LASER PHOTOMETER
MODEL 8587A

OPERATION AND SERVICE MANUAL

P/N 1980538, REVISION D
JULY 2015

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LASER PHOTOMETER
MODEL 8587A

OPERATION AND SERVICE MANUAL

Manual History

The following is a history of the Model 8587A Laser Photometer Operation and Service Manual (Part Number 1980538).

Revision	Date
A	December 2005
B	April 2008
C	March 2009
D	July 2015

Warranty

Part Number 1980538 / Revision D / July 2015

Address TSI Incorporated / 500 Cardigan Road / Shoreview, MN 55126 / USA

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Limitation of Warranty and Liability
(effective February 2015)

Seller warrants the goods, excluding software, sold hereunder, under normal use and service as described in the operator's manual, to be free from defects in workmanship and material for **12 months**, or if less, the length of time specified in the operator's manual, from the date of shipment to the customer. This warranty period is inclusive of any statutory warranty. This limited warranty is subject to the following exclusions and exceptions:

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Safety

This section provides instructions to ensure safe and proper operation and handling of the Model 8587A Laser Photometer.

Laser Safety

The Model 8587A Laser Photometer is a Class I laser-based instrument. During normal operation, you will not be exposed to laser radiation. However, you must take certain precautions or you may expose yourself to hazardous radiation in the form of intense, focused visible light. Exposure to this light can cause blindness.

Take these precautions:

- Do ***not*** remove any parts from the Laser Photometer unless you are specifically told to do so in this manual.
- Do ***not*** remove the Laser Photometer housings or covers while power is supplied to the instrument.

WARNING

The use of controls, adjustments, or procedures other than those specified in this manual may result in exposure to hazardous optical radiation.

WARNING

Although the Laser Photometer is appropriate for monitoring inert process gases such as nitrogen or argon, it should not be used with hazardous gases such as hydrogen or oxygen. Using the Laser Photometer with hazardous gases may cause injury to personnel and damage to equipment.

Description of Safety Labels

This section acquaints you with the advisory and identification labels on the instrument and used in this manual to reinforce the safety features built into the design of the instrument.

Caution

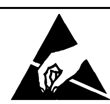
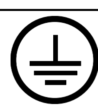
Caution
Caution means ***be careful***. It means if you do not follow the procedures prescribed in this manual you may do something that might result in equipment damage, or you might have to take something apart and start over again. It also indicates that important information about the operation and maintenance of this instrument is included.

Warning

WARNING
Warning means that unsafe use of the instrument could result in serious injury to you or cause irrevocable damage to the instrument. Follow the procedures prescribed in this manual to use the instrument safely.

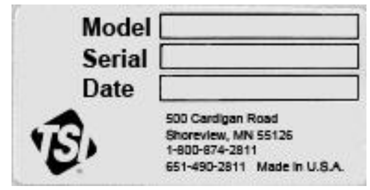
Caution or Warning Symbols

The following symbols may accompany cautions and warnings to indicate the nature and consequences of hazards:

	Warns you that uninsulated voltage within the instrument may have sufficient magnitude to cause electric shock. Therefore, it is dangerous to make any contact with any part inside the instrument.
	Warns you that the instrument contains a laser and that important information about its safe operation and maintenance is included. Therefore, you should read the manual carefully to avoid any exposure to hazardous laser radiation.
	Warns you that the instrument is susceptible to electro-static dissipation (ESD) and ESD protection procedures should be followed to avoid damage.
	Indicates the connector is connected to earth ground and cabinet ground.

Labels

Advisory labels and identification labels are attached to the outside of the Laser Photometer housing and to the optics on the inside of the instrument. Labels for the Model 8587A Laser Photometer are described below:

1. Serial Number Label (back panel)	
2. Laser Radiation Label (located internally on the optics housing)	

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About This Manual

Organization

The following is a guide to the organization of this manual:

- **Chapter 1: Introduction**
  Describes the instruments and provides a brief overview of operation.
- **Chapter 2: Unpacking and Setting Up the Laser Photometer**
  Describes the unpacking of the instrumentation, physical setup of the Laser Photometer, connection of sampling and vacuum line tubing.
- **Chapter 3**: **Technical Description**
  Provides significant detail on instrument components.
- **Chapter 4: Instrument Operation**
  Provides a guide to using the instrument for respirator fit tests and filter testing.
- **Chapter 5: Maintenance and Service**
  Provides a guide to instrument maintenance and service.
- **Appendix A: Specifications**
  Provides instrument specifications.
- **Appendix B: Laser Photometer CD**
  Provides useful information and describes the software programs for expanding the functionality of the instrument.
- **Appendix C: Technical Information for Program Development Using USB Communications**
  Describes the software development library found on the Model 8587A Laser Photometer CD-ROM supplied with the instrument.

Submitting Comments

TSI values your comments and suggestions on this manual. Please use the comment sheet on the last page of this manual to send us your opinion on the manual's usability, to suggest specific improvements, or to report any technical errors. If the comment sheet has already been used, please mail your comments on another sheet of paper to:

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CHAPTER 1

Introduction

This chapter contains an introduction to the Model 8587A Laser Photometer and provides a brief explanation of how the instrument operates.

Product Description

The Model 8587A Laser Photometer measures aerosol concentrations for determining the *fit factor* of particle protection respirators, and for determining air filter *efficiency.*

To perform a fit factor test or filter efficiency test, aerosol is sampled from two separate sampling ports. The sample ports are found at the back of the instrument labeled UPSTREAM and DOWNSTREAM. When the Model 8587A is used for fit testing, the UPSTREAM port is used to sample aerosol from the test chamber. The DOWNSTREAM port is used to sample aerosol from within the mask.

For filter efficiency testing, the UPSTREAM port samples aerosol before it passes through the filter, the “challenge aerosol”. The DOWNSTREAM port is used to sample the aerosol concentration after passing through the filter.

The Model 8587A Laser Photometer sensor has special features which make it unique from older light scattering devices using white light as their light source. These features have dramatically improved sensitivity, simplified operation and reduced maintenance. The special features of the sensor are listed below:

- Solid-state laser diode light source and photodiode detector
- 45 degree off-axis light collection angle
- Sheath-air flow design
- Fast purge mode capability
- Microprocessor driven
- Automatic gain selection (six decades)
- Remote operation capability using a computer
- Front panel switch for selecting between two sampling ports, Downsteam and Upstream.

Figure 1-1
Model 8587A Laser Photometer

How it Works

The Model 8587A Laser Photometer determines aerosol concentration by measuring the level of scattered light produced by aerosol particles as they are passed through a collimated laser beam in the aerosol sensor assembly. Scattered light is collected by a photosensitive detector, and a voltage signal is produced. This signal, minus a small voltage offset, is proportional to the aerosol mass concentration.

The Laser Photometer transmits signal voltage readings to the front panel LCD display in scientific notation. Voltages can be accessed by a computer too, connected to the RS-232 Serial or USB connectors using a communications cable. Computer control enables automated respirator fit and filter testing, in addition to other applications.

CHAPTER 2

Unpacking and Setting Up the Laser Photometer

Use the information in this chapter to unpack the Model 8587A Laser Photometer and set it up.

Unpacking

The following instruments and accessories comprise the Model 8587A Laser Photometer.

Packing List

Table 2-1 shows the components shipped with your Model 8587A Laser Photometer.

Table 2-1
Model 8587A Laser Photometer Packing List

Qty.	Description	Part No.
1	Operation manual	1980538
1	Power cord 110-120V	1303053
	220-224V	1303075
1	Exhaust filter	1602230
1	Purge air filter	1602094
1	Sheath air filter	1602051
1	9-pin serial interface cable 6-foot	962002
1	6-foot USB interface cable	1303740
1	CD with USB terminal program	1031502

AC Power Connection

The Laser Photometer uses an on-board power supply capable of operating with supplied AC power in the range of 100–240 VAC and 50-60 Hz. A detachable power cord is provided and is connected at the cabinet back. Plug the power cord into a suitable voltage source.

Vacuum Pump and Connection

The Laser Photometer requires the use of a high vacuum pump, sufficient to draw >2 L/min (.07 cfm) at 55 kPa (8 psi) vacuum pressure and provide a free flow of between 12 and 30 L/min (0.43–1.1 cfm).

The vacuum pump is connected to the back of the instrument at the 6.4 mm (¼ in.) tube connection labeled VACUUM. Use a plastic tube to connect from the vacuum inlet port on the pump to the instrument. Use tubing which will not collapse under the vacuum load >55 kPa (8 psi).

Flow Check

The Model 8587A verifies the airflow provided by an external vacuum pump by monitoring the vacuum during upstream and downstream sample modes. This ensures that a critical pressure is maintained during sampling, and in turn, a critical airflow for sampling. An operating pressure and airflow of >55 kPa at 2 L/min (8.0 psi at 0.07 cfm) are recommended. The minimum vacuum and airflow required is 30 kPa at 1.79 L/min. (4.4 psi at 0.063 cfm) but at the minimum vacuum and airflow, the test data will not be repeatable.

Note

Stable airflows are extremely important in obtaining repeatable test results. TSI strongly suggests the instrument be operated with a vacuum greater than 55 kPa (8.0 psi). At a vacuum of greater than 55 kPa (8.0 psi) an internal critical orifice limits and stabilizes the sample airflow to 2.0 L/min (0.07 cfm). Repeatable test results will ONLY be obtained with stable sample airflows.

When the vacuum is greater than 30 kPa (4.4 psi), the FLOW STATUS light on the front panel turns ON. *An illuminated FLOW STATUS light indicates proper operation.* If the FLOW STATUS is BLINKING, the vacuum is not sufficient and less than 30 kPa (4.4 psi). If the FLOW STATUS is not ON or BLINKING, first check to make sure the unit is operating in the UPSTREAM or DOWNSTREAM modes. The FLOW STATUS is not functional in the PURGE mode. Second, check that there are no leaks in the vacuum line. Third, if more than one Laser Photometer shares the same vacuum source, make sure all instruments are connected and none are in PURGE mode. If one instrument is in the PURGE mode, a minimum vacuum of 30 kPa (4.4 psi) will not be maintained to the other instruments.

To independently verify the vacuum, place the Laser Photometer in the UPSTREAM mode and connect a vacuum gauge to a tee placed in the vacuum line. If a differential gauge is used, connect to the low pressure port of the gauge to the vacuum line. TSI strongly recommends a vacuum of greater than 55 kPa (8 psi). The minimum vacuum must be greater than 30 kPa (4.4 psi).

Connecting the Sample Lines

Upstream and Downstream sample lines must be connected at the back of each Laser Photometer. Tube stubs for tubing connections are labeled accordingly; UPSTREAM and DOWNSTREAM. Clear ID 4.8 mm ($^{3}/_{16}$ in.) vinyl tubing is recommended for the sample lines. The tubing must be pushed completely over each tube stub. A touch of silicone grease applied to the outside of the tube stub will simplify the connection.

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CHAPTER 3
Technical Description

This chapter identifies the basic features of your Model 8587A Laser Photometer and provides general technical information. Detailed instrument specifications are provided in Appendix A.

Cabinet

Cabinet dimensions (WDH):	17.8 cm × 33.0 cm × 25.4 cm (7 in. × 13 in. × 10 in.)
Cabinet weight:	5.5 kg (12 lb.)

Front Panel

Front panel features include a 2-line liquid crystal display (LCD), a 3-button membrane keypad and instrument status lights. The display presents the photometer signal voltage and indicates the current operation mode, i.e., UPSTREAM, PURGE, DOWNSTREAM.

The keypad control buttons are found under the display and are used to select the sampling mode indicated on the button face, UPSTREAM, DOWNSTREAM, and PURGE. When sampling upstream or downstream, the instrument draws sample from the respective sample port at the back of the Laser Photometer (see the following section). When the photometer is in the PURGE mode, particle free air is drawn at a high airflow rate into the photometer's laser optics chamber and through the purge air filter shown in the schematic of Figure 3-3.

Keypad and LCD Display

The keypad enables manual switching for sampling from the different sample ports (UPSTREAM and DOWNSTREAM) and to place the instrument in a PURGE mode. The keypad buttons are labeled as to function, UPSTREAM, UPSTREAM, and PURGE.

Note: *When switching between UPSTREAM and DOWNSTREAM it is necessary to pass through the PURGE mode by pressing the PURGE keypad button.*

Status Lights

The POWER light indicates the instrument is ON or OFF. An illuminated POWER light indicates the power is ON.

The FLOW STATUS light has three indications.

OFF	During the PURGE mode, the FLOW STATUS is not functional and will be off. If the FLOW STATUS light is OFF during the UPSTREAM or DOWNSTREAM modes, the instrument is malfunctioning.
ON	*An illuminated FLOW STATUS light indicates proper operation.* The FLOW STATUS light is illuminated during the UPSTREAM and DOWNSTREAM sampling modes if more than 30 kPa (4.4 psi) of vacuum is being supplied to the respective sample port. 30 kPa (4.4 psi) is the minimum vacuum needed to obtain the sample airflow for proper measurements.
BLINKING	A blinking FLOW STATUS light indicates the UPSTREAM or DOWNSTREAM vacuum is less than what is required to obtain proper measurements. The FLOW STATUS light will blink if the UPSTREAM or DOWNSTREAM vacuum is less than 30 kPa (4.4 psi). If the FLOW STATUS light is blinking, check for leaks in the vacuum system or a faulty vacuum pump.

