TSI®

Model 3550/3560 Series Integrating Nephelometer

Instruction Manual
April 2001

Manual History

The following is a history of the *Model 3550/3560 Series Integrating Nephelometer Instruction Manual*, part number 1933563.

Revision	Date
Preliminary	February 1994
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A	May 1996
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The manual was published as a Final after Chapter 5, "Using Nephelometer Software (Windows)" was added in November 1994.

In revision A, TSI's "Limitation of Warranty and Liability" on page iii was updated.

In revision B, Tables A-1 and A-2 in Appendix A were revised.

In revision B1, TSI's area code changed from 612 to 651.

In revision C, TSI's Limitation of Warranty and Liability and TSI's Software License were updated.

In revision D, Analog Outputs were removed.

Part Number 1933563 / Revision D / April 2001

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(effective July 2000)

Seller warrants the goods sold hereunder, under normal use and service as described in the operator's manual, shall be free from defects in workmanship and material for (12) months, or 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:

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b. Parts repaired or replaced as a result of repair services are warranted to be free from defects in workmanship and material, under normal use, for 90 days from the date of shipment.

c. Seller does not provide any warranty on finished goods manufactured by others or on any fuses, batteries or other consumable materials. Only the original manufacturer's warranty applies.

d. Unless specifically authorized in a separate writing by Seller, Seller makes no warranty with respect to, and shall have no liability in connection with, goods which are incorporated into other products or equipment, or which are modified by any person other than Seller.

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Software License
(effective March 1999)

Service Policy

Knowing that inoperative or defective instruments are as detrimental to TSI as they are to our customers, our service policy is designed to give prompt attention to any problems. If any malfunction is discovered, please contact your nearest sales office or representative, or call TSI's Particle Instrument Division at 1-800-874-3893 (USA) or (651) 490-3893.

Safety

This section gives instructions to promote safe and proper handling of the Model 3550/3560 Series Integrating Nephelometers.

Caution
High temperatures that can cause burns.
To avoid personal injury, disconnect power to the Nephelometer and allow the halogen lamp and the lamp housing to cool before handling.

WARNING
High voltages that can shock or burn.
The box that houses the photomultiplier tubes (PMT) contains a high voltage source. Components within this box should only be serviced by a qualified technician. Disconnect all power to the Nephelometer and contact TSI personnel before disassembling the PMT box.

Caution
Light sensitive components.
To avoid damage to the photomultiplier tubes (PMT), remove power from the Nephelometer and open the PMT box in subdued lighting. Exposing the photomultiplier tubes to direct light may affect tube performance.

WARNING
Moving parts that can cause serious personal injury.
Disconnect power to Nephelometer before inserting anything into the aerosol inlet. The ball valve and position sensor are motorized and can move if power is applied.

Labels

Figure 1 shows the special warning and caution labels and their approximate location inside the Nephelometer.

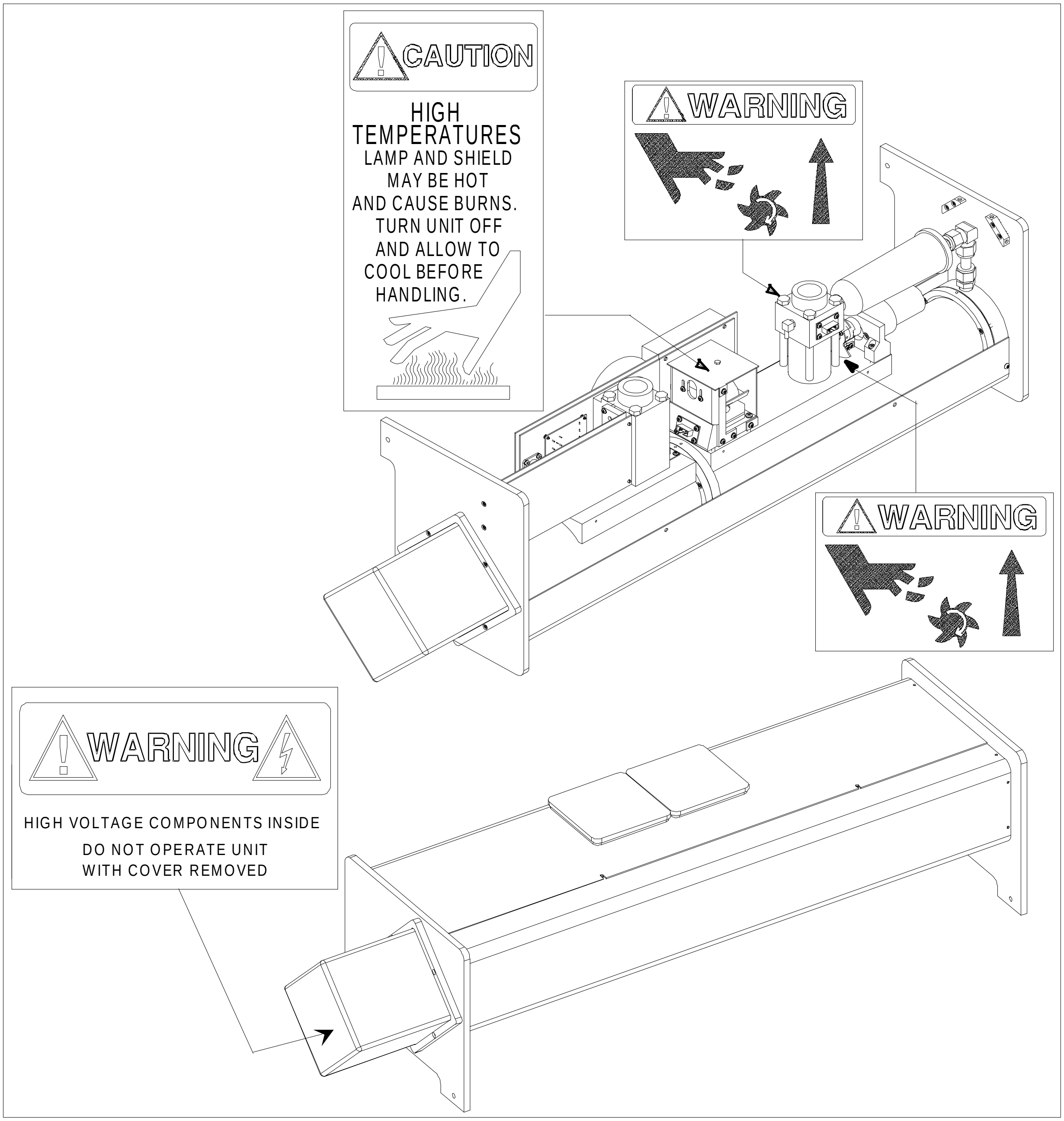

Figure 1
Nephelometer Warning and Caution Labels

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About This Manual

Purpose

This is an instruction manual for the operation and maintenance of the Model 3550/3560 Series Integrating Nephelometers.

Reusing and Recycling

As part of TSI Incorporated's effort to have a minimal negative impact on the communities in which its products are manufactured and used:

- ❑ This manual uses recyclable paper.
- ❑ This manual has been shipped, along with the instrument, in a reusable carton.

Submitting Comments

TSI values your comments and suggestions on this manual. Please use the comment sheet, located 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, mail or fax your comments on another sheet of paper to:

Particle Instrument Division
TSI Incorporated
P.O. Box 64394
St. Paul, MN 55164
Fax: (651) 490-3860

Notational Conventions

This manual uses the following conventions when describing software:

<Enter>	Denotes the "Return" or "Enter" key on the keyboard.
<xx>	Denotes an alphanumeric key on the keyboard. For instance, **<F4>** means press the function "F4" on the keyboard.
`examples`	Examples of what you see on the screen and the text you type are shown in monospace type resembling computer output.
italic	Variable information in computer responses, commands, and options you must supply and type are shown in italics in a font that resembles computer font.
UPPERCASE	Uppercase letters indicate names of programs, files or commands.
Bold	Bold type indicates names of fittings as they appear on the instrument and commands appearing on the display.

CHAPTER 1
Product Overview

This chapter contains a product description and a list of features for the Model 3550/3560 Series Integrating Nephelometer, as well as a brief description of how the instrument works.

Product Description

The Model 3550/3560 Series Integrating Nephelometer, shown in Figure 1-1, is designed for long-term monitoring of visual range and air quality in ground-based and airborne studies. It continuously monitors the light scattering coefficient of airborne particles.

Figure 1-1
TSI Incorporated's Nephelometer

Applications

TSI Integrating Nephelometers are designed specifically for studies of direct radiative forcing of the Earth's climate by aerosol particles, or studies of ground-based or airborne atmospheric visual air quality in clean areas. They may also be used as an analytical detector for aerosol particles whenever the parameter of interest is the light-scattering coefficient of the particles after a pretreatment step, such as heating, humidification, or segregation by size.

The light-scattering coefficient is a highly variable aerosol property. Integrating Nephelometers measure the angular integral of light scattering that yields the quantity called the *scattering coefficient,* used in the Beer-Lambert Law to calculate total light extinction.

Beer-Lambert Law

$$I/I_o = e^{(-\sigma x)}$$

where:

I_o = intensity of light source
I = intensity of light after passing through atmospheric path
x = thickness of medium through which light passes
σ = total extinction coefficient
(= scattering coefficient + absorption coefficient)

How the Nephelometer Operates

A small, turbine blower draws an aerosol sample through the large diameter inlet into the measurement volume (Figure 1-2). There, the sample is illuminated over an angle of 7 to 170° by a halogen lamp directed through an optical light pipe and opal glass diffuser.

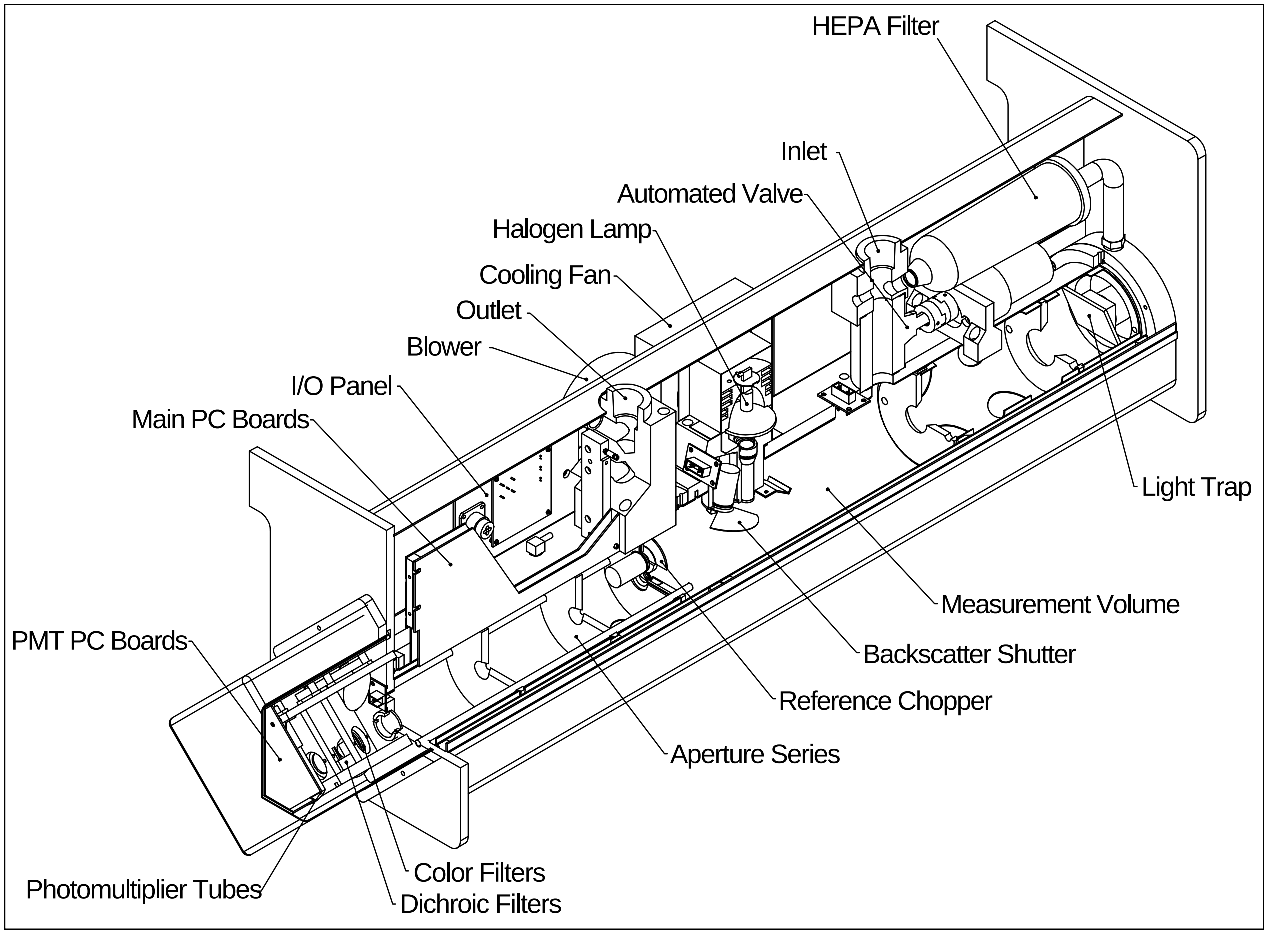


Figure 1-2
A Cross-Section View of the Nephelometer

The sample volume is viewed by three photomultiplier tubes (PMT) through a series of apertures set along the axis of the main instrument body. Aerosol scattering is viewed against the backdrop of a very efficient light trap. The light trap, apertures, and a highly light-absorbing coating on all internal surfaces of the instrument combine to give a very low scatter signal from the walls of the instrument.

Dichroic filters, in front of the PMT tubes, split and direct the light, which has been scattered by aerosol. The light is directed into three bandpass filters, blue, green and red. A constantly rotating reference chopper has separate areas to provide three types of signal detection. The first area gives a measure of the aerosol light-scattering signal allowed by an opening in the rotating chopper. The second area blocks all light from detection and gives a measurement of the PMT dark current that which is subtracted from the measurement signal. The third area is a translucent portion of the chopper, illuminated by the halogen lamp, which provides a measure of the light-source signal. In this way, over time, any change in the light source or in detector efficiency is compensated.

In backscatter mode, the backscatter shutter rotates under the lamp to block light in the 7 to 90° range. When light is blocked, only light scattered in the backward direction is transmitted to the PMT detectors. The backscatter signal can be subtracted from the total signal to calculate forward-scattering signal data. When this measurement is not of interest, the backscatter shutter can be "parked" in the total scatter position.

Periodically, an automated valve built into the inlet can be activated to divert all of the aerosol sample through a high-efficiency (HEPA) filter. This gives a measure of the clean-air signal for the local environment. This signal is subtracted, along with the PMT dark-current signal, from the aerosol-scatter signal to give only that portion of the scatter signal provided by the sample aerosol. Particle-scattering parameters for all three wavelengths of total and backscatter signal are continuously averaged and passed to a computer or data logger for permanent storage.

CHAPTER 2

Unpacking and Setting Up the Hardware

Use the information in this chapter to unpack and set up the hardware components of a Model 3550/3560 Series Integrating Nephelometer.

This chapter contains these main sections:

- ❑ Packing List
- ❑ Unpacking instructions
- ❑ Connecting power
- ❑ Connecting a computer
- ❑ Mounting the Nephelometer
- ❑ Connecting an external blower

Packing List

Table 2-1 gives a packing list for the Nephelometer and the power supply module. The packing list for the Data Analysis Center is included in one of the two or three Data Analysis Center shipping cartons.

Table 2-1
Packing List with Accessories

Qty	Description	Part Number
1	Nephelometer	3551, 3553, 3561 or 3563
1	Power supply module	3590
1	Power supply cable	1035564
1	Power cord (24 volts dc)	1035551
1	Blower bypass	1035545
1	Serial data cable (9-pin, 12 ft.)	962002
1	Serial cable adapter (25F-9M)	962003
1	Program disk (3.5 in. format)	1906118
1	Instruction manual	1933563
1	White HEPA filter	1602051
1	Blue DQ filter	1602080
1	Set (2) fan filters (foam inserts)	1602071
1	Lamp (halogen)	2201111

Unpacking Instructions

The power supply module and power cord are in one box; the Nephelometer sensor, power cable, manual, software disk, and other accessories are in another box. Keep the packing material in case you have to send the Nephelometer back to TSI.

The Nephelometer sensor comes fully assembled. If anything is missing or appears to be damaged, contact your TSI representative, or contact Customer Service at 1-800-874-3893 (USA) or (651) 490-3893. Chapter 9, "Contacting Customer Service," gives instructions for returning the Nephelometer to TSI Incorporated.

Connecting Power

This section describes connecting power to the power supply module and connecting the power supply module to the Nephelometer sensor, as well as using another power source for the Nephelometer sensor.

Connecting Line Voltage to the Power Supply Module

Use the line cord (supplied) to connect the TSI power supply module to any line voltage from 85–260 volts AC at 50–60 Hz (Figure 2-1). The auto-switching power supply automatically adjusts to the AC voltage provided.

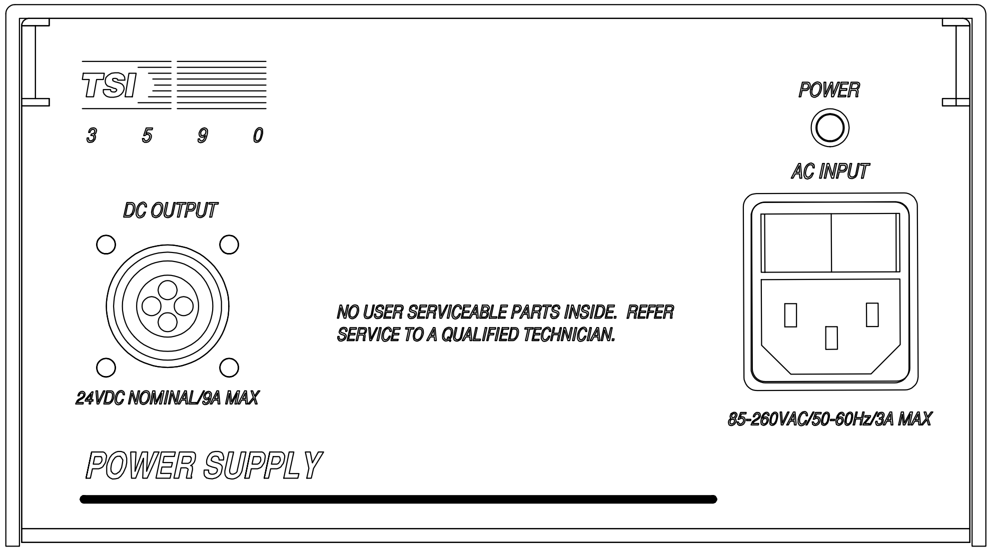


Figure 2-1
Power Supply Module

Connecting the Power Supply Module to the Nephelometer

The power supply module includes a 4-meter (12-ft.) cord with four-conductor, quarter-turn quick connectors. Before connecting the cord, make sure the power switch is in the Off position. Connect the pin end to the power supply and the socket end to the POWER AC INPUT connector (Figure 2-1) on the Nephelometer sensor.

The TSI power supply module can be oriented in any direction, but the cooling fan intake and exhaust vents should be free from obstructions at all times (Figure 2-2).

Note: *The power supply module contains no user-serviceable parts. If the module is not operating properly, use the information in Chapter 9, "Contacting Customer Service," to contact TSI.*

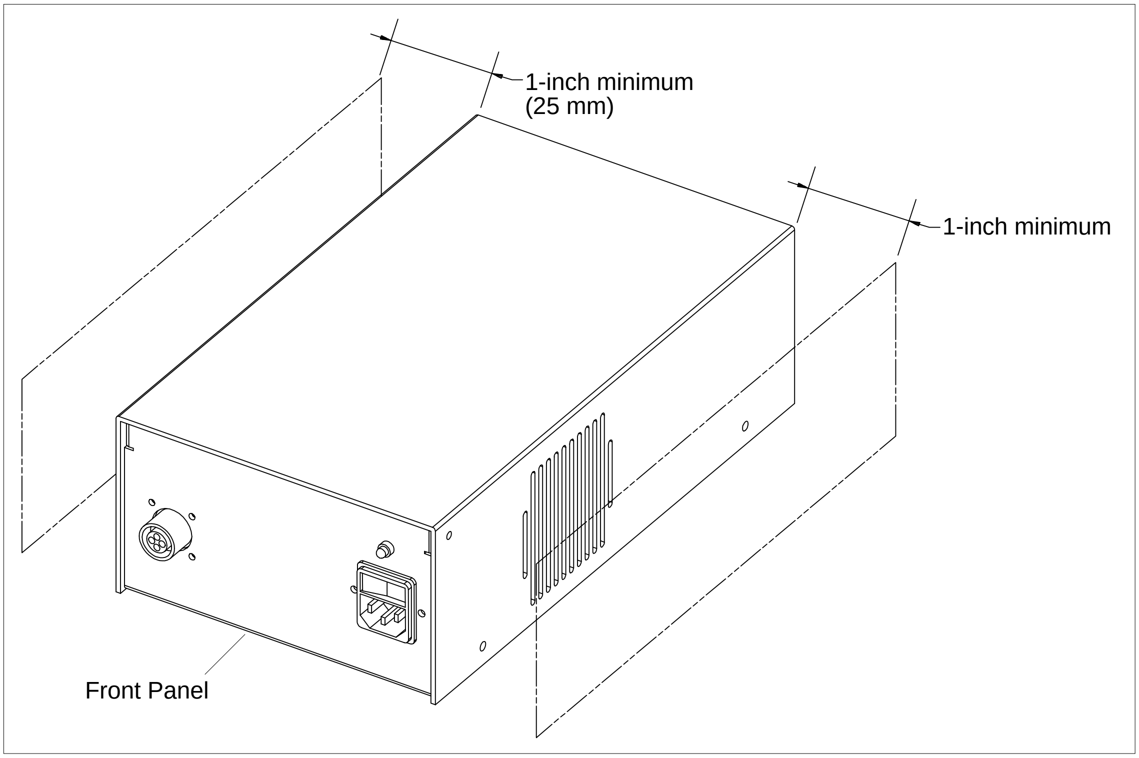


Figure 2-2
Ventilation Requirements

Using Another Power Supply

As an option, you can connect the Nephelometer sensor to a 24–28 volts DC source. The lamp power is maximum at the higher end of the DC range. You may order an extra cable (1035564) and wire one end by connecting the red wire to +, the white wire to –, and the green wire to chassis ground.

