turret 6/FO

6-Position Temperature-Controlled Cuvette Turret for Fiber Optic Spectroscopy

Manual & Product Overview

turret 6 Cuvette Holder

TC 1 Temperature Controller

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1. GETTING STARTED

Thank you for purchasing a Quantum Northwest ***turret*** 6/FO! 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 web site: www.qnw.com. A copy of this manual can be found on the site under the SUPPORT tab.

A. Your Shipment Will Contain:

turret 6 package

1. ***turret*** 6 Temperature-Controlled Cuvette Holder
2. **TC 1** Temperature Controller
3. **BATH 10** Submersible Pump and Bucket
4. power cable
5. USB cable
6. ***turret*** 6 accessory kit (slits, wrench, blanks, and 6 magnetic stir bars)
7. vinyl tubing to connect water and gas

Depending on Your Order, Your Shipment May Contain:

Lens Systems

1. two **t6-QCL** Collimating Lens for absorbance measurements
2. **t6-QIL/ex** Imaging Lens for Excitation
3. **t6-QIL/em** Imaging Lens for Emitted Light
4. **t6-QMP** Mirror Plug
5. Plastic cap for covering unused ports

T-App software

T-App, provided on a CD, is a program that permits external computer control of the **TC 1** Temperature Controller. The temperature of the sample holder and a temperature sensed by an external probe may be plotted vs time. Simple text scripts may be used to automate multiple operations.

B. System Setup

1. Place the ***turret*** 6 on a table. For stability you may wish to use screws to attach the ***turret*** 6, using the holes in the edge of the base.

2. 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 85 to 264 at 50 or 60 Hz.)

3. Supply circulating water to the Peltier unit. If you choose to use the **BATH 10**, then attach 1/8-inch ID tubing from the submersible pump to either one of the water hose barbs on the ***turret*** 6. Attach another piece of tubing from the ***turret*** 6 back to the bucket. Direction of flow is not important. Put water in the bucket. Plug the pump's circular DIN connector into the 12 Volt outlet on the back of the TC 1 labeled "IO." Briefly turn on the **TC 1** and check to be sure that water is flowing back into the bucket. Check for leaks.

4. If you plan to work at low temperatures, connect a source of dry gas (typically nitrogen) to release on the cuvette windows. Attach a length of tubing with 1/16-inch inside diameter, to the small hose barb on the base of the ***turret*** 6. (A 1/8 to 1/16-inch barbed reducer fitting is included with the ***turret*** 6, to prevent any difficulty connecting to this unusually small size tubing.) Set the dry gas flow rate to about 50 cc/min.

5. The ***turret*** 6 has two electrical cables, one for drive currents and the other for sensitive sensor signals. Connect them to the back of the **TC 1** Temperature Controller on the 15-pin connectors labeled "Sample" and "Reference".

6. Insert optics and attach sources and detectors as needed by your experiment. Optical options are described below.

C. Lens System Installation

There are two basic optical configurations for the ***turret*** 6: one to measure absorbance and the other to measure fluorescence.

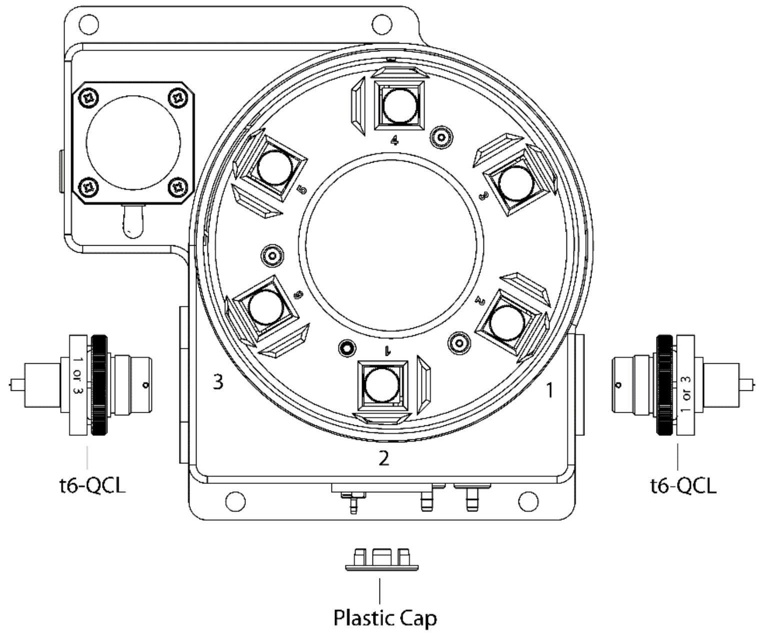


Figure 1. Absorbance configuration with collimating lenses on each side of the cuvette

As shown in Figure 1, to set the ***turret*** 6 up for absorbance measurements insert collimating lens (QCL/t6) at positions 1 and 3 and screw into place. Put a black plastic cap from the ***turret*** 6 accessory kit in position 2. The collimating optics produce a 5 mm diameter beam that passes through the cuvette centered at 8.5 mm above the outside bottom surface. Attach fiber optics as describe below. Typically, light is passed from position 1 through the optical slit and cuvette and collected at position 3. If the slit is not being used, direction is not important.