(continued on next page)

Back Panel

The photometer back panel contains the DOWNSTEAM and UPSTREAM sample and VACUUM ports, the AC power connection/main power switch, the RS-232 serial port connection, the USB connection, the cabinet cooling fan, and the analog output BNC connector. The back panel is shown below:

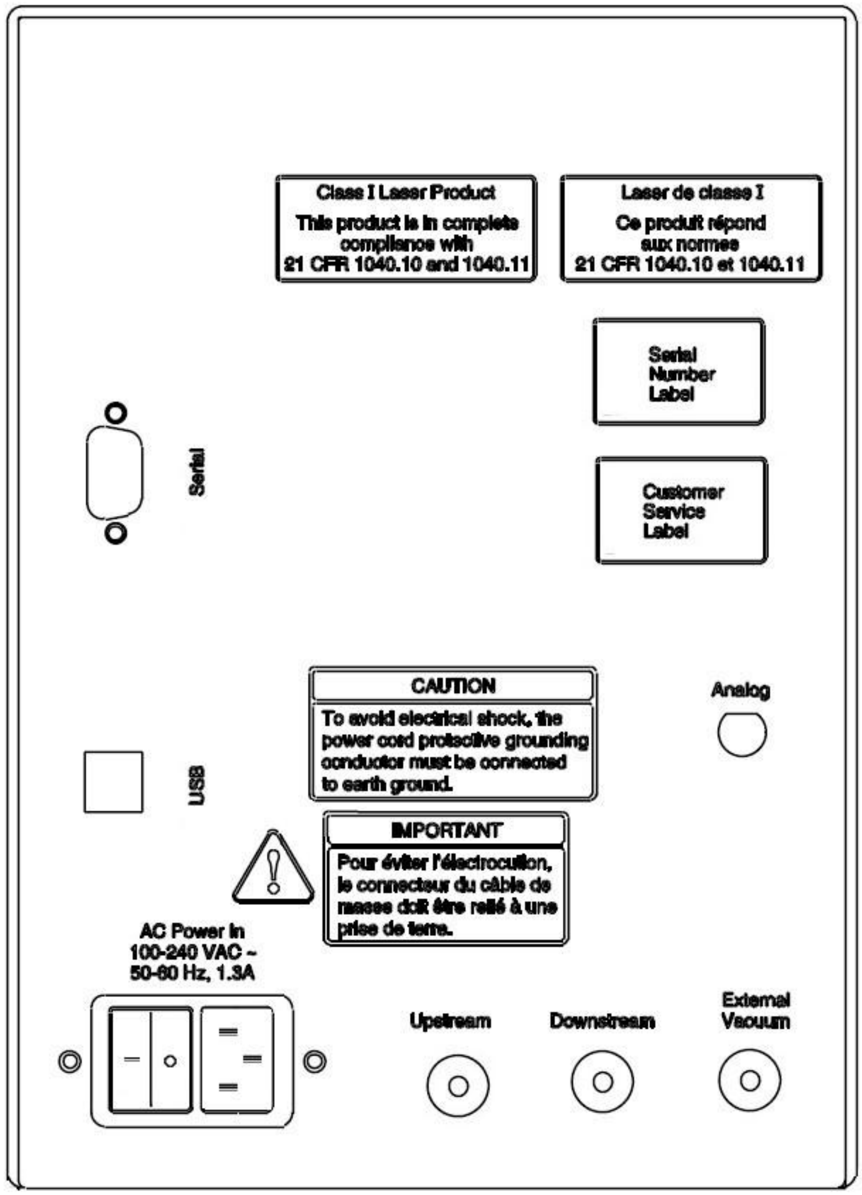

Figure 3-1
Back Panel of the Model 8587A Laser Photometer

1 Upstream and downstream sample ports
2. Port for external vacuum pump connection
3. Power connection
4. 9-PIN D-type female serial connector
5. USB type B connector
6. Analog voltage BNC connector

Upstream and Downstream Sample Ports

Internally the DOWNSTREAM and UPSTREAM sample ports are connected via plastic tubing to a three-way solenoid valve that switches to control which port is used.

Tubing is connected from the UPSTREAM sample port to a chamber or the challenge aerosol side of a filter holder when performing quantitative respirator fit testing or filter testing.

Tubing is connected from the DOWNSTREAM sample port to a mask or downstream of the filter when performing fit testing or filter testing, respectively.

Switching between sample ports is achieved manually by pressing the appropriate front panel keypad button, or through the RS-232 or USB interface connectors using computer control codes. It is necessary to select PURGE as an intermediate step when switching between sampling modes.

Vacuum Port

A vacuum source (vacuum pump) is required to draw the sample airflow into the photometer scattering chamber. The vacuum pump is connected to the port labeled VACUUM on the back panel using flexible tubing pushed over the tube stub. Tubing must be sufficiently rigid so it does not collapse under the vacuum load.

The instrument is designed for a vacuum of >55 kPa (8 psi) which results in a very stable sample airflow of 2 L/min (0.071 cfm). TSI strongly recommends operation with a vacuum greater than 55 kPa (8.0 psi) in order to obtain repeatable test results. The instrument will function with a minimum vacuum and airflow of 30 kPa @ 1.79 L/min (4.4 psi @ 0.063 cfm) but the test data may not be repeatable.

Note

Stable airflows are extremely important in obtaining repeatable test results. TSI strongly suggests the instrument be operated with a vacuum greater than 55 kPa (8.0 psi). At a vacuum of greater than 55 kPa (8.0 psi), an internal critical orifice limits and stabilizes the sample airflow to 2.0 L/min (0.07 cfm). Repeatable test results will ONLY be obtained with stable sample airflows.

Analog Output BNC Connector

The BNC electrical connector on the back panel can be used to monitor the analog voltage from the Laser Photometer sensor. The output is 0–10 volts at the minimum detector gain setting. The output has a limited usefulness at lower signal voltages. Resolution is limited to .01 volts.

Serial Communications Port

A standard nine-pin RS-232 Serial Communications port connector is provided on the back panel of the instrument for control and data acquisition. The connector is a 9-pin, D-type female subminiature type shown. The figure has been rotated 90 degrees clockwise. Pin function is identified in Table 3-1. For detailed information on communications refer to the section, "Serial Communications Protocol" found later in this chapter.

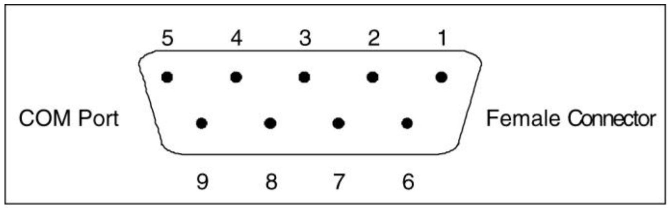

Figure 3-2
Serial Communications Port

Table 3-1
Pin Function for Serial Communications Port

Pin Number	RS-232 Signal
1	GND
2	Transmit
3	Receive
4	Reserved
5	GND
6	-
7	-
8	-
9	

USB Communication Port

USB communications is provided for plug and play connection to a computer. Connect using a standard USB type B connector cable, USB 2.0 compatible.

Serial Communications Protocol

A 9 pin RS-232 connector (see earlier section "Serial Communications Port") provides two-way communication between the Laser Photometer and microcomputer. The default serial communication protocol is presented below. A baud rate of 1200 is the default. A baud rate of 115K can also be set. The low baud rate default has been selected to meet existing requirements for the Model 8587 operated with older software.

Baud rate:	1200
Data bits:	8
Stop bits:	1
Parity:	none
Handshake:	none

A single cable from the computer to each photometer is required to enable communications.

A terminal emulator program such as HyperTeminal provided with Windows can be used to send and receive serial data.

Change baud rate from 1200 to 115K by holding Upstream key for 5 seconds. Use the Downstream key to select the baud rate. Save and exit using the Purge key.

USB Communications

Note: *Do **not** plug your device (Laser Photometer) USB cable into your computer before the USB driver program is installed.*

Before USB communications can be used, a TSI USB *driver* program must be installed on your computer. Install the program using the CD supplied with your instrument. Refer to Appendix B for instructions on installing the driver.

Once the driver is installed, USB communication is achieved by simply connecting your laser photometer USB connection to the USB port on your computer using the supplied USB cable, type B connector.

USB Terminal Emulator Program

Note: *Do **not** plug your device (Laser Photometer) USB cable into your computer before the USB driver program is installed.*

A USB Terminal Emulator program is provided on the CD supplied with your Model 8587A. This enables you to, send and receive ASCII characters for external instrument control and data acquisition. Refer to Appendix B for information on installing and using the USB Terminal Emulator program.

Refer to the section "Command Strings for Instrument Control and Data Acquisition" later in this chapter for information on instrument control and data acquisition.

The Model 8587A is a "client" USB device receiving and transmitting data from a computer. The Model 8587A ***cannot*** act as a USB host.

Command Strings for Instrument Control and Data Acquisition

The Laser Photometer accepts command strings from the microcomputer via its serial port or USB port for control internal switching of valves, transmitting digital voltage data and performing other functions. The command strings and their functions are given below. Command strings must be followed by a Carriage Return.

Table 3-2. Laser Photometer ASCII Command Strings

Command String	Function	String Returned	Delay Needed After Sent
V1N	VALVE 1 ON	NONE	NONE
V2N	VALVE 2 ON	NONE	NONE
V3N	VALVE 3 ON	NONE	NONE
V1F	VALVE 1 OFF	NONE	NONE
V2F	VALVE 2 OFF	NONE	NONE
V3F	VALVE 3 OFF	NONE	NONE
R	RESET RUNNING AVERAGE	NONE	NONE
D	SEND HEX DATA, RESET AVG	See "Hex Data Retrieval Section" below.	See "Hex Data Retrieval Section" below.
K	SEND DECIMAL DATA, RESET AVG	See "Decimal Data Retrieval Section" below.	See "Decimal Data Retrieval Section" below.
S	SEND VALVE STATUS	VX *	NONE
L	LOCK OUT VALVE SWITCH	NONE	NONE
U	UNLOCK VALVE SWITCH	NONE	NONE
M	SWITCH VALVES DOWNSTEAM	NONE	0.5 SEC. (if from purge)
C	SWITCH VALVES TO UPSTREAM	NONE	0.5 SEC. (if from purge)
P	SWITCH VALVES TO PURGE	NONE	0.5 SEC.
IMPORTANT: All ASCII commands must be sent in upper case followed by a CR. All strings returned will be in upper case. All strings returned by the photometer will be followed by a line feed character.			

*Valve status return string "VX" where X = Code for the current valve status see below:

X	**Valve 1**	**Valve 2**	**Valve 3**
0	off	off	off
1	on	off	off
2	off	on	off
3	on	on	off
4	off	off	on
5	on	off	on
6	off	on	on
7	on	on	on

Hex Data Retrieval

The voltage data is passed from the instrument as a string of 8 hexadecimal characters in ASCII when the “D” serial command is received. This number must be converted to decimal and then be divided by 10^7 to obtain the true signal voltage reading matching the front panel reading. The process is outlined in the example below:

<u>0 A 4 6 C 3 D 8</u>

	Hex Character Received		Decimal Value
1st	0	0×16^7 =	0
2nd	0	0×16^6 =	0
3rd	4	4×16^5 =	4194304
4th	6	6×16^4 =	393216
5th	C	12×16^3 =	49152
6th	3	3×16^2 =	768
7th	D	13×16^1 =	208
8th	8	8×16^0 =	8

The sum of the numbers divided by 10^7 = 0.4637656 volts.

The voltage data string which is returned after the “D” command is sent represents a continuous average since the last time the voltage was read, or since the last reset "R" string was sent to the Laser Photometer. A “D” command also resets the average after data is sent.

Decimal Data Retrieval

When a “K” command is passed to the Laser Photometer, the signal voltage data is returned as a string of 8 ASCII characters in scientific notation, having five characters of mantissa, a sign (±), and a two character exponent:

Decimal voltage data is presented in the following 8 character string example:

<u>3 . 7 6 E – 0 3</u>

These eight characters translate to 3.76×10^{-3} or 0.00376 volts.

The voltage data string which is returned after the “K” command is sent represents a continuous average since the last time the voltage was read with the “K” or “D” command, or since the last reset "R" string was sent to the Laser Photometer.

DATA Averaging

Each one-tenth of a second, an average of over 100 A/D readings is taken and summed by the Laser Photometer microprocessor. The number of tenth second readings is recorded and at the time the data is polled, the sum of voltage readings is divided by the number of readings since the last reset (“R”, “D” or “K” command sent), to give an average of the data accumulated. The LCD display is updated approximately every 1 second.

Programming Note

When writing a program to perform a specific testing application, the M, C and P commands should be used rather than switching individual valves. This simplifies the process and prevents switching the wrong valves. These commands also incorporate a 0.5 second delay automatically when switching from the purge mode. The delay sequence helps prevent flow surges from introducing aerosol particles into the sensor cavity.

Flow System

A flow schematic of the Laser Photometer is shown in Figure 3-3. Three solenoid valves (V1, V2, V3) are required for controlling the following functions: (V1) selects whether the instrument samples from the sampling ports (UPSTREAM or DOWNSTREAM) or the PURGE port, (V2) selects the sample port UPSTREAM or DOWNSTREAM, (V3) selects the whether the pump pulls flow through the restricted orifice (the sample flow) or the unrestricted flow (the purge flow). The solenoid valves are a common three way type operated at 24 VDC.

The valves must be switched correctly for each operation mode. As discussed earlier, the valves are controlled via the front panel switches or through the computer interface.

