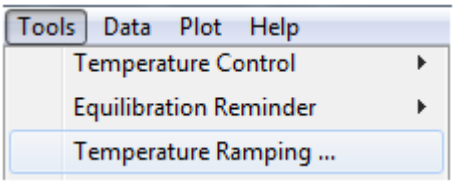
If your system is a dual Temperature Controller with linking turned off, clicking on the "Temperature Control" menu item will present two submenu items, "Sample" and "Reference"; clicking on either of these submenus will present the three choices for changing settings for that holder (shown for Sample below).



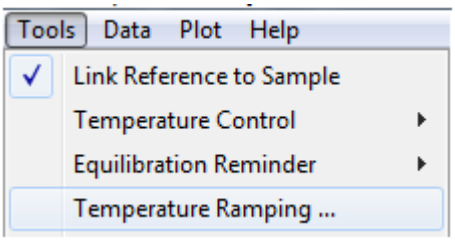
Note: If **Link Reference to Sample** is checked, the Sample/Reference choice will not be available (the menu behavior will be identical to a single **Controller**.

12.7. Temperature Ramping

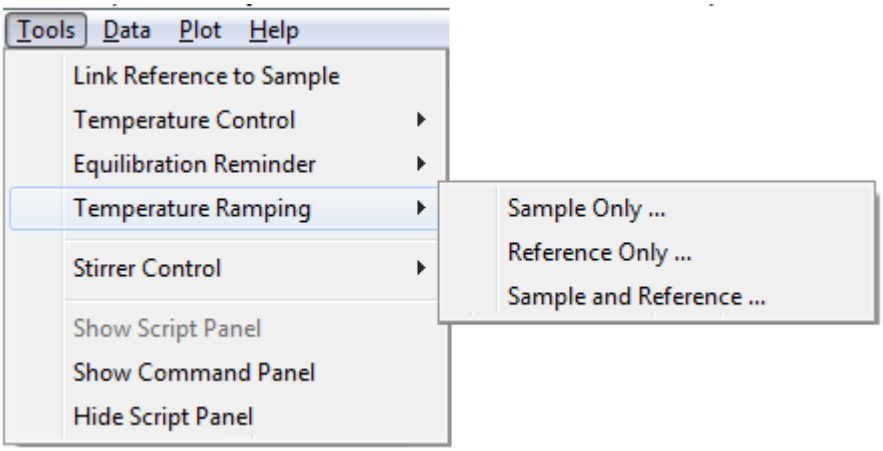
Single sample holder system (including multiple sample position systems).



Dual sample holder system with **Reference Linked to Sample**.



Dual sample holder system with Reference not linked to Sample.



When you click on one of the Temperature Ramping menu items, a small parameter entry dialog will be presented for entry of two parameters.

The first parameter determines the temperature at which the ramping process will stop (and will reset the Target Temperature to that value).

The second parameter determines the rate for the temperature ramp (degrees C/min). This parameter is always a positive decimal number and must be greater than or equal to 0.01. The maximum value is 10.0.

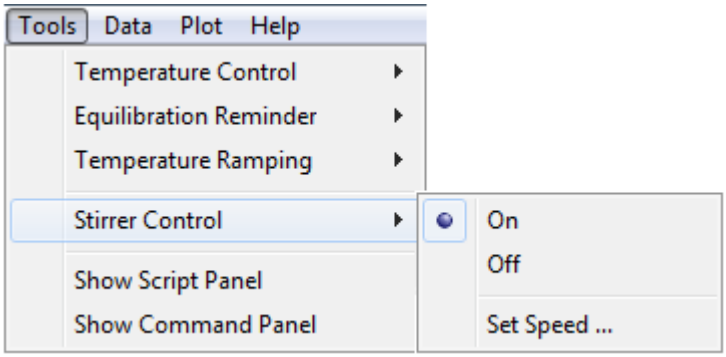
When the entry dialog is closed (if temperature control is turned on), the sample holder temperature will begin to change at the specified rate from the current temperature to the new target temperature. The direction of the ramp (up or down) is determined by these two temperatures.

If you need to stop the ramp before it is completed, set the ramp rate to zero. The system will then heat or cool at maximum capacity to move the sample holder temperature to the Target Temperature.

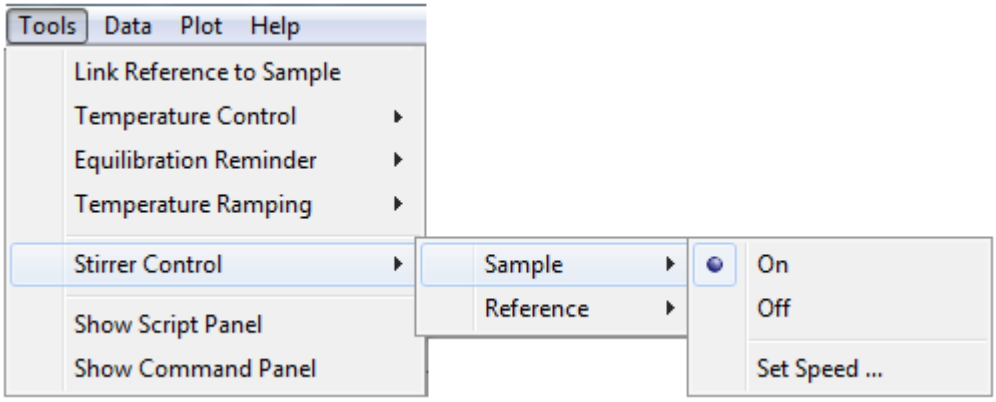
In a dual system, if temperature control is on for both sample and reference then the countdown will not begin until both are stable at the target temperature.

12.8. Stirrer Control

Single sample holder system (including multiple sample position systems).

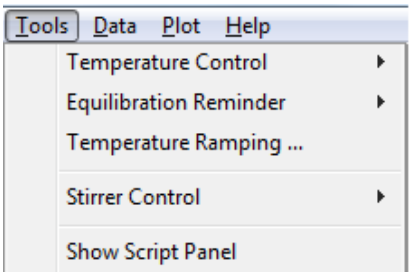


Dual sample holder system.