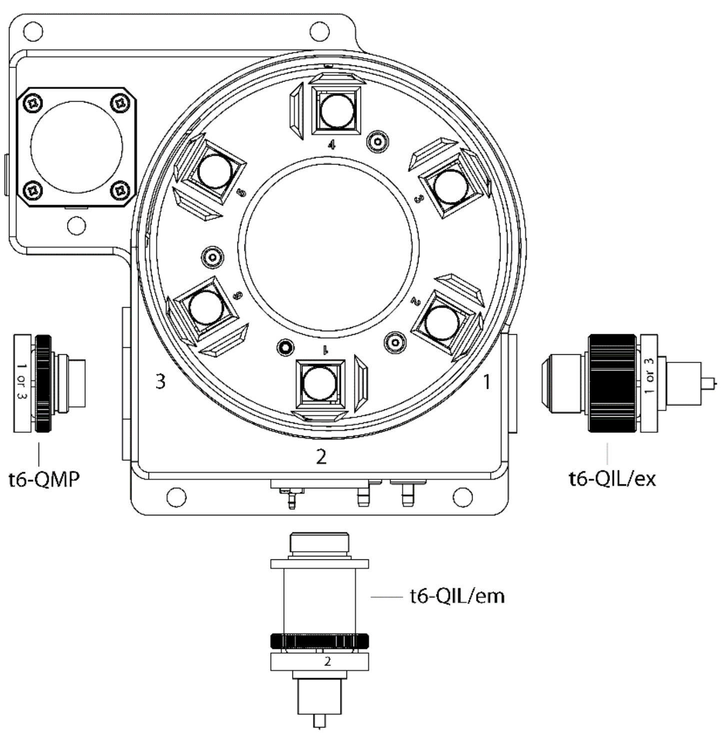


Figure 2. Fluorescence configuration with excitation and emission through imaging lenses and a mirror to reflect the incident light back on itself

As shown in Figure 2, to set the ***turret*** 6 up for fluorescence measurements insert the imaging lens for excitation (t6-QIL/ex) into position 1. This lens accepts the light from a fiber using a numerical aperture of 0.22 and focuses an image of the end of the fiber into the center of the cuvette using a magnification of 2.7. Insert the imaging lens for emission (t6-QIL/em) in position 2. This lens images the center of the cuvette onto the end of the collection fiber using a magnification of 1.0. To enhance collection efficiency, a spherical mirror (60 mm radius of curvature) may be placed in position 3 to reflect the excitation source back on itself.

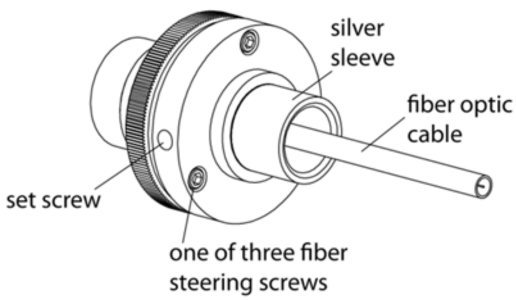


Figure 3 - Components of a lens assembly

1. Use the 5/64-inch hex screwdriver from the ***turret*** 6 accessory kit to loosen the set screw (Figure 3).

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 ***turret*** 6.

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.

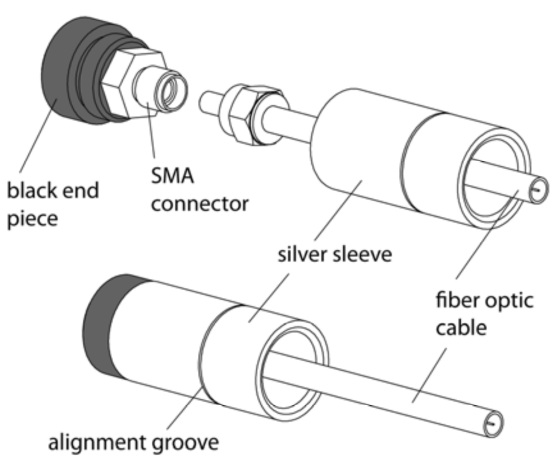


Figure 4 - Attaching the fiber optic to the SMA connector

5. Now, unscrew the silver sleeve from the black end piece revealing the SMA connector (Figure 4).

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.

D. Software Installation

NOTE: IF YOU PURCHASED THE T-App PROGRAM, DO NOT PLUG IN THE USB CABLE UNTIL THE SOFTWARE IS LOADED! IF YOU DO, WINDOWS MAY AUTOMATICALLY INSTALL AN INCORRECT DRIVER THAT WILL BE DIFFICULT TO REMOVE.

1. If you purchased the **T-App** program for external control of the ***turret*** 6, insert the CD into the drive. If the installation does not start automatically, locate the SETUP.exe file in the root directory and run it. The installation process starts with a small black window that is shown during installation of the drivers needed to control the ***turret*** 6 through a USB connection. This window will then be replaced by the software installation window. Follow the onscreen prompts to complete the installation.