Note: *When using the keypad to change between sampling modes, you must always select the PURGE keypad button between sample selections.*

Vacuum Pump

An external vacuum pump is required to draw the sample airflow into the photometer. During the UPSTREAM and DOWNSTREAM sampling modes, TSI strongly recommends a vacuum and airflow of greater than 55 kPa @ 2 L/min (>8.0 psi @ 0.071 cfm). At a vacuum of greater than 55 kPa (>8.0 psi) an internal critical orifice limits and stabilizes the sample airflow to 2.0 L/min (0.071 cfm). The Photometer will operation with a vacuum and airflow as low as 30 kPa @ 1.79 L/min (4.4 psi @ 0.063 cfm) but stable sample airflows will not be obtained and test results will not be repeatable.

N o t e

Stable airflows are extremely important in obtaining repeatable test results. TSI strongly suggests the instrument be operated with a vacuum greater than 55 kPa (8.0 psi). At a vacuum of greater than 55 kPa (8.0 psi) an internal critical orifice limits and stabilizes the sample airflow to 2.0 L/min (0.07 cfm). Repeatable test results will ONLY be obtained with stable sample airflows.

For the PURGE mode, the pump must provide a *free flow* of between 12 to 30 L/min (0.43 to 1.1 cfm).

The vacuum pump is connected to the port labeled VACUUM on the back panel. Refer to the Chapter 4, "Instrument Operation" for more information on pump requirements.

Flow Schematic Model 8587A Laser Photometer

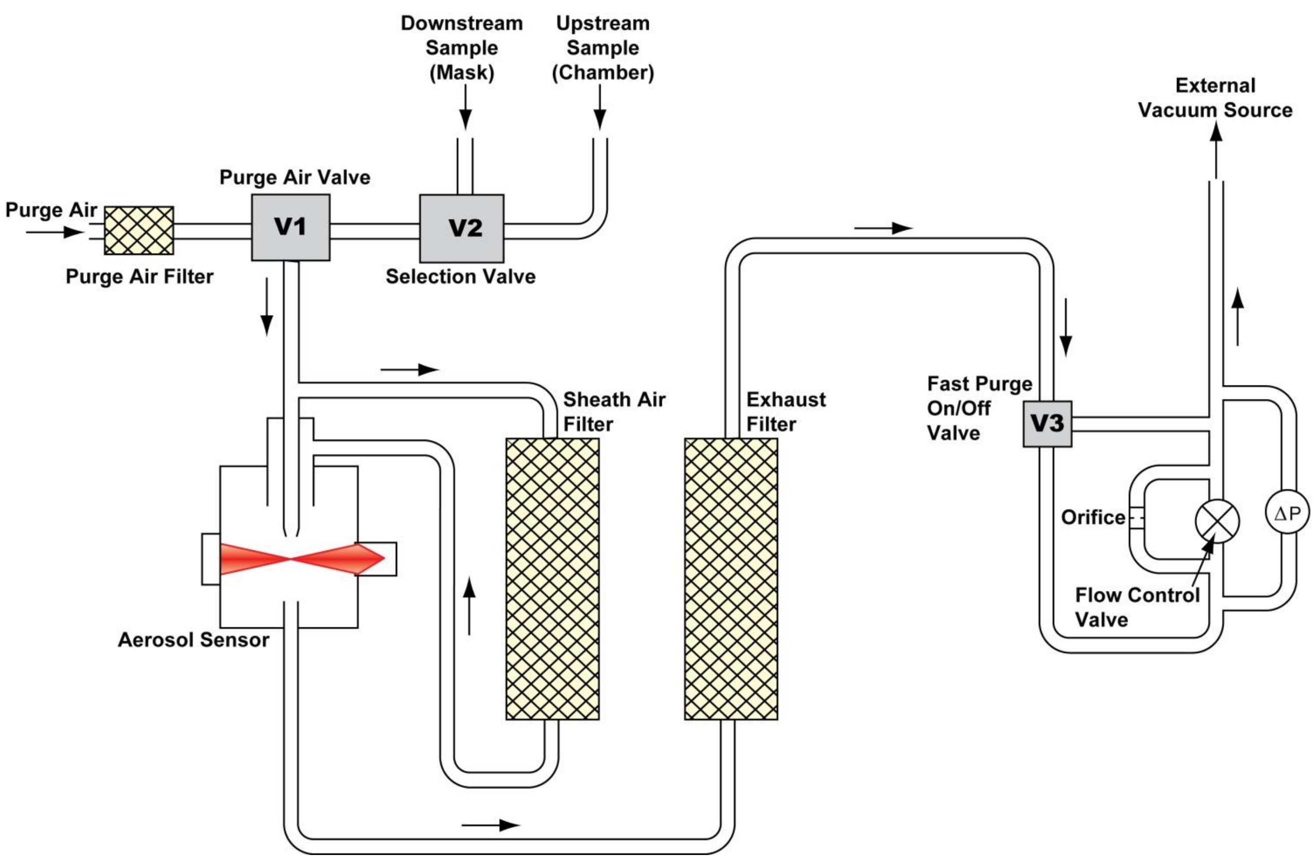

Figure 3-3
Flow Schematic Model 8587A Laser Photometer

Sensor (Scattering Chamber)

The Laser Photometer aerosol sensor (scattering chamber) is depicted schematically in Figure 3-3. Relative aerosol concentration measurements outside and inside a mask, or upstream and downstream of the filter are made here.

For particle detection in the scattering chamber, a 30 mW laser diode light source is used, focused with a collimating lens and a series of apertures to create a narrow high intensity beam. Particles in the sampled air are directed through the beam and scatter light in relation to the mass concentration of aerosol. The scattered light is collected by means of lenses and focused on a PIN photodiode detector. The signal voltage output from the detector is fed into a gain amplification circuit and processed to obtain the concentration measurements over a large dynamic range. The photometer assembly is extremely reliable (MTBF >85000 hours), due to the solid-state laser diode and PIN photodiode detector. These devices are inherently stable and rugged.

As a means of improving photometer reliability, a special sheath-air flow system is designed into the scattering chamber (Figure 3-4). The sheath-air system works by isolating the aerosol stream with a surrounding clean air stream. This keeps the sampled aerosol away from the lenses, apertures, light stop, and walls of the scattering chamber. Keeping the inside surfaces clean minimizes stray light inside the chamber and allows the photometer to operate for longer periods of time without needing cleaning. The clean sheath-air is obtained from the incoming sample air. The photometer sample flow is split at the inlet and divided into a clean air stream and an aerosol stream. The sheath-air flow system is optimized when operating at a flow rate of 2 L/min (0.07 cfm); however, the photometer can sample throughout the range of .5 to 3 L/min (0.05 to 0.10 cfm) where the sheath-air column is effective.

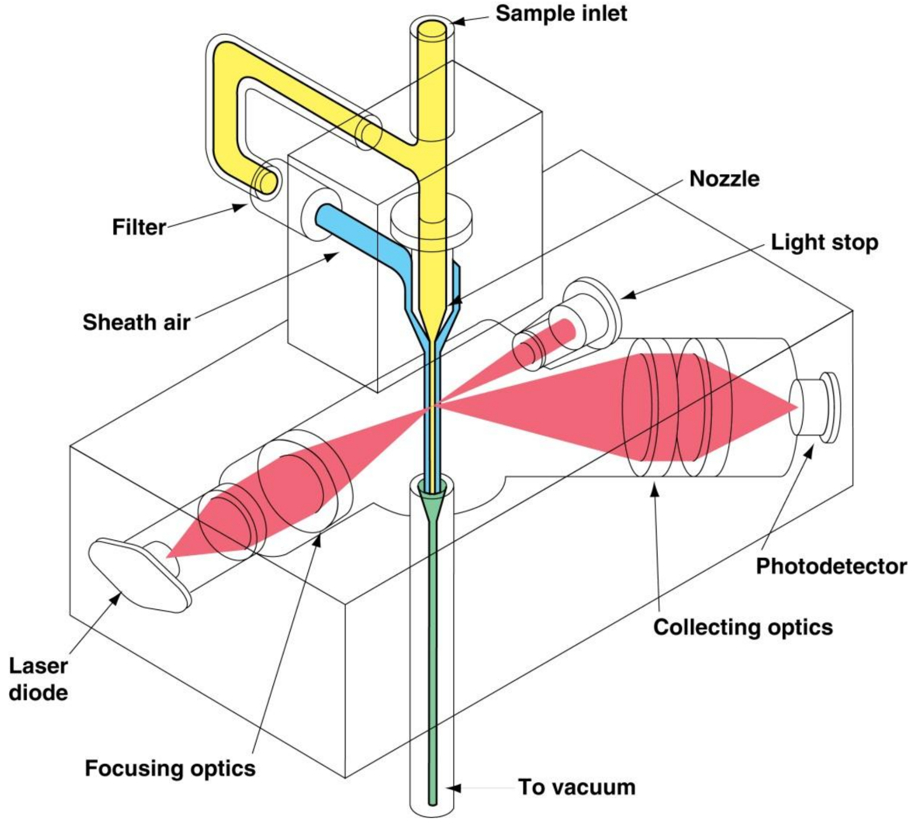

Figure 3-4
Sheath Air Flow System

Laser Photometer Electronics

The function of the photometer electronics is to measure and display the photodetector voltage. The photometer electronics incorporates a 12 bit successive approximation A/D (Analog to Digital) converter combined with a 6 decade gain amplification circuit to measure photodetector voltages. This combination allows the photometer electronics to measure photodetector voltages from as low as 4.5 microvolts up to 45 volts. The photodetector board is mounted to the photometer scattering chamber to minimize electrical noise which could interfere with the photodetector signal. The photodetector board contains the PIN photodiode and gain amplification circuit.

The electronics incorporated into the photometer assembly consists of photodetector PC board having the photodetector circuitry, the laser driver circuit, and the instrument motherboard, providing instrument control, communications, and display functions.

The motherboard contains a microprocessor and other circuitry which performs the following functions:

1. Read the photodetector signal from the photodetector board.
2. Automatically adjust the photodetector signal gain over 6 decades as needed.
3. Display the photometer output on the front panel.
4. Send the photometer output as an analog 0–10 volt output to a back panel connector.
5. Control the laser diode to emit at a constant power.
6. Control internal valves to select one of three aerosol sources (downstream, upstream, filtered purge air).
7. Indicate current operating mode on the LCD.
8. Read the front panel keypad switch.
9. Communicate with an external computer to send photometer output signals or switch valves.

The instrument is controlled through on-board firmware. A single cable connects the photodetector board to the motherboard

Internal Instrument Components

The internal components are shown in Figure 3-5 and are described on the following pages.

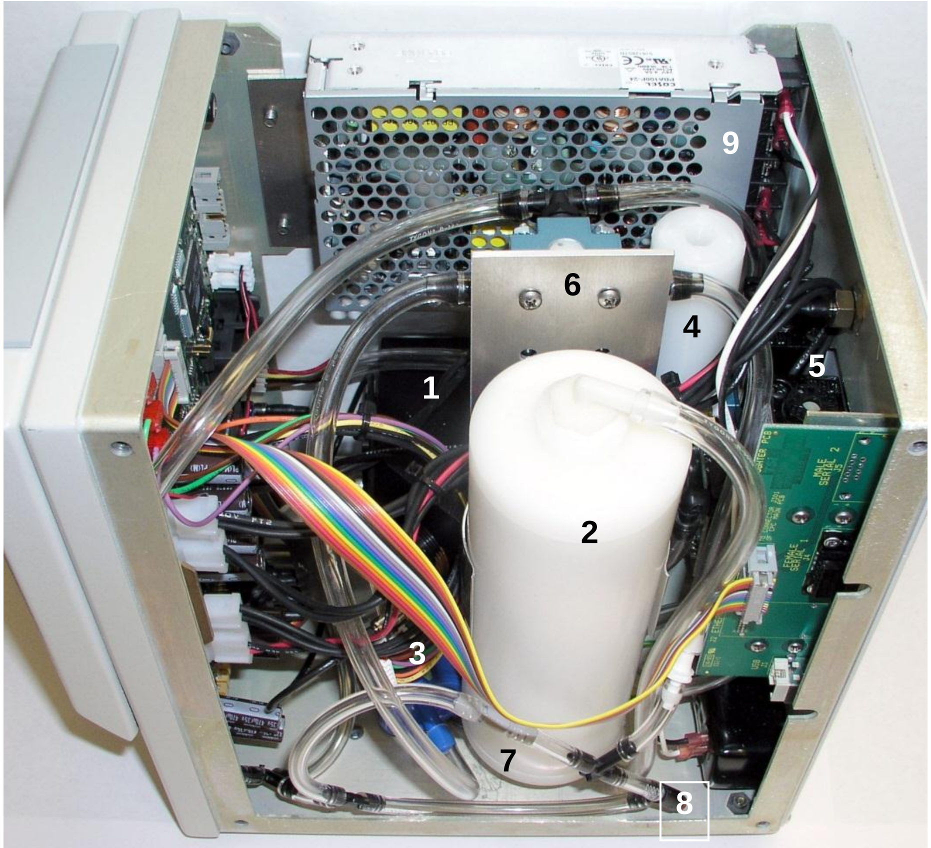

Figure 3-5
General Location of Internal Components of the Model 8587A Laser Photometer

1. Sensor assembly
2. Sheath filter
3. Exhaust filter
4. Purge filter
5. Sample mode valves
6. Flow valve
7. Gray fixed orifice, sample flow
8. Adjustable orifice, sample flow
9. Power supply

Sensor Assembly

The sensor assembly consists of the aluminum block scattering chamber, laser mount and laser driver board, photodiode detector and detector electronics PCB and sampling inlet with unique sheath air design using a sheath filter.

Aerosol is drawn into the sensor assembly at nominally 2 L/min (.07 cfm). in sampling modes, UPSTREAM and DOWNSTREAM, and at higher flow >12 L/min (0.43 cfm) in the PURGE mode.

