Temperature-regulated Cuvette Holder

CUV-TLC-50F

Installation and Operation Manual

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Offices:

Ocean Optics, Inc.
830 Douglas Ave., Dunedin, FL, USA 34698
Phone (727) 733-2447
Fax (727) 733-3962
8:30 a.m.–6 p.m. EST

Ocean Optics B.V. (Europe)
Nieuwgraaf 108 G, 6921 RK DUIVEN, The Netherlands
Phone 31-(0)26-3190500
Fax 31-(0)26-3190505

E-mail:

Info@OceanOptics.com	**(General sales inquiries)**
Info@OceanOpticsBV.com	**(European sales inquiries)**
Orders@OceanOptics.com	**(Questions about orders)**
TechSupport@OceanOptics.com	**(Technical support)**

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About This Manual

Document Purpose and Intended Audience

This document provides you with an installation section to get your system up and running. In addition to the Maxwell system installation and operation instructions, this manual also includes information for locating the OOIBase32 installation instructions (see *Product-Related Documentation* below).

What's New in this Document

This version of the *Temperature-regulated Cuvette Holder Installation and Operation Manual* adds performance data, new configuration drawings, and optional equipment.

Document Summary

Chapter	Description
Chapter 1: *Introduction*	Provides information on product features and system setup.
Chapter 2: *Operation*	Contains configuration information for absorbance and fluorescence measurements, and optical adjustments.
Chapter 3: *System Operation*	Contains instructions for using the CUV-TLC-50F, and a list of error conditions.
Chapter 4: *Specifications*	Provides product specifications and a mechanical drawing.
Appendix A: *Serial Control for the CUV-TLC-50F*	Provides information specific to serial control via the serial interface on the PC.

Product-Related Documentation

You can access documentation for Ocean Optics products by visiting our website at **http://www.oceanoptics.com**. Select *Technical → Operating Instructions*, then choose the appropriate document from the available drop-down lists. Or, use the **Search by Model Number** field at the bottom of the web page.

You can also access operating instructions for Ocean Optics products on the *Software and Technical Resources* CD included with the system.

Engineering-level documentation is located on our website at *Technical → Engineering Docs.*

Upgrades

Occasionally, you may find that you need Ocean Optics to make a change or an upgrade to your system. To facilitate these changes, you must first contact Customer Support and obtain a Return Merchandise Authorization (RMA) number. Please contact an Ocean Optics Application Scientist for specific instructions when returning a product.

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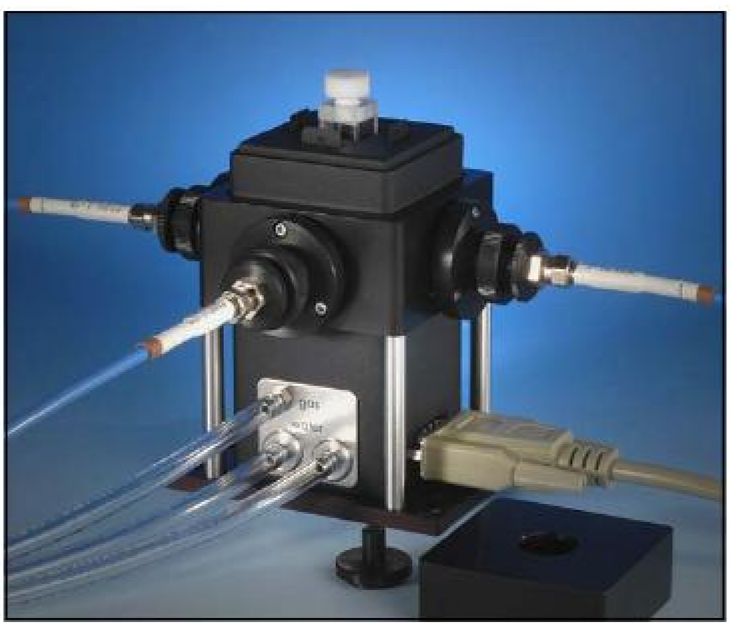
Chapter 1

Introduction

Overview

The CUV-TLC-50F Temperature-regulated Cuvette Holder is a high-quality, versatile sample chamber with a Peltier temperature controller calibrated against a NIST-traceable thermometer. The device controls the temperature of the holder from -40 °C to 85 °C and maintains a constant temperature within ±0.02 °C. The CUV-TLC-50F includes the cuvette holder and the external temperature controller box. Both collimating and focusing lens systems are available in AR-coated fused silica. SMA 905 optical fiber connectors are provided with the lens systems. To run the thermoelectric cooler efficiently, we offer a simple water pump and water container.

The CUV-TLC-50F forms the core of a fiber optic spectroscopy system. The holder provides rapid and precise control of the temperature of a standard 1 X 1-cm cuvette. Since the height of the optical centerline (the center of the optical path through the cuvette) is 8.5 mm above the outside bottom of the cuvette, the CUV-TLC-50F readily accommodates a variety of standard micro-cuvettes that depend on this dimension for small volume work. Fibers and combined lenses can be attached at any combination of the optical ports.