Connecting a Computer

Connect the serial port of an IBM-compatible computer to the COM PORT connector on the Nephelometer sensor (Figure 2-3). Use the 4-meter cable provided, and if you need additional length, use a standard IBM 9-pin, serial extension cable.

***Note**: Refer to Chapter 4 for instructions on using TSI software and refer to Chapter 6 for information on using serial data commands.*

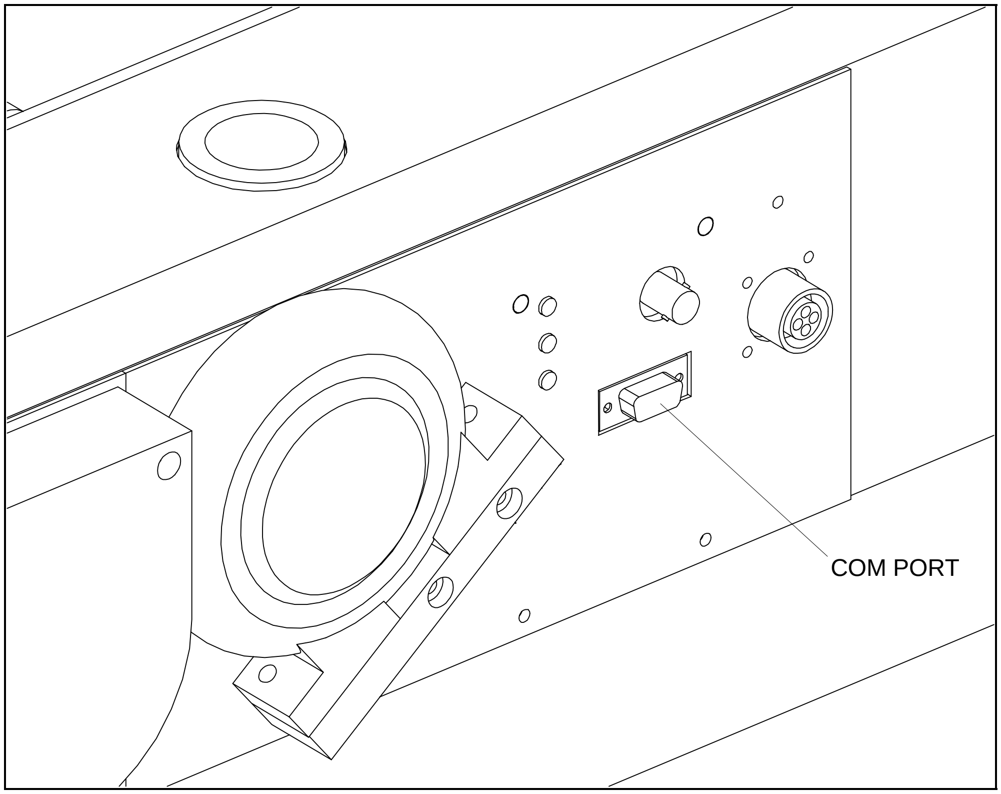


Figure 2-3
COM PORT Connector

Mounting the Nephelometer

You can mount the Nephelometer in a variety of positions depending on the application. Normally, the Nephelometer rests on its feet (Figure 2-4), but the best position is a vertical mount with the PMT box at the top and the light trap end at the bottom (Figure 2-5).

***Note:** Other positions are possible but consider dust collection opposite the lamp or on the lens. Dust raises the background noise level and necessitates cleaning more often.*

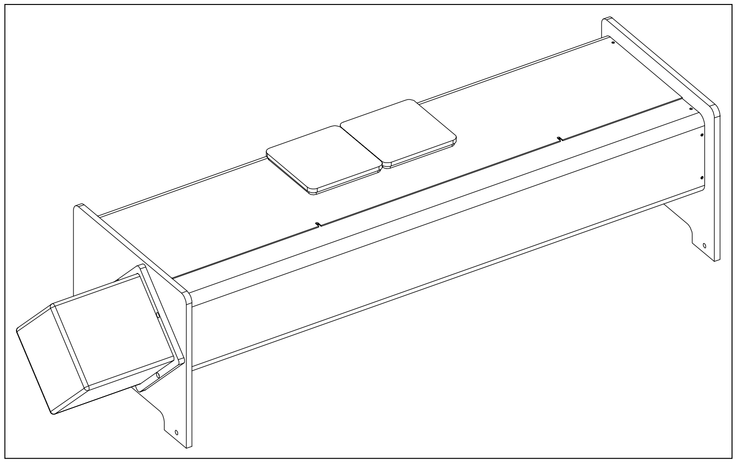


Figure 2-4
Nephelometer Resting on its Feet

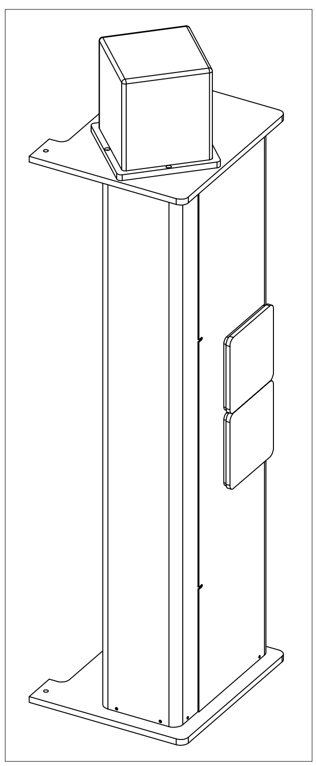


Figure 2-5
Nephelometer in the Optimal Orientation

Space Requirements

The Nephelometer sensor requires a rectangular space (Figure 2-6). You also need to allow room for the power supply module, air ventilation, and a cable to reach the sensor. If you are using a computer to set up the sensor, allow space for that as well.

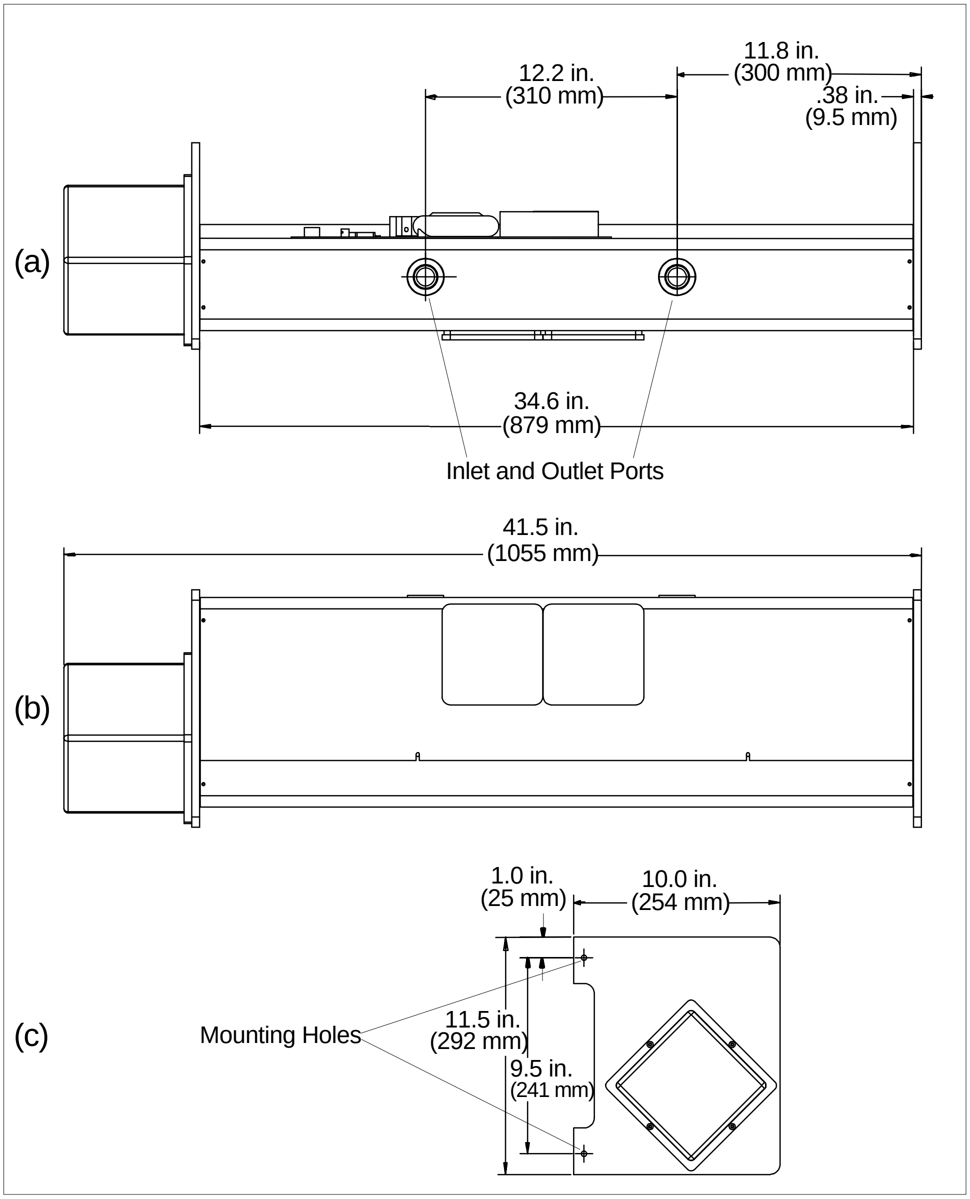


Figure 2-6
As-Built Dimensions (Space Requirements)

Mounting Holes

Use the four mounting holes, two on each leg, to mount the Nephelometer sensor (Figure 2-6c). Use four 6 mm (¼ in.) diameter bolts or screws to mount the instrument to a secure bracket, if needed.

Inlet and Outlet Ports

The inlet and outlet ports are 1 in. diameter female NPT (pipe threaded) fittings (Figure 2-6a). These fittings can be used with adapters to mate to smaller or larger rigid tubing or can be fastened directly to 1 in. pipe with a 1 in. NPT end. Rigid PVC tubing is often used to bring a sample into the instrument and to exhaust the sample from the instrument.

Keep in mind that the inlet and outlet tubing should have at least 8 inches of straight length to allow the cover to be easily removed for maintenance.

Environmental Concerns

The Nephelometer is a highly sensitive instrument that detects light-scattering from air (gas) molecules and particles present in the sample chamber. The Nephelometer also detects undesirable scatters from insects, birds, and rodents that may come into the sampling chamber. Pests can severely limit the Nephelometer's ability to measure scattering from particles.

One way to minimize pests is to use insect screens, fly, or insect traps in the upstream sampling line to prevent insects or small pests from coming into the sampling chamber. Use metal screens to prevent larger pests from coming into the sampling chamber.

It is good to keep in mind that humidities above 50–70% will enhance scattering extinction (normally assumed to be small) by particles. You may want to consider a heater or desiccant on the inlet flow to keep the humidity below this level. Although the Nephelometer incorporates a heater in the body, this is intended to compensate for any cooling effects of the instrument body. It is *not* intended to reduce the humidity through the instrument.

If the instrument will be used to sample from a warm, moist environment, while located in a cooled enclosure, you should consider insulating the inlet tubing and using the Nephelometer heater feature (see H command in Chapter 6).

In designing the inlet and plumbing systems, be aware that changes in building pressure or a venturi effect caused by high winds, can cause flow changes and reversals through the Nephelometer.

Note: *Minimize flow restrictions and particle loss when taking these measures.*

Connecting an External Blower

You can use the Nephelometer with an external blower to move the sample though the instrument. If you use an external blower, you can remove the onboard blower and replace it with the blower bypass fitting to reduce pressure drop through the sampling volume.

Note: *You need custom software to control the external blower. As of this date, TSI software does not include an interface to control an external blower.*

To remove the onboard blower and install the external blower:

1. Remove the top cover of the Nephelometer using the instructions in Chapter 8, "Performing Maintenance."
2. Remove the two screws attaching the blower bracket to the Nephelometer (Figure 2-7).
3. O-ring seals on the ports hold the blower in place. *Firmly* pull the blower away from the mounting plate.
4. Insert the blower bypass fitting into the pair of holes previously occupied by the blower.

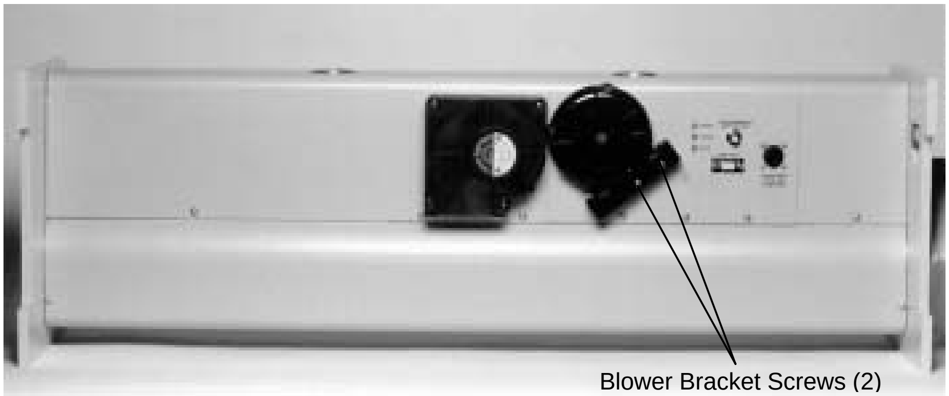


Figure 2-7
Blower Bracket

5. Install the external blower bypass fitting by pressing it into the hole in the mounting plate (Figure 2-8) and reattaching the blower bracket.

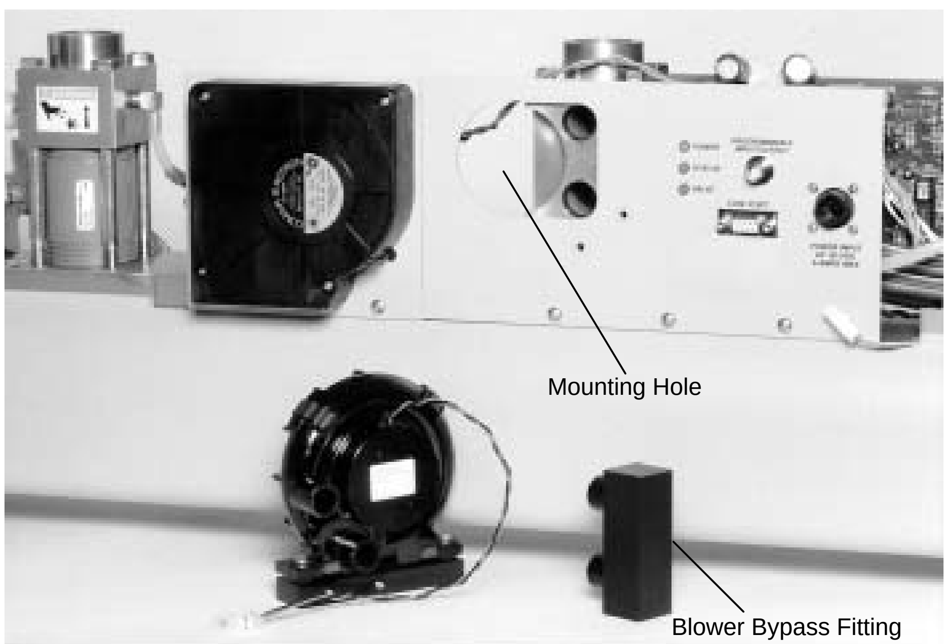


Figure 2-8
Mounting the External Blower

Calibrating the Nephelometer

After you set up the Nephelometer, take a sample reading and make a printout of the reading. To check the Nephelometer calibration, use the sample reading to compare with a reading taken during calibration. See the "Performing Calibration" section in Chapter 4 for the calibration procedure.

CHAPTER 3

Operations Overview

Before you set up the Nephelometer, it is important to consider how you will use the data you collect. This chapter provides an operations overview with these main sections:

- ❑ Serial Communications
- ❑ Hardware Components
- ❑ Setting Up Parameters

For more detailed information on operating and timing parameters, refer to Chapter 6, "Using Serial Data Commands."

Serial Communications

Nephelometer operation is controlled though the serial communications interface (COM PORT). After the Nephelometer is configured, data can be logged by a computer connected to the serial interface (COM PORT).

Data gathered by a computer connected to the serial interface provides the greatest flexibility in the post processing of data.

Hardware Components

This section describes some of the main hardware components of the Nephelometer from an operations standpoint. Refer to Chapter 8, “Performing Maintenance," for information on taking the Nephelometer apart and cleaning or replacing components.

Power Failures

The Nephelometer is designed to be a long term monitoring device with watch-dog circuitry. This circuitry allows the Nephelometer to restart itself automatically in the event of a power failure or disruption. Operating parameters are preserved in battery backed-up RAM so that you do not have to reconfigure the Nephelometer after a power failure.

Lamp Power

Lamp power is typically set to 75 watts power. This setting allows for a lamp life of approximately 2000 hours.

In some cases, like airborne measurements of short duration, when fast response time (short averaging time) and high sensitivity are desired, you can increase the lamp power. Increasing the lamp power to 90 watts will improve sensitivity but will reduce the lamp life.

Photomultiplier Tubes (PMTs)

The Nephelometer PMTs convert scattered photons of light into electronic pulses that can be counted by internal processing electronics. The gain of each PMT is controlled by an applied voltage between 0 and 1200 volts DC. The voltages are set through serial data commands sent to the Nephelometer though its communications interface. PMT voltages are set at TSI for optimal sensitivity and usually do not require adjustment.

Generally, increasing the voltage increases the gain, which results in higher sensitivity. However, increasing the voltage also increases the "dark current" of the PMT until a point is reached where the dark current is increasing faster than signal gain. As this occurs, sensitivity decreases.

The PMT dark current is also affected by temperature. If the temperature of the environment is much above 70° F (21° C), as the dark current increases, sensitivity decreases and the PMT voltage may not be optimal. In this case, voltages may need to be lowered.

Heater

If the Nephelometer is installed in an air conditioned area and is sampling hot, humid air, use the Nephelometer heater to prevent condensation. Generally the Nephelometer produces enough heat to maintain a sample temperature that is equal to or above the inlet temperature. However, if the sample temperature is below that of the inlet temperature, condensation may occur, which affects particle scattering inside the instrument.

Blower Settings

Unless the blower is turned off, the Nephelometer provides full power to the blower during an auto zero cycle. This allows the Nephelometer to have the blower set to a lower power during measurement (reducing contamination build-up) and a fast purge during the auto zero cycle.

Response time is the time required for the Nephelometer to respond to a step change in aerosol scattering. Response time is a combination of the time for the actual aerosol to change within the instrument (as low as a few seconds) and the averaging time. The speed setting of the blower and restrictions in the flow path determine how long it actually takes the aerosol to be exchanged.

Humidity and Temperature Sensors

The Nephelometer has one humidity and two temperature sensors. The humidity sensor and one temperature sensor are located near the sample outlet and the other temperature sensor is located at the sample inlet.

The outlet temperature sensor is positioned as close to the sample volume as possible to provide an accurate reading of the sample temperature. The outlet temperature sensor is used in the calculations as the sample temperature.