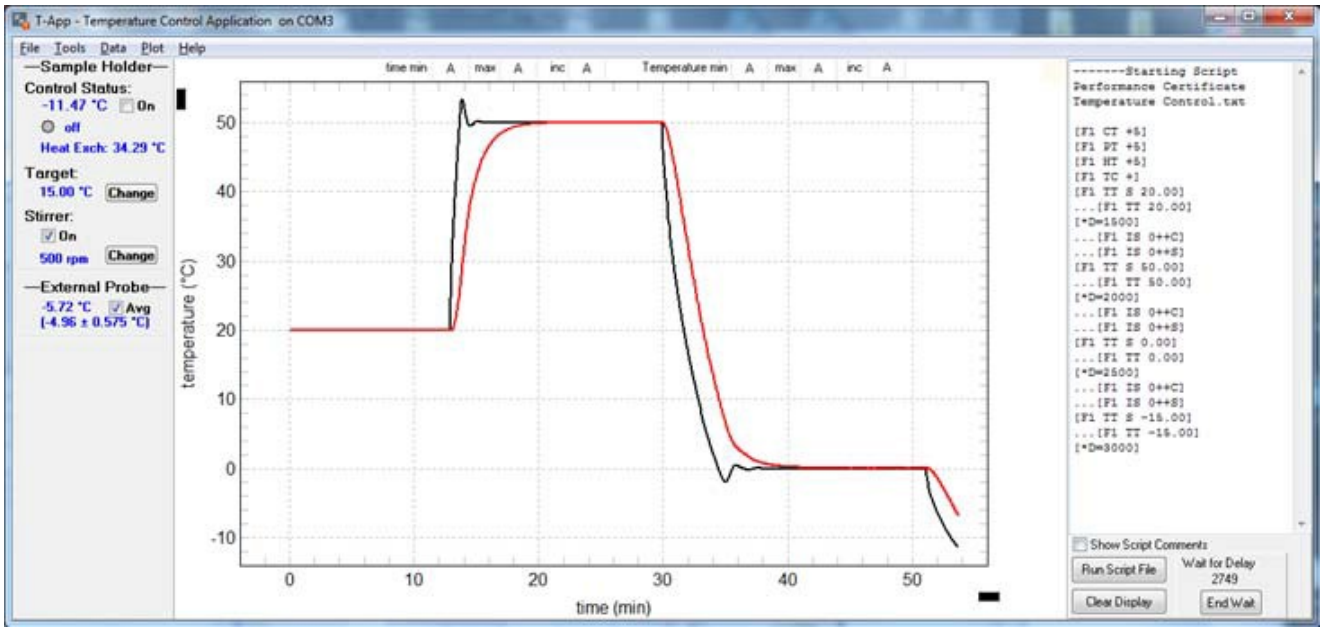
Note: If **Link Reference to Sample** is checked, the Sample/Reference choice will not be available.

12.9. Show Script Panel



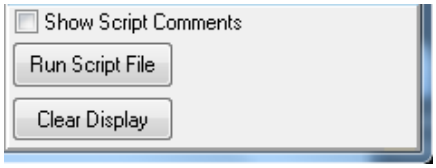
When this menu item is clicked, the right side of the Application Control Window will open to show a vertical panel containing a text display with button controls and other information near the bottom.

The snapshot below was taken when the program was in the middle of running a script. This particular script is used to do a performance run on each sample holder. The performance run for each sample holder is included in the Calibration Certificate found in the hardware manual.

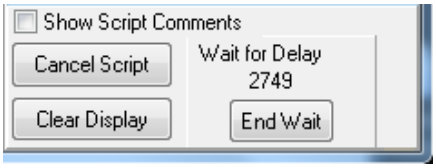


Generally, you should click on the "Clear Display" button before running a script.

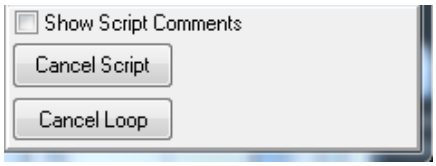
The controls below the text window change depending on whether a delay or wait command is being executed and on whether the current command being executed is inside a loop. Click on the individual control below (where the pointer changes to a hand) for further information on that control.

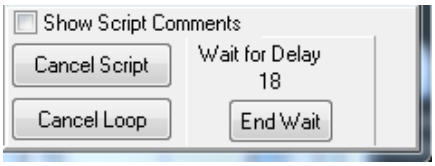


NO SCRIPT RUNNING.



DELAY/WAIT COMMAND NOT INSIDE A LOOP.





CURRENT COMMAND IS INSIDE A LOOP. DELAY/WAIT COMMAND INSIDE A LOOP.

12.10. Command Text Box

This edit box may be used to send commands to the Temperature Controller.

The edit box content always starts out as "ENTER / SELECT". When you click on it the first time this content is automatically selected, ready to be replaced when a command entered using the keyboard.

Clicking the arrow at the right end of the edit box will present a drop-down list as shown (below left). Initially the list will include only prototype commands. Click on the command wanted and it will appear in the edit box (below, center). Change the prototype symbol '±' to a plus or minus; '#' to an appropriate number (below right).

To send the command to the QNW Temperature Controller either hit the Enter key on the keyboard (while still in the command edit box) or click on the Send Command-> button.

See the Controller Serial Command List for more information on the serial commands that are available.

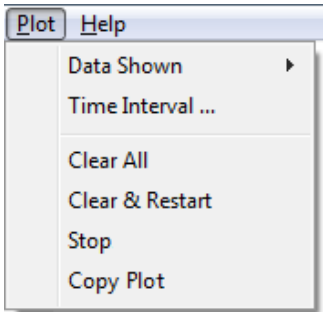
The Listing Control subset of the Program Commands may also be used. For example, the command [*LCT -] tells the program not to display sample holder temperature (CT) replies from the Temperature Controller in the multi-line text box.

New commands can be added to the list. For example, to insert the command [F1 TT S 37] (above right) hold the Shift key down while hitting the Return key (the blinking cursor must be in the edit box). The command will be inserted into the list but will not be sent to the Controller.

Commands can be removed from the list by selecting the command (so it appears in the edit box) then hold the Shift key down while hitting the Delete key.

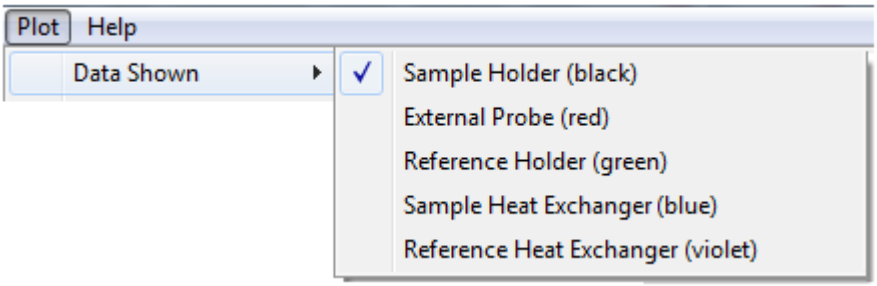
12.11. Plot Menu

Click on the individual menu item (where the pointer changes to a hand) for further information on that menu item.