Features

Features of the CUV-TLC-50F include the following:

- Magnetic stirring (in the CUV-TLC-50F). A stir bar is included.
- Dry gas purge: Limits condensation and excludes oxygen from around the cuvette. Tubing for water and gas connections is included.
- Optical slits: Control the illuminated volume. Several removable optical slits are included.

An optional PC-based CUV-TLC-ADP adapter package comes with Windows-compatible software that allows you to remotely start a test sequence, operate the controller box and monitor experiments. Without the CUV-TLC-ADP, you can control the cuvette holder’s temperature mechanically from the controller box.

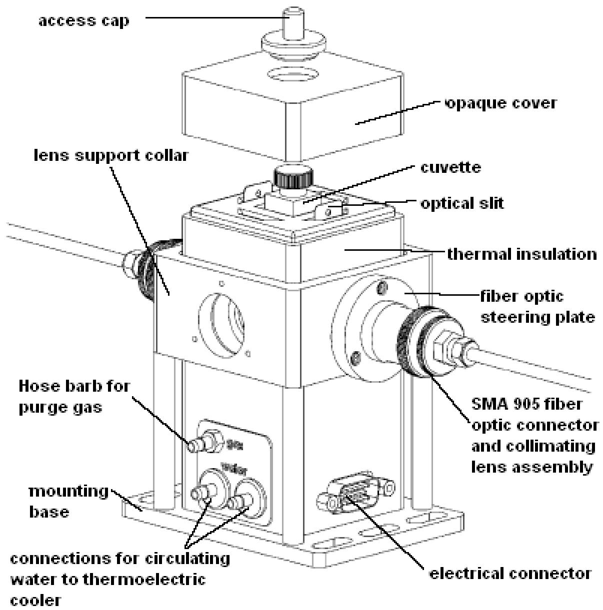
One side of the holder is open for visual inspection, or may be blocked with a blank slit. The other three sides can be left open or fitted with a removable lens system. Both collimating and focusing lens systems are available in either AR-coated BK7 glass or AR-coated fused silica and can be used in a variety of configurations. Typically two collimating systems are used on opposite sides for absorbance measurements, or two imaging lens assemblies are used at right angles for fluorescence measurements. SMA 905 optical fiber connectors are provided with the lens systems.

System Setup

► *Procedure*

1. Firmly fasten the CUV-TLC-50F to your table using the holes in the base of the instrument.
2. Connect a water source to either one of the two hose barbs labeled “water” on the rear side of the CUV-TLC-50F. Use a length of tubing with 1/8” (3mm) inside diameter such as the 3603 Tygon provided. Cooling water is required for the functioning of the thermoelectric cooler. Tap water may be used. However, a more convenient source would be a circulating bath or a small submersible pump in a container of water.
3. Connect tubing from the other hose barb to a drain or back into the source of circulating water. Do not exceed an input water pressure of 25 psi (1.7 bar), as damage may occur inside the TLC50.
4. Set and maintain a cooling water flow rate of about 200 – 300 ml per minute. This flow should require a pressure of approximately 3 – 5 psi (0.2 – 0.3 bar). If a circulating bath is used as the water source, it may not be possible to maintain this flow rate. However, a slower rate will likely be adequate for low temperature work, if precooled circulating water is used.
5. If using dry gas, connect a source of dry gas (typically nitrogen or air that has passed through a desiccant) using a length of tubing with 1/8” (3mm) inside diameter, to the hose barb labeled “gas” on the side of the CUV-TLC-50F. A flow of gas must be used to prevent condensation on the faces of the cuvette when working below the dew point temperature. Set the dry gas flow rate to 50 – 200 cc/min.
6. Connect the Temperature Controller to a power source and to the CUV-TLC-50F using the electrical cords provided.

Components



CUV-TLC-50F Components

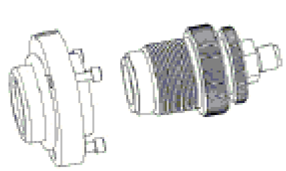
Optional Equipment

The following optional components and packages are also offered for specific applications. Contact Ocean Optics for additional information.

Optical Components

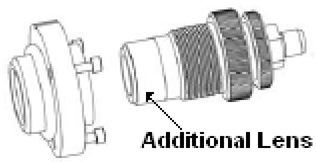
CUV-TLC-CL Collimating Lens

The CUV-TLC-CL is an AR-coated fused silica collimating lens with SMA 905 connector and fiber optic steering plate The CL-UV collimating lens collimates the diverging light from the end of a fiber and passes it through the cuvette, or alternatively focuses collimated light onto the end of another fiber. The collimating lens is mounted on a fiber optic steering plate that provides fine adjustments of the position of the end of the fiber relative to the cuvette. The secondary knurled ring shown in the picture permits the movement of the end of the fiber relative to the lens and cuvette, thus permitting an adjustment of the degree of collimation. Collimating lenses are typically used for absorbance measurements.