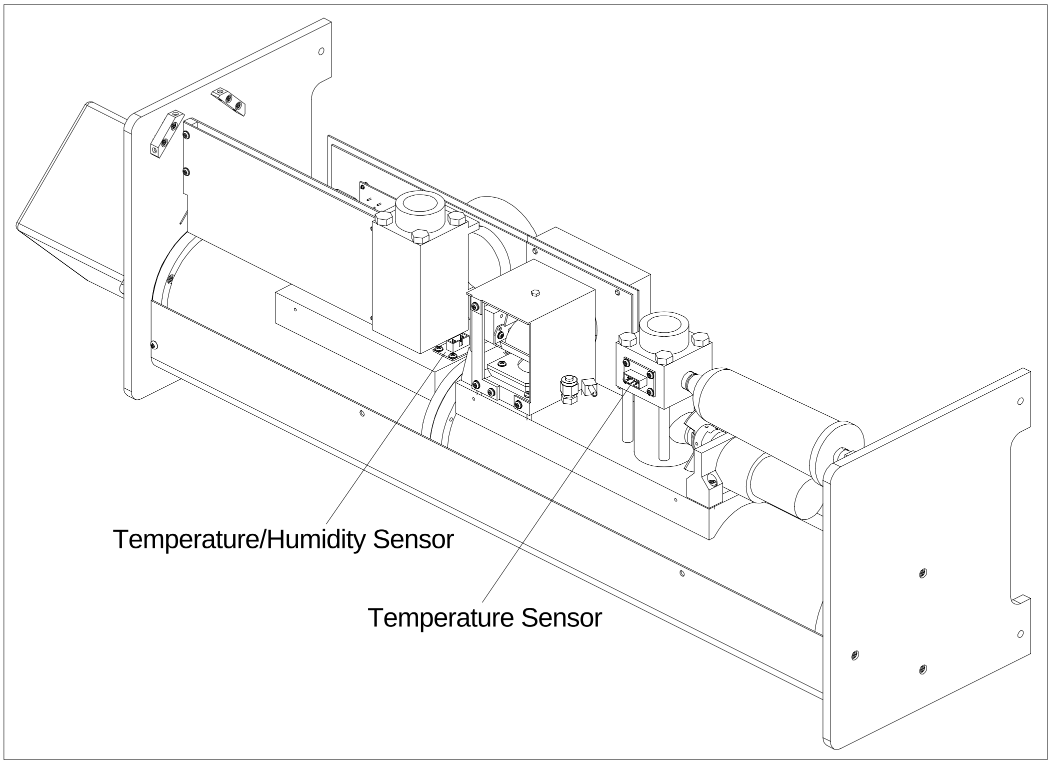


Figure 3-1
Humidity and Temperature Sensor Locations

Setting Up Parameters

This section discusses some considerations you should make before collecting data with the Nephelometer. This section contains these main subsections:

- Operating Parameters
- Timing Parameters
- Polled and Unpolled Communications

Operating Parameters

All of the Nephelometer's operating parameters are set with the serial interface through the COM PORT. While many of the operating parameters can be adjusted using a computer and the DOS-based software described in Chapter 4, all of the parameters can be set using the firmware commands described in Chapter 6 or by using the terminal emulation program on a computer.

Note: *Although many of the operating parameters are mentioned in this section, refer to Chapters 4 and 6 for instructions on actually setting the parameters.*

Sensitivity

The aerosol scattering coefficient is the primary measurement of the Nephelometer. The coefficient is the light scattering by particles in units of inverse meters. Particle scattering is measured by taking the total scattering value of the sample and then subtracting contributions of scattering from air molecules (Rayleigh scattering) and the instrument background. Ultimately, the maximum sensitivity that can be achieved is relative to the amount of light detected or captured from the sample.

Many factors relating to sensitivity have been addressed during the design of the Nephelometer. Sample averaging time and lamp power are the two primary user-controlled parameters affecting sensitivity.

Backscatter Measurements

Nephelometer Models 3561 and 3563 are equipped with a backscatter shutter. The motor-operated shutter either runs synchronously with the reference chopper (in backscatter mode) or is parked (in total scatter mode).

When operating in backscatter mode, the Nephelometer is measuring total scatter half of the time and measuring the back scatter fraction the other half. In backscatter mode, Nephelometer's total scatter sensitivity drops by 0.7 $[1 / \sqrt{2}]$ because the sample time is effectively cut in half. For this reason the backscatter mode should be used only if backscatter data is desired.

Vibration can also be a consideration in choosing backscatter mode. During backscatter operation, vibration or rapid shifts in the position of the Nephelometer (when airborne, for example) can cause a loss of synchronization between the reference chopper and the backscatter shutter. No data is taken until synchronization is reestablished. Although loss of motor synchronization can be monitored via the status flags accessible through the serial interface (see RF command in Chapter 6), use the backscatter mode only when backscatter data is desired.

Zero Baseline Measurements

At times, the light scattering from particles can be very small compared to that of the air and the instrument background. The Nephelometer has built-in pressure and temperature sensors that provide compensation for the changes in the scattering of air as its density changes. This compensation, however, cannot correct for the value of the instrument's background scattering, which will also change over time as dirt and contamination from the sample deposit on the walls of the Nephelometer.

The Nephelometer has a HEPA particle filter and a motorized valve that provide the ability to accurately measure the scattering from air and the instrument background. This zero baseline measurement (sometimes referred to as zero measurement) occurs when the Nephelometer switches the motorized valve at the inlet, causing all of the sampled air to flow through the high efficiency filter. Particles are eliminated from the air flowing through the Nephelometer and the scattering value measured by the Nephelometer is from air and instrument scatter.

Particle-free air is measured for several minutes to obtain the zero baseline scattering value. The valve is again switched to remove the filter from the sample flow. Normal sampling resumes. The zero baseline value is used to obtain the actual instrument scatter. This value along with the scatter of air (determined from its temperature and pressure) are subtracted from the sample's total scatter signal to determine the scattering from particles.

Autozero Modes

Zero baseline measurements can be initiated in three ways as determined by the autozero mode setting of the Nephelometer: manual, normal, and air-chop. Refer to the SMZ command in Chapter 6.

Manual Mode

In manual mode, an automatic zero measurement occurs only when initiated by a direct command to the communications port (see the Z command in Chapter 6).

Once the command is received, the Nephelometer changes the position of the filtered air valve, measures the zero baseline value, and then repositions the valve for normal sampling.

Normal Mode

In normal mode, the Nephelometer makes an auto zero measurement at preset intervals (see "Time Parameters" in this chapter).

Air-Chop

Air chop mode is similar to normal mode, but the zero baseline calculation is based on two or more auto zero cycles. This mode is generally used in very “clean” (low particle scatter) environments.

Time Parameters

This section discuss the several user-controlled time parameters for Nephelometer operation. Also refer to Figures 6-2 and 6-3 in Chapter 6. These figures detail the Nephelometer timing sequences and the relationships between the time parameters described in this section.

Averaging Time

The most important parameter is the “sample averaging time” or just “averaging time.” The averaging time value can be set between 1 and 9999 seconds by using the software or by using the STA command (Chapter 6).

Longer averaging times increase the Nephelometer's sensitivity at the sacrifice of response time. Sensitivity increases by the square root of the averaging time, so quadrupling of the sample time results in a doubling of the sensitivity. Typically, averaging times of less then 30 seconds are used only for testing purposes, or if the data is to be post-processed.

Zero Time

The “zero time” setting is the time the Nephelometer takes to make a zero baseline measurement. This time, which can be set between 1 and 9999 seconds, is typically 300 seconds (see the STZ command in Chapter 6). Generally the zero time should *not* be less than the sample averaging time setting.

Auto Zero Period

The auto zero period occurs between subsequent zero measurements during normal or air chop modes. The auto zero period must be small enough to follow changes in instrument background due to the build up of contaminates. Generally a value of 3600 seconds is sufficient for ground-based measurements. For extremely clean environments where air chop mode is used, the auto zero period should be shorter to provide equal zero and measurement periods. See Table 3-1, “Typical Operating Parameter” in this chapter, and the STP command in Chapter 6.

Valve Blanking Time

When a zero measurement cycle is initiated, there is a period of time, called blanking time, during which the filtered air valve turns and the Nephelometer switches between clean and sample air (or visa-versa).

During blanking time, the data is in transition and should not be used. Blanking time represents the number of seconds in which data is disregarded and not used for either the zero or measurement data. Typically, blanking time is set to 30 seconds, but use a longer blanking time if the flowrate though the Nephelometer is reduced causing a longer purge or transition time.

See the STB command in Chapter 6.

Polled and Unpolled Communications

The Nephelometer communicates in two ways: polled mode and unpolled mode. There are advantages and disadvantages with either mode. In polled mode, the Nephelometer waits for a command from an external computer or terminal and responds only when a command is sent. (TSI Nephelometer software uses polled mode.) In unpolled mode, the Nephelometer automatically sends data to the communications port once every averaging period.

Although the Nephelometer updates data records as fast as once per second, this data is averaged in a running or boxcar average. The averaged data is completely updated once every averaging time period. Therefore, to avoid double averaging, the computer should poll the Nephelometer at a rate greater than the averaging time.

To reduce the burden on the external computer to provide accurate timing, the Nephelometer has an unpolled communications mode . In unpolled mode the Nephelometer automatically reports selected data at intervals equal to the averaging time.

When data is recorded in unpolled mode, you can use a shorter averaging time to provide more detail in the data (faster time response) at the expense of having more data to process. This also provides more flexibility in post processing of data as short averaged data can be combined into longer averages. This is useful in airborne work where several hours of fast response data may be taken. Ground-based measurements may opt for longer averaging times to reduce the amount of data gathered over long-term operation.

The following chart represents some typical settings for the previously mentioned time parameters.

Table 3-1
Typical Time Settings

Parameter	Ground Based	Ground Based (clean)	Airborne
Avg Time	60 to 300	1500	30
Zero	300	300	300
Blanking	30	30	30
AZ Period	3600	720	Manual
AZ Mode	Normal	Air Chop (SMZ = 5)	Manual

When using long averaging times (greater than 300 seconds), all timing parameters should be set to integer multiples of the boxcar size (see the STA command under "Set Commands" in Chapter 6). This minimizes data loss that may occur if autozero transitions occur during the middle of a measurement boxcar.

CHAPTER 4

Using Nephelometer Software (DOS)

This chapter contains installation and operating instructions for the DOS-based software, designed for exclusive use with the Model 3550/3560 Series Integrating Nephelometer.

This chapter contains these main sections:

- Hardware and software requirements
- Installing and starting the software
- Keys and conventions
- Menus and command options
- Performing Calibration

Hardware and Software Requirements

To operate the Nephelometer software you need an IBM personal computer or 100% IBM-compatible computer with the following:

- 80386 or higher processor
- One hard drive with at least 100 Mb storage capacity (recommended for data logging)
- One 3.5-in. floppy drive
- 4 Mb or more of random-access memory (RAM)
- One RS-232 serial port for connection to the Nephelometer
- DOS version 3.3 or higher.

Note: *The DOS-based Nephelometer software may be unstable if used with multiple applications under Microsoft®Windows.*

Installing and Starting the Software

To load the Nephelometer software on the computer hard drive:

1. Apply power to the computer.

2. Insert the 3.5 inch software disk in the floppy drive of the computer.

3. Go to the root directory on the C drive (hard drive):

```
C:\>
```

4. Make a subdirectory for the Nephelometer, like "nephdos":

```
C:\nephdos
```

5. Copy the contents to the software disk into the subdirectory. These files are copied:

```
NEPH.DAT
NEPHCALB.EXE
NEPHCFG.EXE
NEPHCNFG.DAT
NEPHMAIN.EXE
NEPHPOLL.EXE
NEPHSET.EXE
NEPHTERM.EXE
RAYSCAT.DAT
```

6. Start the software by typing:

```
nephmain.exe
```

The main menu screen is displayed (Figure 4-1).

```
+-------------------------------------+
¦ TSI Nephelometer Software           ¦
+-------------------------------------+
+---------Main Menu--------------+
¦ Set Commands Menu              ¦
¦ Calibration                    ¦
¦ Data Collection (Polled)       ¦
¦ Configuration Menu             ¦
¦ Terminal Mode                  ¦
¦ Com Port and Data Path         ¦
¦ Exit                           ¦
+--------------------------------+
```

Figure 4-1
Main Menu Screen

Note: *The DOS-based Nephelometer software may be unstable if used along with multiple applications under Microsoft® Windows.*

Keys and Conventions

This section gives key functions, and command conventions for the Nephelometer software. Table 4-1 gives the keyboard functions; software command conventions are shown in Figure 4-1.

Table 4-1
Keyboard Functions

Key	**Function**
Hot keys	Type the first letter of a menu option to cursor to that option.
F10	Press **F10** to quit either the calibration, terminal, or polled mode.
Esc	Press **Esc** to return at any time to the previous screen, or to return to the DOS prompt from the main menu screen.
Arrow keys (←↑→↓)	Press an **Arrow** key to move within a screen field, or to move up and down a list of menu options.
Tab	Press **Tab** to move from field to field within a screen.
Enter	Use **Enter** in combination with other keys (like Arrow keys) or conventions (like <Read>) to select an option, to enter a parameter, or to read a parameter.

```
+--------------------------------------------------¦
¦      < Set >      < Read >      < Cancel >       ¦
+--------------------------------------------------+
```

Figure 4-2
Software Command Conventions

<Set> Sends a parameter, set by the user, to the Nephelometer.

<Cancel> Returns to the previous screen without entering any selections or new parameters.

<Read> Reads the parameter that is currently being used by the Nephelometer.

Menus and Command Options: A Reference Guide

This section describes the software menus and command options in the order they appear on menu screens. Figure 4-3 shows a structural overview with the three menus (Main, Set Commands, and Configuration).

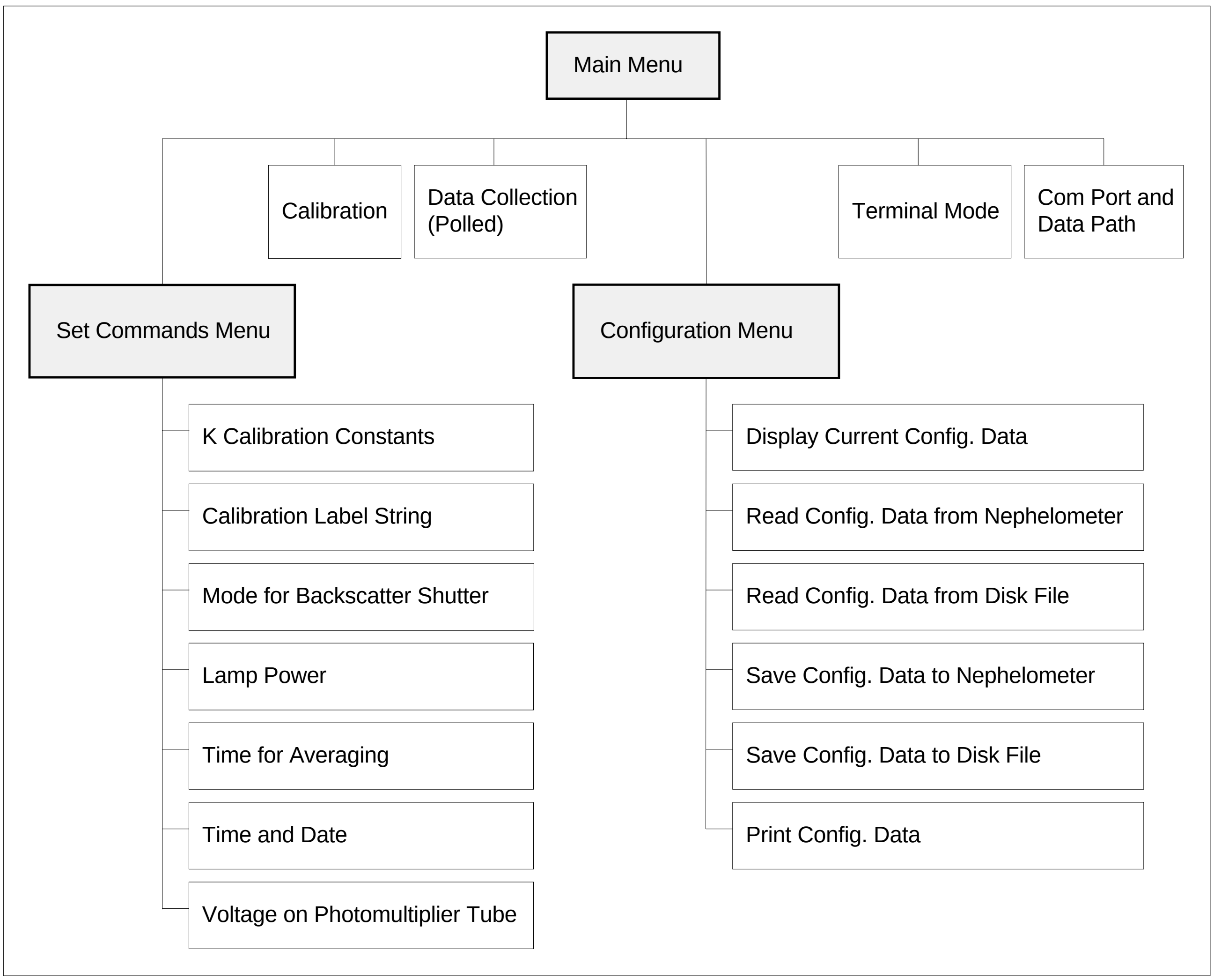


Figure 4-3
Software Menu Structure

Main Menu

The Main Menu screen is displayed when you start the Nephelometer software (Figure 4-4). When you select any menu option, a message describing the option is displayed at the bottom of the screen.

***Note**: Start the software by typing* `nephmain.exe` *under the subdirectory created for the Nephelometer program.*

```
+-----------------------------------+
¦ TSI Nephelometer Software v1.x    ¦
+-----------------------------------+

+---------Main Menu--------------+
¦ Set Commands Menu              ¦
¦ Calibration                    ¦
¦ Data Collection (Polled)       ¦
¦ Configuration Menu             ¦
¦ Terminal Mode                  ¦
¦ Com Port and Data Path         ¦
¦ Exit                           ¦
+--------------------------------+
```

Figure 4-4
Main Menu Screen

Main/
Set Commands Menu

The Set Commands Menu screen (Figure 4-5) contains options that allow you to set up the operating parameters for the Nephelometer. These options correspond to some of the set commands described in Chapter 6.

Note: *You can use the Terminal option under the Main Menu to enter any serial data commands for parameters not included in the Set Commands Menu.*

Go to the Set Commands Menu by selecting the Set Up Nephelometer option from the Main Menu screen. When you select an option from the Set Commands Menu, a message describing the option is displayed at the bottom of the screen.

```
+-------Set Commands Menu------------------+
¦ K Calibration Constants                  ¦
¦ Calibration Label String                 ¦
¦ Mode for BackScatter Shutter             ¦
¦ Lamp Power                               ¦
¦ Time for Averaging                       ¦
¦ Time and Date                            ¦
¦ Voltage on Photomultiplier Tube          ¦
¦ Exit                                     ¦
+------------------------------------------+
```

Figure 4-5
Set Commands Menu

Set Command/
K Calibration Constants Option

The K Calibration Constants option (Figure 4-6) allows you to choose calibration constants for each of the three detection colors (blue, green, and red). The K calibration constants , 1 through 4, are further defined in the SK command under "Set Commands" in Chapter 6. In order to read the current K Calibration Constants for a particular channel (blue, green, or red), you have to select the channel and then <Read> followed by <CR>.

Note: *Models 3551/3561 only require calibration constants for the green channel.*

```
+--------------- K Constants --------------+
¦ K1 (1-65535 picoseconds):                ¦
¦+----------------------------------------+¦
¦0                                        ¦¦
+-----------------------------------------+¦
¦ K2 (Total Scatter):                      ¦
¦+----------------------------------------+¦
¦0.000E+0                                 ¦¦
+-----------------------------------------+¦
¦ K3 (Rayleigh Scatter):                   ¦
+-----------------------------------------+¦
¦0.000E+0                                 ¦¦
+-----------------------------------------+¦
¦ K4 (Backscatter):                        ¦
¦+----------------------------------------+¦
¦0.000E+0                                 ¦¦
+-----------------------------------------+¦
¦               -- Channel --              ¦
¦  ( ) Blue                                ¦
¦  ( ) Green                               ¦
¦  ( ) Red                                 ¦
+------------------------------------------¦
¦    < Read >    < Set >    < Cancel >     ¦
+------------------------------------------+
```

Figure 4-6
K Calibration Constants Option

Set Command/ Calibration Label String Option

The Calibration Label String option allows you to send an identifying label for the calibration constants to the Nephelometer (Figure 4-7). As an example, "Last Calibration 1/30/93". The Calibration Label String option corresponds to the SL command under "Set Commands" in Chapter 6.

```
+----------------- Calibration Label ----------------+
¦                                                    ¦
¦ Label String (up to 50 char.):                     ¦
¦+-------------------------------------------------+¦
¦SL                                                 ¦¦
+--------------------------------------------------+¦
¦                                                    ¦
+---------------------------------------------------¦
¦       < Set >       < Read >       < Cancel >      ¦
+----------------------------------------------------+
```

Figure 4-7
Calibration Label Option

Set Command/ Mode for BackScatter Shutter Option

The Mode for BackScatter Shutter option (Figure 4-8) allows you to disable the backscatter shutter for total scatter measurements, or to enable the backscatter shutter so that you can take total scatter and backscatter measurements. This option corresponds to the SMB command under "Set Commands" in Chapter 6.