2. Connect the ***turret*** 6 to your computer using the USB cable provided. The New Hardware installation process will begin automatically and take a few moments to finish.

E. System Operation

1. Use liquid samples in standard 1 x 1-cm square cuvettes and place the cuvettes in the ***turret*** 6.

2. Place a magnetic stir bar in each cuvette.

3. If you wish to monitor the temperature inside a 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 solution, where it will not occlude the spectrometer light beam.

4. Turn on the **TC 1** controller using the switch on the back panel.

Menu Button

5. The controller display begins on the **Start** page. Use the left or right arrows on the Menu Button to cycle through the five pages of options. On the **Set Position** page use the top and bottom arrows to choose a position, say position 5. Press set and the turret will rotate to this position and the menu will return to the **Start** page. To set a temperature, go to the **Set Temperature** page and use the up and down arrows to set a target temperature, say 37.0 °C. Press **SET** to initiate temperature control. The temperature will rise and stabilize. The menu will then advance to the **Set Stirrer** page. Use the up and down arrows to set a speed, say 1200 rpm, and press **SET** to start the stirrer.

6. When temperature control is running and the **Start** page is being displayed, press **SET** to turn off temperature control.

7. After measurements are completed, turn off power on the back of the **TC 1** controller and turn off the water source.

F. Using the Menu Button

Use the right and left arrows to cycle through five pages:

– Display – Set Position –Set Temperature – Set Stirring – Set Ramping –

```
Holder =  37.0 ˚C
Target =  37.0 ˚C
Probe  =  36.9 ˚C
Current Position = 5
```

Display: This main page shows the actual cuvette *Holder* temperature, the *Target* temperature and a *Probe* temperature (if a probe is present). The page will also show the current turret position. After a few seconds of inactivity, all other pages will switch back to the **Display** page.

When seeking a temperature, the green led on the front panel will flash slowly. When it 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.

```
Set Position

Position = 5
Current Position = 1
```

Set Position: To rotate the ***turret*** 6, use the up and down arrows to choose the new position and press **SET**. The controller will return to the **Display** page.

```
Set Temperature

Target =  37.0 °C
Current=  20.0 °C
```

Set Temperature: To set the *Target* temperature, use the up and down arrows. Press **SET** to retain this new *Target* and initiate temperature control.

```
Set Stirring

Stir Speed = 1200rpm
Current = 0rpm
```

Set Stirring: To turn on magnetic stirring, use the up and down arrows to choose an approximate stirring speed between 1 and 2500 rpm. Press **SET** to turn on stirring at this speed.

```
Set Ramping

Ramp = 0.55 °/min
Current = 0 °/min
```

Set Ramping: To perform a ramp, set the Ramping rate using the up and down arrows, and press **SET**. With ramping set, turning on temperature control will generate a linear ramp to the target temperature. When the sample holder reaches the target temperature, the ramp rate will be set back to 0°/minute.

The fastest possible ramp is determined by how fast the cuvette holder could reach the target temperature without ramping. If you attempt to ramp too quickly, especially at high and low temperature extremes, you will obtain a nonlinear ramp. The slowest ramp that may be set on this page is 0.01 °C/minute. (If needed, much slower ramps may be set through software commands.)

2. *FEATURES OF THE turret 6*

A. General Description

The ***turret*** 6 has a rotating, temperature-controlled, metal cuvette tower which holds up to six cuvettes. An insulating cover of urethane plastic encloses the cuvette tower, providing thermal insulation. A floor is attached to the bottom of the tower, and the rotating body of the holder contains a Peltier element sandwiched between this floor and a brass heat exchanger. Water flows through the heat exchanger to draw off heat generated when the temperate of the cuvette tower is lowered.