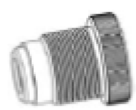
CUV-TLC-IL Imaging Lens

The CUV-TLC-IL is an AR-coated fused silica imaging lens doublet with SMA 905 connector and fiber optic steering plate. The CUV-TLC-IL imaging lens doublet is identical to the CUV-TLC-CL, except that an additional lens is snapped into place to shorten the focal length. The imaging lens images the end of the optical fiber into the cuvette, or focuses an image of the center of the cuvette onto a fiber. Again, the steering plate can be used to adjust the position of the focused image inside the cuvette, and to maximize the detected signal. The secondary knurled ring shown below permits movement of the focused image to nearly any depth in the cuvette. Imaging lens doublets are usually used for fluorescence measurements, although they are also useful for absorbance measurements on small sample volumes. The CUV-TLC-IL can be easily converted to the CUV-TLC-CL by removing the attached Convergence lens.



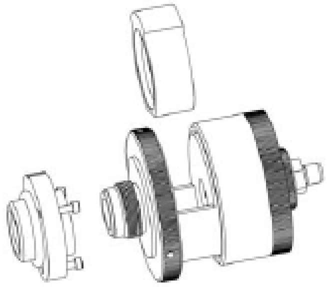
CUV-TLC-MP Spherical Mirror Plug

The spherical mirror plug replaces a fiber with a spherical mirror that reflects an image of the illuminated volume at the center of the cuvette back onto itself. Thus the mirror plug can return the excitation beam back through the sample for a second pass, or permit one detector to collect the light from opposite sides of the cuvette. For some fluorescence experiments, use of two mirror plugs can nearly quadruple the measured signal. Purchase the spherical mirror plug to perform fluorescence measurements when weak signals are anticipated.



CUV-TLC-FH Filter Holder Assembly

The CUV-TLC-FH filter holder assembly with collimating lens, SMA 905 connector, and fiber optic steering plate places standard 1-inch filters in a light-tight compartment after a collimating lens. The light-tight cap backs away and the filters, mounted in a filter holder insert, are lifted out of the assembly. The filter holder insert holds a single 1-inch round optical filter or a stack of such up to a thickness of 3/8 of an inch. One insert is provided with the filter holder assembly, although other inserts can be purchased separately. The filter holder assembly, mounted on a fiber optic steering plate, can be used directly in place of a collimating lens. You can add a convergence lens to convert the filter holder assembly to an imaging lens system.



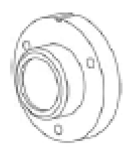
Additional Accessories

The following additional accessories are available from Ocean Optics for your CUV-TLC-50F:

- CUV-TLC-ADP PC adapter package for remotely operating the cuvette holder.

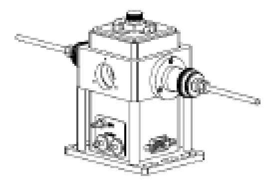
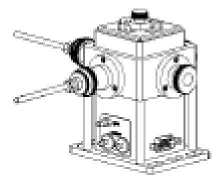
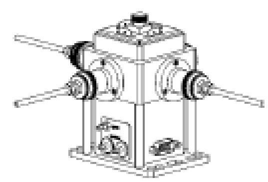
  The serial interface is used for external computer control of the temperature controller. The option includes a serial cable, a control program, a library of functions in DLL form to simplify serial communications with the controller, and a sample script for demonstrating the basic functions of the sample holder. The control program simplifies the entry of individual commands, permits the use of prewritten scripts for external operation of the controller and provides a convenient plot of the sample holder temperature as a function of time. The serial interface option is required for temperature ramping.

- CUV-TLC-SP steering plate that mounts a lens or mirror plug onto the cuvette holder. The fiber optic steering plate attaches to one of the optical ports and provides the receptacle for a lens system. Adjustment of three screws in the plate provides small movements of the end of the optical fiber that can be used to optimize alignment of the image within the cuvette, thus optimizing signal output. Each lens or mirror assembly is provided with its own fiber optic steering plate. An additional plate can be purchased to allow an optical component to be moved frequently or to place a mirror plug at an unoccupied site.



- CUV-TLC-BATH water pump and bucket for efficient operation of the thermoelectric cooler. The CUV-TLC-BATH circulates cooling water to the thermoelectric device in the sample holder. The accessory consists of a submersible pump, a brass fitting and plastic bucket. Attach the fitting to the pump and connect the sample holder via 1/8-inch I.D. vinyl tubing. Run the return water back into the bucket. To lower the temperature, just add ice to the bucket. Add enough ice, and the water in the bucket goes immediately to 0.0ºC.

Packages for Specific Applications

Application	Item Code	Description	Figure
UV/VIS spectroscopy	CUV-TLC-ABSKIT	CUV-TLC 50F cell holder, two CUV-TLC-CL collimating lenses (with SMA fiber optic connectors, lenses and steering plates), CUV-TLC-ADP serial interface and CUV-TLC-BATH water pump with bucket.	
Fluorescence	CUV-TLC-FLKIT	CUV-TLC 50F cell holder, two CUV-TLC-IL imaging lenses (with SMA fiber optic connectors, lenses and steering plates), two CUV-TLC-MP mirror plugs, two additional CUV-TLC-SP steering plates, CUV-TLC-ADP serial interface and CUV-TLC-BATH water pump with bucket.	
UV/VIS and fluorescence	CUV-TLC-MPKIT	CUV-TLC-50F cell holder, two CUV-TLC-IL imaging lenses, two CUV-TLC-CL collimating lenses, two CUV-TLC-MP mirror plugs, CUV-TLC-ADP serial interface and CUV-TLC-BATH water pump with bucket.	