Scattered light from particles creates a voltage proportional to aerosol mass concentration as the aerosol particles pass through a focused laser beam and scattered light is collected by the detector. Refer back to the section "Sensor (Scattering Chamber)".

Filters

Three filters are used with the Laser Photometer and identified in Figure 3-5. The purge filter is used during purge mode to remove particle from the sensor scattering chamber. The sheath air filter is a part of the sensor assembly and helps provide a clean sheath of air around the particle stream, confining particles and keeping them from depositing on the internal surfaces and lenses in the scattering chamber. The exhaust filter removes aerosol particles before they enter the vacuum pump.

Solenoid Valves

Solenoid valves control the routing of flow from the sampling ports and through the purge filter. Refer to the schematic shown in Figure 3-3.

V1 switches between purge and sample, V2 switches between sample ports upstream and downstream, V3 switches between the high flow vacuum purge and flow controlled by the orifice and needle valve.

Pressure Transducer

A pressure transducer measures the differential pressure across the orifice and valve (see Figures 3-3 and 3-5) to ensure the required vacuum creates the correct sample airflow. At the factory, the sample airflow is set with a differential vacuum of 55 kPa (8 psi) or greater, generating a “critical airflow” of 2 L/min (0.071 cfm).

As shown in the data table below, vacuum greater than 55 kPa (8 psi) will result in a constant 2 L/min (0.07 cfm) sample or “critical airflow”.

Although the ideal vacuum is >55 kPa (8.0 psi), the instrument will operate correctly at vacuums as low as 30 kPa (4.4 psi). However, when the vacuum across the orifice falls below 30 kPa (4.4 psi), the pressure transducer indicates a flow error, causing the flow status light to blink.

Pressure		Volumetric Flow		
kPa	**psi**	**L/min**	**cfm**	
18	2.6	1.50	0.053	Vacuum and airflow is too low. FLOW STATUS indicator light blinks.
22	3.2	1.60	0.057	
26	3.8	1.70	0.060	
30	4.4	1.79	0.063	Acceptable vacuum and airflow range. FLOW STATUS indicator light is on.
42	6.1	1.90	0.067	
45	6.5	1.95	0.069	
55	8.0	2.00	0.071	
60	8.7	2.00	0.071	
71	10.3	2.00	0.071	
81	11.7	2.00	0.071	

Electronics Boards

Four electronics boards are used in the Model 8587A. The boards include Main PC board, laser board, detector board, communication connector board. The main board has the microprocessor and performs all intelligent functionality, controlling valves and reading inputs and performing basic calculations. The laser and detector boards power the laser and detect scattered laser light from particles in the aerosol stream. The detector board has relays for gain control. The communications board supports the USB and RS-232 serial connectors.

CHAPTER 4

Instrument Operation

This chapter describes the basic operation of the Model 8587A Laser Photometer and provides information on the use of controls, indicators, and connectors found on the front and back panels.

Turning on the Laser Photometer

The Laser Photometer power switch is located to the left of the power cord at the back of the instrument. When the Laser Photometer is turned on, the photometer defaults to the PURGE mode. The LCD display shows the voltage level.

Keypad Pushbuttons

Depress the labeled keypad to perform the indicated functions:

UPSTREAM	Instrument samples from the UPSTREAM port, used for chamber concentration for fit testing and challenge aerosol concentrations for filter testing.
PURGE	Instrument samples at high airflow through a high efficiency filter when obtaining a zero detector background level and prior sampling.
DOWNSTREAM	Instrument samples from the DOWNSTREAM port, used for mask concentrations for fit testing and downstream filter concentration for filter testing.

Important Note
When switching between upstream and downstream sample modes, it is necessary to press the PURGE button.

Vacuum Pump Requirements

The Laser Photometer requires an external vacuum pump to operate. The vacuum pump is connected to the back of the instrument at the 6.4 mm (¼ in.) tube connection labeled VACUUM. The connection is made using a stiff-walled plastic tubing that does not collapse at vacuum pressures greater than ½ atmosphere.

For each Model 8587A Laser Photometer connected to the vacuum pump, TSI strongly recommends a vacuum and airflow supply during UPSTREAM and DOWNSTREAM modes, of greater than 55 kPa (8 psi) and 2 L/min (.07 cfm). At a vacuum of greater than 55 kPa (8.0 psi) an internal critical orifice limits and stabilizes the sample airflow to 2.0 L/min (0.07 cfm). Repeatable test results will ONLY be obtained with stable sample airflows. The instrument will operate with vacuum and airflows as low as 30 kPa @ 1.79 L/min (4.4 psi @ 0.063 cfm) but the sample airflow will not be stable which will result in test data that is not repeatable.

Note

Stable airflows are extremely important in obtaining repeatable test results. TSI strongly suggests the instrument be operated with a vacuum greater than 55 kPa (8.0 psi). At a vacuum of greater than 55 kPa (8.0 psi) an internal critical orifice limits and stabilizes the sample airflow to 2.0 L/min (0.07 cfm). Repeatable test results will ONLY be obtained with stable sample airflows.

During PURGE mode the free airflow must be between 12 and 30 L/min (0.42 and 1.05 cfm). For example, a pump supporting three Model 8587A instruments should ideally provide >6 L/min (0.21 cfm) for upstream and downstream sample modes and 45 to 90 L/min (1.6 to 3.2 cfm) for purge modes. Refer to the important note below.

Important Note

When multiple instruments are used with the same vacuum source, the sampling and purge functions must be coordinated. All instruments must be in PURGE mode at the same time or UPSTREAM or DOWNSTREAM modes at the same time. Failure to coordinate the modes will result in low airflows, a blinking FLOW STATUS light and errant data. If it is not possible to coordinate the modes an independent vacuum source for each photometer must be provided.

Connecting Sample Lines

Upstream sample and downstream sample lines must be connected at the back of each Laser Photometer. Tube stubs for tubing connections are labeled accordingly—UPSTREAM and DOWNSTREAM. Clear 4.7 mm ($^{3}/_{16}$ in.) vinyl tubing is recommended for the sample lines. The tubing must be pushed completely over each tube stub. Silicone grease applied to the outside of the tube stub will simplify the connection.

It is recommended that the tube lengths not exceed 3 meters (10 ft).

Flow Setup

The Model 8587A laser photometer is factory adjusted to draw in air at a rate of approximately 2 L/min (.07 cfm) during UPSTREAM and DOWNSTREAM sampling modes. The airflow rate is not critical for fit testing or filter testing measurements however, a stable repeatable airflow is required. Stable airflow is achieved using a high vacuum pump and critical orifice.

PURGE flow is not controlled with an orifice but should be in the range of 12 to 30 L/min (0.43 to 1.1 cfm). This depends on the pump used. Pump requirements are discussed in an earlier section of this chapter and in Chapter 2.

There is no special adjustment needed for flow setup, however sample flow can be adjusted or changed for special applications as described in Chapter 5, "Maintenance."

Fit Test Chamber Requirements

Test chamber and aerosol generators are required when performing respirator testing. The test chamber must provide a stable challenge aerosol of corn oil or other suitable non-toxic material. The aerosol is generated using an aerosol nebulizer such as a "Laskin" nozzle to disperse fine aerosol particles at concentrations sufficiently high to produce a photometer signal greater than 0.1 volts when the chamber is sampled. Chamber oil aerosol concentrations of 30 mg/m^3 are typically used. Higher concentrations are generally needed to achieve best results for the highest fit factors >100,000.

Performing Fit Tests

Respirator fit testing using TSI's Model 8587A Photometer can be accomplished using these suggestions.

Test Control

The Laser Photometer has been designed specifically for use with an external control and data acquisition program through its RS-232 or USB communications port. The instrument provides a set of control and data acquisition commands for this purpose.

The instrument is also capable of making respirator or filter test measurements as a standalone instrument by manually selecting the operation mode and recording the data by hand.

Performing a Fit Test Manually

This manual test sequence is performed without the use of a specific software program for performing fit testing.

The following test recommendations are suggestions only and should be considered a minimum requirement. The operator must fully understand their own requirements and develop appropriate protocols for their measurements.

Manual Test

To complete a manual respirator fit test using the UPSTREAM, DOWNSTREAM and PURGE buttons on the front of the Laser Photometer follow these steps.

1. Connect the vacuum and sample lines to the Laser Photometer as described in Chapter 2, "Unpacking and Setting Up." The Downstream sample line (DOWNSTREAM) must connect to the suitable port on the respirator and the Upstream line (UPSTREAM) routed into the chamber at a location from which a representative sample can be obtained.
2. Press the **PURGE** keypad switch to enter the purge mode. Wait for the voltage reading to stabilize (10 seconds). Record the voltage reading on the display. This is the Zero Voltage.
3. Press the **UPSTREAM** keypad to enter the Chamber sample mode. Wait 20 seconds for the signal voltage to stabilize. Record the voltage data.
4. Press the **PURGE** keypad switch to enter the purge mode. Switch and wait for the scattering chamber to clear of aerosol and voltage to stabilize (15 seconds).

5. Press the **DOWNSTEAM** keypad to switch to the downstream sample mode. Wait for the voltage to stabilize (20 seconds). Over a minute interval, record 10 data points. Fit factor is often based on the worst-case, e.g., highest aerosol level, include the highest voltage seen. This value is used to determine worst-case Fit Factor.

$$\text{Fit Factor (worst case)} = \frac{\text{Upstream voltage - Zero voltage}}{\text{Highest Downstream voltage - Zero voltage}}$$

Average fit factor can be determined by averaging the voltages and subtracting the Zero Voltage.

$$\text{Average fit factor} = \frac{\text{Upstream voltage - Zero voltage}}{\text{Average Downstream voltage - Zero voltage}}$$

Fit Test Under Computer Control

The following is an example sequence for performing fit tests using a computer program for control and data acquisition. Delay and sample times are presented as examples. Actual delays and sample times should be determined based on lengths of tubing and other characteristics or limitations of the test system.

The mask sample presented here is averaged. Often it is necessary to know instantaneous leak rates to evaluate worst-case fit. When this is necessary, mask data should be taken and recorded at short intervals (e.g., each second) and the highest number used to characterize fit. When exercises are performed mask data can vary significantly over the mask test sequence.

Table 4-1. Example Fit Test Sequence

Operation	ASCII CODE	Description of Function
SEND	U	Unlock valves
SEND	P	Set PURGE mode
Delay 20 seconds		Delay for sensor to purge of aerosol
SEND	R	Reset running average
Delay 10 seconds		Average 10 seconds of purge signal data (ZERO)
SEND	D or K	Request data as HEX (D) or Decimal (K)
RECEIVE 8 char		Receive string voltage data
Convert	-	Convert data to decimal long integer (ZERO)
SEND	C	Set UPSTREAM sample mode (chamber)
Delay 20 seconds		Delay for UPSTREAM sample to stabilize
SEND	R	Reset running average
Delay 10 seconds		Average 10 seconds of UPSTREAM (chamber) signal data
SEND	D or K	Request data as HEX (D) or Decimal (K)
RECEIVE 8 char		Receive voltage data
Convert	-	Convert UPSTREAM (chamber) data to decimal long integer
SEND	M	Set DOWNSTREAM sample mode (mask)
SEND	V3F	Set high flow mask purge (mask sample at high flow)
Delay 10 seconds		Delay for mask to purge
SEND	V3N	Set flow for mask sample mode
Delay 20 seconds		Delay for DOWNSTREAM (mask sample) to stabilize
SEND	R	Reset running average
Delay 60 seconds		DOWNSTREAM (mask) signal data averaged over 60 second interval, since reset.
SEND	D or K	Request averaged data as HEX (D) or Decimal (K)
RECEIVE 8 char		Receive voltage data
Convert	-	Convert DOWNSTREAM (mask) data to decimal long integer
Calculate average fit factor (see discussion above)		$\text{Fit factor} = \dfrac{\text{UPSTREAM voltage (chamber) - ZERO voltage}}{\text{DOWNSTREAM avg. voltage (mask) - ZERO voltage}}$

Filter Testing Aerosol

Instruments using light scattering such as the Model 8587A are widely specified for filter testing, particularly since good correlation exists between light scattering and a mass measurement. TSI uses the same aerosol sensor in the Model 8587A Laser Photometer as is used in its popular Model 8130 Filter Tester.

Aerosols of Dioctyl-Phalate (DOP), Emery Oil, or Olive oil or a mean diameter of 0.2 to 0.3 microns and geometric standard deviation (GSD) of approximately 1.6 or less are typically used for filter testing.

Particle size is very important for filter testing since test results will depend on the size used. The aerosol size indicated above is desirable in that it is in the most penetrating particle size range for typical non-electret filters.

Performing a Filter Test

Performing a filter test is very similar to performing fit testing described in the previous section. The UPSTREAM sample is drawn from the filter holder, providing the challenge aerosol. The DOWNSTREAM sample is taken after the filter.

Filter efficiency is calculated as a percent from the following equation;

$$\%\,\text{Penetration} = \frac{\text{Downstream voltage - Zero voltage}}{\text{Upstream voltage - Zero voltage}} \times 100$$

$$\text{Penetration} = \frac{\text{Downstream voltage} - \text{Zero voltage}}{\text{Upstream voltage} - \text{Zero voltage}}$$

$$\%\,\text{Efficiency} = 100 - \%\,\text{Penetration}$$

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CHAPTER 5

Maintenance and Service

The Laser Photometer is designed to be low in maintenance and has few user serviceable parts. User maintenance will consist of occasional filter replacement and monitoring of specific system performance parameters.

TSI recommends that the Laser Photometer be returned to the factory on a yearly basis for service.