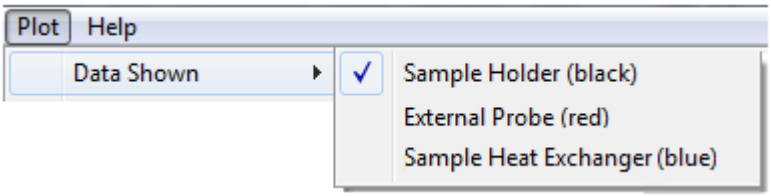


12.12. Data Shown

Dual with external probe



Single (or multi-sample) with external probe

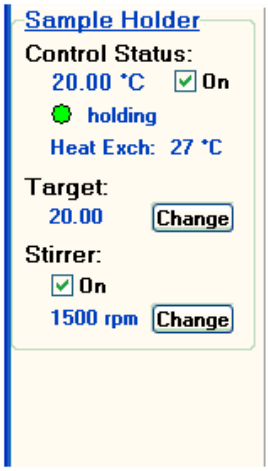


12.13. Status Panel

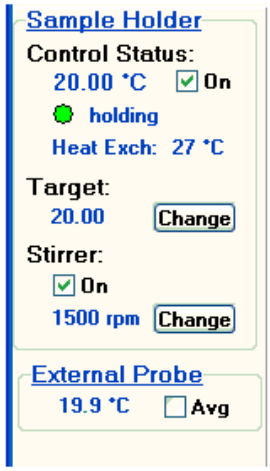
Click on the individual controls where the pointer changes to a hand for further information on that control.

Single cuvette holder

WITHOUT PROBE ATTACHED

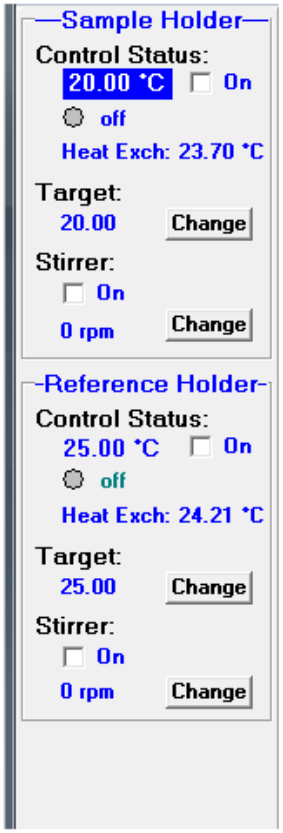


WITH PROBE ATTACHED

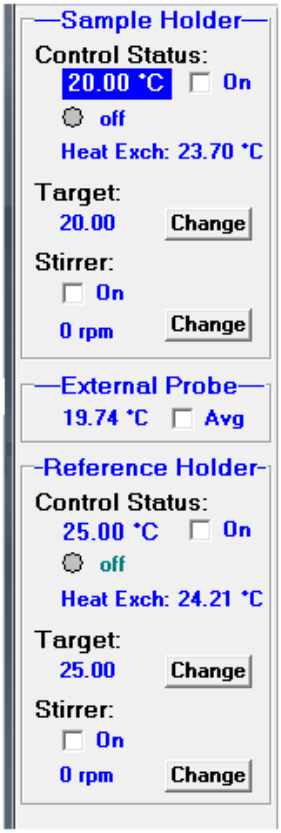


Dual cuvette holder

WITHOUT PROBE ATTACHED

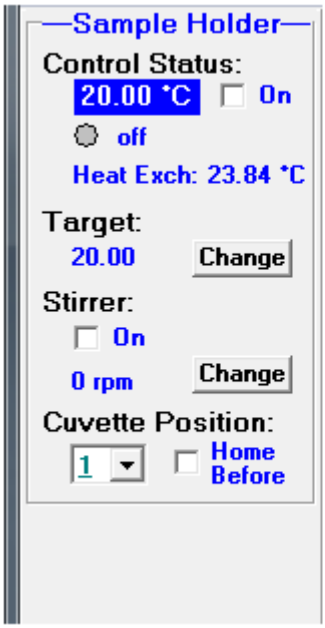


WITH PROBE ATTACHED

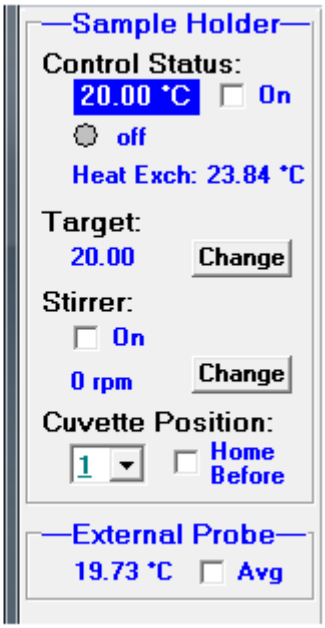


Multi cuvette holder

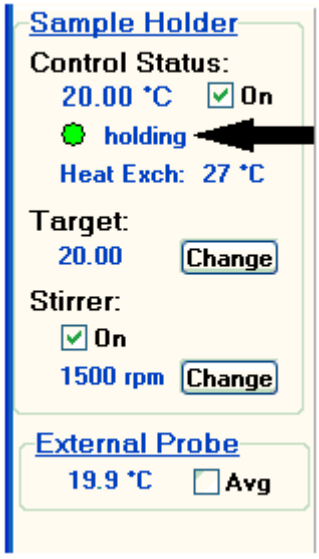
WITHOUT PROBE ATTACHED



WITH PROBE ATTACHED



12.14. Temperature Control Status



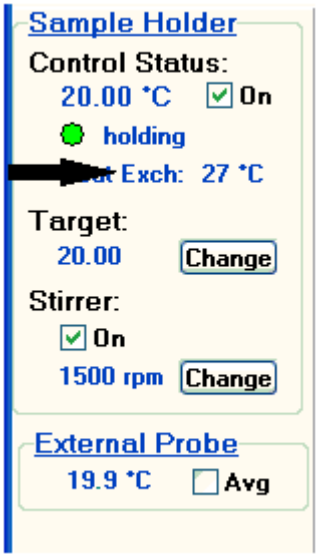
When temperature control is off, the circle will be a steady gray and the label will read "off".

When temperature control is on but the sample holder temperature is not stable, the small circle will alternate slowly between green and gray and the label to its right will read "seeking".

When temperature control is on and the sample holder temperature is stable, the circle will be a steady green and the label will read "holding".

If an error condition occurs that causes temperature control to be turned off the circle and the caption to its right will alternate rapidly between red and gray.

12.15. Heat Exchanger Temperature



The temperature of the heat exchanger in the sample holder is displayed here.