Chapter 2

Operation

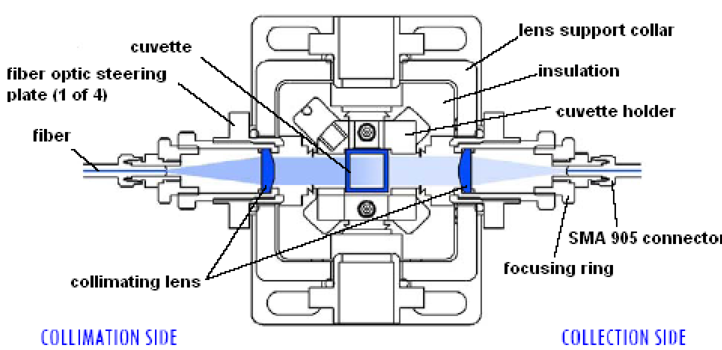
Optics

The CUV-TLC-50F provides ports for viewing or illuminating 1-cm square cuvettes from four directions. Lenses are available to purchase separately to allow you to choose the best lenses for your application. For absorbance and transmission measurements, position two CUV-TLC-CL Collimating Lenses at 180°. For fluorescence applications, position two CUV-TLC-IL Imaging Lenses at 90° and position two CUV-TLC-MP Mirror Plugs in the remaining two collimator positions to redirect energy to the sample or into a lens.

- **Collimating Lens**—The Collimating Lens system, containing a single lens, collimates the fiber output or focuses collimated light onto the end of another fiber. The collimating lens system is typically used in absorption measurements.
- **Imaging Lens**—The Imaging Lens system, containing two lenses, focuses an image of the end of the fiber into the cuvette, or light in the center of the cuvette onto another fiber (magnification of approximately one). For added versatility, the second lens of the Imaging Lens system may be removed so that it may be used as a Collimating Lens. The Imaging Lens system is typically used in fluorescence measurements.

Typical Configuration for Absorbance Measurements

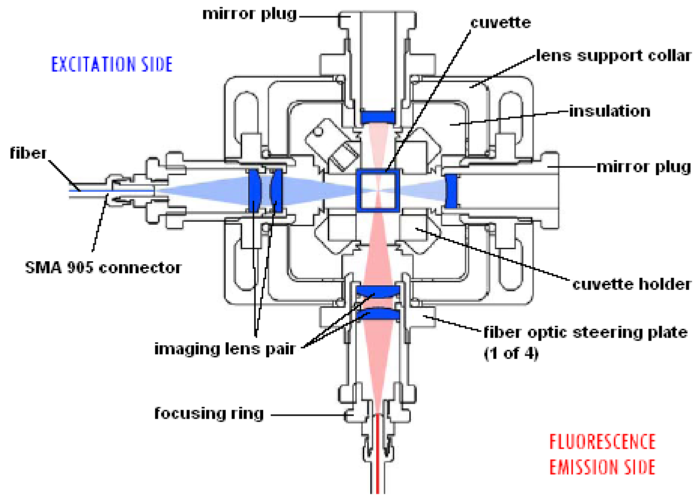
To measure Absorbance, a single collimating lens is placed on each side of the cuvette. In the following figure, lenses and cuvette are shown in blue. Note that each lens holder has an alignment adjustment as well as focusing capability.



CUV-TLC-50F Typical Configuration for Absorbance Measurements

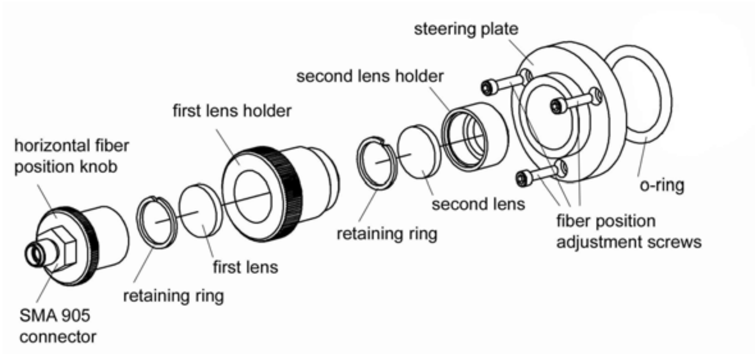
Typical Configuration for Fluorescence Measurements

To measure fluorescence, Imaging Lens systems are placed at 90 degrees to each other. The first lens system focuses the light as a small image inside the cuvette Emitted light from this small illuminated volume is then focused at a right angle onto the second fiber. Mirrors can be mounted opposite each lens system, nearly quadrupling measured light intensities.



CUV-TLC-50F Typical Configuration for Fluorescence Measurements

The following figure shows the components of an imaging lens system.



Components of an Imaging Lens System

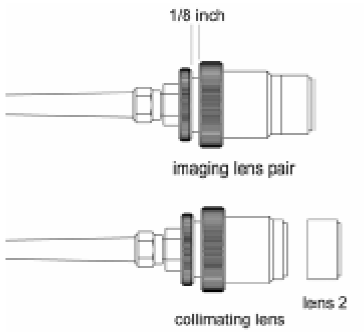
Optical Adjustments

The fiber position adjustment screws use the steering plate to compress a soft o-ring. They may be used to wobble the end of the fiber horizontally and vertically about its position and can substantially enhance optical throughput. Take care not to over compress the o-ring. Alternatively, no adjustment is possible if the steering plate is not in contact with the o-ring. Screwing in or unscrewing the horizontal fiber position knob may vary the distance between the end of the fiber and the center of the cuvette.