Filter Replacement

There are three filters used in the Laser Photometer—purge, sheath air, and exhaust filter. The filters are shown and identified in Figure 3-5. A filter replacement schedule is presented below.

A filter replacement kit, part number 1083636, can be ordered from TSI

TSI Incorporated
500 Cardigan Road
Shoreview, Minnesota 55126, USA
FAX: (651) 490-3868
Phone: 1-800-874-2811 (USA) or (651) 490-2811
E-mail Address: particle@tsi.com

Table 5-1. Filter Replacement Schedule

TSI Filter Replacement Kit		Replacement Schedule
1803636	Purge air filter	2000 hours
	Sheath air filter	1000 hours
	Exhaust air filter	2000 hours

Notes on filter replacement: *When replacing the exhaust and sheath air filters, refer to Figure 3-3 for filter location. Note the filter direction and tubing connections.*

Filter Replacement Instructions

When replacing the filters, first unplug the Laser Photometer power cord. Remove the four screws at the top of the instrument cabinet and loosen the screws at the base. Remove the cover by pulling it up. The sheath and purge filters are clearly visible. Use Figure 3-5 as a guide to identifying filters. The exhaust filter is located at the base of the instrument.

WARNING

To avoid electrical shock, the instrument must be unplugged prior to performing filter replacement operations.

Caution

To avoid damaging or disconnect wiring, use great care when removing and replacing filters.

The sheath filter uses barbed fittings to make the tubing attachments. To remove the purge air filter, grasp the filter housing and turn counter-clockwise until the filter separates from the valve. If the brass pipe nipple is removed with the filter, rather than staying in the valve, separate it from the filter and apply pipe compound and replace it in the valve. Discard the used filter and select the new one. Apply a small amount of pipe compound to the interior threads of the filter and replace it. The exhaust filter is found on the bottom of the cabinet.

Sensor Contamination

Over time the photometer optics and internal surfaces of the scattering chamber may become contaminated with particles. The result will be an increase in Zero voltage level. The Zero voltage is measured during the PURGE mode of operation and is normally between 7×10^{-6} and 3×10^{-5} volts. Since this voltage is subtracted from signal measurements, a change in this value is normally not important. If the detector zero is very high, $>8 \times 10^{-5}$ volts, accuracy will be lost.

Periodically check the reading during the purge mode operation. If the zero voltage is approaching 8×10^{-5} volts, the Laser Photometer may need to be returned to the factory for service. This will depend somewhat on the application requirements.

Changing Sample Flow

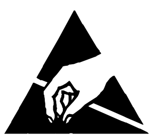
The Laser Photometer sample flow is set at the factory for a flow of 2 L/min (0.07 cfm) by adjusting the fine flow control needle valve placed in parallel with an orifice. Refer to Figures 3-3 and 3-5. Both orifice and valve are identified in the schematic and photograph. At the factory the flow is set while operating at a critical flow, the pump pulls a vacuum greater than 55 kPa (8 psi).

To set the sample you will need a TSI Model 4140 Flowmeter which can be obtained on the TSI website at www.tsi.com.

1. Unplug the instrument.
2. Remove the cover by loosening the four screws at the base of the chassis and remove the four screws at the top of the instrument cover.
3. To calibrate the instrument you will need to supply power. High voltage is present at the power cord connection at the back of the instrument and in wires running from the power connection to the power supply, see item 9, in Figure 3-5. Take care ***not*** to touch exposed wiring or circuit boards with tools to avoid shock or possible damage to the electronics.

W A R N I N G

To avoid electrical shock, keep hands and tools away from electrical wiring. High voltage is present at the back of the instrument, at the power connection.



C a u t i o n

To avoid damaging sensitive static components, avoid touching electrical boards. If possible employ proper ESD precautions including using a grounding strap.

4. Plug the power cord back into the instrument and turn the TSI Model 4140 Flowmeter on.
5. Connect your flowmeter to the UPSTREAM port.
6. Connect the high vacuum pump to the VACUUM port at the back of the instrument and turn the pump on.
7. Find the small adjustable needle valve, item 8 in Figure 3-5. Use a screwdriver to adjust the needle valve. The soft red material used to prevent screw movement will yield when the screw is turned.
8. Adjust until the desired flow is achieved.
9. Unplug the instrument and replace the cover.

Technical Contacts

- If you have any difficulty installing the Laser Photometer, or if you have technical or application questions about this instrument, contact an applications engineer at TSI Incorporated, (651) 490-2811 or email particle@tsi.com.
- If the Laser Photometer fails, or if you are returning it for service, visit our website at http://service.tsi.com or contact TSI at:

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Phone:	+1-800-874-2811 (USA) or +1 (651) 490-2811
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TSI Instruments Ltd.
Stirling Road
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High Wycombe, Bucks
HP12 3ST
UNITED KINGDOM

Telephone:	+44 (0) 149 4 459200	E-mail:	tsiuk@tsi.com
Fax:	+44 (0) 149 4 459700	Web:	www.tsiinc.co.uk

Returning the Laser Photometer for Service

Visit our website at http://rma.tsi.com or call TSI Customer Service at 1-800-874-2811 (USA) or (651) 490-2811 for specific return instructions. Customer Service will need this information when you call:

- The instrument model number
- The instrument serial number
- A purchase order number (unless under warranty)
- A billing address
- A shipping address.

Use the original packing material to return the instrument to TSI. If you no longer have the original packing material, seal off the sampling inlet to prevent debris from entering the instrument and ensure that the indicator lights and the connectors on the instrument front and back panels are protected.

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APPENDIX A

Specifications

Table A-1 contains the operating specifications for the Model 8587A Laser Photometer These specifications are subject to change without notice.

Table A-1
Model 8587A Laser Photometer Specifications*

Photometer	
Concentration range	1.0 microgram/m^3 to greater than 200 milligrams/m^3 (0.000001 - 0.200 grams/m^3
Dynamic range	Fit factors up to 100,000, Filter efficiency up to 99.999 percent
Gain selection	Automatic
Zeroing	Manual or software
Pump	User-supplied vacuum source (see requirements below)
Optics and Laser	
Light source	30 mW laser diode, 780 nm wavelength
Collection angle	45 degrees
Lens protection	Sheath air prevents aerosol from contacting optics
Flow Rate	
Sample	2.0 L/min (controlled with critical orifice and valve)
Purge	Approx. 20 L/min (uncontrolled)
Instrument Control	
Manual	Front panel buttons
Remote	Computer control via RS-232 or USB
Size (HWD)	25.4 cm × 17.8 cm × 33 cm (10 in. × 7 in. × 13 in.)
Weight	5.5 kg (12 lb.)
Vacuum pump requirements** (User-supplied vacuum source)	
Sampling	2.0 L/min (0.07 cfm) @ >55 kPa (8 psi) vacuum
Purging	>20 L/min (0.7 cfm) @ 0 psig (ambient atmospheric pressure)

Communications	
Analog output	0–5 VDC
USB	USB 2.0 Compatible, 12Mbps
RS-232	9-pin D-Type connector, ASCII, Baud 1200 or 115 K (selectable), N,8,1 USB type B female connector,
Software provided	Documentation of 8587A command set (ASCII) 8587A USB driver software for Windows XP/2000 USB terminal emulation software (for interactive control via USB port) (Use HyperTerminal for RS-232 communication) USB library files for programmers
Power	100–240 VAC, 50/60 Hz (auto-sensing), 1.3 Amps, IEC 320 power line connector with switch
Environmental operating conditions	Indoor use Inlet pressure 75 to 105 kPa. Operating temperature range 15-35°C. Safe operating temperature range 5-40°C Ambient humidity 0-90 RH non-condensing.
Front Panel	16 character × 2 line LCD
Control buttons	Upstream, Purge, Downstream
Back Panel	IEC 320 power line connector with integral switch
Upstream sample port	0.25 diameter
Downstream sample port	0.25 diameter
Vacuum port	0.25 diameter
Analog	0–5 VDC output BNC female connector
RS-232 Com port	DB9F connector for RS-232
USB Port	USB Type B female connector

*Specifications are subject to change without notice.

**The purge flow is the determining factor when selecting a vacuum pump. Most vacuum pumps that can provide the needed purge flow at atmospheric pressure will have no difficulty providing the needed flow during sampling.

In order to use one vacuum pump simultaneously with two or more 8587A photometers, it is necessary to coordinate (synchronize) the sampling and purge functions. Normally, it is not possible to sample with one photometer while another photometer is purging. This is because there is no significant flow restriction during high-flow rate purging and most vacuum pumps will be unable to maintain the vacuum needed for other photometers to sample while one or more photometers are purging. Therefore, all photometers that share a vacuum source must all sample at the same time and must all purge at the same time. The alternative to this is to provide an independent vacuum source for each photometer.

APPENDIX B
Laser Photometer CD

The CD-ROM provided with the Laser Photometer includes useful information and programs for expanding the functionality of the instrument.

The CD-ROM provides a terminal emulation program for USB interface applications. This program enables control commands to be sent to the instrument and to request and receive data for aerosol concentration.

For users who want to develop USB application program software for instrument operation, the disk contains a library and header files developed for MS Visual C++ 6.0.

Note: *USB terminal emulation software and the USB drivers are not needed to communicate via the RS-232 serial port. For RS-232 terminal emulation use HyperTerminal® software that is included with Microsoft Windows®.*

Accessing the Laser Photometer CD

With the computer on and Windows running, insert the Model 8587A CD-ROM in your CD drive.

- If AutoPlay is enabled on your PC, the setup program begins automatically and the introduction screen is displayed on the Windows desktop (see Figure B-1).
- If AutoPlay is not enabled, select **Run** from the **Start** menu and type: `D:\autorun` in the Open box and press **OK**. (D is the letter corresponding to your CD drive.)

The Introduction Screen and Main Menu will appear as shown in Figure B-1.

®HyperTerminal is a registered trademark of Hilgrave Inc.

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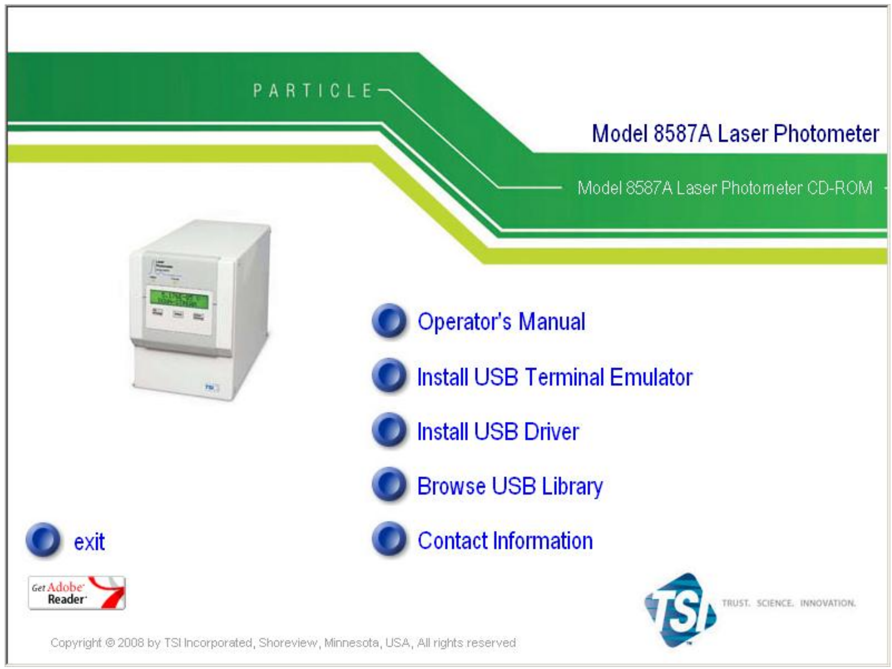

Figure B-1
Introduction Screen

USB Terminal Emulator Program

This section outlines the use of the USB Terminal Emulator program found on the CD-ROM supplied with the Model 8587A Laser Photometer. The USB Terminal Emulator program enables remote control of the photometer functions and access to instrument data through a USB cable connected to a computer via the USB port (Figure 3-1).

The USB Terminal Emulator program, **TerminalUSB.exe** communicates using commands from the defined set described in the section "Command Strings for Instrument Control and Data Acquisition." The commands are shown in Table 3-2.

Installing the USB Terminal Emulator

Note
The USB cable **MUST NOT** be connected to the Photometer or computer during the installation of the USB Terminal Emulator program.

To install the USB terminal emulator and USB drivers, follow these steps:

1. Shut down (exit) all other programs/applications other than the Laser Photometer application.

2. To install the USB terminal Emulator program, click “Install USB Terminal Emulator” with your mouse. The InstallShield Wizard will appear as shown in Figure B-2.