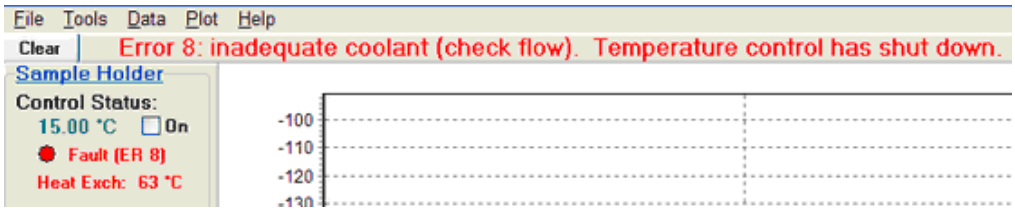
The heat exchanger temperature is dependent on the temperature and the rate of flow of the water being circulated through the sample holder and on the temperature control settings.

As a warning, when the heat exchanger temperature is within 10 °C of the preset limit (typically 60 °C, the color of the label will change to orange. To correct the problem, you must reduce the temperature of the water (for example, by adding ice or cold water to the coolant container).

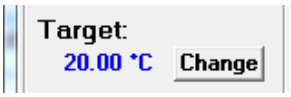
If the heat exchanger temperature exceeds that preset limit, temperature control will automatically be turned off to prevent damage to the system.

If temperature control does turn off, the label will turn red and an error message will display below the menu bar as illustrated below; also, the Temperature Control Status will show the error number and begin flashing red. The error message (and the flashing of the status control) can be removed at any time by clicking on the Clear button to the left of the message.

Once the problem with the heat exchanger temperature is corrected, you can restart temperature control by clicking on the Temperature Control On/Off checkbox or using the menu item Tools>(Temperature Control)>On. The error screen on the TC 1 will be cleared by restarting temperature control using **T-App**; this screen can also be cleared by pressing the SET button on the front of the TC 1.



12.16. Target Temperature



The Target Temperature is the Sample Holder Temperature that you want to use. If Temperature Control is On, the **Controller** will either be driving the holder temperature to the target or maintaining the holder temperature at the target.

The number displayed is the current Target Temperature. When the Change button to the right of the number is clicked a small parameter entry dialog will appear where you can change the Target Temperature setting.

The Tools>(Temperature Control)>(Set Target) menu item may also be used to change the Target Temperature.

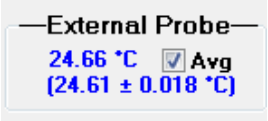
12.17. Magnetic Stirrer Controls

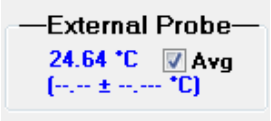
The checkbox may be used to turn the magnetic stirrer on (checked) or off (unchecked).

Click on the Change button to reset the speed of the stirrer. The current speed setting is shown to the left of the button. The submenus of the Tools>(Stirrer Control) menu item may also be used to change the stirrer properties.

12.18. External Probe Status

The External Probe Status will be displayed only if a Series-400 or Series-500 thermistor probe is connected to the 1/4-inch phone jack in the back of the sample holder. This probe input is intended to provide a means to directly measure the temperature of the sample in the cuvette.





The number to the left of the Avg checkbox is always the most recent temperature from the probe. If a probe temperature is not yet available, the digits will be replaced by dashes.

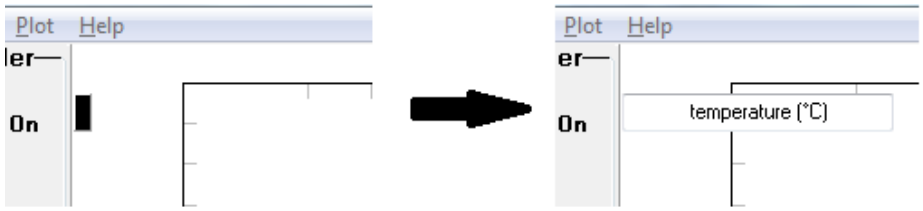
The left image shows the display for when the Avg box is not checked.

When the Avg checkbox is checked (by clicking on it), all controller models send probe readings with two decimal digits. The numbers in parentheses beneath the checkbox (middle image) list the mean value of the most recent 20 temperatures for the probe followed by the average deviation from that mean. The mean value should provide a more reproducible sample temperature if it has been stable long enough for 20 temperatures from the stable period to have been acquired.

If 20 temperatures are not yet available, the mean and average deviation are replaced by dashes (image on the right).

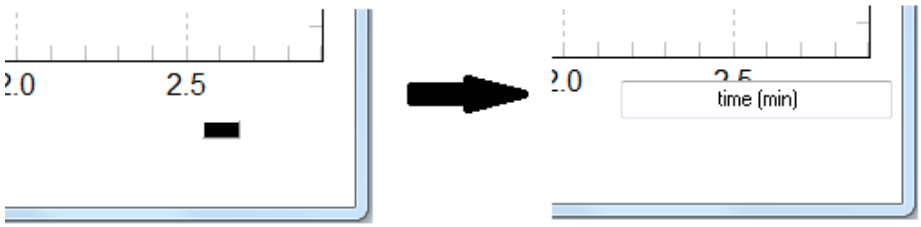
12.19. Plot Axis Label Manipulation

The label on the vertical axis can be changed by clicking on the small black rectangle near the upper-left corner of the plot; this will make a text box appear for changing the label. After new text has been entered, hitting the Tab or Return key will cause the text box to close and the modified axis label to appear on the plot.



BEFORE CLICKING ON THE BLACK RECTANGLE. AFTER CLICKING ON THE BLACK RECTANGLE.

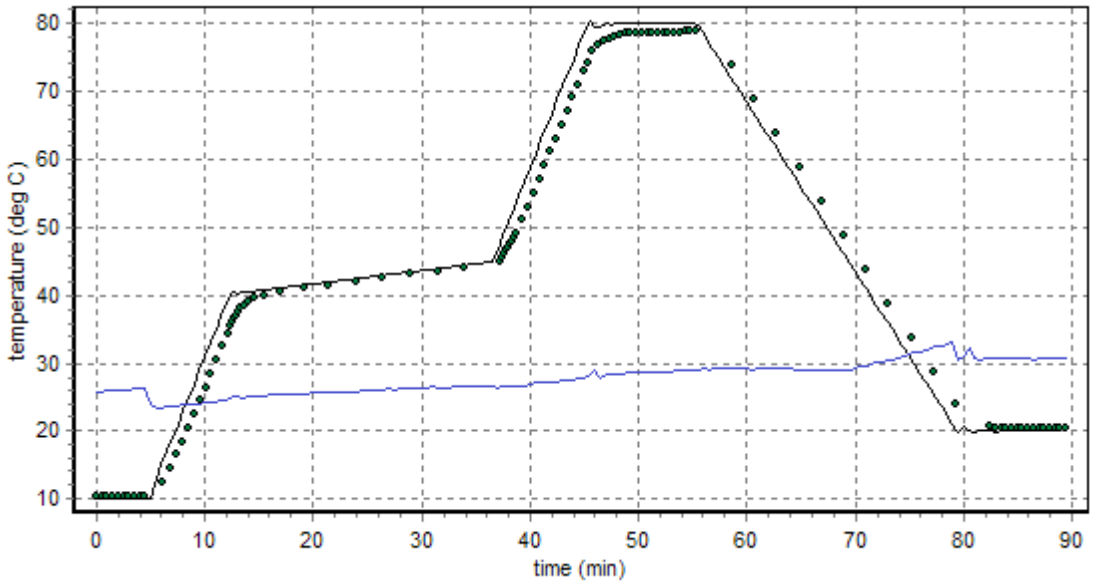
The label on the horizontal axis can be changed by clicking on the small black rectangle near the lower-right corner of the plot; this will make a text box appear for changing the label. After new text has been entered, hitting the Tab or Return key will cause the text box to close and the modified axis label to appear on the plot.