Caution

Be sure to first loosen the fiberoptic SMA 905 connection, so as not to apply torsion to the fiber.

This adjustment varies the position of focus in the sample when desired for specific experiments, or to compensate for lens aberrations to maximize optical throughput. For normal operation the distance between the knurled ring on the horizontal fiber position knob should be set 1/8 inch from the knurled ring on the first lens holder (see the following figure).



Imaging and Collimating Lenses

Converting an Imaging Lens into a Collimating Lens

The second lens of the imaging lens system is simply snapped onto the end of a collimating lens (see figure above). To remove the second lens, use a piece lens tissue to prevent your fingers from touching the lens. With the lens tissue in your hand, firmly grasp the second lens holder and snap it off of the collimating lens.

System Operation

► ***Procedure***

1. Turn on the power to the CUV-TLC-50F system using the switch located on the left side of the rear panel of the temperature control unit.
2. Place the liquid sample in a standard 1 x 1-cm square fluorescence cuvette to reach a height of 22 mm.

Note

The CUV-TLC-50F is intended to hold a cuvette with a standard wall thickness of 1.25 mm and total width of 12.5 mm. Cuvettes with unusually thick walls will not properly fit and may damage the holder. Also, unusually short cuvettes will be difficult to remove after being pushed all of the way to the bottom of the holder.

3. Place the cuvette and sample in the sample holder.
4. Use the provided optical slits or blanks around the cuvette in a manner that correctly limits the excitation and emission light.
5. If needed, place the magnetic stir bar in the cuvette and turn the magnetic stirrer knob located on the front of the temperature control until the desired speed is reached.
6. Place the opaque plastic cover over the cuvette holder.
7. Place the access lid in the hole in the plastic cover.
8. Set the target temperature using the up/down buttons located to the right of the display window. The normal temperature range is -10 °C to +80 °C, although temperatures from –40 °C to +85 °C may be used under special circumstances (see *Temperature* in Chapter 3: *Specifications*).
9. Briefly depressing either the up or down button displays the target temperature. Otherwise, the current temperature will be displayed.
10. To begin controlling the temperature, press the Run/Stop button located to the left of the display. Pressing the Run/Stop button a second time turns temperature control off.
11. When the sample holder approaches the target temperature, the red light (located on the upper left corner of the front panel of the temperature controller) flashes slowly.
12. When the sample holder reaches within ± 0.02 °C of the target temperature, the red light will remain constant.
13. After measurements are completed, depress the run/stop button to stop temperature control, and turn off power and water sources.

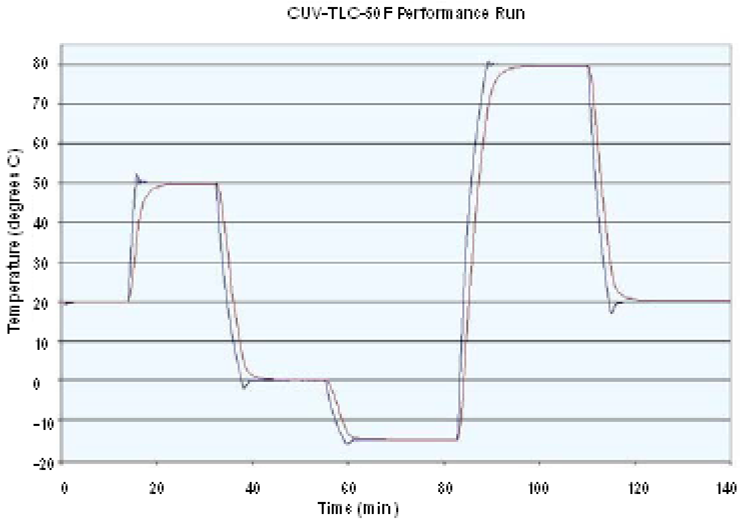
Performance

The graphs in this section show typical performance results for the CUV-TLC-50F under the following conditions:

- *Temperature Equilibration*
- *Low Temperatures*
- *Temperature Ramping*

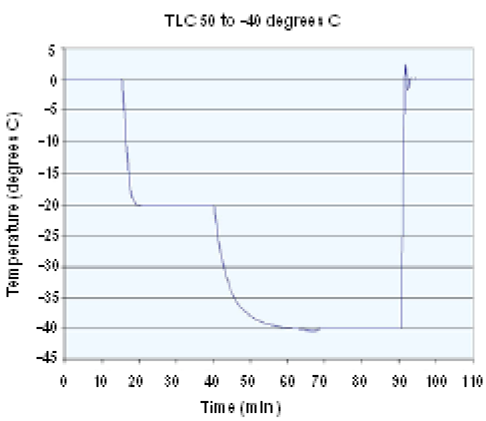
Temperature Equilibration

The serial control option was used to automatically cycle the CUV-TLC-50F through a series of temperatures. The blue line shows the resulting temperature of the sample holder next to one of the optical ports. The red line shows the temperature measured inside a cuvette. The cuvette, containing ethylene glycol and water, was stirred using the magnetic stirring feature of the CUV-TLC-50F. Note the rapid changes in sample holder temperature, followed in a few minutes by the temperature equilibration of the sample.