Refer to the Backscatter Measurements section in Chapter 3, "Operations Overview," to determine how to set this option.

```
+-- BackScatter Shutter Mode --+
¦                              ¦
¦           -- Mode --         ¦
¦  ( ) Total Scatter Only      ¦
¦  ( ) Backscatter             ¦
¦                              ¦
+-----------------------------¦
¦ < Set > < Read > < Cancel >  ¦
+------------------------------+
```

Figure 4-8
BackScatter Shutter Mode Option

Set Command/ Lamp Power Option

The Lamp Power option (Figure 4-9) allows you to set the intensity of the halogen lamp, which is used as a light source inside the Nephelometer. The setting for the Lamp Power option directly affects the life of the lamp. The Lamp Power option corresponds to the SP command under "Set Commands" in Chapter 6.

Refer to the Lamp Power section in Chapter 3, "Operations Overview," to determine how to set this option.

```
+-------- Lamp Power ---------+
¦                             ¦
¦  Power in watts (0 - 150):  ¦
¦                             ¦
¦   +--------------------+    ¦
¦   ¦0                   ¦    ¦
¦   +--------------------+    ¦
+-----------------------------¦
¦ < Set > < Read > < Cancel > ¦
+-----------------------------+
```

Figure 4-9
Lamp Power Option

Set Command/ Time for Averaging Option

The Time for Averaging option allows you set the averaging time, in seconds, over which the sample is measured (Figure 4-10). The Time for Averaging option corresponds to the STA command under "Set Commands" in Chapter 6.

Refer to the Averaging Time section in Chapter 3, "Operations Overview," to determine how to set this option.

***Note**: Averaging times in the valid range that do* not *fall on a boxcar boundary, will be rounded up to the next valid boxcar boundary averaging time. That is, if set to 604, because the boxcar size is 3 seconds, the next valid averaging time is 606. The Nephelometer uses this number.*

```
+------- Averaging Time --------+
¦                               ¦
¦  Time in seconds (1 - 9960):  ¦
¦                               ¦
¦    +--------------------+     ¦
¦    ¦0                   ¦     ¦
¦    +--------------------+     ¦
+-------------------------------¦
¦  < Set >  < Read >  < Cancel >¦
+-------------------------------+
```

Figure 4-10
Time for Averaging Option

Set Command/ Time and Date Option

The Time and Date option allows you to set the time and date for the Nephelometer's internal clock (Figure 4-11). The Time and Date option can be accessed with the STT command, the RT command, or in unpolled mode with the UT command. Refer to the "Commands" section in Chapter 6.

```
+--------- Date/Time ---------+
¦                             ¦
¦       Date:                 ¦
¦      +---------------+      ¦
¦      ¦05-10-1994     ¦      ¦
¦      +---------------+      ¦
¦                             ¦
¦       Time:                 ¦
¦      +---------------+      ¦
¦      ¦13:20:47       ¦      ¦
¦      +---------------+      ¦
¦                             ¦
+-----------------------------¦
¦ < Set > < Read > < Cancel > ¦
+-----------------------------+
```

Figure 4-11
Time and Date Option

Set Command/ Voltage on Photomultiplier Tube Option

The Voltage on Photomultiplier Tube option (Figure 4-12) allows you to set the voltage that drives each PMT tube, blue, green, and red. The range for this option is 1–1200 volts. This option corresponds to the SV command under "Set Commands" in Chapter 6. In order to read the current Voltage on Photomultiplier Tube option for a particular channel (blue, green, or red), you have to select the channel and then <Read> followed by <CR>.

Note: *Models 3551/3561 only require voltages for the green tube.*

Refer to the Photomultiplier Tubes section in Chapter 3, "Operations Overview," to determine how to set this option.

```
+-------- PMT Voltage --------+
¦         -- Color --         ¦
¦  ( ) Blue                   ¦
¦  ( ) Green                  ¦
¦  ( ) Red                    ¦
¦                             ¦
¦    PMT Voltage              ¦
¦   +--------------------+    ¦
¦   ¦0                   ¦    ¦
¦   +--------------------+    ¦
¦                             ¦
+-----------------------------¦
¦ < Read > < Set > < Cancel > ¦
+-----------------------------+
```

Figure 4-12
Voltage on Photomultiplier Tube Option

Main/
Calibration Option

Refer to the "Performing Calibration" section at the end of this Chapter.

Main/
Data Collection (Polled) Option

The Data Collection (Polled) option allows you to read data records from the Nephelometer and display the records in a format that is easy to interpret (Figure 4-13). This option also enables you to store the data, in an unpolled record format, to a specified file as it is received from the Nephelometer. This format is displayed in the "Unpolled Record Formats" section in Chapter 6. The specified file is saved to a directory set by the Com Port and Data Path option (refer to that option in this chapter).

Note: *The display screen is updated approximately once per second but data is written to the data files at intervals set by the averaging time (see the "Time for Averaging Option" in this chapter).*

```
+--------------Data Record-------------++--------------Status Record-----------+
¦Current Mode:    Normal Measurement   ¦¦Green Cal (in Hz)          3.196E+05 ¦
¦                 BackScatter          ¦¦                                     ¦
¦Time Remaining:   129                 ¦¦Pressure (MB)                 971.3  ¦
¦(current state)                       ¦¦Sample Temp. (K)              300.4  ¦
¦                                      ¦¦Inlet  Temp. (K)              297.6  ¦
¦       Scattering Coefficient         ¦¦Rel. Humidity(%)               33.8  ¦
¦   Total Scatter     Back Scatter     ¦¦Lamp Voltage                   12.9  ¦
¦                                      ¦¦Lamp Current                    5.9  ¦
¦B  -4.98700E-07       1.08700E-07     ¦¦BNC Input Voltage                16  ¦
¦G   4.71600E-08      -1.45200E-07     ¦¦Status Flags                     OK  ¦
¦R  -9.66400E-08      -1.83400E-08     ¦¦                                     ¦
¦                                      ¦¦                                     ¦
+--------------------------------------++-------------------------------------+
+----------------Photon Frequency in Hz (Blue, Green, Red)---------------------+
¦          Total Scatter                        BackScatter               Sample¦
¦        Cal      Meas      Dark           Cal      Meas      Dark       Press Temp.¦
¦                                                                              ¦
¦B   187332     1205        13        115844       601        10       971.3 300.4¦
¦G   317605     1031        26        197815       493        20       971.3 300.4¦
¦R   195066      534       219        120578       404       209       971.3 300.4¦
¦                                                                              ¦
+------------------------------------------------------------------------------+
(L)og Data   Log (F)ilename    (A)vg Time      Mode                F10-Quit
    OFF       LOGDATA.LOG          60          POLLED      9/20/1994  10:14:40
```

Figure 4-13
Data Collection Polled Option

Main/
Configuration Menu

The Configuration Menu (Figure 4-14) contains options that allow you to display current configuration parameters, and to read the configuration file from either a disk or from the Nephelometer. The options under the Configuration Menu are useful if the Nephelometer configuration data is ever lost or corrupted. The options allow you to quickly analyze a situation because you are able to view all the parameters as a group. You can also store, then easily retrieve different configurations.

Note: *You* cannot *change the contents of Configuration screens using Configuration Menu options, but you can make changes using either the Terminal Mode option or using options under the Set Commands Menu*

```
+------Configuration Menu------------------+
¦ Display Current Config. Data             ¦
¦ Read Config. Data from Nephelometer      ¦
¦ Read Config. Data from Disk File         ¦
¦ Save Config. Data to Nephelometer        ¦
¦ Save Config. Data to Disk File           ¦
¦ Print Config. Data                       ¦
¦ Exit                                     ¦
+------------------------------------------+
```

Figure 4-14
Configuration Menu

Configuration/
Display Current Config. Data Option

The Display Current Config. Data option displays the configuration data in the software buffer, either data read from the Nephelometer or data from the disk file (Figures 4-15 and 4-16).

```
+------------------Nephelometer Configuration Data------------------------------+
¦Analog Output Range:               Zero V    Full Scale                        ¦
¦         Relative Humidity   ->        0  -      0                             ¦
¦         Barometric Pressure ->        0  -      0                             ¦
¦         Sample Temperature  ->        0  -      0                             ¦
¦         Scattering          ->        0  -      0       (Offset=0.000E+00)    ¦
¦                                                                               ¦
¦Channel   Type                         Channel   Type                          ¦
¦    0     0 (External PC Control)          5     0 (External PC Control)       ¦
¦    1     0 (External PC Control)          6     0 (External PC Control)       ¦
¦    2     0 (External PC Control)          7     0 (External PC Control)       ¦
¦    3     0 (External PC Control)          8     0 (External PC Control)       ¦
¦    4     0 (External PC Control)                                              ¦
¦                                                                               ¦
¦Calibration Points:             Low Bits  Low Value   High Bits  High Value    ¦
¦         Relative Humidity  ->       0          0          0          0        ¦
¦         Barometric Pressure->       0          0          0          0        ¦
¦         Sample Temperature ->       0          0          0          0        ¦
¦         Inlet Temperature  ->       0          0          0          0        ¦
¦                                                                               ¦
¦Calibration Constants:   K1        K2            K3            K4              ¦
¦            Blue ->        0   0.00000E+00   0.00000E+00   0.00000E+00         ¦
¦            Green->        0   0.00000E+00   0.00000E+00   0.00000E+00         ¦
¦            Red  ->        0   0.00000E+00   0.00000E+00   0.00000E+00         ¦
+Screen 1 of 2------------------------------Press any key to Next Screen-------+
```

Figure 4-15
Display Current Config. Data Option

```
+------------------Nephelometer Configuration Data-----------------------------+
¦Data Delimiter: Comma                                                         ¦
¦                                                                              ¦
¦Calibration Label:                                                            ¦
¦                                                                              ¦
¦Backscatter Shutter Mode:             Total Scatter Mode ONLY                 ¦
¦Autozero Baseline Measurement:        Manual Mode                             ¦
¦                                                                              ¦
¦Lamp Power (Watts)              :     0                                       ¦
¦Auxiliary BNC Output (millivolts):     0                                      ¦
¦                                                                              ¦
¦Time for Averaging  (sec.)         :     0                                    ¦
¦Time to Blank Valve (sec.)         :     0                                    ¦
¦Time between Autozeros (sec.)      :     0                                    ¦
¦Time for AutoZero Measurement (sec.):     0                                   ¦
¦                                                                              ¦
¦PMT Voltage: Blue  =     0                                                    ¦
¦             Green =     0                                                    ¦
¦             Red   =     0                                                    ¦
¦                                                                              ¦
¦Zero Baseline Values:  Total Scatter     BackScatter     Rayleigh Scatter     ¦
¦             Blue  ->     0.000E+00        0.000E+00        0.000E+00         ¦
¦             Green ->     0.000E+00        0.000E+00        0.000E+00         ¦
¦             Red   ->     0.000E+00        0.000E+00        0.000E+00         ¦
+Screen 2 of 2-------------------------Press any key to return to Menu---------+
```

Figure 4-16
Display Current Config. Data Option

Configuration/ Read Config. Data from Nephelometer Option

The Read Config. Data from Nephelometer option allows you to read the configuration data residing in the Nephelometer to the software buffer. This offers a tool to help you quickly analyze any operating problems.

Configuration/ Read Config. Data from Disk File Option

The Read Config. Data from Disk File option allows you to read the contents of the disk file into the software buffer. You can then select "Display Current Config. Data" to review this data before you send it to the Nephelometer.

Configuration/ Save Config. Data to Nephelometer Option

The Save Config. Data to Nephelometer allows you to save the configuration data residing in the software buffer to the Nephelometer. The operating parameters in this file become the operating parameters for the Nephelometer.

Configuration/ Save Config. Data to Disk File Option

The Save Config. Data to Disk File option allows you to save the configuration data residing in the software buffer to a disk file for easy access should the Nephelometer's configuration become corrupt.

Configuration/ Print Config. Data Option

Sends a copy of the Config. Data to the printer attached to your parallel port.

Main/ Terminal Mode Option

The Terminal Mode option provides a basic serial interface to the Nephelometer, where you can type in serial data commands and send them directly to the Nephelometer. This option is useful for troubleshooting Nephelometer operating parameters, the calibration process, or configuration data.

Examples of the commands you might enter in terminal mode are commands that are normally set once, and not changed during the course of taking sample data. These include any of the set commands for mapping analog outputs (like SA, SB, and SX), action commands that control the mechanical components, read commands and unpolled commands (refer for Chapter 6, "Using Serial Data Commands").

Main/ Com Port and Data Path Option

The Com Port and Data Path option allow you select the serial communications port of the computer and to designate a data path for storage of data files (Figure 4-17). Use DOS conventions in naming a directory path. Any files stored will go to the directory set by this option.

```
+---------------- Data Path ---------------+
¦               COM Settings               ¦
¦                                          ¦
¦  ( ) Com1                                ¦
¦  ( ) Com2                                ¦
¦                                          ¦
¦  Directory Path For Data Files (*.dat):  ¦
¦                                          ¦
¦ +------------------------------------+   ¦
¦ ¦C:\SOFT                             ¦   ¦
¦ +------------------------------------+   ¦
¦                                          ¦
+------------------------------------------¦
¦         < OK >        < Cancel >         ¦
+------------------------------------------+
```

Figure 4-17
Com Port and Data Path Option

Performing Calibration

You should calibrate the Nephelometer before an intensive experiment, calibrate periodically to verify no drift has occurred, calibrate if the reference chopper is dirty or scratched, or if you clean the chopper as part of periodic maintenance.

The Calibration option under the Main menu allows you to easily calibrate the Nephelometer using two span gases. The Calibration option allows you to compare the results between air (low span) and CO_2 (high span).

Hardware Setup

Set up the gas before begin you begin calibration. Gas should be approximately room temperature as it reaches the Nephelometer. One way to ensure this is to use a 6- to 9-meter (20- to 30-foot) length of 6-mm (¼-in.) diameter tubing from the CO_2 tank to the Nephelometer. (The length of the tubing affects the temperature of the CO_2.) Gas of 99.9% purity or better is typically used with ambient air for calibration.

Caution
Use calibration gases only in a well-ventilated area or exhaust the gases outside. Many gases used for calibration can cause asphyxiation if used in a confined area.

Using the Main/ Calibration Option

Calibrate the Nephelometer by selecting the Calibration command from the Main Menu . The interactive calibration screen is displayed (Figure 4-18).

- ❑ The top section of the calibration screen displays the current calibration settings stored in the Nephelometer and any new calibration settings not yet saved to the Nephelometer.
- ❑ The middle section of the screen displays calibration data in frequency (Hz) for low span and high span gas in each wavelength (blue, green, and red). Calibration data is displayed for both total scatter and backscatter modes.

❑ The bottom section of the screen lists the steps you will use to calibrate the Nephelometer. Perform each step in the order given. As you complete each step, press **<Enter>**. A check (√) is displayed next to each command as the command is executed.

```
+--------------Calibration Parameters Table----------------------------------+
¦         Current(B)  New(B)      Current(G)  New(G)      Current(R)  New(R)   ¦
¦K2      4.325E-03   0.000E+00   4.484E-03   0.000E+00   4.614E-03   0.000E+00 ¦
¦K4      9.533E-03   0.000E+00   9.717E-03   0.000E+00   1.035E-02   0.000E+00 ¦
+----------------------------------------------------------------------------+
+--------------Calibration Data in Hz---------------------------------------+
¦                   Total Scatter                BackScatter                 ¦
¦           Cal        Meas        Dark         Cal        Meas        Dark    ¦
¦LOW SPAN GAS                                                                ¦
¦Blue   0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00¦
¦Green  0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00¦
¦Red    0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00¦
¦HIGH SPAN GAS                                                               ¦
¦Blue   0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00¦
¦Green  0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00¦
¦Red    0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00¦
+-------------Calibration Steps----------------------Elapsed Time(s):---     -+
1. set low span gas     (Air       )     9. feed CO2 into line    (manual)
2. set high span gas    (CO2       )     A. start data collection-high gas
3. switch valve filter                   B. clear buffer
4. start data collection-low gas         C. store high span gas data
5. clear buffer                          D. write calibration label
6. store low span gas data               E. save cal data (K2 & K4) to Neph
7. toggle blower to off (OFF)            F. zero w/ clean air
8. plug inlet & outlet  (manual)              F8-Avg Time F9-Restart F10-Quit
```

Figure 4-18
Calibration Option

Note: *If you are using air as the low span gas and CO_2 as the high span gas, perform the calibration steps in the order given. If you are using a gas other than air as the low span gas (like helium), refer to calibration process given at the end of the Calibration Procedure.*

Table 4-2
Calibration Procedure

Step	**Explanation**
1. Set low span gas	Select to choose the low span gas. Air is the default. When you select step 1, a menu is displayed with different gases.
2. Set high span gas	Select to choose a high span gas, or a gas with a higher scattering coefficient than the low span gas, such as CO_2. When you select step 2, a menu is displayed with different gases.

(continued)

Table 4-2
Calibration Procedure (*continued*)

Step	**Explanation**
3. Switch valve filter	Select to switch the filtered air valve to the zero (closed) position and to switch the blue DQ filter in-line with the air inlet. When you select step 3, a blanking time begins. The blanking time is the time it takes the filtered air valve to move to the zero position plus the time it takes to purge the Nephelometer with filtered air. The blanking time is set using the STB command (see Chapter 6).
4. Start data collection-low gas	Select to begin low span gas data collection. After you select step 4, data collection begins after the blanking time described in step 3. The low span gas area of the calibration screen is updated, but not the high span area. If you want to observe the filtered air purge, press **<F8>** to select a smaller averaging time of 5 seconds. The number in the Meas field should fluctuate, not rise and fall. When the Meas field is stable, press **<F8>** to select a 300-second averaging time and proceed to step 5.
5. Clear buffer	Select to clear the Nephelometer internal buffers of the data collected during step 4. Wait at least 300 seconds (see the Elapsed Time(s) field), then proceed to step 6.
6. Store low span gas data	Select to store in the software, the 300-seconds of low span gas data collected in step 5. Selecting step 6 causes the low span gas area of the calibration screen to freeze and low span data is no longer updated.
7. Toggle blower to off (OFF)	Select to turn off the blower. High span gas should be regulated at the source. ***Note:*** *Step 7 is a toggle function and can also be used to toggle on the blower.*
8. Plug inlet & outlet (manual)	Remove the top cover of the Nephelometer using the procedure in Chapter 8. Plug the aerosol inlet and outlet of the Nephelometer (Figure 4-19).
9. Feed CO2 into line (manual)	Remove the tubing from the inlet of the blue DQ filter and connect the tubing from the high span gas to either the inlet tubing or to the inlet block (Figure 4-19). Turn on the gas until the flowrate is approximately 5 lpm. You should feel gas exiting through the DQ filter in the opposite direction of the arrow on the filter. Proceed to step A.
A. Start data collection-high gas	Select to begin high span gas data collection. The high span gas area of the calibration screen is updated, but not the low span area. If you want to observe the high span gas purge, press **<F8>** to select smaller averaging time of 5 seconds. The number in the Meas field should fluctuate, not rise and fall. When the Meas field is stable with minimal fluctuation, press **<F8>** to select a 300-second averaging time and proceed to step B.

(continued)

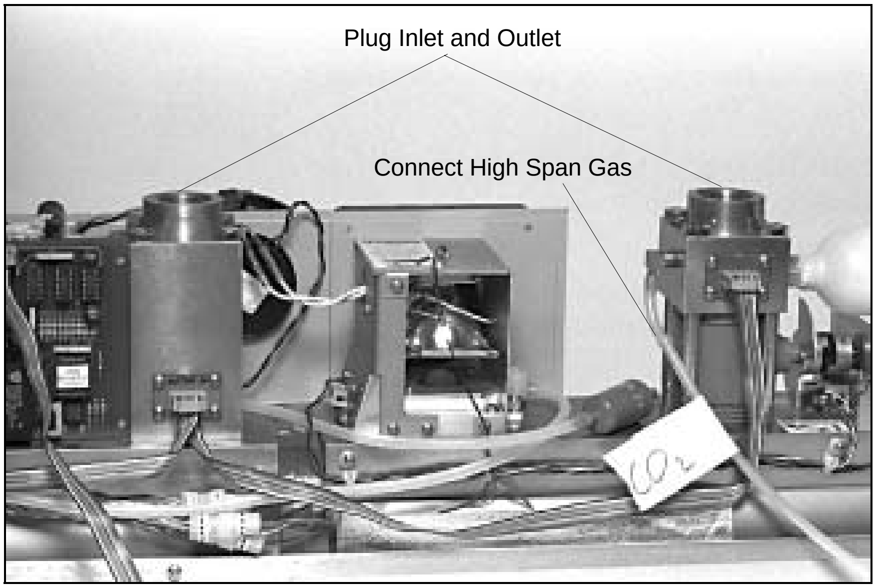


Figure 4-19
Plugs for Inlet and Outlet and Gas Line With the Blue DQ Filter

Table 4-2
Calibration Procedure (*continued*)

Step	**Explanation**
B. Clear buffer	Select to clear the Nephelometer internal buffers of the data collected during step A. Remain at this step for at least 300 seconds (see the Elapsed Time(s) field), then proceed to step C.
C. Store high span gas data	Select to store to the software the 300 seconds of high span gas data collected in step B. Selecting step C causes the high span gas area of the calibration screen to freeze and high span data is no longer updated. ***Note:*** *At this time, new calibration constants (K2 and K4) are calculated and the top section of the screen is updated. If the new constants are not satisfactory, you can recalibrate without changing the constants, as long as you do* not *perform step E.*
D. Write calibration label	Select to write an identifying label for the calibration performed. The label can include the serial number of the Nephelometer, the calibration date, the low span and high span gases used, and the initials of the person performing the calibration.