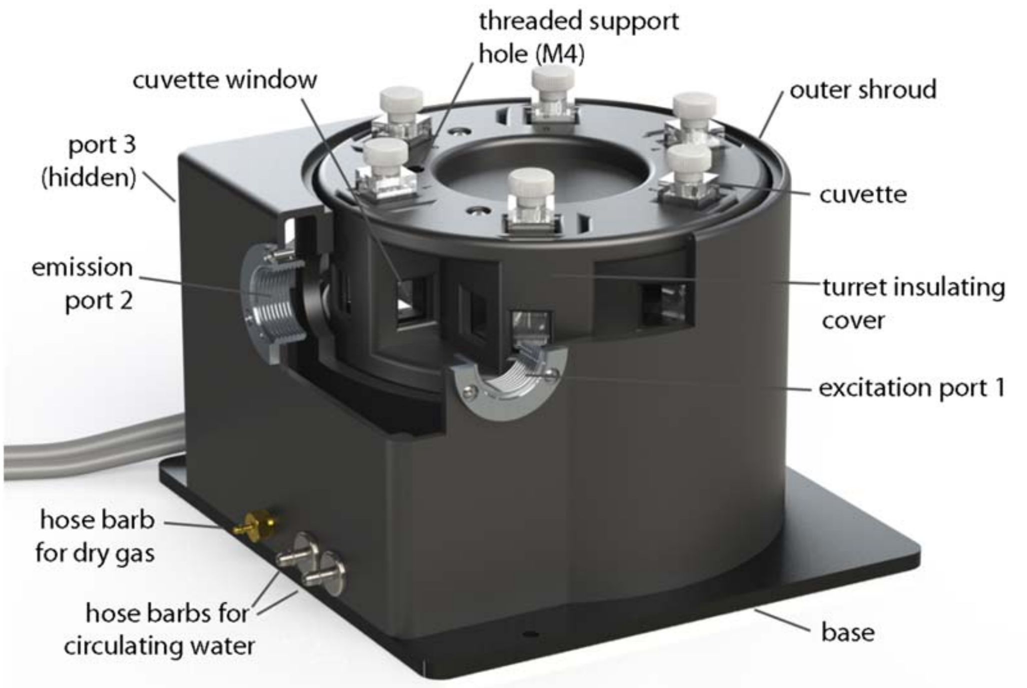


Figure 5. ***turret*** 6 with a section cut away to show the optic access to one of the cuvettes

A miniature stepping motor resides under each cuvette to drive rotating magnet. Dry gas enters a 1/16-inch hose barb on the front of the instrument and is carried through a manifold in the floor of the turret to small holes on the bottom of the 18 cuvette windows. This flow of gas will keep the windows free of condensation when working below the dew point temperature. The rotating body is mounted on a large precision bearing and rotated via gears, using the external Vexta stepping motor (not visible in this view).

Two wires exit below the Vexta stepping motor. One conducts the drive currents for the stepping motor and Peltier unit. The other conducts the sensor lines. The two brass 1/8-inch hose barbs for water provide access to the heat exchanger. A 1/16-inch brass hose barb is used for the dry gas.

CAUTION: Accidently attaching a water line to the dry gas barb will severely damage the instrument! Attach the lines with care.

B. Cuvettes

The ***turret*** 6 holds standard 10 x 10 mm cuvettes with outside dimensions of 12.5 x 12.5 mm. A metal clip is used to push each cuvette into one of the corners of its individual space for reproducible positioning and to favor temperature transfer. Walls of the turret body are relieved to prevent scratching of the optical surfaces of the cuvette.

Cuvettes should be 45 mm or taller, otherwise they will be difficult to recover from the cuvette holders.

C. Cuvette z-Height

The "z height" of a cuvette is the distance between the bottom 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 cuvettes in the ***turret*** 6 is 15 mm.

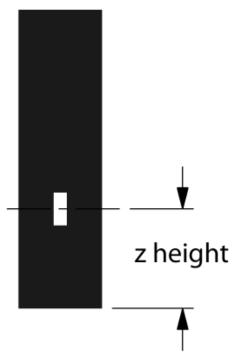


Figure 6. The z height of a typical microcuvette

D. Cooling Water for the Peltier

The Peltier element (or "thermoelectric cooler") is a heat pump. When cooling, it transfers heat from the turret body to a 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. This is accomplished with flowing water through the heat exchanger.

A source of water (or other cooling fluid) must be connected to the ⅛-inch hose barbs on the front of the ***turret*** 6. This can be done with the **BATH 10**, which is provide with the ***turret*** 6. The **BATH 10** consists of a submersible aquarium pump, the appropriate fittings for connecting tubing, and a plastic bucket. Connect the pump to the ***turret*** 6, place it in the bucket with water, and run a return tube to the bucket. You may also provide the cooling water from another source, such as a refrigerated cooling bath or even a tap for brief use.

You will need a flow rate of 100 - 300 ml/minute. This flow should require a pressure of about 3 - 5 psi (0.2 - 0.3 bar). Do not exceed an input water pressure of 25 psi (1.7 bar), as damage may occur inside the ***turret*** 6. The heat exchanger and hose barbs are brass, and the tubing inside the ***turret*** 6 is silicone. Be sure that any circulating fluid used, other than water, will not degrade these materials.

The temperature of the heat exchanger in the ***turret*** 6 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 (see External computer control below).

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.

E. Dry Gas Purging

Dry gas flows into the ***turret*** 6 via the 1/16-inch brass hose barb on the rear side. The gas passes through small channels in the base of the turret body, to partially equilibrate in temperature, before passing up through small holes on both the inside and outside cuvette surfaces. A flow of dry gas to prevent condensation is necessary any time the ***turret*** 6 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.

F. External Temperature Probe

A ¼-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. When a probe is plugged into the jack, the probe temperature is presented on the display of the TC 1. Place the probe in a sample to measure the actual temperature of the sample, which will lag in time from the temperature of the cuvette tower.

We do not sell the probe, but there are many Series 400 and 500 probes on the market. Quantum Northwest’s preferred probe is the YSI 423 available from Cole Parmer. The YSI 423 is reasonably resistant to immersion and responds rapidly to temperature changes. Also, the fine, coiled wires of the YSI 423 conduct very little ambient heat to the thermistor at the end.