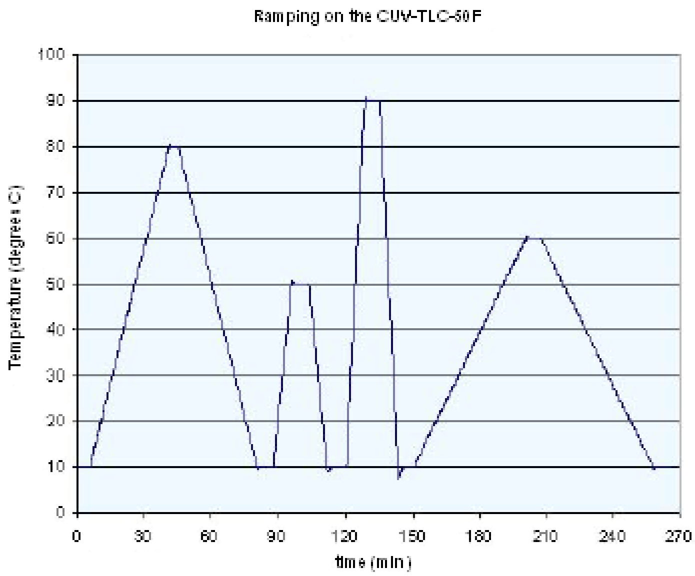
Low Temperatures

To go to low temperature, additional insulation was applied to the CUV-TLC-50F and the unit was connected to a refrigerated water bath containing a methanol and water mixture at approximately -13.00 °C. The sample holder was equilibrated at 0.00 °C, taken to -20.00 °C, and then taken down to -40.00 °C. Dropping the sample holder temperature from 0.00 to -20.00 °C required about 4 minutes. Dropping from -20.00 °C to -40.00 °C required about 20 minutes.



Temperature Ramping

Each of the sample holders from Quantum Northwest has a function for temperature ramping programmed into its microcontroller. The user first allows equilibration at a particular temperature. To initiate the ramp, the user then specifies a final temperature and increments for temperature and time. The serial control option, allowing external control from a computer, is required for temperature ramping.



Error Conditions

Rapid flashing of the red light indicates an error condition. The common errors that will display are the following:

- **Error conditions E5, E6 and E7 – Check Cables.** One or more of these error conditions is likely to arise if the electrical connection between the Temperature Controller and the CUV-TLC-50F is not secure. In this case, turn off the power to the unit, check the cable, turn on the power, and resume work.
- **Error condition E8 – Low water flow.** This error condition indicates that the heat exchanger on the thermoelectric cooler is getting too warm. This heating will occur if insufficient cooling water is flowing into the device. Error condition E8 will automatically shut down temperature control to prevent damage to the unit. If this occurs, improve cooling water flow and restart temperature control.

Chapter 3

Specifications

Specifications Table

Specification	Value
Temperature	-40 to 85 °C
Precision	±0.02 °C
Reproducibility	±0.05 °C
Maximum Luminated Area (h x w)	12 x 10 mm
Height of Optical Center Above Table	70 mm
Optical Center Above Bottom of Cuvette	8.5 mm
Magnetic Stirring	yes
Dry Gas Purge	yes

Temperature

Thermoelectric temperature control maintains the sample to a precision of ±0.02 °C within a range of -40.00 °C to +85.00 °C. Depending on the humidity and ambient temperature (with dry gas purge) the CUV-TLC-50F will operate down to about -10 °C without the formation of frost on the optical components. Below this temperature, the CUV-TLC-50F requires additional insulation. We recommend that the sample holder be carefully wrapped in bubble wrap or similar packing materials. Such materials are inexpensive and function well. Very low temperature operation (down to -40 °C) requires the use of precooled circulating water of a temperature within about 25 degrees of the target temperature. It will also operate safely between 80 °C and 85 °C, although such high temperatures may adversely effect the lifetime of the thermoelectric device. Temperatures of the sample holder are reproducible within ±0.03 °C. Reproducibility represents the temperature range, expressed as ± one standard deviation, over which the temperature of the cuvette holder may vary from hour-to-hour or day-to-day as measured by a NIST-traceable thermometer. Calibration data is provided with each sample holder. For experiments in which knowledge of the exact sample temperature is critical, independent verification is required.

Variable Speed Magnetic Stirring

Variable speed magnetic stirring is provided for experiments in which it is important to rapidly remove photoproducts from the illuminated volume. A stir bar is included.