(continued)

Table 4-2
Calibration Procedure (*continued*)

Step	**Explanation**
E. Save cal data (K2 & K4) to Neph	If the new K2 and K4 calibration constants are satisfactory, select E to write the new K2 and K4 constants to the Nephelometer. After selecting step E, **1.** Remove the high span gas and the inlet and outlet plugs from the Nephelometer. **2.** Reconnect the DQ filter to the inlet block, with the arrow of the filter pointing *away* from the inlet block. **3.** Replace the top cover of the Nephelometer, attaching the cover with the four screws. **4.** Select 7 to toggle on the blower and to purge the Nephelometer of high span gas. ***Note:*** *To allow the Nephelometer to be completely purged of high span gas, wait at least 600 seconds with the blower on before proceeding to step F.*
F. Zero w/clean air	*Optional*—Select to purge the Nephelometer with clean air and to perform a zero background measurement. **<F9>** resets the check marks. **<F10>** exits the calibration. Go to the Main Menu and choose the Configuration option for options to store the calibration file to disk.
If you are using a low span gas other than air, perform the calibration steps in this order:	**1.** See step 1. **2.** See step 2. **3.** See step 3. **7.** See step 7. **8.** See step 8. **9.** Remove the tubing from the inlet of the blue DQ filter and connect the tubing from the low span gas to either the inlet tubing or to the inlet block (Figure 4-19). Turn on the gas until the flowrate is approximately 5 lpm. You should feel gas exiting through the DQ filter in the opposite direction of the arrow on the filter. **4.** See step 4. **5.** See step 5. **6.** See step 6. **9.** See step 9. **A.** See step A. **B.** See step B. **C.** See step C. **D.** See step D. **E.** See step E. **F.** See step F.

CHAPTER 5

Using Nephelometer Software (Windows)

This chapter describes the Windows™ version of the Nephelometer software including:

- ❑ The setup procedure that loads the program onto your computer.
- ❑ A “Quick Start” section to walk you through the steps necessary to collect data and perform other basic operations.
- ❑ A reference section to describe each program menu and its commands.

This chapter assumes you have Microsoft® Windows™ on your computer and that you are familiar with how Windows works. If you are not familiar with Windows, please refer to the documentation and other information that came with Windows before you load and use this program.

The Nephelometer software is provided in a Windows-based format because Windows offers a popular and easy-to-use interface to work from.

Hardware and Software Requirements

To use this software program you will need an IBM personal computer or 100% IBM-compatible computer with the following minimum features, components, and software:

- ❑ A 386 microprocessor (80386) or better.
- ❑ A hard drive large enough to accommodate Windows, the Nephelometer program (approximately 2.5 Mb), and Nephelometer data files.
- ❑ One 3.5-in. floppy drive.
- ❑ 4 Mb or more of random access memory (RAM).
- ❑ A mouse or similar pointing device.
- ❑ An RS-232 serial interface port (in addition to the one that may be required for the mouse).
- ❑ MS-DOS, version 5.0 or higher.
- ❑ Microsoft Windows version 3.1 or Microsoft Windows for Workgroups version 3.11.

Installing and Starting the Software

Set up the Windows-based Nephelometer software as follows:

1. Verify that Windows version 3.1 or Windows for Workgroups 3.11 is installed and running and that your MS-DOS version is at least 5.0. To verify your version of Windows, select *About Windows* from the Windows Help menu or type:

   `WINVER`

   at the DOS prompt and press **<Enter>**.

   To verify your MS-DOS version, type:

   `VER`

   at the DOS prompt and press **<Enter>**.

2. Insert the Nephelometer setup disk in your 3.5-in. floppy drive (generally this is your A: or B: drive).

3. Start the setup program by selecting **RUN** from the File menu and typing the following in the command box:

   `A:\SETUP` **<Enter>** (or `B:\SETUP` **<Enter>**).

   Note*: The Nephelometer program is compressed on the setup disk, you cannot load it without running the Setup program.*

4. A setup screen appears and indicates the drive and directory in which the program will be installed (the default directory), Figure 5-1. If you want the program installed in another directory or on another drive, you must enter the drive and/or directory name.

   Note*: You must select a hard drive for program installation. You cannot install the Nephelometer program onto floppy diskettes or run it from a floppy drive.*

Figure 5-1
Select the Destination Directory for Program Installation

5. Select **Continue**. The program files are automatically decompressed and stored on your hard drive.

Note: *If you are re-installing the Nephelometer software and the NEPHCNFG.DAT file on your computer is different than the one on the setup disk, you will be asked if you want to overwrite the existing file. Select **Yes** if you want to overwrite the NEPHCNFG.DAT file. See "Neph Config Data" section later in this chapter for more information on NEPHCNFG.DAT.*

When setup is complete, the README.TXT file opens automatically. The README.TXT file contains information that could not be included in this manual. Read the file and then close it. You can access the file anytime using a text editor such as NOTEPAD.

The setup program creates a directory called NEPHWIN on your hard disk (assuming you accepted the default directory name) that contains the required program files. Refer to Appendix E for a list of program files and their contents.

The Setup program also creates a new group called TSI APPLICATIONS and an icon for the program called NEPH for Windows (Figure 5-2).

Note: *Before creating a TSI APPLICATIONS group, the Setup program checks for an existing one. If one is present, it adds the Nephelometer icon only.*

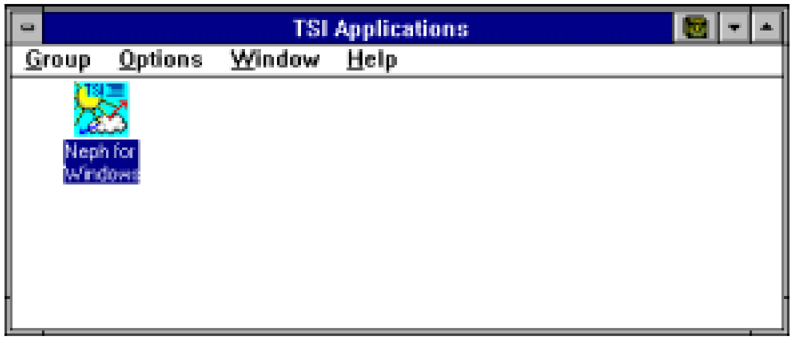


Figure 5-2
Setup Creates a Program Group and Icon

Once the program icon has been installed, you can start the Nephelometer program by double-clicking on its icon.

Quick Start

This section is designed to give you a quick introduction to the basic operation of the Nephelometer Windows program. Using these instructions, you will:

- ❑ Verify the Com Port setting of the Nephelometer.
- ❑ Start collecting sample data
- ❑ View the data as it is being collected and check the status of the Nephelometer.
- ❑ Pause and Restart data collection from the Nephelometer.
- ❑ Print a graph of the collected data.
- ❑ Perform a manual background (zero baseline) measurement.

Before you begin, verify the Nephelometer is powered up and connected to the computer.

Start the Nephelometer program by double-clicking on its icon. The main menu appears (Figure 5-3).

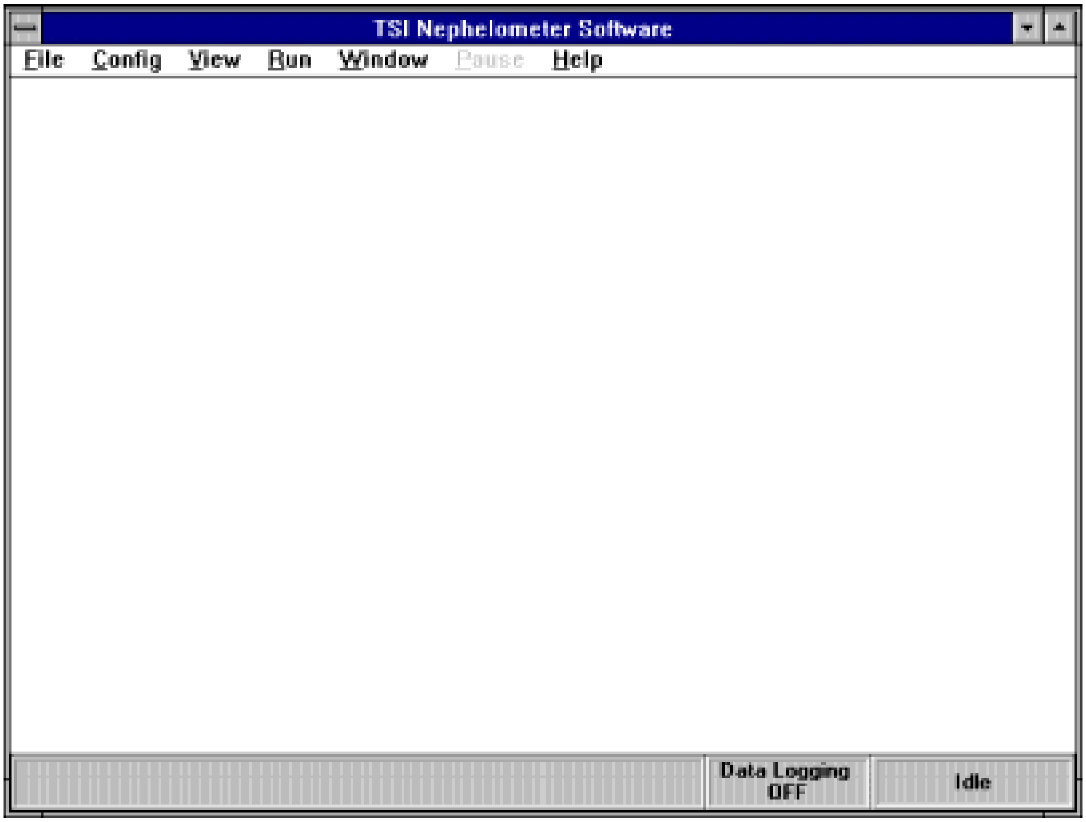


Figure 5-3
The Main Menu of the Windows-Based Nephelometer Program

Step 1. Verify Com Port

Choose the **Com Port** command from the Config menu. The COM Port Setup display is shown (Figure 5-4).

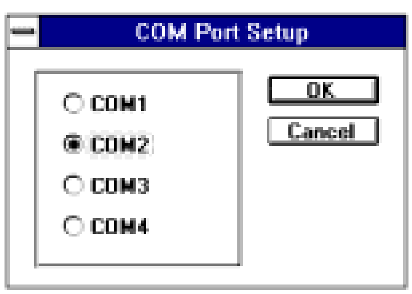


Figure 5-4
The COM PORT Setup Display

Verify that the communications port indicated on this display is the one connected to your Nephelometer (refer to Chapter 2 if necessary). The default is COM2. Select another communications port if necessary.

Note: *Most computers have only two active communications ports, COM1 and COM2. Typically, COM1 is used to connect a serial mouse, so COM2 is most likely available for the Nephelometer connection.*

Select **OK** to exit this display.

Step 2. Start Data Collection

To start collecting data you should first open a log file and then start collecting data.

1. Select the **Log Data** command from the File menu. When the Log Data Setup window appears, type in:

   ONETEST.DAT

   and press **OK**. Watch the lower right corner of the display, it will indicate Data Logging is to ONETEST.DAT.

2. Select the **Data Collection** command from the Run menu. Immediately, four windows are automatically opened and minimized on your screen (Figure 5-5) and data collection begins.

   The icons that appear on the screen represent the Data, Graph, Photon Frequency, and Neph State commands available under the View menu.

   Note: *If you receive a message that the program is unable to communicate with the Nephelometer, the wrong COM PORT may have been selected in Step 1. Verify cabling between the computer and the Nephelometer, then verify the correct COM PORT is selected and that the Nephelometer is on.*

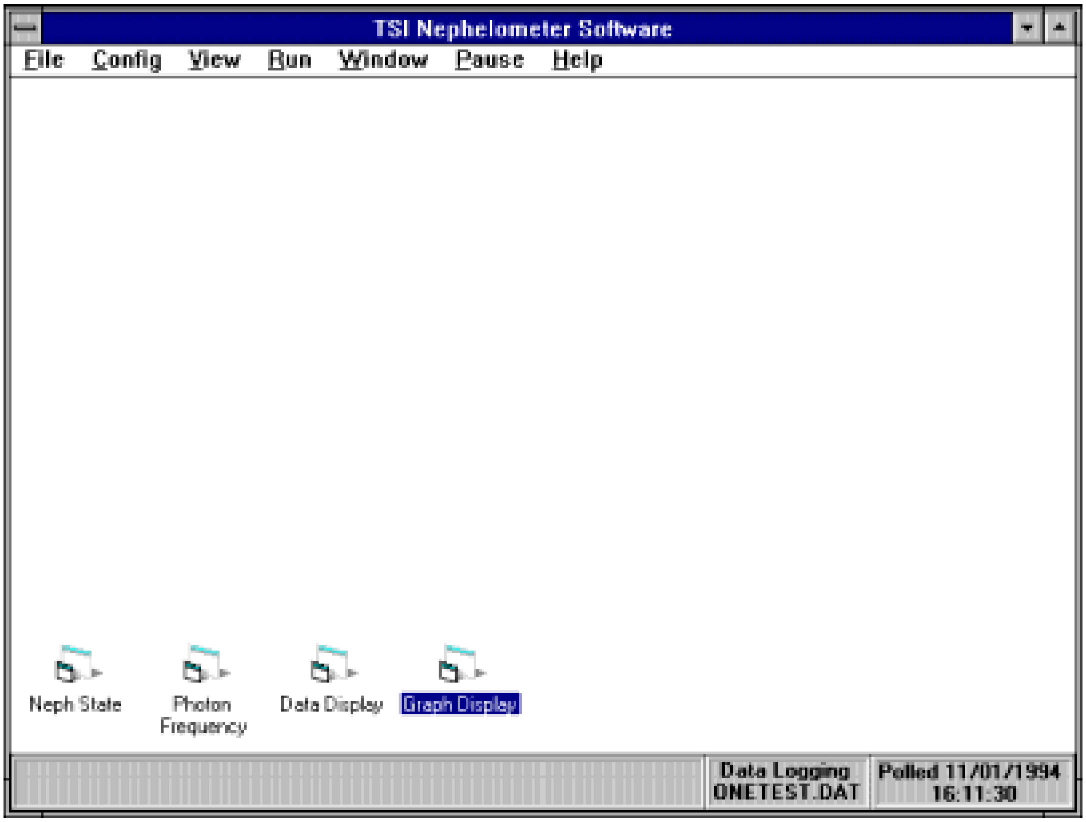


Figure 5-5
Choosing Data Collection from the Run Menu Starts Data Collection

Step 3. View Data and Nephelometer Status

Follow these steps to view data and the status of the Nephelometer:

1. Double-click on the **Data Display** icon to display current data (Figure 5-6).

   This display lets you view Nephelometer data as it is being collected, and the information displayed should resemble that shown in Figure 5-6.

   Data is updated on this display at approximately one second intervals but data is written to the data files at intervals set by the averaging time. If no data is displayed after 60 seconds, check that the Nephelometer is running.

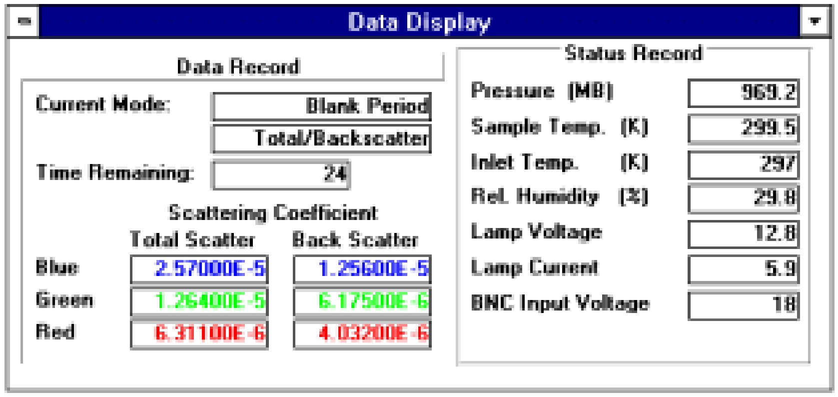


Figure 5-6
Select Data Display to View Data as it is Collected by the Nephelometer

2. Double-click on the **Neph State** icon (you don't need to close the Data Display window) to display the Neph State window, Figure 5-7.

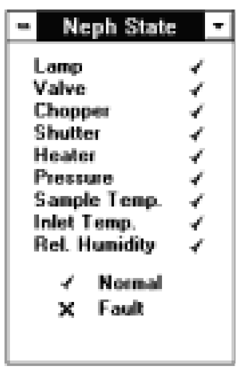


Figure 5-7
The Nephelometer State Display Shows the Status of the Nephelometer

This window displays the status of various Nephelometer components. They should all be marked with checkmark (✔) to indicate they are functional. If any are marked with an **✗**, then there is a problem with the component. Refer to Chapters 2, 6, 8 and 9 for information to help you troubleshoot the problem.

3. Double-click on the **Photon Frequency** icon (you don't need to close either the Data Display window or the Neph State window) to display the Photon Frequency window (Figure 5-8).

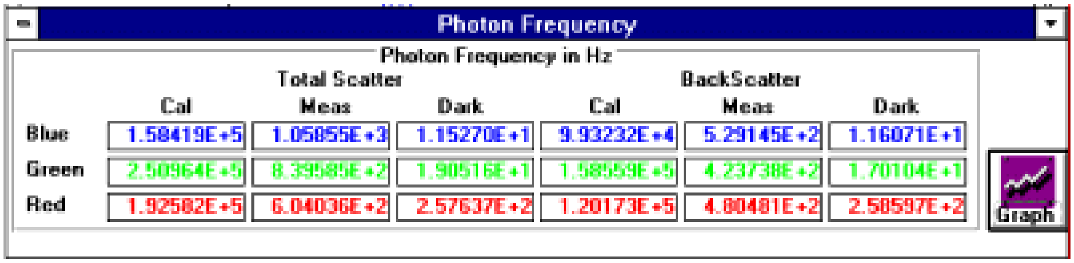


Figure 5-8
The Photon Frequency Display Shows the Current Photon Frequency Calculations

This window displays the raw photon frequency calculated by the software from the raw photon counts collected by the Nephelometer.

4. Double-click on the **Graph Display** icon (you don't need to close any of the other windows) to display the information that has been collected by the Nephelometer so far (Figure 5-9).

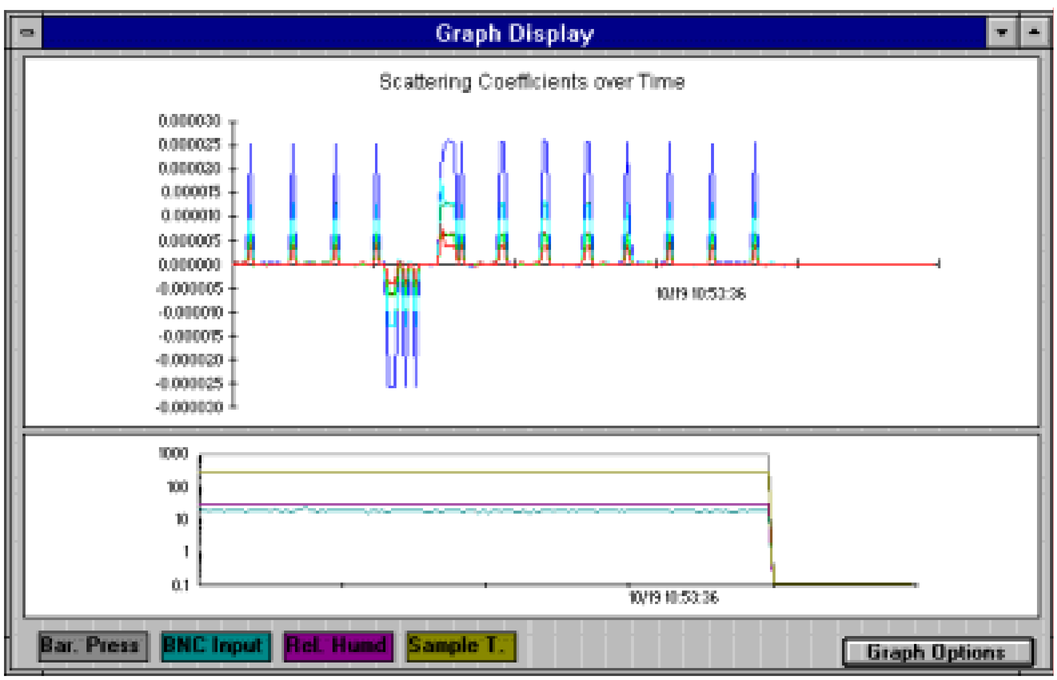


Figure 5-9
The Graph Display Shows Current Data

The graph displays the data that has been collected by the Nephelometer up to this point.