Excellent Series 500 probes can be obtained with diameters less than a mm, providing access to small volumes. A disadvantage of these probes is that they are not pre-calibrated.

G. External Computer Control

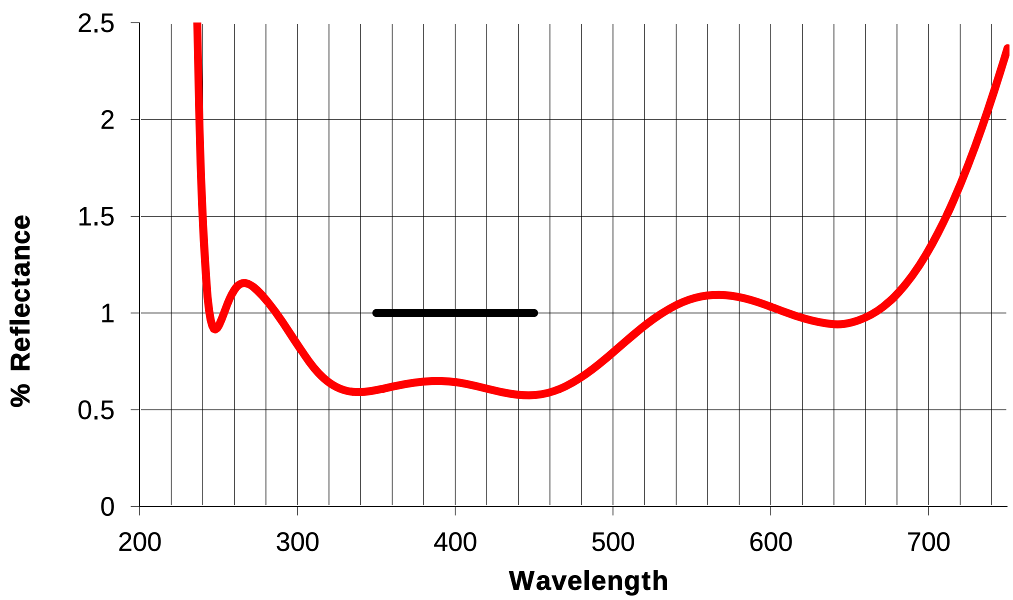
All functions may be accessed either through a Serial (RS 232) or a USB located on the back of TC 1 Temperature Controller. You may write your own program or purchase our application program T-App. T-App will plot temperatures of the probe, cuvette tower or even the Peltier element heat exchanger *vs* time. It will also permit you to set up temperature ramps. If you wish to do your own programming, please see the Appendix for communication instructions and the set of text commands that may be used and responses to the commands.

H. Description of Lens Systems

The t6-QCL collimating lens is a 6 mm diameter, 18 mm focal length, fused silica lens that collects light from the source fiber at a numerical aperture of 0.22 and focuses a 5 mm diameter collimated beam through the cuvette at a z height of 15 mm. A second t6-QCL reverses the process and focuses the collimated light onto a collection fiber.

There are two kinds of imaging lens systems. Each contains a pair 12.5 mm diameter, 30 mm focal length, plano-convex, fused silica lenses with their flat sides outward. The excitation lens (t6-QIL/ex) focuses an image of the end of the source fiber into the middle of the cuvette with a magnification of 2.7. The emission lens (t6-QIL/em) focuses a small region of the illuminated volume in the center of the cuvette onto the end of the emission collection fiber using a magnification of 1.0.

The magnification of the excitation lens represents a compromise required to back the lens away from the cuvette to permit the rotation of the turret. If high fluorescence sensitivity is required, we recommend a more direct coupling of the source with the cuvette, bypassing the excitation fiber.
Figure 7. Broadband anti-reflection (AR) coating used on the standard fused silica lenses.



3. ERROR CODES

When errors occur, the line 1 of the 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, please contact us through our website, www.qnw.com.

E5– 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.

E6 – 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.

E7 – 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.

E8 – 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.

4. SPECIFICATIONS SUMMARY

temperature range	-20 to +110 °C
temperature precision	±0.02 °C
cuvette size (outside dimensions)	12.5 x 12.5 mm
minimum cuvette height	30 mm
cuvette z height	15 mm
optical port dimensions	12 mm high x 10 mm wide
magnetic stirring speed	1-2500 rpm

APPENDIX 1. TEMPERATURE SPECIFICATIONS FOR THE TURRET 6

Enoch W. Small and Louis J. Libertini
26 July 2013

Temperature Range: -15 °C to + 80 °C

The TC 1 Temperature Controller can set temperatures between -40 °C and 110 °C. Under normal conditions, as used inside a spectrophotometer, the ***turret*** 6 will achieve temperatures in the range of -15 °C and 80 °C using room temperature water (~22 °C). Somewhat lower temperatures can be obtained by the use of iced water. Temperatures above 80 can usually be attained by using warm water (recommended). In some cases higher temperatures may require operation without coolant flow, but special procedures are required.
An input connection for purging with dry gas is provided.