   ***Note**: Installing the USB Terminal Emulator will automatically cause the USB drivers to be installed first. It is not necessary to install the USB driver separately (by clicking “Install USB Driver”) unless you want to install the driver without also installing the terminal emulator.*

Figure B-2
TSI USB Device Driver InstallShield Wizard Screen

3. Continue by pressing **Next**.

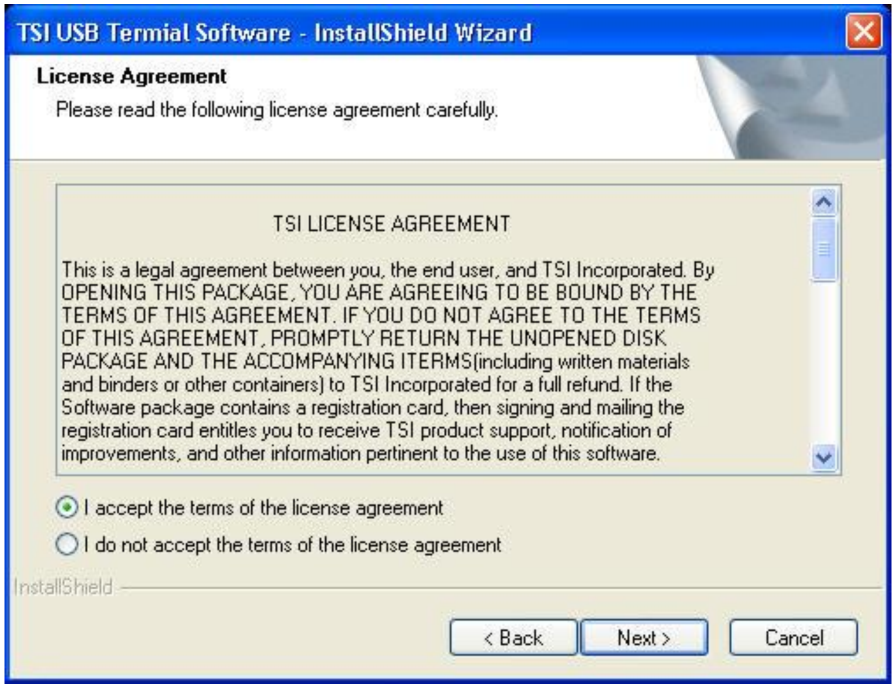

Figure B-3
License Agreement Screen

4. Accept the license agreement and press **Next**.

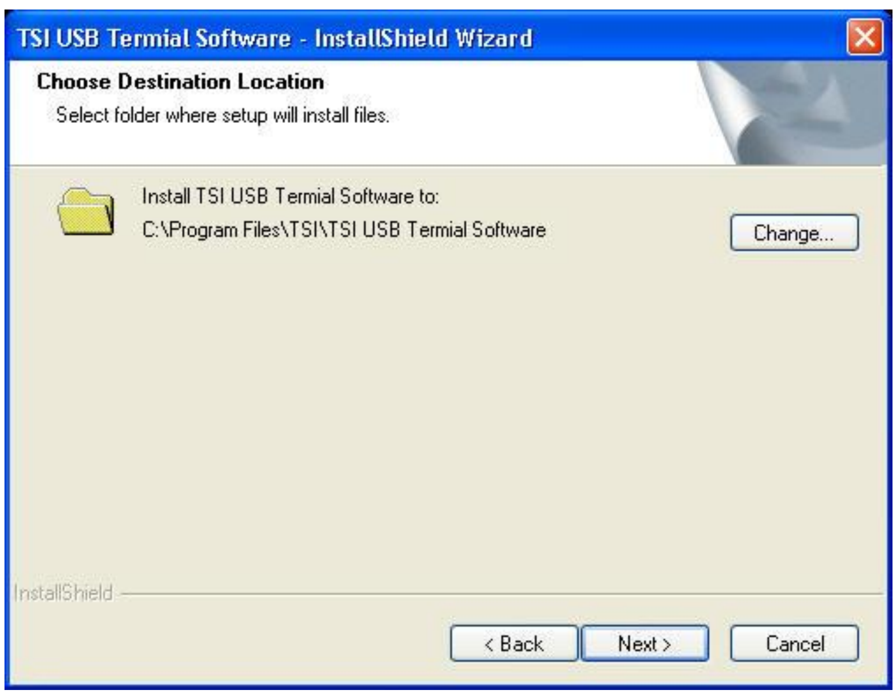

Figure B-4
Choose Destination Location Screen

5. Click **Next** to install the program into the folder shown. To specify a different location click **Change**.

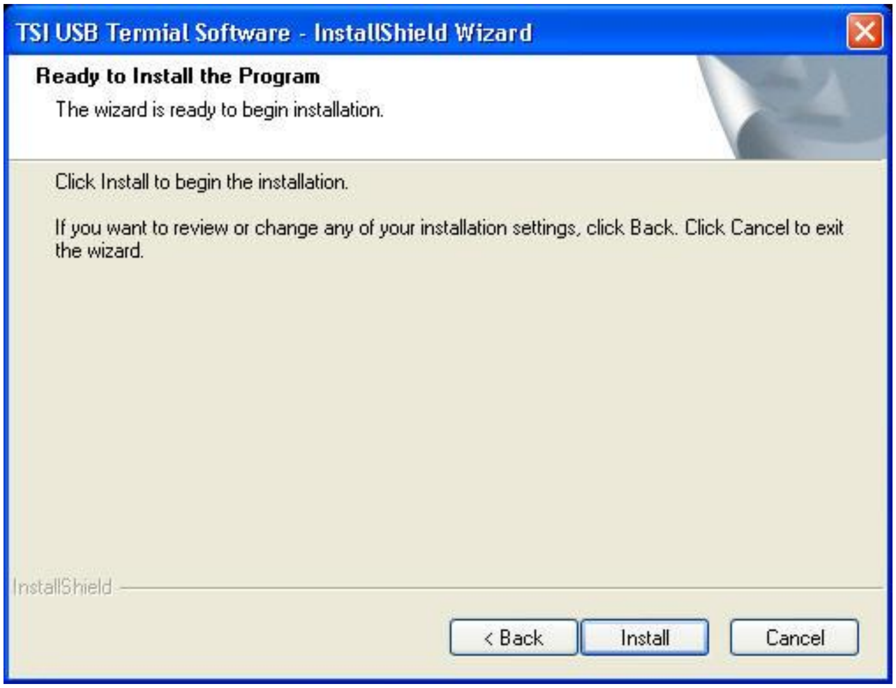

Figure B-5
Begin Installation Screen

6. Click **Install** to begin the install process.

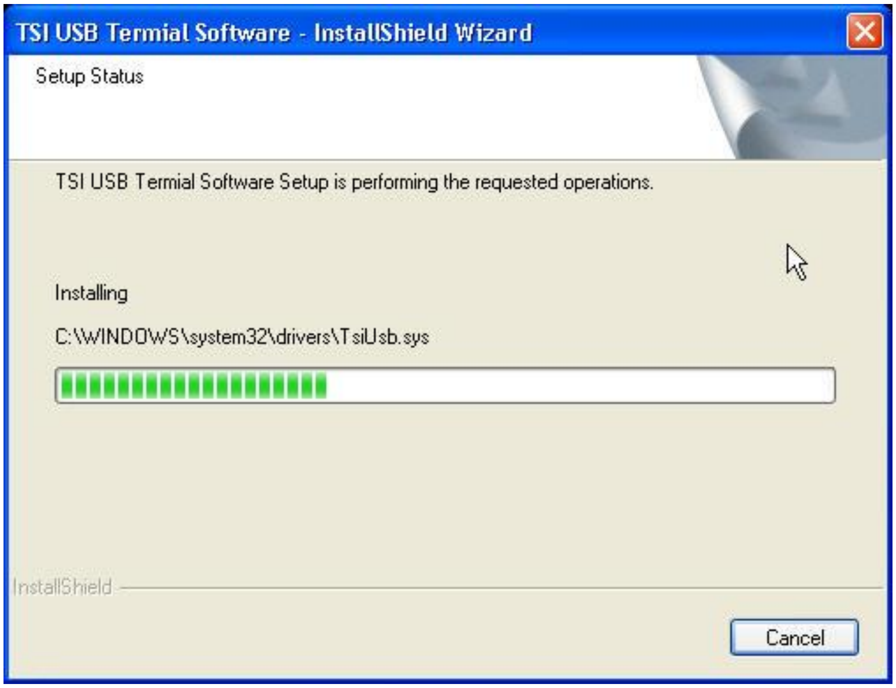

Figure B-6
Setup Status Screen

7. Once the files are installed, the computer will need to be restarted. Select "**Yes, I want to restart my computer now**" as shown in Figure B-7 and click the **Finish** button.

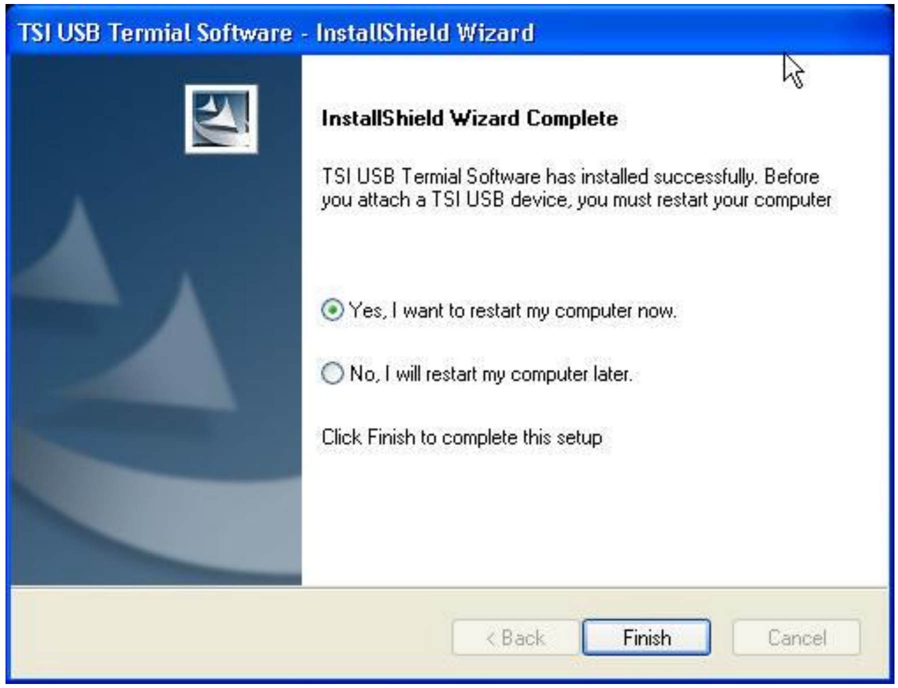

Figure B-7
InstallShield Wizard Complete Screen

8. Remove and store the CD-ROM in a safe place for later use if needed.

After the installation of the USB Driver and USB Terminal Emulator programs are complete, a shortcut icon appears on the desktop for starting and running the USB Terminal Emulator program.

Figure B-8
TSI USB Terminal Shortcut Icon

To connect the USB, follow the instructions in the next section "Connecting USB for the First Time."

Connecting USB for the First Time

To use the USB communications feature, the USB driver program from the CD-ROM included with your instrument must be installed. This process was described in the sections above. In addition, the computer needs to add the Model 8587A Laser Photometer to a list of recognized devices. Steps for adding the Laser Photometer as a new device are described below. Once this process is completed, the computer will recognize the Laser Photometer. It will not be necessary to repeat this procedure.

1. Make sure the USB Driver and USB Terminal Emulation programs have been installed as described in the previous section.
2. Start-up the computer.
3. Turn-on the Laser Photometer.
4. Plug the USB cable into the USB port on the back panel of the Laser Photometer and into a free USB port on the computer.
5. The computer will not initially recognize the Laser Photometer. The Found New Hardware Wizard (Figure B-6) will start automatically.

Figure B-9
Found New Hardware Wizard Screen

6. You should not insert the CD as indicated because the USB device driver was already pre-installed (if you have been following directions properly). Select the **Next** button to install the software using the "recommended" method.

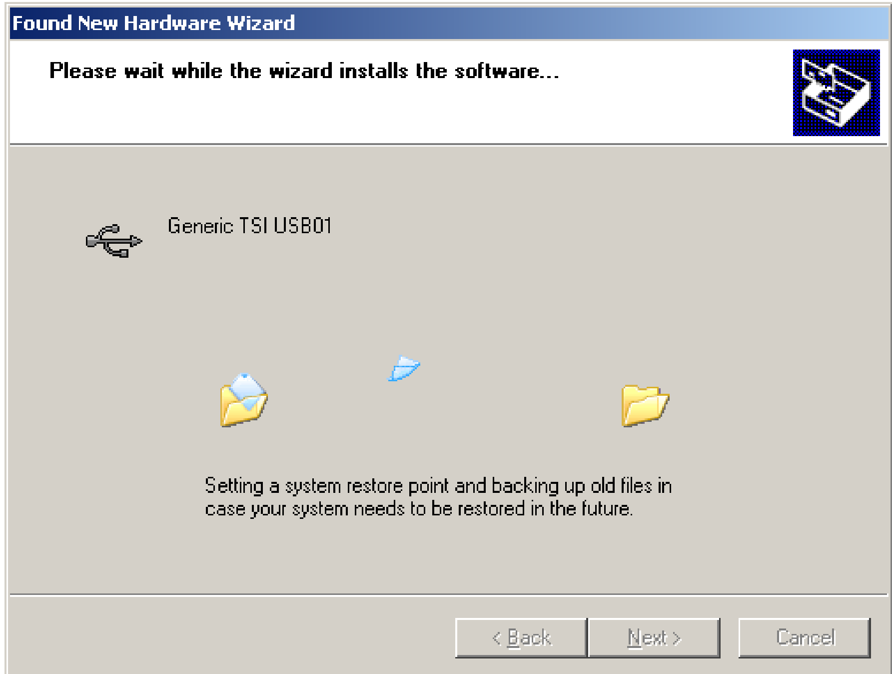

Figure B-10
Hardware Wizard Installing Software

7. The unsigned driver warning will be displayed. Select the **Continue Anyway** button to proceed with the installation.