Step 4. Print a Graph

There are two ways to print this graph. You can select either **Print** or **Print Screen** from the File menu.

Before doing either, however, select **Pause** from the main menu. You should always Pause data collection before printing.

Before using the Print Screen function, the Print Screen key must be pressed to capture the current active screen to the clipboard. The Print Screen function will print the entire screen, including menu bars, elevators and the like. It is being used to print log data graphs and may be suitable for draft prints or quick snaps of data.

When you choose **Print**, you are asked to select either a scatter data graph or a status graph and to enter a header message.

Choose **Scatter Data Graph** and enter the header message “This is test data collected by (enter your initials).” Then press **OK**. The data will be printed in landscape mode.

Step 5. Perform a Background (Zero Baseline) Measurement

Zero baseline measurements are important so that the Nephelometer’s background scattering can be deducted from sample data measurements. Normally, zero baseline measurements are performed automatically; however, to introduce you to the Terminal function of the Windows program, you should perform a manual zero baseline measurement as follows.

1. Select the **Terminal Mode** command from the Run menu. The Terminal Display appears, Figure 5-10. This display allows you to communicate with the Nephelometer using the Serial Data Commands, described in Chapter 6.)

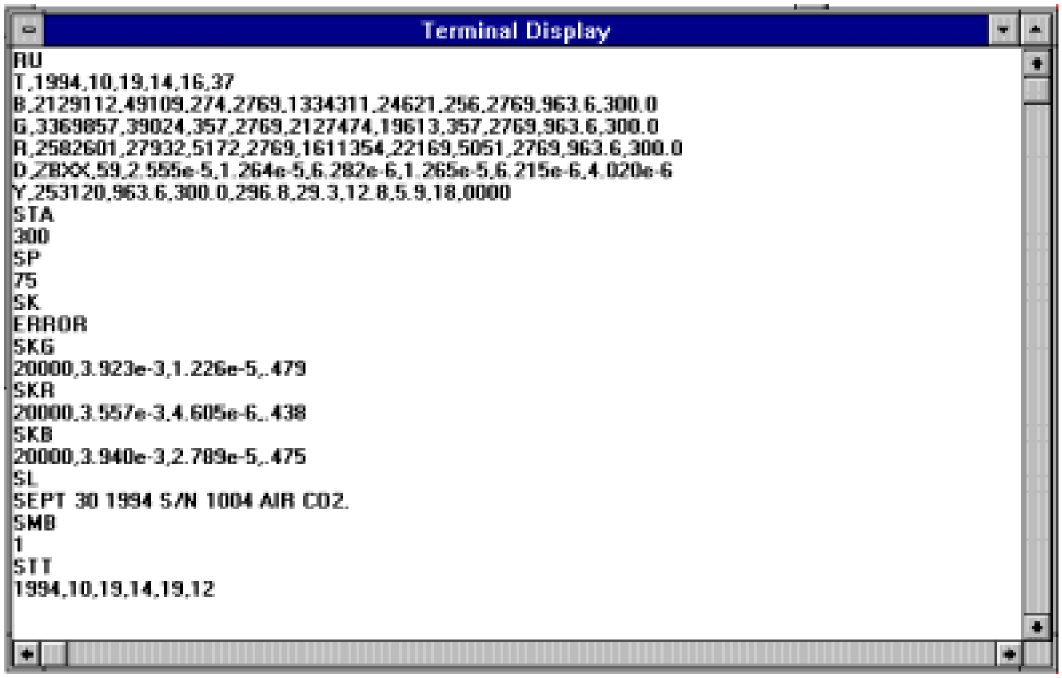


Figure 5-10
The Terminal Mode Display

2. Enter a **Z** command (type the letter Z) and press **<Enter>**. This begins a zero measurement.

3. Select the **Terminal Mode** command from the Run menu to close Terminal Display.

4. Look at the Data Display, refer to Figure 5-6. It should show the Time Remaining counting down toward 0 (zero). The current mode should first be changed to Blank Period, then to the Zero Measurement, and eventually to Normal Measurement when the time remaining reaches 0. This indicates that zero measurement has been taken and stored to the log data file.

Basic Nephelometer Operations

Although it does not list all of the functions available in the Windows Nephelometer program, Table 5-1 lists many of the most basic operations you might want to perform. Use the instructions provided to get better acquainted with how the program works, or as a quick reference.

Although you may be comfortable using the program from these instructions, take the time to read the detailed information provided in the reference portion of this chapter so you are familiar with it when you have specific questions about program operation.

Table 5-1
Basic Windows Nephelometer Operations

To...	**Perform the Following Steps**
Log data to a file	**1.** Select **Log Data** from the File menu. **2.** Enter the filename and select **OK**. **3.** Select **Data Collection** from the Run menu. *or* Perform Step 3 then 1 then 2.
Start collecting data (not logged to a file)	Select **Data Collection** from the Run menu.
Pause/resume data collection	Select **Pause** or **Resume** from the main menu.
View raw data currently being collected by the Nephelometer	**1.** Verify Data Collection is proceeding. **2.** Double-click on the Data Display icon.
View the Nephelometer configuration data	Select **Neph Config Data** from the View menu.
View a graph of current Nephelometer activity	**1.** Verify Data Collection is proceeding. **2.** Double-click on the **Graph Display** icon.
View data already saved to a file	**1.** Verify Data Collection is OFF. **2.** Select **Open Log File** from the Log menu. **3.** Enter the name of the file and select **OK**.
View a graph of data already saved (closed file)	**1.** Verify Data Collection is OFF. **2.** Select **Open Log File** from the Log menu. **3.** Enter the name of the file and select **OK**. **4.** Select **Graph** from the display.

(continued)

Table 5-1
Basic Windows Nephelometer Operations (*continued*)

To...	Perform the Following Steps
Send serial data commands to the Nephelometer	**1.** Select **Terminal Mode** from the Run menu. **2.** Type the Serial Data Command (see Chapter 6) and press **<Enter>**.
Print a graph	**1.** View a graph. **2.** Select **Print** from the File menu. **3.** Select **Info to Print** and **Header Message** (if desired) **4.** Select **Print**.
Print whatever is displayed on the screen	**1.** Press **<Print Screen>** key. **2.** Select **Print Screen** from the File menu (or press <**F9**>).
Run a background (zero baseline) measurement manually	**1.** Verify Data Collection is OFF or paused. **2.** Select **Terminal Mode** from the Run menu. **3.** Type Z and press **<Enter>**. **4.** Close the Terminal Display. **5.** Resume Data Collection.
Get online help	Select the **Contents** command from the Help menu *or* Press <**F1>**.
Exit the program	**1.** Verify Data Collection is stopped. **2.** Close all windows. **3.** Select **Exit** from the File menu.
Arrange windows or icons on the screen	Select **Cascade**, **Tile**, or **Arrange Icons** command from the Window menu.
Select a communications port for the Nephelometer	**1.** Verify Data Collection is OFF. **2.** Select **Com Port** from the Config menu. **3.** Select a communications port and press **OK**.
Set up the Nephelometer (or make changes to its set up)	**1.** Select **Nephelometer** from the Config menu. **2.** Make changes to the setup and Exit the screen.

Clean Air Test

Before you begin using the Nephelometer, you should conduct a clean air test to make certain the instrument is calibrated properly. Proceed with this test step only after you have verified the program is communicating with the Nephelometer and it is able to collect data.

1. Select **Pause** from the main menu to temporarily stop data collection.

2. Select the **Nephelometer** option from the Config menu. The Set Nephelometer Parameters display appears (Figure 5-11).

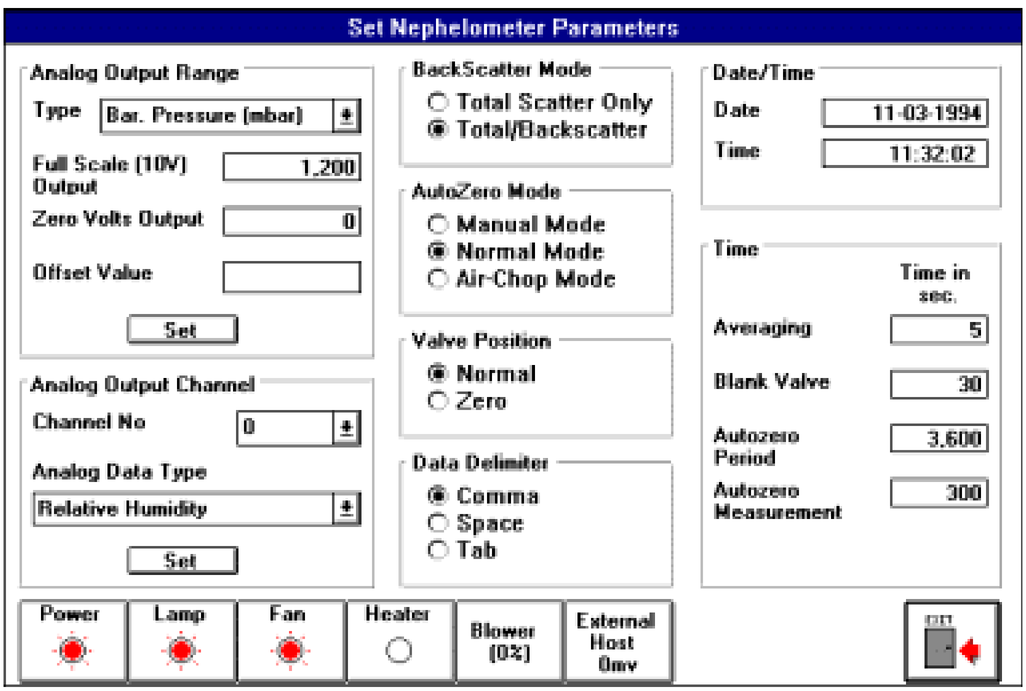


Figure 5-11
The Set Nephelometer Parameters Display Shows the Current Parameters of the Nephelometer

3. Change the Valve Position parameter to Zero (in the middle of the display) and note the Averaging Time (just to the right). The Averaging Time is the interval between data collection points.

4. Exit from the screen (use the Exit door in the lower right).
5. Resume data collection.

   Clean air is now entering the Nephelometer and the Scattering Coefficient numbers, refer to Figure 5-6, should read in the E-7 or E-8 range. This is the normal background noise level of the Nephelometer. The numbers should fluctuate about zero (from negative to positive).

   If the noise level is within this range, the Nephelometer is properly zeroed and calibrated and ready for use.

   If the numbers are greater than E-7 or E-8 (an occasional E-6 is okay), the Nephelometer is not calibrated properly. (The Nephelometer is calibrated before shipment, but the software settings may have been corrupted or lost.)

   Refer to the calibration procedure described later in this chapter to use the Windows-based calibration procedure or refer to Chapter 4 to use the DOS-based calibration procedure. The procedures themselves are identical.

Menus and Commands: A Reference Guide

This section describes the menus and commands of the Windows-based Nephelometer software. The section is organized like the main menu—commands available under each menu follow the menu name. The seven menu items are:

- ❑ File
- ❑ Config
- ❑ View
- ❑ Run
- ❑ Window
- ❑ Pause/Resume
- ❑ Help

Using the File Menu

The File menu commands let you perform functions related to software file maintenance.

Open Log File Command

Choose the **Open Log File** command from the File menu to select the filename of an existing log file to open and display its data (Figure 5-12). You can type the filename (including drive and directory) in the filename box or select a file using the list boxes. Log files have a .DAT extension.

If you want the AutoZero Data stored in the file (if available) to be displayed along with the sample data, select (mark) the Include AutoZero Data box.

Select the **OK** button when done and watch the bottom of the display for confirmation that the file is being processed. Large files can take a long time to open. After the file is opened, the file's data appears in the Log Data Table window.

Refer to the description of the Log Data Table command under the View menu, see below, for the options that are available for viewing, graphing, copying and printing this data.

Log Data

Choose the Log Data command from the File menu to identify the file you want the Nephelometer to log data to (Figure 5-13). The filename defaults to the last name you specified (file extension .DAT).

You can type the filename (including drive and directory) in the filename box or select a file using the list boxes. The file can be a new file or an existing file.

Note: *Before data is logged to a file, you MUST have selected a filename using the Log Data command. You can begin data collection (select Data Collection from the Run menu), but unless you specify a filename here, data is not saved to any file.*

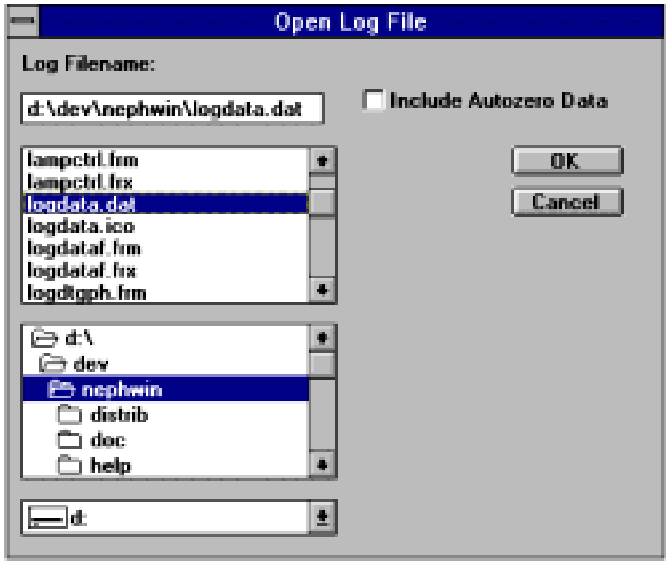


Figure 5-12
Select a Filename After Choosing the Open Log File Command

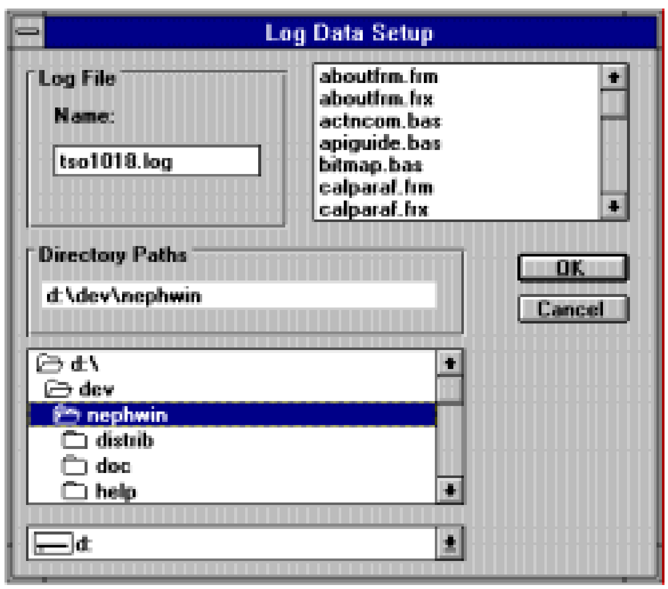


Figure 5-13
Select a Filename After Choosing the Log Data Command

After you select the file and press **OK**, observe the bottom right corner of the display. It should indicate the name of the currently selected log file.

To stop logging data to a file, select the **Log Data** command again and verify that the logging status is OFF.

You can begin data collection with or without selecting log data file.

Print

Choose the **Print** command from the File menu to print graphs of the data currently being logged (the file selected with the Log Data command).

You can print a scatter data graph or a status graph and, if desired, add a message header to describing the graph (Figure 5-14). The Date/Time Stamp box lets you automatically imprint the time and date the graph was printed. Graphs are printed in landscape mode.

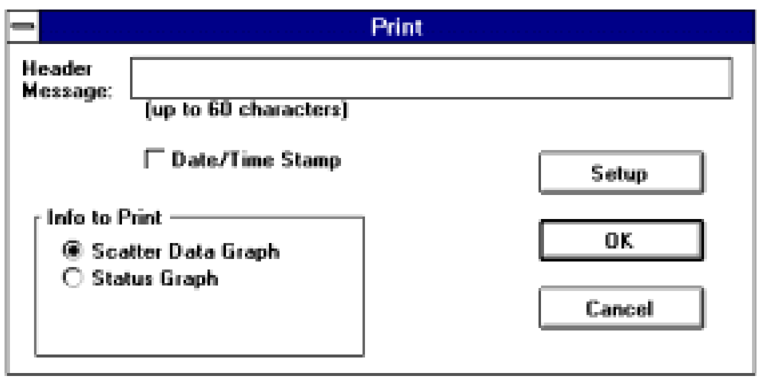


Figure 5-14
Select the Print Command from the File Menu

Before you print a graph, be certain you Pause data collection. (Select **Pause** from the main menu.) Once you send the graph to the printer, select **Resume** to continue collecting data.

Select the **Setup** button from the Print display to set up the printer.

Note: Normally, you will not need to use Setup or you will only need to perform Setup once, since any settings you make will be stored with the program. Refer to your Windows documentation to change printer options and setup parameters.

Figure 5-15 shows a typical scatter data graph (top) and status graph (bottom).

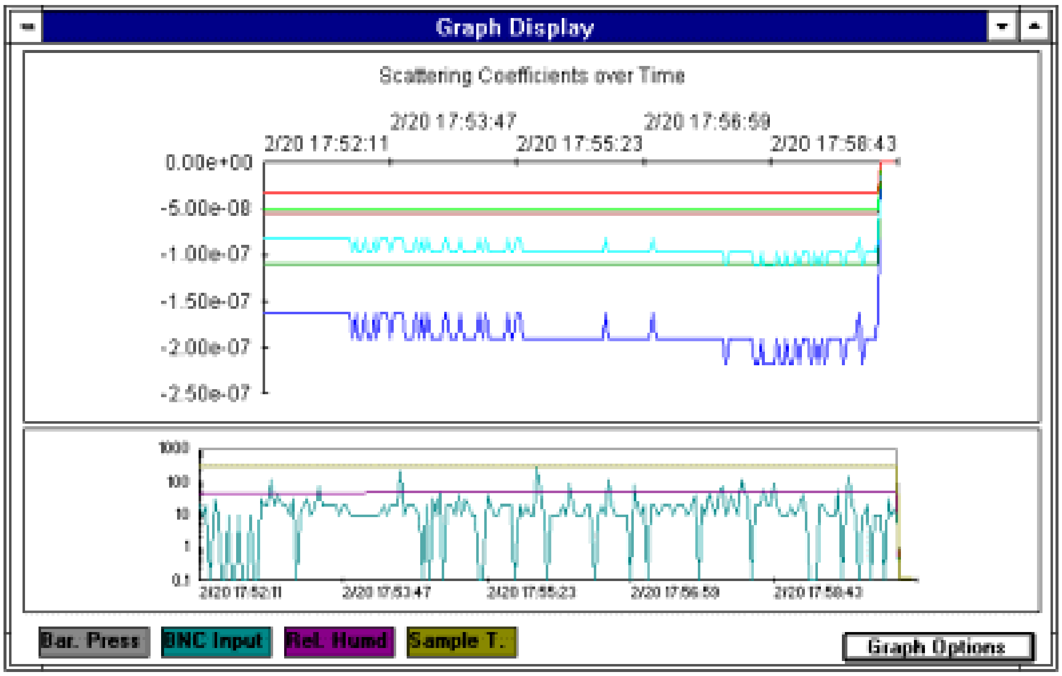


Figure 5-15
Types of Graphs. Scatter Data Graph (top) and Status Graph (bottom)

Print Screen

Press the <**Print Screen**> key to capture the information currently on your display and then select the **Print Screen** command from the File menu or press **<F9>** to print it.

When you select the command, the screen information is captured and sent to the printer. Only the information visible on your display monitor is printed.

Exit

Choose the **Exit** command to exit (close) the program and return to Windows.

Using the Config Menu

The Config menu commands let you configure the Nephelometer and select the communications port that the Nephelometer is connected to.

Nephelometer

Choose the **Nephelometer** command from the Config menu to read the current parameters of the Nephelometer or make changes to the Nephelometer settings (Figure 5-16).

Note: *Setup is not the same as calibration. Select the Calibration command from the Run menu to calibrate or recalibrate the Nephelometer.*

Table 5-2 lists the parameters that can be set or modified from this display. For more detailed information about these settings refer to Chapter 6, “Serial Data Commands.”

Changes take affect immediately. Use the Exit button when changes are completed.