Temperature Precision: ± 0.02 °C

Temperature precision is the average deviation from the set temperature of temperature readings returned from the temperature-controlled ***turret*** 6 for set temperatures between -15 °C and + 110 °C. Thus, it is a measure of the ability of the cuvette holder to hold a constant temperature.
The precision of the temperature actually held in the solution should be even better than the precision for the cuvette holder. Unfortunately, we have no current means of measuring it.

Table 1. Average deviation from the set temperature vs set temperature for 50 points.

Set temperature	-15	0.0	20.0	40.0	60.0	80.0	100	110
Average deviation	0.0046	0.064	0.002	0.0084	0.008	0.0066	0.0082	0.0116

Temperature Accuracy: ± 0.25 °C over the range of -20 °C to + 110 °C.

Temperature Accuracy indicates how well the TC 1 controller display, after calibration, compares with the actual temperature of the sample holder measured using a NIST-traceable RTD temperature probe (probe accuracy ±0.03 °C from -99.9 °C to +99.9 °C) inserted in the metal block of the cuvette holder.

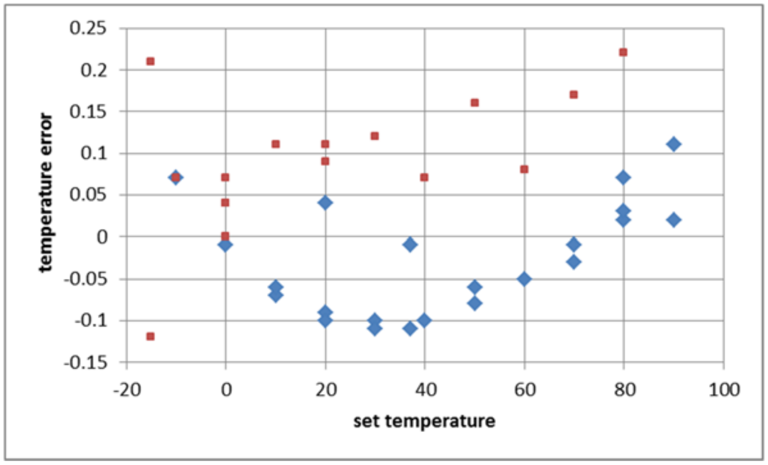


Figure 1. An NIST-traceable RTD thermometer (accuracy ±0.03 °C from -99.9 °C to +99.9 °C) was inserted in the body of the cuvette holder and the temperature readings (y axis) compared to the value set by the TC 1 temperature controller (x axis). Data points shown as red squares are results were obtained with the temperature decreasing; the blue diamonds indicate results obtained with the temperature decreasing.

Temperature Reproducibility: better than ± 0.15 °C over the range of 0 °C to 80 °C

Temperature reproducibility is a measure of the ability of the temperature to return to an original value (See Figure 1.). It accounts for differences depending on the direction of temperature change and differences from day to day. Reproducibility is measured using a NIST-traceable RTD temperature probe inserted in the metal block of the cuvette holder.

Example of Temperature Performance

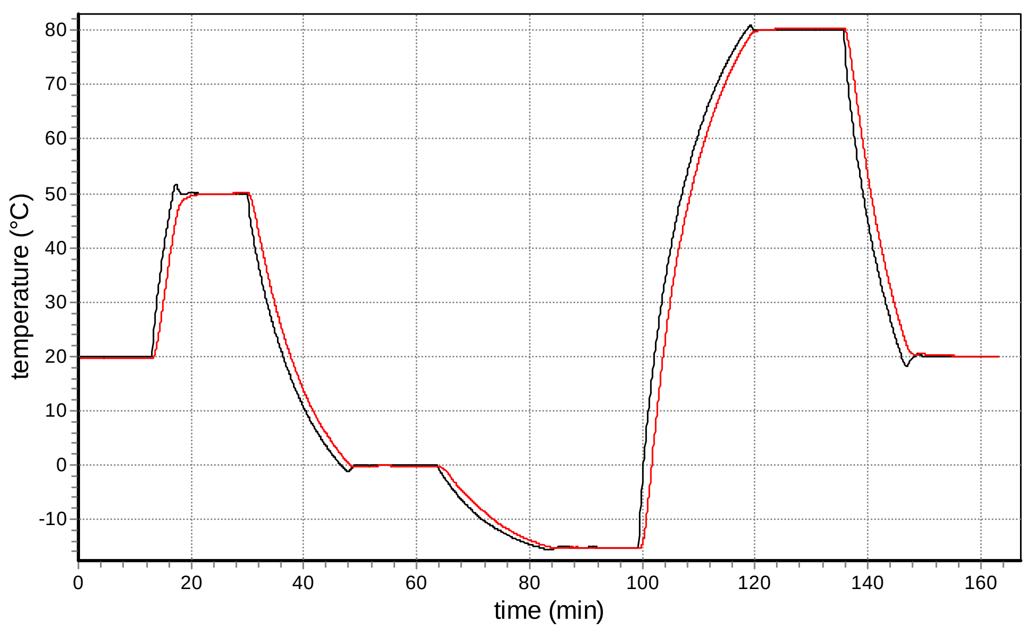


Figure 2. ***turret*** 6 cuvette holder temperature and sample temperature (red, measured with a thermistor probe connected to the ***t***2) as the target temperature setting was progressed through 20.0 °C, 50.0 °C, 0.0 °C, -15.0 °C, 80.0 °C and 20.0 °C degrees .