BEFORE CLICKING ON THE BLACK RECTANGLE. AFTER CLICKING ON THE BLACK RECTANGLE

12.20. Plot of Data Collected

This plot shows an example of temperature as a function of time data that would result from using the Example Script.



black - temperature of the sample holder. blue - temperature of the heat exchanger.

dotted black - temperature of the external probe (with the thermistor tip in the liquid sample).

Individual time/temperature points are shown for the external probe data to illustrate special methods of reporting probe temperatures used in the Example Script. Normally the probe data are shown as a red line.

12.21. Scripts: Program Script Commands

The Program Script Commands are used to control the behavior of a script and are not sent to the **QNW Temperature Controller**.

Delay and Wait commands

Progress of the Delay and Wait commands is tracked in the Delay/Wait Countdown Display at the bottom of the Script Panel.

[*D #] - Delay # INTERVALS before running the next command. Example: [*D 120] will cause a delay of 120 of the INTERVAL units as defined in the first line of the script (see the Example Script which sets the INTERVAL to 0.01 minutes).

While the delay is active, a countdown of the number of script INTERVALs remaining is included in the **Countdown Display** (see **Window View 2** in the **Script Panel**).

[*WRP>=#] [*WRP<=#] These commands are included to be compatible with older scripts. **T-App** now interprets them as **[*WCT>=#]** and **[*WCT<=#]**

[*WCT>=#] - Wait until the current (holder) temperature exceeds or equals a particular value (# as an integer).

[*WCT<=#] - Wait until the current temperature decreases to or below a particular value (# as an integer).

The current temperature is the temperature of the metal body of the sample cuvette holder.

[*WPT>=#] - Wait until the probe temperature exceeds or equals a particular value (# as an integer).

[*WPT<=#] - Wait until the probe temperature decreases to or below a particular value (# as an integer).

The probe temperature is the reading of the standard 400 series or 500 series probe (usually the probe is inserted in the sample cuvette).

[*WRT>=#] - Wait until the reference temperature exceeds or equals a particular value (# as an integer).

[*WRT<=#] - Wait until the reference temperature decreases to or below a particular value (# as an integer).

The reference temperature is the temperature of the metal body of the reference cuvette holder (dual **Controller** only).

[*WT #] - This command will be interpreted as a [*WT 1000 1] command to maintain compatibility with older script files.

[*WT (#1) (#2)] - This program command will cause the script to Wait until the sample holder

Temperature is stable before continuing to the next script command in the list. Temperature stability is determined by an algorithm built into the **QNW Temperature Controller**. The parameter (#1) determines how often the program sends a status query to the **Controller** ([F1 IS ?], see the Controller Serial Command List). Each time this query is received, the **Controller** returns a status reply which includes information as to whether the temperature is still changing or has met the criteria for being stable (controlled). The parameter (#2) specifies the maximum number of status queries that will be sent before the wait is canceled.

The time between status queries is the product of the parameter (#1) and the script INTERVAL as defined in the second line of the script (see the Example Script).

While the wait is active, the number of times the **Controller** has been queried is displayed followed by a countdown to the next query.

Note: if the command [F1 IS +] has been sent to the **Controller**, the instrument status reply will be sent by the **QNW Temperature Controller** automatically when the sample holder temperature becomes stable. In this case the command form [*WT (#1) 1] is recommended where (#1) is chosen to give a 10-minute period (for example, if INTERVAL IS 0.6 seconds or 0.01 minutes, then (#1) should be set to 1000). Typically, stable sample holder temperature is attained within 10 min of setting a new target temperature.

[*WD #] - This command is no longer accepted because it does not work in Windows XP or later.

Beep Control commands

[*BCT +] or **[*BCT-]** - Turn on (+) or off (-) beeping by the computer whenever a sample holder (current) temperature report is received from the **Controller**.

[*BPT +] or **[*BPT-]** - Turn on (+) or off (-) beeping by the computer whenever a probe temperature report is received from the **Controller**.

[*BRT +] or **[*BRT-]** - Turn on (+) or off (-) beeping by the computer whenever a reference holder temperature report is received from the **Controller**.

Warning Control commands

[*E+] or **[*E-]** - These commands are no longer supported because they are not needed for **T-App** version 2.00. Older scripts that include these commands will still run without generating an error response.

Listing Control command

[*LIS +] or **[*LIS -]** - Enable (+) or Disable (-) listing of Instrument Status replies during running of a script.

[*LER +] or **[*LER -] -** Enable (+) or Disable (-) listing of Error Message replies during running of a script.

[*LCT +] or **[*LCT -] -** Enable (+) or Disable (-) listing of Current Temperature replies during running of a script.

[*LPT +] or **[*LPT -] -** Enable (+) or Disable (-) listing of Probe Temperature replies during running of a script.

[*LRT +] or **[*LRT -] -** Enable (+) or Disable (-) listing of Reference Temperature replies during running of a script.

These ten program commands can be used to control whether the indicated information, sent from the **Controller** to the program, are to be listed (displayed) in the Script Panel or the Command Panel while a script is running. Disabling the listings may be useful to make progress of the script clearer since, under some conditions, large numbers of Instrument Status replies and Temperatures replies may be generated while the script is running. Disabling affects only the listing of these various replies -- the replies will still have their normal effects in the Main Window.

Note: some earlier versions of **T-App** defaulted to listing temperature replies in the Command/Script panel. **T-App** version 2.00 defaults to not listing them.

Miscellaneous commands

[*R] - This program command is used only at the end of a script. It will cause the script to be repeated, starting at the beginning. The script will then repeat forever or until the Cancel Script button is clicked.