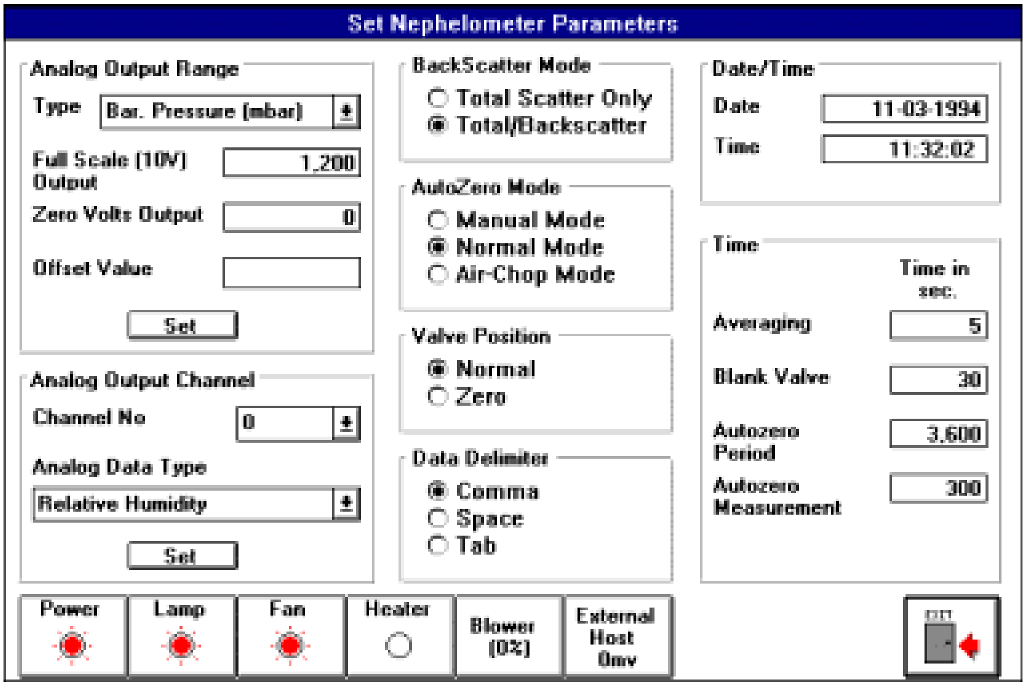


Figure 5-16
Choose Nephelometer from the Config Menu

Table 5-2
Nephelometer Setup Parameters

Parameter	Equivalent Serial Data Command	Description
Analog Output Range	SA*cm,v,b.bbbe-b*	This group of parameters is used to set the ranges for PROGRAMMABLE I/O (BNC]. Ranges can be set for relative humidity, barometric pressure, sample and inlet temperatures, and scattering values. Select the **Set** button after making changes to a specific type of port.
Type		Select **Barometric Pressure**, **Relative Humidity**, **Sample & Inlet Temperature** or **Scattering**.
Full Scale (10V) Output		Enter a value within these ranges: Barometric Pressure (1–1200 Mbar) Relative Humidity (1–100%) Sample & Inlet Temperature (1–400K) Scattering (1–10)

(continued)

Table 5-2
Nephelometer Setup Parameters *(continued)*

Parameter	**Equivalent Serial Data Command**	**Description**
Zero Volts Output		Enter a value within these ranges: Barometric Pressure (0–1199 Mbar) Relative Humidity (0–99%) Sample & Inlet Temperature (0–399K) Scattering (4–10)
Offset Value		Relates only to Scattering. The offset value added to the scattering data allows negative values (0.000e–11 to 9.999e–3).
Analog Output Channel	SB*c,t*	This group of parameters is used to map (assign) an analog data type to a hardware output on the PROGRAMMABLE I/O (BNC) connector. Select the **Set** button after assigning a data type to each channel.
Channel No.		0 = PROGRAMMABLE I/O port
Analog Data Type		Select one of the following data types for each channel (the default channel number is shown in parenthesis): External Host Value (not assigned) Barometric Pressure (1) Sample Temperature (2) Blue σsp (3) Green σsp (4) Red σsp (5) Blue σbsp (6) Green σbsp (7) Red σbsp (8) Relative Humidity (0) Inlet Temperature (not assigned)
Back Scatter Mode	SMB*z*	Select **Total Scatter Only** to measure only the total scatter. Select Total/Backscatter to enable the backscatter shutter, measuring total scatter **and** backscatter.

(continued)

Table 5-2
Nephelometer Setup Parameters *(continued)*

Parameter	**Equivalent Serial Data Command**	**Description**
AutoZero Mode	SMZ*v*	Sets the mode used to zero baseline drift using filtered air. In Manual Mode, zeroing of the baseline only occurs when a Z command is given. In Normal Mode, an autozero is performed at the Autozero Period [0 to 9999] In Air-Chop Mode, [2 to 24]. Similar to normal mode except the last number of autozero baselines are averaged together to provide a reading.
Valve Position	V*c*	Normal is used for normal measurements. Zero is used for zeroing of the baseline.
Data Delimiter	SD*x*	Sets the character used to delimit data in the output file. Select comma, space, or tab
Date/Time	STT	Sets the date and time of the Nephelometer's internal clock. Enter date as mm-dd-yyyy Enter time as hh:mm:ss
Time		Set the time intervals for various parameters/operations.
Averaging	STA*ttt*	Sets the averaging time, in seconds, over which the sample is measured.
Blank Valve	STB*ttt*	Sets the blanking time, in seconds, when the valve is switching.
Autozero Period	STP*ttt*	Sets the time, in seconds, between autozeros.
Autozero Measurement	STZ*ttt*	Sets the time, in seconds, the Nephelometer spends measuring filtered air during a zero baseline measurement.
Power	L	Turns the Nephelometer on or off.
Lamp	SP	Turns the Nephelometer lamp on or off and allows you to adjust lamp power.
Fan	F	Turns the fan on or off.
Heater	H	Turns the heater on or off.
Blower (xx%)	B	Allows you to adjust blower power from 0 (off) to 255 (full power)
External Host xmv	SX	Sets external host analog value to a specified voltage (0 to 5000).

Com Port

Choose the **Com Port** command from the Config menu to select the communications port that the Nephelometer is attached to (Figure 5-17). The default is Com Port 2.

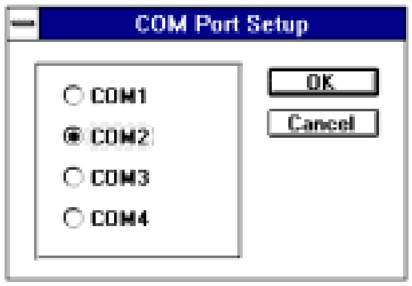


Figure 5-17
Use the COM Port Setup Display to Select the Appropriate Communications Port

If you need to change the communications port, select another communications port and press **OK**.

Using the View Menu

The View menu commands let you display information collected by the Nephelometer and check Nephelometer configuration and status.

Note*: The Data, Graph, Photon Frequency, and Neph State commands can be selected only when data collection is ongoing.*

Data

Select the **Data** command from the View menu to display data as it is being collected by the Nephelometer (Figure 5-18).

Note*: When you start data collection, the Data Display window is automatically opened and minimized. You can double-click on the Data Display icon to open its window instead of selecting it from the View menu.*

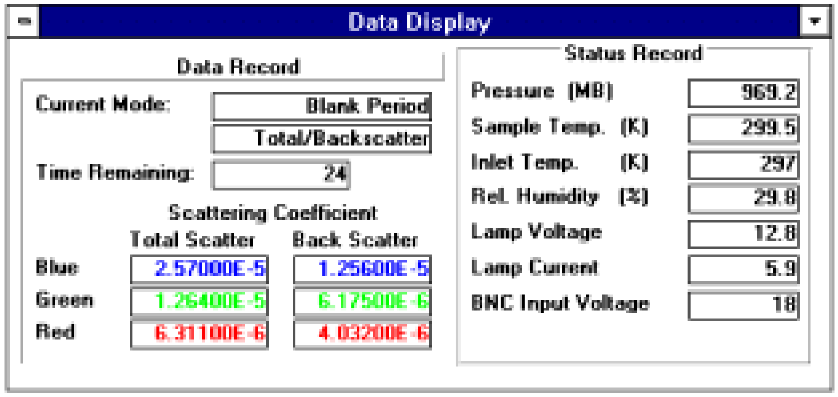


Figure 5-18
The Data Display Shows Current (raw) Data Values Collected by the Nephelometer

The Data Display shows current data values (raw data) and selected status information. Each parameter is described in Table 5-3.

Note: *The displayed data is updated approximately once a second, but data is written to the log data file only at the intervals set by the averaging time parameter.*

Table 5-3
Data Display Parameters

Parameter	**Description**
Data Record	The parameters displayed in these fields show the current measurement mode, time remaining in the current measurement, and the scattering coefficients calculated by the Nephelometer.
Current Mode	The mode displayed in the top box can be: Blank Period, Zero Measurement, or Normal Measurement. The mode displayed in the bottom box can be: Total/Backscatter or Total Scatter.
Time Remaining	Displays the time remaining in the current measurement mode.
Scattering Coefficient	These parameters show the data as it is collected and calculated by the Nephelometer.

(continued)

Table 5-3
Data Display Parameters (*continued*)

Parameter	**Description**
Status Record	The information displayed here are current parameters calculated by the Nephelometer.
Pressure (MB)	The current barometric pressure in millibars (mb)
Sample Temp. (K)	The current sample temperature in °K
Inlet Temp (K)	The current temperature at the Nephelometer inlet in °K
Rel. Humidity	The relative humidity of the sample in %
Lamp Voltage	The current voltage applied to the lamp in volts DC
Lamp Current	The current amperage applied to the lamp in amperes
BNC Input Voltage	The current input voltage to the BNC

Graph

Select the **Graph** command from the View menu to display Nephelometer data graphically as it is being collected (Figure 5-19).

Note: *When you start data collection, the Graph window is automatically opened and minimized. You can double-click on the Graph Display icon to open its window instead of selecting it from the View menu.*

The default graph options show the scattering coefficients over time in the top graph and status parameters in the lower graph.

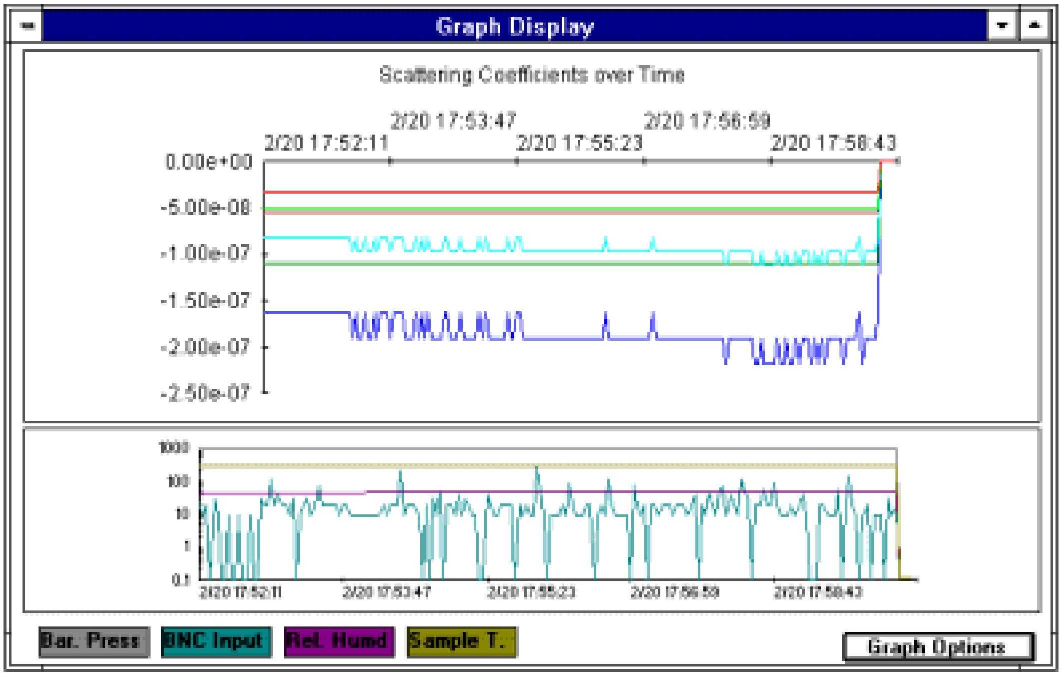


Figure 5-19
Graph Data of the Current Log Data File

Select **Graph Options** from the Graph Display to customize the graph (Figure 5-20). The parameters you can select are described in Table 5-4. To print the graph, select **Print** from the File menu.

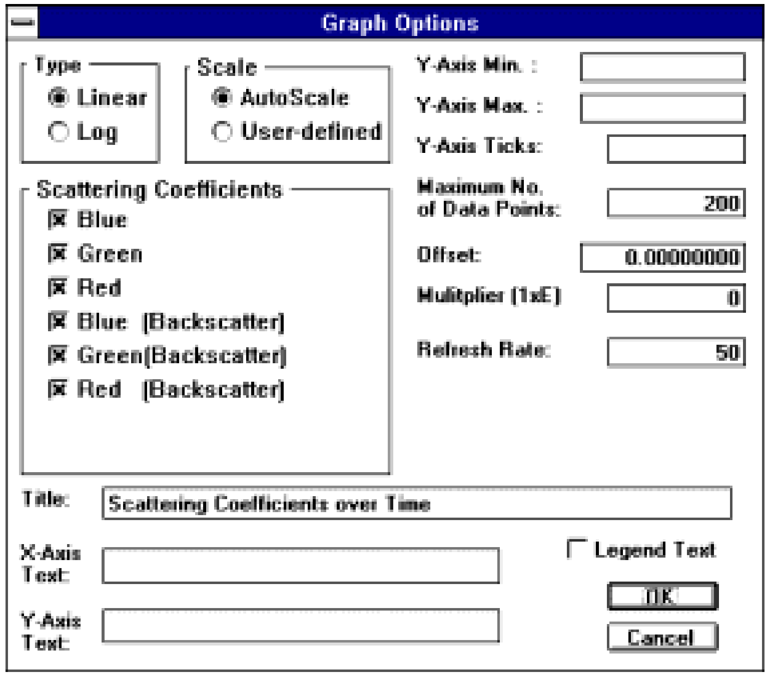


Figure 5-20
The Graph Options Window Lets You Customize Your Graphs

Table 5-4
Graph Options for the Graph Display

Parameter	Description
Type (scattering coefficients only)	Select linear or log(rithmic) to set the x-axis scale of the graph. The maximum value is automatically determined by the maximum value of the data displayed.
Scale	Select AutoScale or User-defined to set the y-axis of the graph. If you select User-defined, you must also set the following parameters: Y-Axis Min.—The minimum value for the y-axis. Y-Axis Max.—The maximum value for the y-axis. Y-Axis Ticks—The value between each mark (tick) on the y-axis.
Scattering Coefficients	Indicates the type of data to be graphed. The default is all data. Select (deselect) each checkbox.

(continued)

Table 5-4
Graph Options for the Graph Display (*continued*)

Parameter	Description
Maximum No. of Data Points	The maximum number of points to include on the graph. If the Log Data file includes more than this number of data points, only the most current points are displayed.
Offset	Offset the y-axis from 0 (zero) by this amount.
Refresh Rate	How often (in percentage) the graph display is updated (refreshed). This is independent of the averaging data time.
Title	Enter a title for the graph. Maximum 60 characters.
X-Axis Text	Enter a label for the x-axis.
Y-Axis Text	Enter a label for the y-axis.
Legend Text	Check this box to include the legend on the graph. The legend identifies the type of data displayed by each line.

Photon Frequency

Choose the **Photon Frequency** command from the View menu to display the photon frequency data (in Hz) as it is collected from the Nephelometer (Figure 5-21) and calculated by the software.

Note: *When you start data collection, the Photon Frequency window is automatically opened and minimized. You can double-click on the Photon Frequency icon to open its window instead of selecting it from the View menu.*

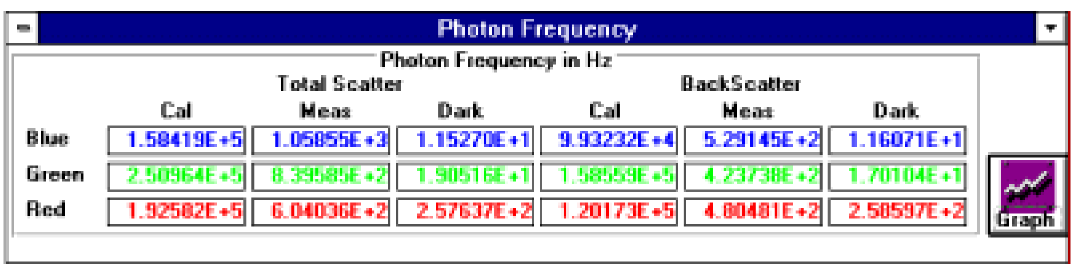


Figure 5-21
Photon Frequency Display

The Photon Frequency display shows the raw photon frequency calculated by the software from the raw photon counts collected by the Nephelometer. The raw photon frequency is displayed for each section of the calibrate shutter (calibrate, measure, dark), at each wavelength (blue, green, red). The data is updated approximately once a second.

Note: *For more details about photon frequency and calibrate shutter, see "Signal Processing" in Chapter 7.*

Select **Graph** from this display to graphically view the data that has been collected in the current Log Data file (Figure 5-22).

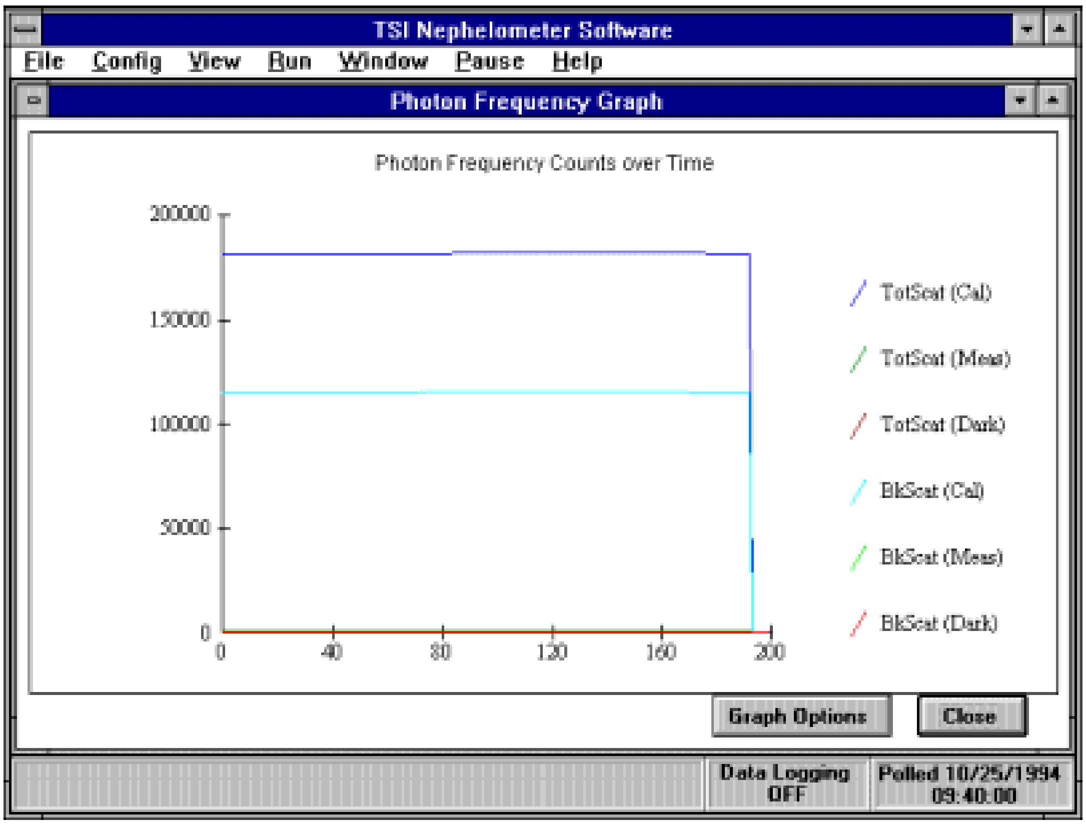


Figure 5-22
The Photon Frequency Graph Displays Current Measurements

Select **Graph Options** from the Photon Frequency Graph display to customize this graph. The options are nearly identical to those described in Table 5-4 except you must select a color (wavelength) to indicate the data you want shown on the graph.

Neph State

Choose the **Neph State** command from the View menu to display the operational status of selected Nephelometer components (Figure 5-23). Use this display to verify general Nephelometer status and to troubleshoot problems with the Nephelometer.

Note: *When you start data collection, the Neph State window is automatically opened and minimized. You can double-click on the Neph State icon to open its window instead of selecting it from the View menu.*

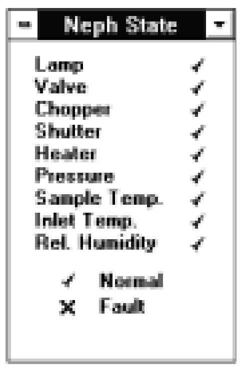


Figure 5-23
The Status of the Nephelometer is Displayed by Selecting Neph State from the View Menu

All items on the display should be marked with a check mark (✔). If they are marked with an **✕**, the component/parameter is reporting a hardware fault. Review Chapters 2 and 3 and refer to Chapter 8 for troubleshooting procedures to correct the problem.

Neph Config Data

Choose the **Neph Config Data** command from the View menu to display Nephelometer configuration parameters (Figure 5-24). Current Nephelometer configuration parameters are stored in a text file named NEPHCNFG.DAT, which is the default config file used by the software.