Typical Temperature Equilibration Data

A Turret was equilibrated at one temperature and then the target temperature was changed to a higher or lower value.

Table 2. Time required for cuvette holder temperature changes. Three time are shown: the time required to get within 1 °C, the time to get within the lock on temperature of ±0.05 °C from the target and the final time indicating that the TC 1 indicates the temperature is stable.

Temperature range (°C)	20 to 80	80 to 110	80 to 20	20 to -15
Circulating water T (°C/min)	21	none	21	Iced
Minutes to get within 1 °C (min)	13	38	9.3	15
Minutes to lock on temperature (min)	16	42	13.3	20
Minutes to lock on indicator light (min)	18	54	18	25

APPENDIX 2. SERIAL COMMUNICATIONS FOR THE TC 1 TEMPERATURE CONTROLLER

7/26/2013

This document provides the serial communications protocols for version 1.0 of the firmware on the **TC 1** family of controllers:

> **TC 1**/t2 – for the t2, single temperature controller
>
> **TC 1**/t2x2 – for the t2x2, dual temperature controller for sample and reference
>
> **TC 1**/turret6 – for the turret6, 6-position turret

The version number and the ID (see below) are shown briefly on the display when the temperature controller is turned on.

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. 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 can provide a control program written specifically for control of all functions of the temperature controller. Ask for program T-App.

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.

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

1. Identify

`[F1 ID ?]`	What is the ID number of the sample holder being controlled?
`......[F1 ID 14]`	Sample holder is a **t2** or other single cuvette sample holder.

Assigned Identities:	
ID =	00 – **specialty sample holder** (see command class 14)
	14 - **t2**
	24 - **t2x2**
	34 – reserved for turret or linear multi-sample holder

---

2. Controller Firmware Version

`[F1 VN ?]` What is the version number of the controller firmware?

`......[F1 VN 1.00]` The controller is operating firmware version number 1.00.

---

3. Stirrer

`[F1 MS ?]` What is the maximum stirrer speed?

`......[F1 MS 2500]` The maximum stirrer speed is 2500 rpm.

`[F1 LS ?]` What is the lowest stirrer speed?

`......[F1 MS 300]` The lowest stirrer speed is 300 rpm.

`[F1 SS S 1000]` Set stirrer speed to 1000 rpm.

`[F1 SS S 0]` Turn stirrer off and set the speed to zero.

`[F1 SS +]` Turn stirrer on and set it to the most recent non-zero stirrer speed setting.

`[F1 SS -]` Turn stirrer off.

`[F1 SS ?]` What is the current stirrer speed setting?

`......[F1 SS 1000]` Stirrer speed setting is 1000 rpm.

---

4. Temperature Control

`[F1 TC +]` Turn temperature control on.

`[F1 TC -]` Turn temperature control off.

---

5. Target Temperature

`[F1 TT S 23.10]` Set target temperature to 23.10 ºC.

`[F1 TT ?]` What is the current target temperature?

`......[F1 TT 71.32]` Target temperature is 71.32 ºC.

`[F1 TT +]` Turn on automatic reporting of manual changes to the target temperature.

`[F1 TT -]` Turn off automatic reporting of manual changes to the target temperature.

`[F1 MT ?]` What is the maximum target temperature allowed?

`......[F1 MT 110]` The maximum target temperature allowed is 110 ºC.

`[F1 LT ?]` What is the lowest target temperature allowed?

`......[F1 LT -30]` The lowest target temperature allowed is -30 ºC.

6. Instrument Status

`[F1 IS ?]` What is the current instrument status?

`......[F1 IS 0-+S]` Response is four parameters:
number of unreported errors is 0 (0 to 9)
stirrer is off (+ is on, - is off)
temperature control is on (+ is on, - is off)
temperature is stable (S is stable, C is changing)

`[F1 IS +]` Automatically report instrument status whenever it changes (e.g., due to manual changes at the controller)

`[F1 IS -]` Stop automatic reports of instrument status.

`......[F1 IS R]` The controller has been powered off and back on again.

---

7. Current Sample Temperature

`[F1 CT ?]` What is the current temperature of the 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.

---

8. Error Reporting

`[F1 ER ?]` Report the current error.

`......[F1 ER -1]` No current error.

`......[F1 ER 05]` Cell T out of range (Loose cable? Sensor failure?).

`......[F1 ER 06]` Cell & 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 command that caused the syntax error.

`[F1 ER +]` Automatically report errors when they occur.

`[F1 ER -]` Stop automatic error reports.

---

9. Probe Status and Temperature

`[F1 PS ?]` Is there an external temperature probe connected?