[*P] - If the plot window is displayed while a script is running, the data in the plot may not be automatically updated unless a delay (*D) or wait (*W) command is being processed. This program command will cause the plot window to update (replot to show all data collected to that point).

[*CTD] - This command will clear the time and temperature data from the Time/Temperature Plot of the Application Control Window. In addition, the time parameter in the displays will be restarted at zero and listing of time/temperature data in the display windows will be started. Whatever display interval was in effect at the time this command is executed is retained (set by a script command or by clicking on the (Plot>Set Interval) menu item).

[*MSG + message] or **[*MSG - message] -** This command will stop execution of the script and present a dialog box containing the second command parameter ("message"); change this parameter to the wording you want the dialog box to display. The first parameter (+ or -) determines whether the computer beeps (+) or not (-) while the dialog box is visible. Clicking on the "OK" button in the dialog box closes it and execution of the script continues.

[*LS #] and [*LE] - The [*LS #] command defines the start of a loop (a repeat of a series of commands) within the script; the parameter '#' is an integer specifying how many times the loop is to be run. The [*LE] command defines the end of the series of commands included in the loop. A script may contain more than one loop. Also, smaller loops can occur within larger loops.

[*WPL] -- When the positioning commands

[F2 PL #] = go to position #

or [F2 PI] = go to home and back to the last position

are sent to the **Temperature Controller**, it automatically sends the reply [F2 DL #] when the positioning process is completed. The [*WPL] command waits for this reply before continuing to the next command in the script.

[*PL+] -- This command will cause the sample position to change to the next higher number. If the current position is the highest number position, it will move to position 1.

[*PL-] -- This command will cause the sample position to change to the next lower number. If the current position is 1, it will move to the highest number position.

[*TT+#] or **[*TT-#]** -- Increments or decrements the sample holder target temperature.

[*RT+#] or **[*RT-#]** -- Increments or decrements the reference holder target temperature.

13. Example Controller Scripts for T-App Software

These scripts and others are provided when the **T-App** program is purchased from Quantum Northwest. They are designed to be used with a **TC 1** Temperature Controller connected to a Peltier-based cuvette holder. Each script is a simple text file (.txt) that is read into the **T-App** program and activated. Each script is easily edited to suit the user's needs.

13.1. Controller Scripts for Single Cuvette Holders

The following are scripts designed for use with single cuvette holders, for example the t2 Sport, Versa 20 and Luma 40, with the TC 1 Temperature Controller.

Script, Step 20 to 50 °C at 1 °C Intervals (TC 1 Controller, t2 Sport Cuvette Holder)

```
Controller Script
Interval = .6       Set the time interval between commands to .6 seconds.
------------------
Initial Setup
------------------
[F1 CT +6]          Report current cuvette holder temperature every 6 seconds.
[F1 PT +6]          Report current probe temperature every 6 seconds.
[F1 HT +6]          Report heat exchanger temperature periodically.
[F1 TT S 20]        Set target temperature to 20 deg C
[F1 TC +]           Temperature control on
[F1 SS S 500]       Set stirring to 500 rpm (also turns stirring on)
[*CTD]              Clear time/temperature data and reset time to zero
------------------
Step up to 50 C, 1 C intervals:
------------------
[*LS 32]Start loop
  [*WT 1000 2]      Wait for stable temperature (or 20 min maximum)
  [*D 600]          Wait 6 min for sample equilibration
                    Notify user, with beeping.
  [*MSG + Ready (note T and make measurement)]
  [*TT+1]           Increase target T by 1C
[*LE]
------------------
Clean-up
------------------
[F1 CT -]           Stop periodic sample holder temperature reporting.
[F1 PT -]           Stop periodic probe temperature reporting.
[F1 HT -]           Stop periodic heat exchanger temperature reporting.
[F1 TC -]           Temperature control off
[F1 SS -]           Stirring off
```

Script, Ramp 20 to 50 °C at 1 °C per minute (TC 1 Controller, t2 Sport Cuvette Holder)

Controller Script
Interval = .6 Set the time interval between commands to .6 seconds.

Initial Setup

[F1 CT +6] Report current cuvette holder temperature every 6 seconds.
[F1 PT +6] Report current probe temperature every 6 seconds.
[F1 HT +6] Report heat exchanger temperature periodically.
[F1 TT S 20] Set target temperature to 20 deg C
[F1 TC +] Temperature control on
[F1 SS S 500] Set stirring to 500 rpm (also turns stirring on)
[*WT 1000 2] Wait for stable temperature (or 20 min maximum)
[*D 600] Wait 6 min for sample equilibration

Ramp up to 50:

[F1 RR S 1] Set Ramp rate to 1 deg C.
[F1 TT S 50.00] Set Target Temperature to 50.00 deg C, to start ramping process.
[*CTD] Clear time/temperature data and reset time to zero
[*WCT>=50] Wait until the sample holder temperature reaches 50.00 deg C.

Clean-up

[F1 PT -] Stop periodic probe temperature reporting.
[F1 CT -] Stop periodic sample holder temperature reporting.
[F1 HT -] Stop periodic heat exchanger temperature reporting.
[F1 TC -] Temperature control off
[F1 SS -] Stirring off
[*MSG + Script run is complete] Notify user, with beeping.

Script, Performance Run (TC 1 Controller, t2 Sport Cuvette Holder, with External Probe)

Controller Script
Interval = .6 sec (0.01 min) time interval between commands
[F1 CT +5] Report sample holder temperature periodically.
[F1 PT +5] Report probe temperature periodically.
[F1 TC +] Turn on Temperature Control
[F1 TT S 20.00] Set Target Temperature to 20 C
[*D=1500] Wait 15 minutes
[F1 TT S 50.00] Set 50 C Target
[*D=2000] Wait 20 minutes
[F1 TT S 0.00] Set 0 C Target

[*D=2500]	Wait 25 minutes
[F1 TT S -15.00]	Set -15 C Target
[*D=3000]	Wait 30 minutes
[F1 TT S 80.00]	Set 80 C Target
[*D=3000]	Wait 30 minutes
[F1 TT S 20.00]	Set 20 C Target
[*D=2500]	Wait 25 minutes
[F1 PT -]	Stop periodic probe temperature reporting.
[F1 CT -]	Stop periodic sample holder temperature reporting.
[F1 TC -]	Turn off sample Temperature Control

Script, Multiple Ramp (TC 1 Controller, t2 Sport Cuvette Holder, no External Probe)

Controller Script
Interval = 1.2 Set the time interval between commands to 1.2 seconds (0.02 min).