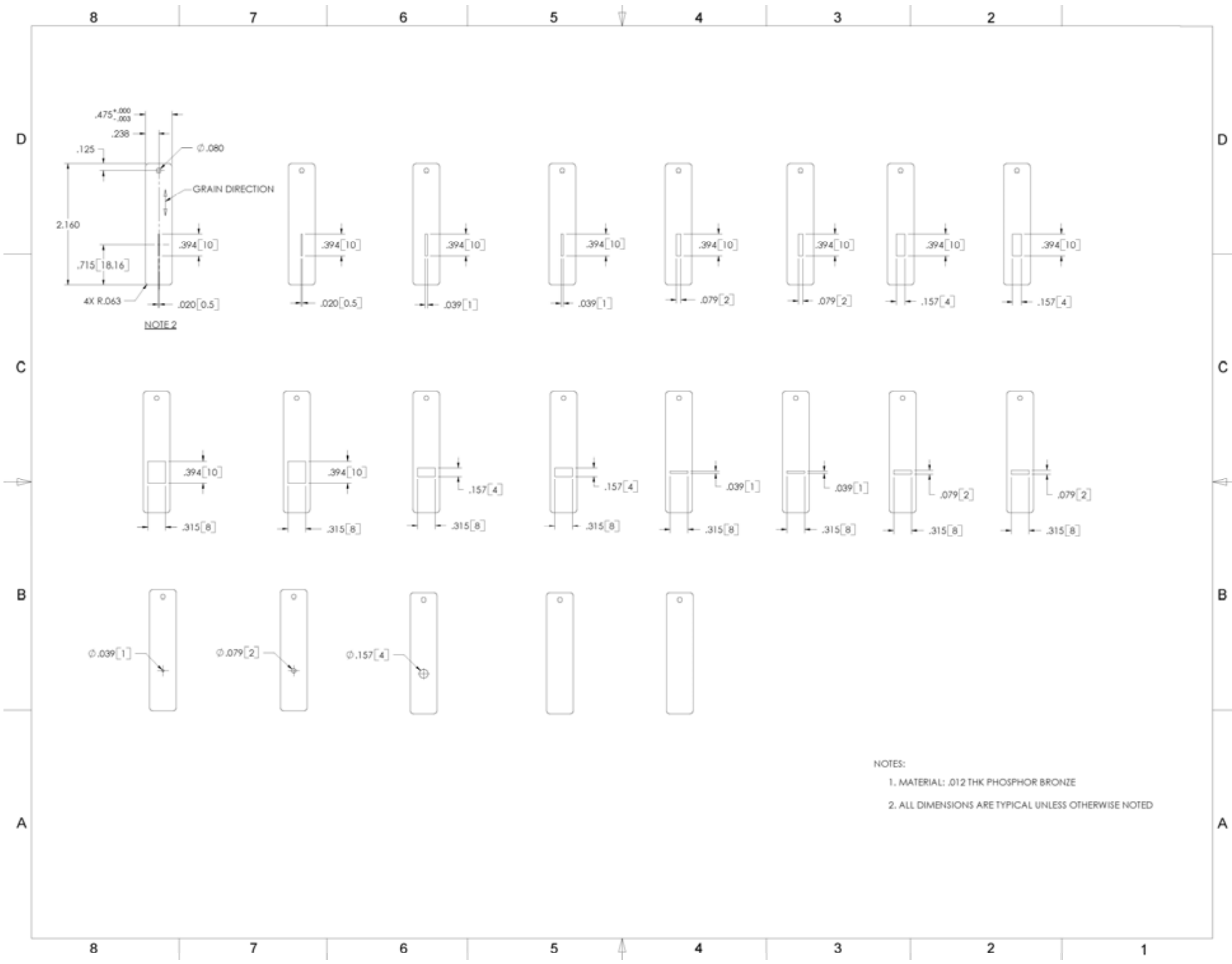
Dry Gas Purge

A dry gas purge is provided. The gas travels through the base of the cuvette holder for temperature equilibration and then blows onto each of the four faces of the cuvette. The gas purge minimizes condensation on optical surfaces. An opaque cap with access hole covers the top of the cuvette to provide isolation from the ambient environment.

Serial Interface

An optional serial interface is available for remote computer control (see Appendix A: *Serial Control for the CUV-TLC-50F*).

Mechanical Diagram



Appendix A

Serial Control for the CUV-TLC-50F

Overview

Serial Control permits the remote temperature control via a serial interface on a computer using a Windows operating system. The option consists of a cable that connects the Temperature Controller with the computer, and software. The software includes QNW_SC.exe, a sample control program that enables control, and recovers and plots temperature data. For those who wish to write their own control programs, example programs and libraries of functions are provided for use with both Borland and Microsoft development systems.

Setup and Software Installation

► ***Procedure***

1. Use the provided cable to connect from the lower (9-pin) connector on the back of the temperature controller to a serial interface of your computer (typically COM1).
2. Place the installation CD in the computer's CD drive and run Setup.exe from the CD. All files will be placed in the directory specified during installation (default is C:\QNW Serial Control), except for QnwSerial.DLL, which will be installed in the Windows System directory.
3. To check the interface, run the program QNW_SC.exe. For instructions on how to use the program, use the program's Help system.

Uninstalling the Software

To uninstall the Serial Control Program files, use the "Add/Remove Programs" control panel by selecting "QNW" from the list.

Serial Control from Other Programs

It may be useful to have temperature control for the CUV-TLC-50F system from other programs (for example data acquisition programs). The installation CD includes code for a simple C++ program that illustrates how to use QnwSerial.DLL for serial communications with the TLC 50™ hardware.