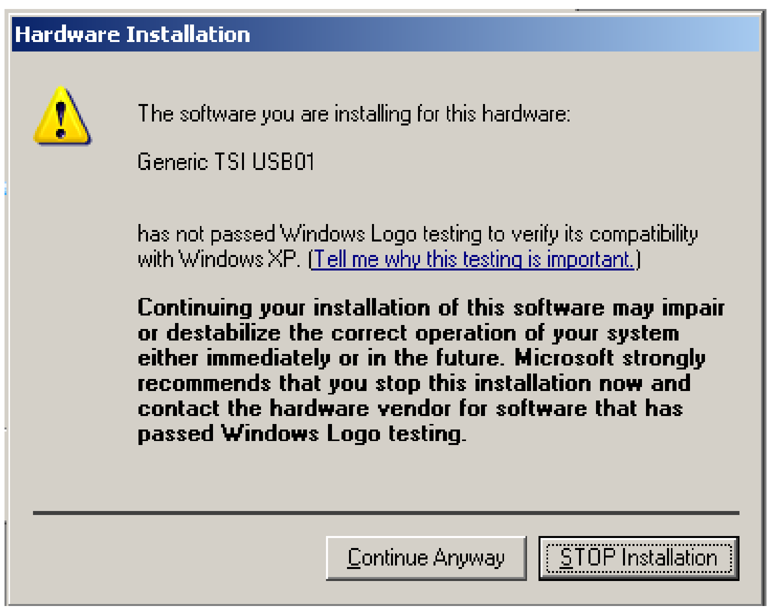

Figure B-11
Unsigned Driver Warning Screen

8. The “Please Wait…” dialog will display until the process is completed.

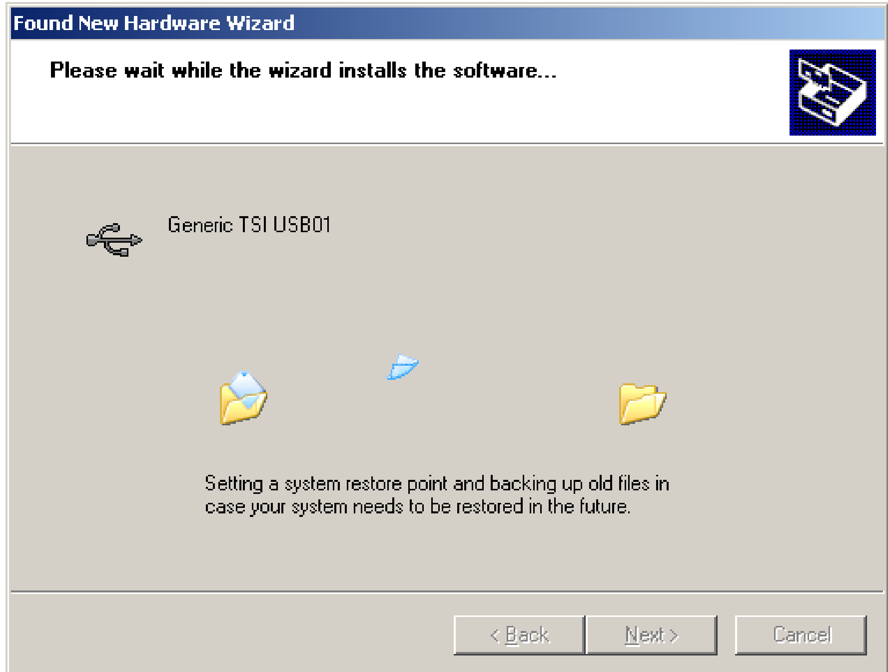

Figure B-12
Please Wait While Wizard Installs Software Screen

9. Select the **Finish** button from the screen below.

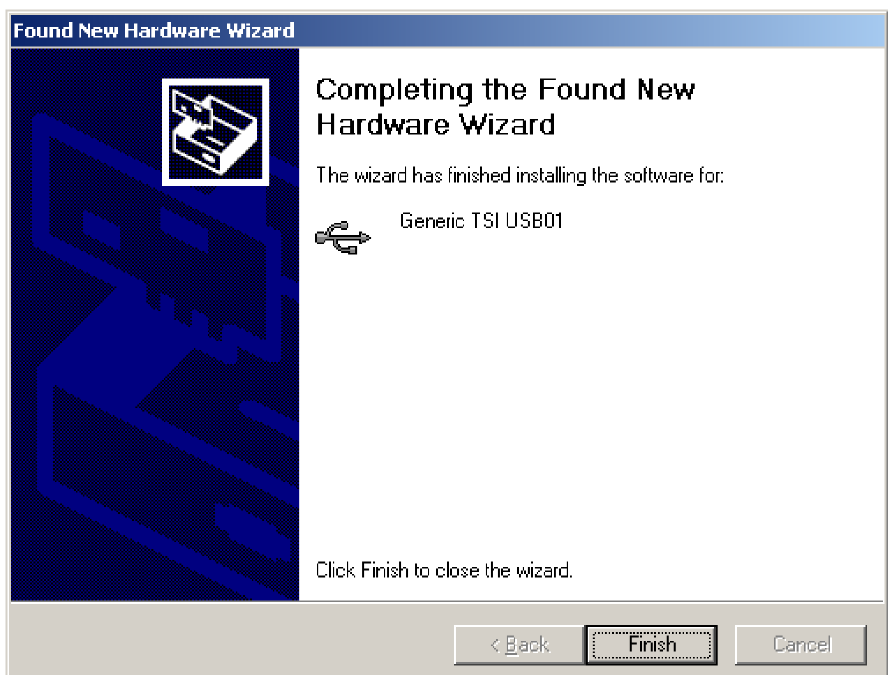

Figure B-13
Completing the Found New Hardware Wizard Screen

Installation Issues That May Arise

Occasionally the first time you install a device on a system, the device will install as an “Unknown Device.” Should this occur or any other device error occur, follow the instructions to uninstall the device. Reboot your computer for the changes to take effect. Then restart the installation process from the beginning.

Stopping the Device

When disconnecting the Laser Photometer use the “**Safely Remove Device**” icon  on the bottom tool bar (green arrow). Right click on the icon and select **TSI Particle Instrument**.

The Laser Photometer may also be disconnected by simply unplugging the USB cable.

Uninstalling the Device

A device using the TSI USB Driver is fully PNP compatible. It will not be shown in device manager when the device is not connected.

To uninstall the device from the computer, use the device manager:

1. Plug in the Laser Photometer.
2. Open device manager through the “Hardware” tab of the system properties wizard.
3. The device is present in the Universal Serial Bus Controller section of the device manager. Right-click on the device and select **Uninstall**.
4. Run the USB Device Driver InstallShield program to remove the TsiUsb.inf, TsiUsb.sys, and TsiUsbApi.dll files from the system.

Driver File Locations

A TSI USB Device Driver Install Shield application has been created for installing the TSI USB device driver file onto a computer. This installation program copies the three files necessary for device operation to the system. These files are installed in the following locations:

1. Tsiusb Driver installation file: **TSIUSB.inf**—This file is copied to: c:\Windows\inf folder.
2. Tsiusb driver file **TSIUSB.sys**—This file is copied to: 7C:\Windows\system32\drivers folder.
3. Tsiusbapi dynamic link library file **TsiUsbApi.dll**—This file is copied to: C:\Windows\system32 folder.

Starting the Program

The USB Terminal Emulator program provides an icon on the computer desktop which can be used to access the program. If the icon is removed, access the program by selecting **Start** on the lower left of the computer screen. Then select **Programs | TSI | TerminalUSB**. The Terminal main window will appear as in Figure B-14.

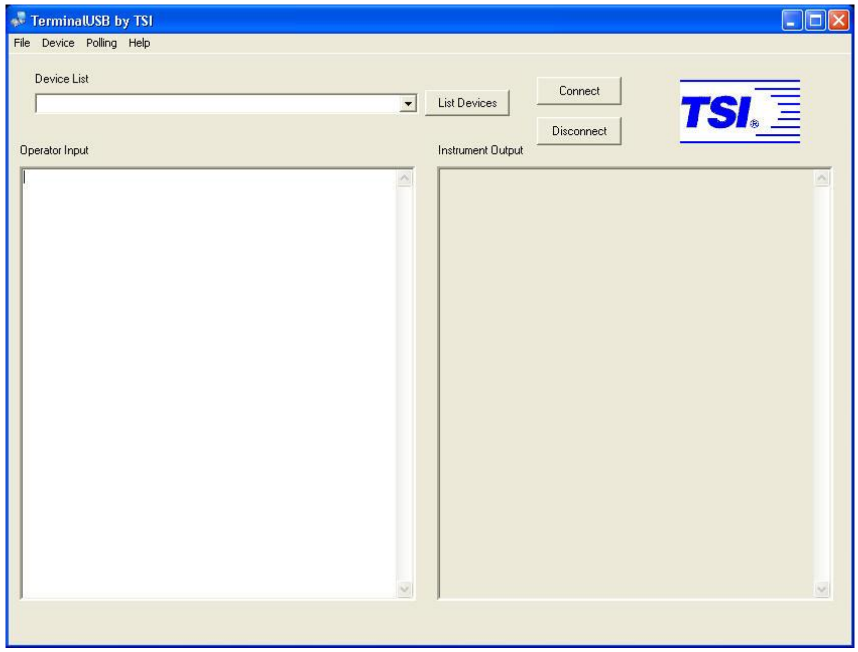

Figure B-14
Terminal Program Screen

Listing Available Devices

If the Laser photometer is not connected to the computer, find the supplied USB interface cable and connect it now. Refer to Figure 3-1 to locate the USB connector at the back of the instrument.

To find available USB devices attached to the computer, click the **List Devices** button in the main window. USB devices can also be displayed by selecting **List Devices** from the **Devices** menu. The available attached devices will appear in the device list.

Connecting to a Device

Select a device from the Device List, and then click the **Connect** button. A message will appear in the **OUTPUT** window indicating if a connection was successfully established.

Sending Commands

To send a command to the attached USB device, click in the **Operator Input** panel (left side) window and type the desired command. Press **Enter** to send the command. Responses from the device will appear in the **Instrument Output** panel (right side).

Disconnecting

Click the **Disconnect** button. A message will appear in the **OUTPUT** window.

Saving Input and Output

The text in the **Operator Input** and **Instrument Output** panels can be saved to a file for future reference. To save the text in the **Operator Input** panel, select the **File** menu and choose **Save Input**. To save the text in the **Instrument Output** panel, select **File | Save Output**.

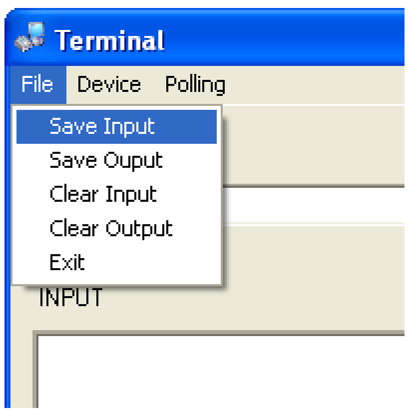

Figure B-15
Saving Input and Output

Setting Timeouts

To set the timeout periods for communications with a device, a connection must first be established with a device. Once the connection has been established, select the **Device** menu, and then choose **Timeout**. A dialog box will appear, and the desired timeout period can be entered into the text box.

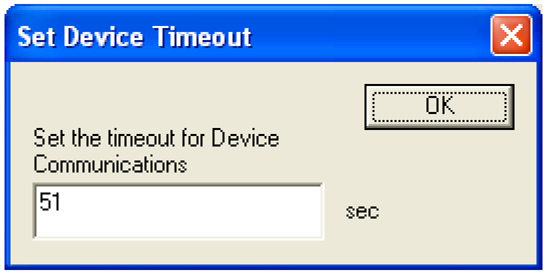

Figure B-16
Set Device Timeout Screen

Setting the Buffer Size

The size of the internal buffer that is used when receiving data from the attached device can be adjusted. From the **Polling** menu, select **Buffer Size**. In the dialog box that appears, enter the desired buffer size in bytes.

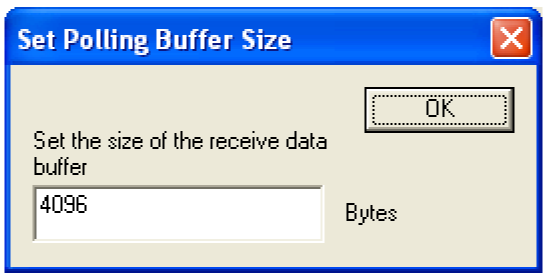

Figure B-17
Set Polling Buffer Size Screen

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APPENDIX C

Technical Information for Program Development Using USB Communications

This appendix concerns the software development library found on the Model 8587A Laser Photometer CD-ROM supplied with the instrument. The purpose of the library is to facilitate user-developed Microsoft Windows software applications that communicate with TSI USB (Universal Serial Bus) devices including the Model 8587A Laser Photometer.

Note: *When programming using RS-232 serial communications, this library is not needed, and information in this appendix does not apply.*

The information presented is pertinent for program development using Microsoft Visual C++ 6.0. Information presented in this appendix is designed for experienced program developers.

This appendix includes information on the following topics.

- Locating the header file
- Locating the library file
- Locating the dynamic link library file
- Using the library
- Error values and interpretation
- Device operation
- Windows registry settings
- Connecting to the Attached device
- Communicating with the attached device
- Retrieving error strings
- Closing the connection

Locating the Header File

The header file to include in all software applications is:

TSIUSBApi.h

This file is located in the CD-ROM root folder \USB.

Locating the Library

The Library file to link into all software applications is:

TSIUSBApi.lib

This file is located in the CD-ROM root folder \USB.

Locating the Dynamic Link Library File

The dynamic link library file to use with all software applications is:

TSIUSBApi.dll

This file is located in the CD-ROM root folder \USB.