Initial Setup

[F1 TC +] Turn on Temperature Controls.
[F1 TT S 10] Set Target Temperature to 10 deg C.
[F1 SS S 500] Set Stirrer Speeds to 500 rpm (turns stirrers on).
[F1 CT +10] Report sample cuvette holder temperature periodically.
[F1 HT +10] Report heat exchanger temperature periodically.
[*CTD] Clear time/temperature displays and reset time to zero
[*MSG - This script requires pre-equilibration to 10 C. Close this message (click OK). Then, when equilibrated, click on the "End Wait" button (lower right corner of window).]
[*D=1500] Wait 30 minutes or until user clicks the "End Wait" button.
[*CTD] Clear time/temperature displays and reset time to zero
[*D=250] Collect temperatures for 5 minutes.

First Ramp to 40 at 4 degC/min:

[F1 RR S 4.0] Set Ramping Rate to 4 deg/min.
[*BPT +] Turn on the option for computer to beep each time a probe temperature report is received.
[F1 TT S 40] Set Target Temperature to 40 deg C, to start ramping process.
[*WCT>=40] Wait until the sample temperature reaches 40 deg C.

Second Ramp to 45 at 0.2 degC/min:

[F1 RR S 0.2] Set Ramping Rate to 0.2 deg/min.
[F1 TT S 45] Set Target Temperature to 45 deg C to start ramping process.
[*WCT>=45] Wait until the sample temperature reaches 45 deg C.

Third Ramp to 80:

[F1 RR S 4.0] Set Ramping rate to 4 deg/min.
[F1 TT S 80.00] Set Target Temperature to 80.00 deg C to start ramping process.
[*D 100] Wait 2 min before changing probe temperatures spacing.
[*WCT>=80] Wait until the sample temperature reaches 80 deg C.

[*BPT -]Turn off the computer beep each time a probe temperature report is received.
[*D 500] Wait 10 min to allow temperatures to stabilize.

Ramp back to 20:

[F1 RR S 2.5] Ramping rate to 2.5 deg C per minute.
[F1 TT S 20] Set Target Temperature to 20 deg C to start ramping process.
[*WCT<=20] Wait until the sample temperature reaches 20 deg C.
[*D 150] Hold 3 minutes to allow the probe temperature to catch up.

Clean up

[*D 350] Wait another 7 minutes for final equilibration.
[F1 CT -] Stop periodic sample holder temperature reporting.
[F1 HT -] Stop periodic heat exchanger temperature reporting.
[F1 TC -] Temperature control off
[F1 SS -] Stirring off
[*MSG + The multiramp script run is complete] Notify user, with beeping.

13.2. Controller Scripts for Dual Cuvette Holders

The following are scripts designed for use with dual cuvette holders, for example the t2x2 Sport, with the TC 1 Temperature Controller.

Script, Step 20 to 50 °C at 1 °C Intervals (TC 1 Controller, t2x2 Sport Dual Cuvette Holder)

Controller Script
Interval = .6 Set the time interval between commands to .6 seconds.

Initial Setup

[F1 CT +6] Report current cuvette holder temperature every 6 seconds.
[F1 PT +6] Report current probe temperature every 6 seconds.
[R1 CT +6] Report reference cuvette holder temperature periodically.
[F1 HT +6] Report heat exchanger temperature periodically.
[R1 HT +6] Report reference heat exchanger temperature periodically.
[F1 TT S 20] Set target temperatures to 20 deg C
[R1 TT S 20] Set target temperature to 20 deg C
[F1 TC +] Temperature controls on
[R1 TC +]
[F1 SS S 500] Set stirring to 500 rpm (also turns stirring on)
[R1 SS S 500]
[*CTD] Clear time/temperature data and reset time to zero

Step up to 50 C, 1 C intervals:

[*LS 32]Start loop
[*WT 1000 2] Wait for stable temperature (or 20 min maximum)

```
  [*D 600]          Wait 6 min for sample equilibration
                    Notify user, with beeping.
  [*MSG + Ready (note T and make measurement)]
  [*TT+1]           Increase target T by 1C
  [*RT+1]
[*LE]
------------------
Clean-up
------------------
[F1 CT -]         Stop periodic sample holder temperature reporting.
[F1 PT -]         Stop periodic probe temperature reporting.
[F1 HT -]         Stop periodic heat exchanger temperature reporting.
[R1 CT -]         Stop periodic reference holder temperature reporting.
[R1 HT -]         Stop periodic reference exchanger temperature reporting.
[F1 TC -]         Temperature controls off
[R1 TC -]
[F1 SS -]         Stirring off
[R1 SS -]
```

Script, Ramp 20 to 50 °C at 1 °C per minute (TC 1 Controller, t2x2 Sport Dual Cuvette Holder)

```
Controller Script
Interval = .6     Set the time interval between commands to .6 seconds.
------------------
Initial Setup
------------------
[F1 CT +6]        Report current cuvette holder temperature every 6 seconds.
[R1 CT +6]        Report reference cuvette holder temperature periodically.
[F1 HT +6]        Report heat exchanger temperature periodically.
[R1 HT +6]        Report reference heat exchanger temperature periodically.
[F1 TT S 20]      Set target temperatures to 20 deg C
[R1 TT S 20]
[F1 TC +]         Temperature controls on
[R1 TC +]
[F1 SS S 500]     Set stirring to 500 rpm (also turns stirring on)
[R1 SS S 500]
[*WT 1000 2]      Wait for stable temperature (or 20 min maximum)
[*D 600]          Wait 6 min for sample equilibration
------------------
Ramp up to 50:
------------------
[F1 RR S 1]       Set Ramp rates to 1 deg C.
[R1 RR S 1]
[F1 TT S 50.00] Set Target Temperatures to 50.00 deg C to start ramping process.
[R1 TT S 50.00]
[*CTD]            Clear time/temperature data and reset time to zero
[*WCT>=50]        Wait until the sample holder temperature reaches 50.00 deg C.
------------------
```

Clean-up

[F1 CT -] Stop periodic sample holder temperature reporting.
[F1 HT -] Stop periodic heat exchanger temperature reporting.
[R1 CT -] Stop periodic reference holder temperature reporting.
[R1 HT -] Stop periodic reference exchanger temperature reporting.
[F1 TC -] Temperature controls off
[R1 TC -]
[F1 SS -] Stirring off
[R1 SS -]
[*MSG + Script run is complete] Notify user, with beeping.