QnwSerial.dll provides functions that simplify opening and closing serial ports, and sending and receiving data over a serial connection. This DLL was developed with Borland C++ Builder 3. QnwSerial.dll can only be used by 32-bit programs. The “Borland Example” and “Microsoft Example” directories contain the code and project files required by Borland C++, version 5.02, and Microsoft Developer Studio Visual C++, version 4.0, respectively, to generate the application. If you have either of these development systems (or newer versions) installed on your computer, you should be able to open the projects (QnwExample.ide or QnwExample.mdp files) and compile and link them to generate the example programs. You will probably need to modify the project directories for Borland’s header and library files in the Borland project so that the system can find the standard Borland files.

The .C and .H files for the Microsoft Example differ from those for the Borland Example in minor ways as described below. For the Microsoft Example, the QnwSerial DLL function prototypes and function calls include an added underscore as the first character of the function names.

One of the standard include lines differs between the two examples, <DIR.H> for Borland and <DIRECT.H> for Microsoft.

In several of the calls to SendDlgItemMessage() the parameter -1 for Borland was changed to (WPARAM)(-1) for Microsoft to suppress a warning message during compilation in the latter development system. The line “#pragma argsused” is included before two of the function definitions only for Borland, again to suppress a warning message during compilation.

The Example Programs

Copies of the resulting executable files, QnwExample.exe and QnwExampleM.exe, are included if you installed the example programming files (“typical” installation choice).

When the programming example is started, it obtains the information needed for connecting to and configuring a serial port from a command list file, QnwExample.lst. If this list file does not exist in the startup directory, default settings are used and a QnwExample.lst file will be created which includes those settings when the program is closed. You can modify this information to change the serial port setup to be used the next time the program is started. The setup line is in the form of a DOS “mode” command for configuring a serial port — “COM1:19200,N,8,1” — and must be the only data on the first line of the file. In the example line above, COM1 specifies the serial port to be used (typically COM1, COM2, etc., but some computers may require different designations). The remaining parameters specify a baud rate of 19200, no parity, 8 data bits and no stop bits, respectively. The parameters “19200,N,8,1” are correct for the CUV-TLC-50F, so you should only need to consider changing the port designation if COM1 does not work.

The list file also may contain a list of command lines which QnwExample loads and inserts into a program drop down list to give the user access to the commands. To use the program, the user either chooses one of the commands from the drop down list (and possibly edits it) or enters a command directly into the edit control provided. That command is sent out the serial port when the user presses the “Send Command” button. QnwExample displays the command at the top of a large display window and subsequently displays any information received through the serial connection. The program also provides a means of deleting commands from the drop down list and for adding new or modified commands to the list. These changes are saved to the list file when the program exits. A “Start/Stop Logging” button is provided to enable/disable logging into a file named QnwExample.log. All information displayed in the large text window is logged as it appears when logging is enabled.

The command list provided with the examples (QnwExample.lst) includes many of the valid command forms for the CUV-TLC-50F. Each command is annotated to the right of the command for convenience. Note, however, that the annotations are possible only because the CUV-TLC-50F ignores any text received that is not included between square brackets.

Ramping Control

Linear temperature changes may be controlled through the ramping option in the Serial Control software. Two parameters, RT (Ramping Temperature – the temperature increment) and RS (Ramping Seconds – the time increment) control the rate of temperature change. Normal temperature control will be replaced by ramping only if both the RT and RS values are non-zero.

To create a temperature ramp, equilibrate the sample holder at the starting temperature. Briefly, stop temperature control and set the RT and RS values. Set the target temperature to the final temperature desired at the end of the ramp and restart temperature control.

RS must be an integer between 1 and 64000 seconds. RT must be an integer between 1 and 32000 in units of hundredths of a °C.

Table 1: Serial Commands

Command	Response
[F1 SS +] [F1 SS -]	Turn stirrer on (stir rate must be set manually) Turn stirrer off
[F1 TC +] [F1 TC -]	Turn temperature control on Turn temperature control off
[F1 TT S 23.1] [F1 TT ?] [F1 TT 71.3]	Set target temperature to 23.1° C Query: What is the current target temperature? Reply: Target temperature is 71.3° C

Table 1: Serial Commands (Cont'd)

Command	Response
[F1 IS ?] [F1 IS 0+-S]	Query: What is the current instrument status? Reply: no unreported error (0 or 1) temperature control is on (+ or -) temperature is stable (S or C) stirrer is off (+ or -)
[F1 IS +5]	Automatically report instrument status every 5 seconds
[F1 IS +]	Automatically report instrument status whenever it changes (e.g., due to manual changes at controller)
[F1 IS -]	Stop, periodic or automatic reports of instrument status
[F1 CT ?] [F1 CT 22.8]	Query: report the current temperature Reply: the current temperature is 22.8° C
[F1 ER +] [F1 ER -]	Automatically report errors when they occur Stop automatic error reports
Ramping Commands	
[F1 RS S XX]	Set Ramping Seconds, the time increment of the ramp rate (positive integer in seconds)
[F1 RT S XX]	Set Ramping Temperature, the temperature increment of the ramp rate (positive integer in hundredths of a °C)

When the Controller is restarted (by being powered off and back on again), it automatically sends the message [F1 IS R] to notify the program of the restart.

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