Using the Library

- Include the TSIUSBApi.h header file into the application using:

  #include "tsiusbapi.h"

- Link the TSIUSBApi.lib library file into the application through the project settings and/or by using the LoadLibrary method or by using the #pragma define. For example:

  #pragma comment (lib, "tsiusbapi")

- The TSIUSBApi.dll dynamic link library file should be placed in the working directory of the application executable.
- The TSIUSB driver installation file is TSIUSB.inf
- The TSIUSB driver executable file is TSIUSB.sys

Error Values and Interpretation

With the exception of DeviceClose(), each call to TsiUsbApi.dll has at least one return value that signifies a successful or unsuccessful completion on the function.

For successful device operation, any command that is sent to the device, e.g., writing data, requesting data, or requesting an action, has two return values that need to be watched. These values are the DWORD return value of the command (the Win32 error code) and the Status value of the device command (the USB Command Status).

A successful completion of a command sent to the device will have the following return values:

- The DWORD win32 Error Code of ERROR_SUCCESS, or 0x0000
- The USB command status value of 0x0000, or USB_OK as defined in the TsiUsbApi.h file.

For successful operation, **ALWAYS** pay attention to the win32 return value and the USB command status returned from the device (when this value is present).

Troubleshooting Win32 Errors

A function is provided that converts a Win32 error code into the appropriate Win32 error string. This function is TsiUsbGetWin32String().

A list of the most common error codes returned by the DLL and some common solutions is presented below. This list does not include standard Win32 error codes. A complete list of Win32 Error Codes and descriptions can be found in the MSDN help article titled “System Error Codes” in the “.Net” Microsoft Development Tools, Debugging and Error Handling Section

Error Descriptions

A non-successful return value of **ERROR_OPERATION_ABORTED** is the value returned when a request of the device has timed out and the current operation has been cancelled.

A non-successful return value of **ERROR_INVALID_HANDLE** is the value returned upon a request of the device that has been closed or the handle returned from DeviceOpen is not valid. Check your connections, device power, and check that the device is available and functioning properly through Windows Device Manager.

A non-successful return value of **ERROR_DEV_NOT_EXIST** or **ERROR_BAD_COMMAND** is the value returned upon a request of the device that is not available. Check your connections, device power, and check that the device is available and functioning properly through device manager.

A non-successful return value of **ERROR_INVALID_PARAMETER** is the value returned upon a request of the device that does not have a valid parameter. Check the function calling the DLL for null parameters.

A non-successful return value of **ERROR_IO_DEVICE** is the value returned upon a request of the device that did not call the driver. Most functions within the DLL initialize the return value to **ERROR_IO_DEVICE**.

A non-successful return value of **ERROR_GEN_FAILURE** is the value returned upon a request of the device that failed at the driver level. The device may not be responding properly to this request.

USB Command Status Errors

A function is provided that converts USB status codes into the appropriate error string. This function is TsiUsbGetStatusString().

Within the DLL most pStatus codes are initialized to 0xffff. If a pStatus is returned with 0xffff, it is probable that a Win32 error occurred.

The defined TSI USB status codes are as follows

USB_OK	0x0000
USB_ERROR_CMD_INVALID	0x0001
USB_ERROR_CMD_LENGTH	0x0002
USB_ERROR_DATALENGTH_INVALID	0x0005
USB_STATUS_BUSY	0x0006
USB_ERROR_BUFFER_LENGTH	0x000c
USB_ERROR_BUFFER_FULL	0x0011

Device Operation

When working with the TsiUsb driver and the TsiUsbApi DLL the normal device communication operation is as follows:

1. Use ListDevices() to determine the number and symbolic links of TSI USB devices attached to the system. The symbolic link is the unique USB device name.
2. Use DeviceOpen() sending the symbolic link attained from ListDevices() to open a connection to the device.
3. Using the set of functions described in the following section labeled "Communicating with the attached device." Use the functions necessary for performing the device communication that is required by your application.
4. Use DeviceClose() to close the connection to the device.

It is best to open and close the device often rather than open the device once and close the device once, over a long period. The device USB connection can be unplugged during device operation. The Driver and DLL will handle this.

Windows Registry Settings

The TsiUsb Device driver and DLL make use of the Windows registry for a few variable values.

These values are maintained within the following registry key:

[HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\TSIUSB\Parameters]

The values are defined as follows:

BusyWaitms	This value is in milliseconds. This specifies the number of milliseconds to wait before resending a command to a device when a USB_STATUS_BUSY is returned. The default value is 5 ms.
TransferTimeout	This value is in seconds. This value specifies the number of seconds to wait for a device to complete a command request. The default value is 2 seconds.

Connecting to the Attached Device

ListDevices

Use the ListDevices() method to determine the number of available devices attached.

UINT ListDevices (LPCTSTR m_tsiUsbDevlist[]);

Parameter	Description	Type
m_tsiUsbDevlist	An array of the symbolic Link Name of each connected available attached device.	LPCTSTR array

Return value:

The unsigned integer returned is the number of available attached devices.

Example Code:

```
int nDevices = 0;
const char *deviceList[256];
nDevices = ListDevices(deviceList);
```

DeviceOpen

To open a connection to the device, use the DeviceOpen() method.

```
HANDLE      DeviceOpen( PSTR szDeviceName,
                        LPDWORD dwRetErrorVal,
                        BOOL bTerminal = FALSE);
```

Parameter	Description	Type
szDeviceName	The szDeviceName parameter is the name of the device to be opened. The device name is returned from the ListDevices() method.	PSTR
dwRetErrorVal	The dwRetErrorVal parameter is a Win32 error code returned from the Windows API. A successful DeviceOpen returns ERROR_SUCCESS (0x0000).	Long Pointer to a DWORD
bTerminal	The size in bytes of the data being transferred to the device. This value should be set to TRUE when opening a connection to a Model 8587A Laser Photometer.	BOOLEAN

Return value:

This method returns a handle to the open device. A successful DeviceOpen returns a handle value that is not equal to INVALID_HANDLE_VALUE (0xFFFF).

Example Code:

```
HANDLE  hDeviceHandle = INVALID_DEVICE_HANDLE;
DWORD dwErrorCode = ERROR_IO_DEVICE;
hDeviceHandle = DeviceOpen(deviceList[0], &dwErrorCode, TRUE);
```

TsiUsbTerminalTransmit

The TsiUsbTerminalTransmit() method writes data to the device.

```
DWORD  TsiUsbTerminalTransmit(IN HANDLE hDevice,
      IN LPVOID pXmitBuff,
      IN DWORD xmitBuffSize,
      IN WORD nTransID,
      IN OUT PULONG pStatus,
      IN OUT LPDWORD lpNumberOfBytesWritten,
      IN WORD wEndpoint = TSI_USB_TERMINAL_READ_EP);
```

Parameter	Description	Type
hDevice	The handle to the connected device returned from DeviceOpen().	HANDLE
pXmitBuff	A pointer to the buffer of data being sent to the device.	PVOID or void*
xmitBuffSize	The size in bytes of the data being transferred to the device.	DWORD or Unsigned LONG
nTransID	The transaction ID of this read transfer. The transaction ID is a value 0x80 – 0xff that will allow matching a response to a request. This is defaulted to 0x80 and only necessary for asynchronous requests and responses.	WORD or Unsigned short
pStatus	A pointer to the status returned from the device.	PULONG or pointer to an unsigned long
lpNumberOfBytesWritten	A pointer to the number of bytes written to the device.	LPDWORD or pointer to an unsigned long
wEndpoint	The index of the device endpoint to write the command. Unless this is documented as different use the default endpoint.	WORD

Return value:

A successful return Win32 Error Code value is Zero or ERROR_SUCCESS.

A non-successful return Win32 Error Code value is non-zero corresponding to any valid Win32 Error Code.

This command does have a Status return from the device. A returned status (referenced by pStatus) of 0x0000 or USB_OK as well as a win32 is a successful return of ERROR_SUCCESS is a successful TsiUsbTerminalTransmit request.

A returned status (referenced by pStatus) of `USB_ERROR_BUFFER_FULL` 0x0011 indicates that the device output buffer is full.

Example Code:

```
Int SendCommand(LPTSTR pBufIn, DWORD dLength,
                LPDWORD lpBytesXmit)
{
   ULONG status      = USB_OK;
   WORD nTransID     = 0x80;
   DWORD dwErrorCode = 0;

   ZeroMemory(pBufIn, dwMaxLength);
   LPDWORD bytesRead = 0;

// send the data out buffer pBufOut of length dwLength
   dwErrorCode = TsiUsbTerminalTransmit ( m_hComm,
         (VOID *) pBufOut,
         dwLength,
         nTransID,
         (ULONG)&status,
         lpBytesXmit);

    return dwErrorCode;
}
```

TsiUsbTerminalReceive

The TsiUsbTerminalReceive() methodreads data from the device.

DWORD TsiUsbTerminalReceive(IN HANDLE hDevice,
   IN OUT LPVOID pRecvBuff,
   IN DWORD recvBuffSize,
   IN OUT LPWORD pTransID,
   IN OUT LPWORD pLevelID,
   IN OUT PULONG pStatus,
   IN OUT LPDWORD lpNumberOfBytesRead,
   IN WORD wEndpoint = *TSI_USB_TERMINAL_READ_EP*);

Parameter	Description	Type
hDevice	The handle to the connected device returned from DeviceOpen().	HANDLE
pRecvBuff	A pointer to a buffer for receiving the data read from the device.	LPVOID or void*
recvBuffSize	The size of the buffer for receiving data read from the device.	DWORD or Unsigned long
pTransID	The transaction ID of this read transfer. The transaction ID is a value 0x80 – 0xff that will allow matching a response to a request. This is defaulted to 0x80 and only necessary for asynchronous responses.	LPWORD or pointer to an unsigned long
pLevelID	The Level ID of this read transfer. The level ID is an indication of what type of response was received. i.e., (data, an error, a warning, etc.). See the List of level Id's below.	LPWORD or pointer to an unsigned long
pStatus	A pointer to the status returned from the device.	PULONG or pointer to an unsigned long
lpNumberOfBytesRead	A pointer to the number of bytes read from the device.	LPDWORD or pointer to an unsigned long
wEndpoint	The index of the device endpoint to read from. Unless this is documented as different use the default endpoint.	WORD

Return value:

A successful return Win32 Error Code value is Zero or ERROR_SUCCESS

A non-successful return Win32 Error Code value is non-zero corresponding to any valid Win32 Error Code.

This command does have a Status return from the device. A returned status (referenced by pStatus) of 0x0000 or USB_OK as well as a win32 is a successful return of ERROR_SUCCESS is a successful device terminal receive request.

This response should always return a *pStatus of `USB_OK`.

The following is a list is level Ids

```
USB_TERMINAL_RESPONSE       0x81
USB_TERMINAL_ERROR          0x82
USB_TERMINAL_WARNING        0x83
USB_TERMINAL_INFORMATION    0x84
USB_TERMINAL_BINARY_DATA    0x8f
```

Example Code:

```
Int ReadResponse(LPTSTR pBufIn,
                 DWORD dwMaxLength,
                 LPDWORD lpBytesRead)
{
   ULONG status      = USB_OK;
   WORD nTransID     = 0x80;
   WORD nLevelID     = 0x80;
   DWORD dwErrorCode = 0;

   ZeroMemory(pBufIn, dwMaxLength);
   LPDWORD bytesRead = 0;

   // read the data in buffer pBufIn of length
  // dwMaxLength
   dwErrorCode = TsiUsbTerminalReceive( m_hComm,
                 (VOID *)pBufIn,
                  dwMaxLength,
                  (LPWORD)&nTransID,
                  (LPWORD)&nLevelID,
                  (ULONG)&status,
                  (LPDWORD)&bytesRead);

    return dwErrorCode;
}
```

Retrieving Error Strings

TsiUsbGetStatusString

The TsiUsbGetStatusString() method returns a device defined status string that describes the device condition that corresponds to the device command status.

VOID TsiUsbGetStatusString(IN HANDLE hDevice ,
IN ULONG ulStatus,
IN OUT LPCTSTR pStatusString);

Parameter	Description	Type
hDevice	Handle returned from DeviceOpen().	HANDLE
ulStatus	The status value returned from the device.	ULONG or an unsigned long
pStatusString	The returned string describing the device status error that occurred.	LPCTSTR

The return value is void.

TsiUsbGetWin32String

The TsiUsbGetWin32String() method returns a win32 string that describes the error code of the Win32 error that is passed in.

```
VOID        TsiUsbGetWin32String (IN HANDLE hDevice ,
            IN DWORD dwWin32Err,
            IN OUT LPCTSTR pWin32ErrStr);
```

Parameter	Description	Type
hDevice	Handle returned from DeviceOpen().	HANDLE
dwWin32Err	The error code returned from the DLL.	DWORD or an unsigned long
pWin32ErrStr	The returned string describing the win32 error that occurred.	LPCTSTR

The return value is void.

Closing the Connection

DeviceClose

This method closes the connection to the USB Device.

```
VOID        DeviceClose(HANDLE hDevice);
```

Parameter	Description	Type
hDevice	Handle returned from DeviceOpen()	HANDLE

The return value is void.

It is best to set the hDevice handle variable that is used by your application to INVALID_HANDLE_VALUE after you call DeviceClose.

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Index

Reader's Comments Sheet

Please help us improve our manuals by completing and returning this questionnaire to the address listed in the "About This Manual" section. Feel free to attach a separate sheet of comments.

Manual Title Model 8587A Laser Photometer P/N 1980538

1. Was the manual easy to understand and use?

   ☐ Yes ☐ No

   Please identify any problem area(s) ______________________________

   ____

   ____

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Organization (finding what you need)	☐	☐	☐
Quality and number of illustrations	☐	☐	☐
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