Script, Performance Run (TC 1 Controller, t2x2 Sport Dual Cuvette Holder, with External Probe)

Controller Script
Interval = .6 sec (0.01 min) time interval between commands

[F1 CT +5]	Report sample holder temperature periodically.
[R1 CT +5]	Report reference holder temperature periodically.
[F1 PT +5]	Report probe temperature periodically.
[F1 TC +]	Turn on sample Temperature Control
[R1 TC +]	Turn on reference Temperature Control
[F1 TT S 20.00]	Set sample Target Temperature to 20 C
[R1 TT S 20.00]	Set reference Target Temperature to 20 C
[*D=1500]	Wait 15 minutes
[F1 TT S 50.00]	Set sample 50 C Target
[R1 TT S 50.00]	Set reference 50 C Target
[*D=2000]	Wait 20 minutes
[F1 TT S 0.00]	Set sample 0 C Target
[R1 TT S 0.00]	Set reference 0 C Target
[*D=2500]	Wait 25 minutes
[F1 TT S -15.00]	Set sample -15 C Target
[R1 TT S -15.00]	Set reference -15 C Target
[*D=3000]	Wait 30 minutes
[F1 TT S 80.00]	Set sample 80 C Target
[R1 TT S 80.00]	Set reference 80 C Target
[*D=3000]	Wait 30 minutes
[F1 TT S 20.00]	Set sample 20 C Target
[R1 TT S 20.00]	Set reference 20 C Target
[*D=2500]	Wait 25 minutes
[F1 PT -]	Stop periodic probe temperature reporting.
[F1 CT -]	Stop periodic sample holder temperature reporting.
[R1 CT -]	Stop periodic reference holder temperature reporting
[F1 TC -]	Turn off sample Temperature Control
[R1 TC -]	Turn off reference Temperature Control

Script, Multiple Ramp (TC 1 Controller, t2x2 Sport Dual Cuvette Holder, no External Probe)

Controller Script
Interval = 0.6 Set the time interval between commands to 0.6 seconds (0.01 min).

Initial Setup

[F1 TC +] Turn on Temperature Controls.
[R1 TC +]
[F1 TT S 10] Set Target Temperatures to 10 deg C.
[R1 TT S 10]
[F1 SS S 500] Set Stirrer Speeds to 500 rpm (turns stirrers on).
[R1 SS S 500]
[F1 CT +10] Report sample cuvette holder temperature periodically.
[F1 HT +10] Report heat exchanger temperature periodically.
[R1 CT +10] Report reference cuvette holder temperature periodically.
[R1 HT +10] Report reference heat exchanger temperature periodically.
[*CTD] Clear time/temperature displays and reset time to zero
[*MSG - This script requires pre-equilibration to 10 C. Close this message (click OK). Then, when equilibrated, click on the "End Wait" button (lower right corner of window).]
[*D=3000] Wait 30 minutes or until user clicks the "End Wait" button.
[*CTD] Clear time/temperature displays and reset time to zero
[*D=500] Collect temperatures for 5 minutes.

First Ramp to 40 at 4 degC/min:

[F1 RR S 4.0] Set Ramp Rates to 4 deg/min.
[R1 RR S 4.0]
[F1 TT S 40] Set Target Temperatures to 40 deg C, to start ramping process.
[R1 TT S 40]
[*WCT>=40] Wait until the sample temperature reaches 40 deg C.

Second Ramp to 45 at 0.2 degC/min:

[F1 RR S 0.2] Set Ramp Rates to 0.2 deg/min.
[R1 RR S 0.2]
[F1 TT S 45] Set Target Temperatures to 45 deg C to start ramping process.
[R1 TT S 45]
[*WCT>=45] Wait until the sample temperature reaches 45 deg C.

Third Ramp to 80:

[F1 RR S 4.0] Set Ramp rates to 4 deg/min.
[R1 RR S 4.0]
[F1 TT S 80.00] Set Target Temperatures to 80.00 deg C to start ramping process.

```
[R1 TT S 80.00]
[*WCT>=80]      Wait until the sample temperature reaches 80 deg C.
[*D 1000]       Wait 10 min to allow temperatures to stabilize.
-----------------
Ramp back to 20:
-----------------
[F1 RR S 2.5]   Ramp rates to 2.5 deg C per minute.
[R1 RR S 2.5]
[F1 TT S 20]    Set Target Temperatures to 20 deg C to start ramping process.
[R1 TT S 20]
[*WCT<=20]      Wait until the sample temperature reaches 20 deg C.
[*D 1000]       Wait 10 minutes.
-----------------
Clean up
-----------------
[F1 CT -]       Stop periodic sample holder temperature reporting.
[F1 HT -]       Stop periodic heat exchanger temperature reporting.
[R1 CT -]       Stop periodic reference holder temperature reporting.
[R1 HT -]       Stop periodic reference exchanger temperature reporting.
[F1 TC -]       Temperature control off
[R1 TC -]
[F1 SS -]       Stirring off
[R1 SS -]
[*MSG + The multiramp script run is complete]    Notify user, with beeping.
```

13.3. Controller Scripts for Multiple-Cell Cuvette Holders

The following are scripts designed for use with multiple cuvette holders, for example the qCHANGER 6, Turret 4 and Turret 6, with the TC 1 Temperature Controller.

Script, Move Any Multi-Cell Cuvette Holder (TC 1 Controller)

```
Controller Script
Interval = .6       (0.01 min)
This script will only work with T-App 1.50 or later
[F2 PL 1]           go to position 1
[*WPL]              wait for position change
[*D 50]             wait 30 seconds
[*LS 50]            loop 50 times
  [*LS 6]           loop 6 times
    [*PL+]          move to next position
    [*WPL]          wait for position change
    [*D 50]         wait 30 seconds
  [*LE]             end of loop 6 times
[*LE]               end of loop 50 times
```

Script, Move the Turret 4 Four-Position Cuvette Holder (TC 1 Controller)

Controller Script
Interval = .6 (0.01 min)
This script will work with any T-App

[F2 PL 1]	go to position 1
[*D 50]	wait 30 seconds
[F2 PL 2]	go to position 2
[*D 50]	wait 30 seconds
[F2 PL 3]	go to position 3
[*D 50]	wait 30 seconds
[F2 PL 4]	go to position 4
[*D 50]	wait 30 seconds
[*R]	repeat from the beginning

Script, Move the Turret 6 or qCHANGER 6 Six-Position Cuvette Holder (TC 1 Controller)

Controller Script
Interval = .6 (0.01 min)
This script will work with any T-App

[F2 PL 1]	go to position 1
[*D 50]	wait 30 seconds
[F2 PL 2]	go to position 2
[*D 50]	wait 30 seconds
[F2 PL 3]	go to position 3
[*D 50]	wait 30 seconds
[F2 PL 4]	go to position 4
[*D 50]	wait 30 seconds
[F2 PL 5]	go to position 5
[*D 50]	wait 30 seconds
[F2 PL 6]	go to position 6
[*D 50]	wait 30 seconds
[*R]	repeat from the beginning