`......[F1 PR +]` A probe is connected.

`......[F1 PR -]` No probe is connected.

`[F1 PS +]` Enable probe status to be sent automatically when a probe is installed or removed. This is the default.

`[F1 PS -]` Disable automatic sending of probe status.

`[F1 PT ?]` What is the current probe temperature?

`[F1 PT +3]` Periodically report the probe temperature every 3 seconds.

`......[F1 PT 22.3]` The current probe temperature is 22.3 degrees.

`......[F1 PT NA]` Probe temperature is not available.

`[F1 PT -]` Stop periodic probe temperature reports.

`[F1 PA S 0.5]` Set the increment for automatic reporting of the probe temperature to 0.5 degrees during a ramp. (Increment must be positive, without sign in tenths between 0.1 and 9.9 degrees, and will work for ramps going up or down.)

`[F1 PA +]` Start automatic reporting of probe temperature every temperature increment (set by the command above).

`......[F1 PT 30.5]` The current probe temperature is 30.5 degrees.

`[F1 PA -]` Stop automatic reporting of probe temperature every temperature increment.

`[F1 PX +]` Change probe temperature returned to a precision of 0.01 degree.

---

10. Temperature Ramping

`[F1 RR S 2.10]` Set the ramp rate to 2.10 °C/minute.

`[F1 RR ?]` What is the current ramp rate?

`......[F1 RR 2.10]` Current ramp rate is 2.10 °C/minute.

For the following three commands, there are no corresponding reference commands ([R1 . . .], see command class 13).

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

`[F1 TL -]` Ramp the sample while the reference remains stable.

`[F1 TL 0]` Ramp the sample and reference independently.

The default is to ramp the sample while the reference remains stable. Ramping both the sample and reference at different rates or to different target temperatures (see below) is not possible.

To Ramp the temperature:

1. equilibrate at the starting temperature,
2. set the ramp rate,
3. set a new target temperature (command class 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 you are done, set the ramp rate to 0. Otherwise, setting a new target temperature later will initiate a ramp to that target temperature.

Notes:

The minimum settable ramp rate is 0.01 °C/minute.

For higher ramp settings, the observed rate may be lower than that calculated from RT and RS 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).

When the ramping process is completed the controller will send a response of the form [F1 TT #] as a notification of the end of the ramp. This response can be blocked at any time by previously sending the command [F1 TT -] (see command class 5).

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11. Heat Exchanger Temperature

`[F1 HL ?]`	What is the high temperature limit for the heat exchanger?
`......[F1 HT 60]`	The heat exchanger high temperature limit is 60 ºC.
`[F1 HT ?]`	What is the current temperature of the heat exchanger?
`......[F1 HT 39]`	The current heat exchanger temperature is 39 ºC.
`[F1 HT +3]`	Start periodic heat exchanger temperature reports every 3 seconds.
`[F1 HT -]`	Stop periodic heat exchanger temperature reports.

---

12. Cell Changing

These commands will have an effect only for a sample holder with multiple cuvette positions.

`[F2 DI]`	Device initialize: move to home position.
`[F2 PI]`	Device initialize: move to home position 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 PI]`	Device initialize: move to home, then to position 1 and reply when done.
`......[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 DD 400]` Set speed to 400 (acceptable range 100 – 500, with a default of 500).

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13. Reference Cuvette

These commands will have an effect only for systems with two independently-controlled sample holders.

`[R1 ...]`

To control and monitor the temperature and status of the reference cuvette using a Dual Temperature Controller, use any commands in classes 3-8, 10 and 11, substituting `R1` for `F1`. There are no corresponding [R1 …] commands for command classes 1, 2, 9 and 12.

If you wish to ramp the temperature of the reference and sample cuvettes together, please note the linking command, `[F1 TL +]`, in command class 10.

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15. Control of Automatic Reports

The TC 1 can be controlled manually using the buttons and the display on the front. When a computer program is in use, the TC 1 will automatically send reports to the program whenever a manual change has been made. The commands in this section are intended to allow the program to prevent the TC 1 from sending those automatic reports.

`[F1 XX R(+/-)]` Stop (R-) or start (R+) reporting all manual changes, including those starting with [R1 and [F2.

By replacing the XX with individual command codes, a program can selectively stop or start reporting of manual changes.

`[F1 SS R-]` Stop reporting manual changes for the sample stirrer.
`[F1 TC R-]` Stop reporting manual changes for the sample temperature control.
`[F1 TT R-]` Stop reporting manual changes for the sample target temperature.
`[F1 PR R-]` Stop reporting manual changes for the external probe connection.
`[F1 RR R-]` Stop reporting manual changes for the sample ramp rate.

`[F2 PL R-]` Stop reporting manual changes for the sample position.

`[R1 SS R-]` Stop reporting manual changes for the reference stirrer.
`[R1 TC R-]` Stop reporting manual changes for the reference temperature control.
`[R1 TT R-]` Stop reporting manual changes for the reference target temperature.
`[R1 RR R-]` Stop reporting manual changes for the reference ramp rate.