You can display current configuration parameters or read a configuration file from disk when the **Use Default Config File** option is selected.

The information in this display is useful for analyzing system problems because you can view all of the parameters as a group. It is also useful because you can store, then easily retrieve, different configurations if the current Nephelometer configuration should become lost or corrupted.

Note: *You cannot make changes to the Nephelometer Configuration Data from this display.*

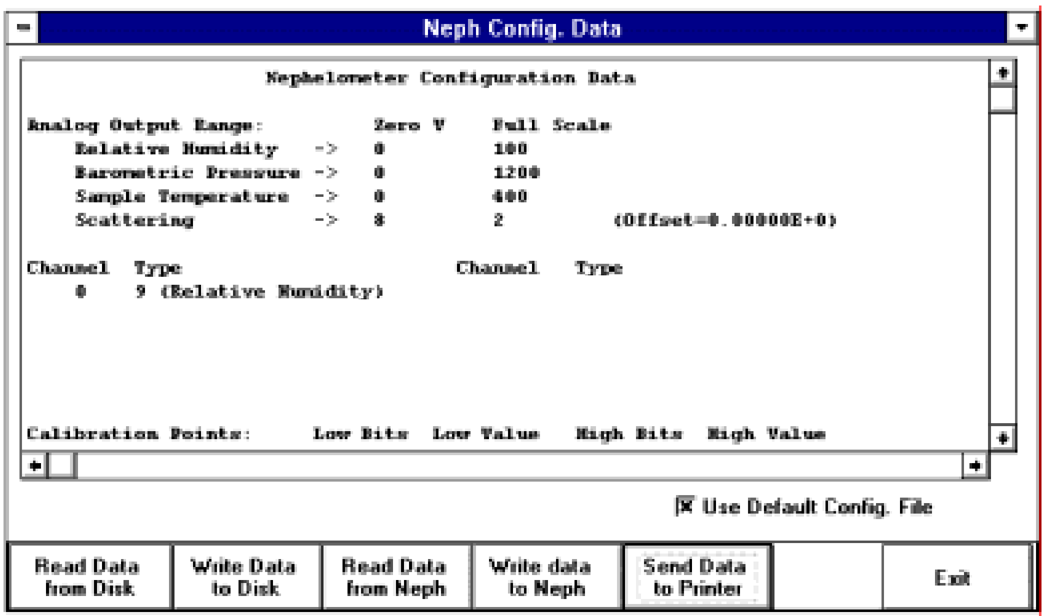


Figure 5-24
Nephelometer Configuration Data is Displayed by Selecting Neph Config Data from the View Menu

The buttons across the bottom of the window let you select the source and destination of the displayed configuration data. If the **Use Default Config. File** is marked (**X**), the information will be written to or read from the default configuration file named NEPHCNFG.DAT. **Do *not* remove this file from your hard drive or change its name.**

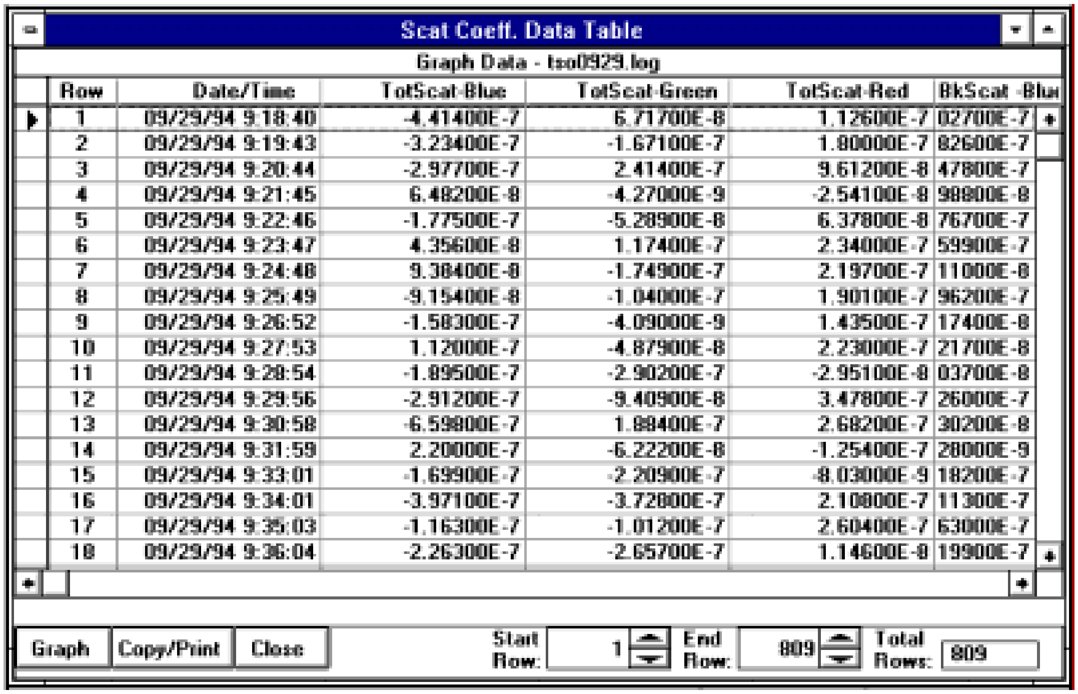
Table 5-5
Nephelometer Configuration Data

Read Data from Disk	Select this button to read Nephelometer Configuration Data from a file other than the default configuration file. You can then review this data before downloading it to the Nephelometer. Enter the complete path and filename of the file to be read.
Write Data to Disk	Select this button to write the currently displayed Nephelometer Configuration Data to a file to save it. **Caution**: You can write over the default configuration file! If the "Use Default Config. File" box is checked and you select Write Data to Disk, the currently displayed configuration information will overwrite the default configuration file. The old default configuration file will then become a backup configuration file (NEPHCNFG.BAK).
Read Data from Neph	Select this button to read the configuration data currently being used by the Nephelometer. Use this button to verify the operating configuration parameters.
Write Data to Neph	Select this button to download the displayed configuration data to the Nephelometer, replacing the configuration parameters that are stored in the Nephelometer.
Send Data to Printer	Select this button to print the currently displayed Nephelometer Configuration Data.

Log Data Table

Choose the Log Data Table command from the View menu to display data from a previously saved log file or the data currently being collected (Figure 5-25).

Note: *To view a previously saved data file, you must open the log file first by choosing the Open Log File command from the File menu. Large files can take a long time to process and load. Watch the bottom of the screen to verify the file is being processed.*



Scat Coeff. Data Table

Graph Data - tso0929.log

Row	Date/Time	TotScat-Blue	TotScat-Green	TotScat-Red	BkScat -Blu
1	09/29/94 9:18:40	-4.41400E-7	6.71700E-8	1.12600E-7	02700E-7
2	09/29/94 9:19:43	-3.23400E-7	-1.67100E-7	1.80000E-7	82600E-7
3	09/29/94 9:20:44	-2.97700E-7	2.41400E-7	9.61200E-8	47800E-7
4	09/29/94 9:21:45	6.48200E-8	-4.27000E-9	-2.54100E-8	98800E-8
5	09/29/94 9:22:46	-1.77500E-7	-5.28900E-8	6.37800E-8	76700E-7
6	09/29/94 9:23:47	4.35600E-8	1.17400E-7	2.34000E-7	59900E-7
7	09/29/94 9:24:48	9.38400E-8	-1.74900E-7	2.19700E-7	11000E-8
8	09/29/94 9:25:49	-9.15400E-8	-1.04000E-7	1.90100E-7	96200E-7
9	09/29/94 9:26:52	-1.58300E-7	-4.09000E-9	1.43500E-7	17400E-8
10	09/29/94 9:27:53	1.12000E-7	-4.87900E-8	2.23000E-7	21700E-8
11	09/29/94 9:28:54	-1.89500E-7	-2.90200E-7	-2.95100E-8	03700E-8
12	09/29/94 9:29:56	-2.91200E-7	-9.40900E-8	3.47800E-7	26000E-7
13	09/29/94 9:30:58	-6.59800E-7	1.88400E-7	2.68200E-7	30200E-8
14	09/29/94 9:31:59	2.20000E-7	-6.22200E-8	-1.25400E-7	28000E-9
15	09/29/94 9:33:01	-1.69900E-7	-2.20900E-7	-8.03000E-9	18200E-7
16	09/29/94 9:34:01	-3.97100E-7	-3.72800E-7	2.10800E-7	11300E-7
17	09/29/94 9:35:03	-1.16300E-7	-1.01200E-7	2.60400E-7	63000E-7
18	09/29/94 9:36:04	-2.26300E-7	-2.65700E-7	1.14600E-8	19900E-7

Figure 5-25
Display Log File Records in Tabular Format by Selecting Log Data Table from the View Menu

Up to eighteen (18) data records are displayed in the window at one time. Use the <↑> or <↓> and <→> or <←> arrow keys to view all the data and all rows of data in the file. The bottom right corner of the window indicates the total number of rows of data.

The information displayed in the table depends on whether you are in the analysis operating mode or polled operating mode.

In the analysis mode you are viewing a file that has been saved (not the current log file), and the following information is displayed:

- ❑ Total Backscattering Coefficients for each wavelength
- ❑ Backscattering Coefficients for each wavelength.
- ❑ Green Sensitivity
- ❑ Barometric Pressure
- ❑ Sample Temperature
- ❑ Inlet Temperature
- ❑ Relative Humidity

- ❑ Lamp Voltage
- ❑ Lamp Current
- ❑ BNC Input Voltage
- ❑ Status Flags

In the polled data mode you are viewing the current log file and the following information is displayed:

- ❑ Total Backscattering Coefficients for each wavelength
- ❑ Backscattering Coefficients for each wavelength.
- ❑ Sample Temperature
- ❑ Barometeric Pressure
- ❑ BNC Input Voltage
- ❑ Relative Humidity

The buttons and indicators at the bottom of the table allow you to graph the displayed data, copy the data to the clipboard or another file, or print the data.

You can graph, copy, or print all rows of data in the table or select a range of rows. The Start Row and End Row boxes indicate the row of data that will be graphed, copied, or printed.

Use the following procedures to identify the rows to include:

- ❑ Point the cursor to the first row of data and highlight it by clicking the mouse button. Continue holding the mouse button and drag the cursor to the last record you want included.

- ❑ Use the <↑> and <↓> arrows on the Start Row box and End Row box to display the first and last record you want graphed.

Once you have defined the rows of data, select **Graph** or **Copy/Print**.

If you select **Graph**, the Log Data Graph Options display appears (Figure 5-26). Select the appropriate type of graph and press **OK**. Figure 5-27 shows the type of information shown in each graph.

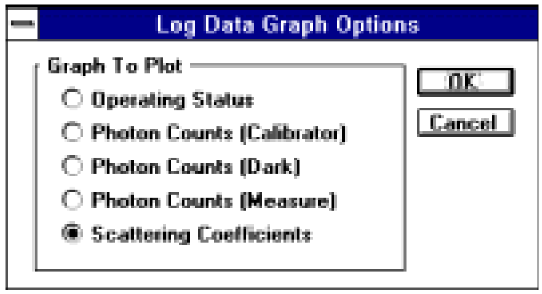


Figure 5-26
Select the Type of Graph from the Log Data Graph Options

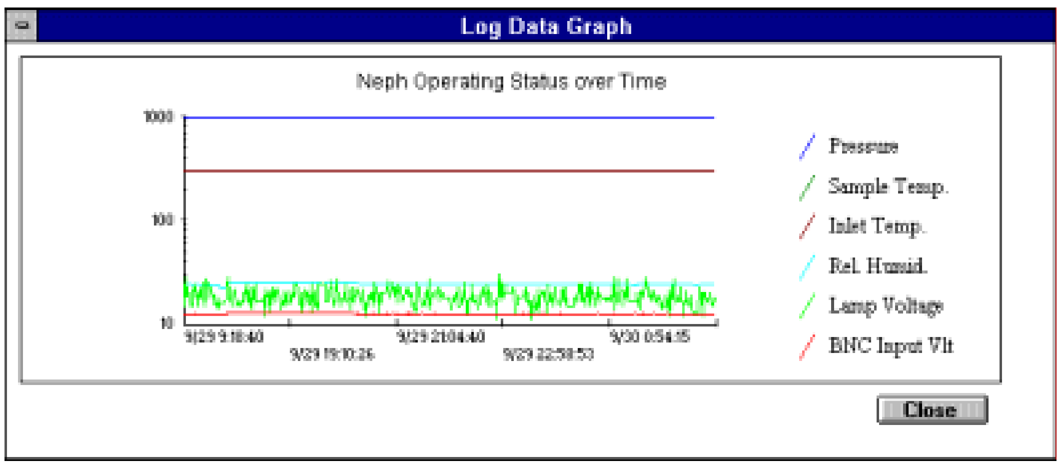


Figure 5-27a
Operating Status Graph

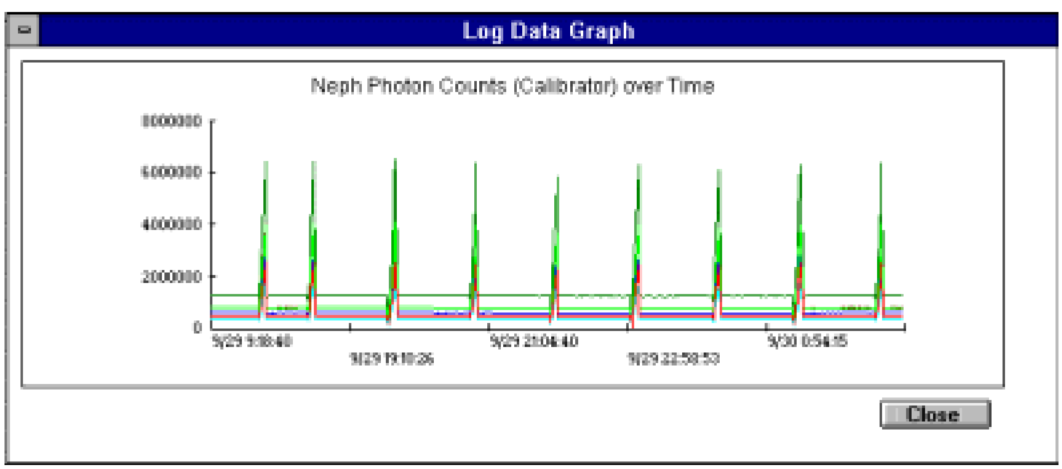


Figure 5-27b
Photon Counts (Calibrator) Graph

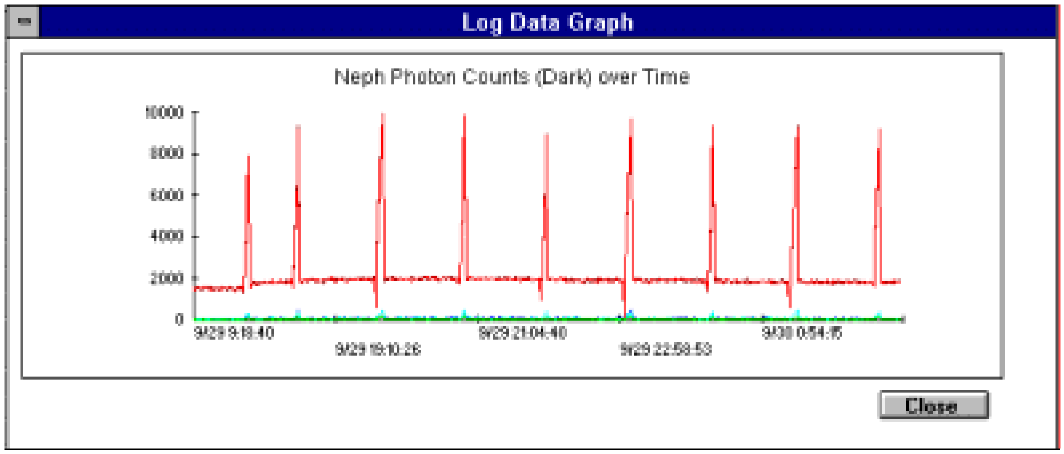


Figure 5-27c
Photon Counts (Dark) Graph

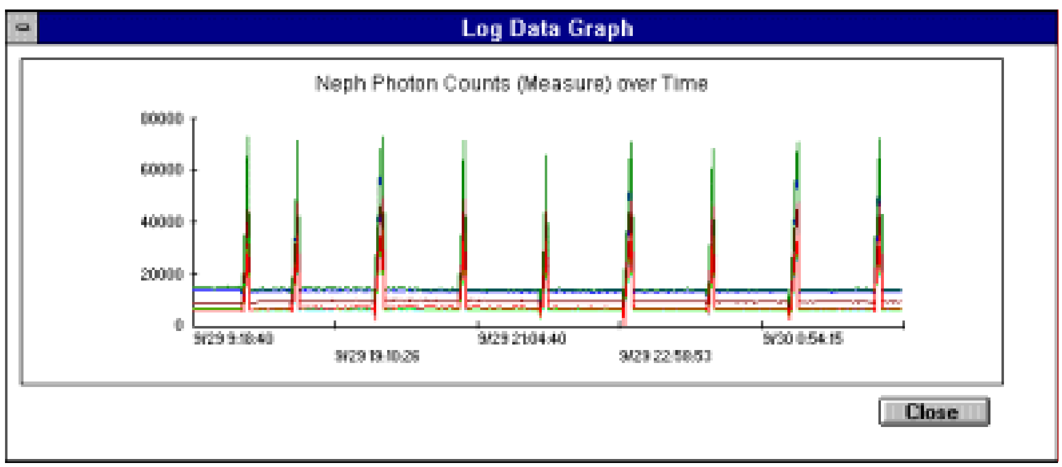


Figure 5-27d
Photon Counts (Measure) Graph

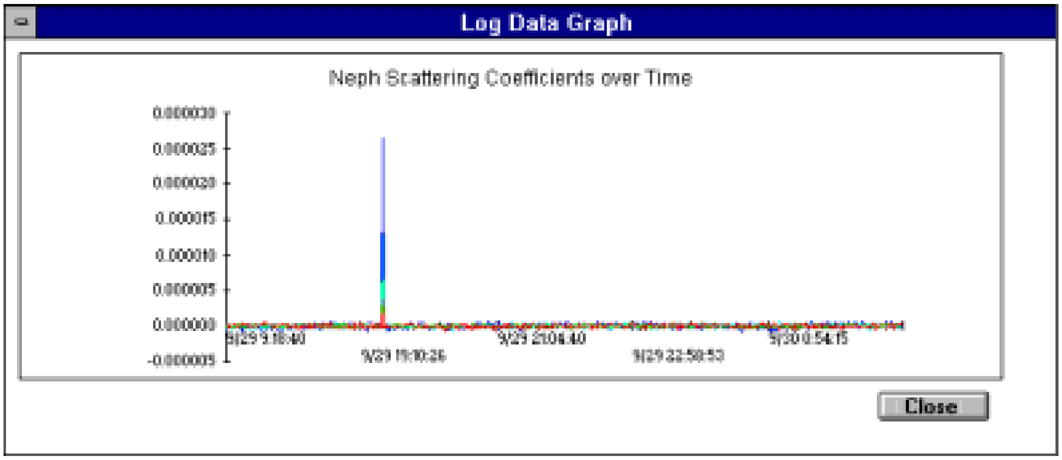


Figure 5-27e
Scattering Coefficients Graph

If you select **Copy/Print**, the Destination dialog box appears (Figure 5-28).

The Destination dialog box lets you select the type of data to be copied (only the record types marked will be copied), the delimiter that will be used between fields, and the destination of the data (clipboard or disk file). If you mark the "Include Header Message," the header information—Row, Date/Time, TotScat...etc.—is copied along with the data.

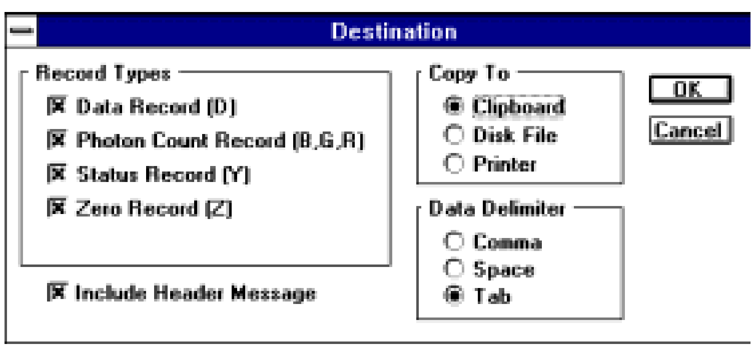


Figure 5-28
The Destination Dialog Box

If you select **Disk File** from the Destination dialog box, a Save Disk File dialog box appears.

If you select **Clipboard**, the data is copied to the Clipboard and can be pasted into another Windows application such as Microsoft Excel.®

If you select **Printer**, the data is sent to the printer.

Using the Run Menu

The Run menu commands let you calibrate the Nephelometer, start data collection, and control the Nephelometer through a terminal (using the serial data commands described in Chapter 6).

Calibration

Choose the Calibration command from the Run menu to calibrate (or recalibrate) the Nephelometer (Figure 5-29).

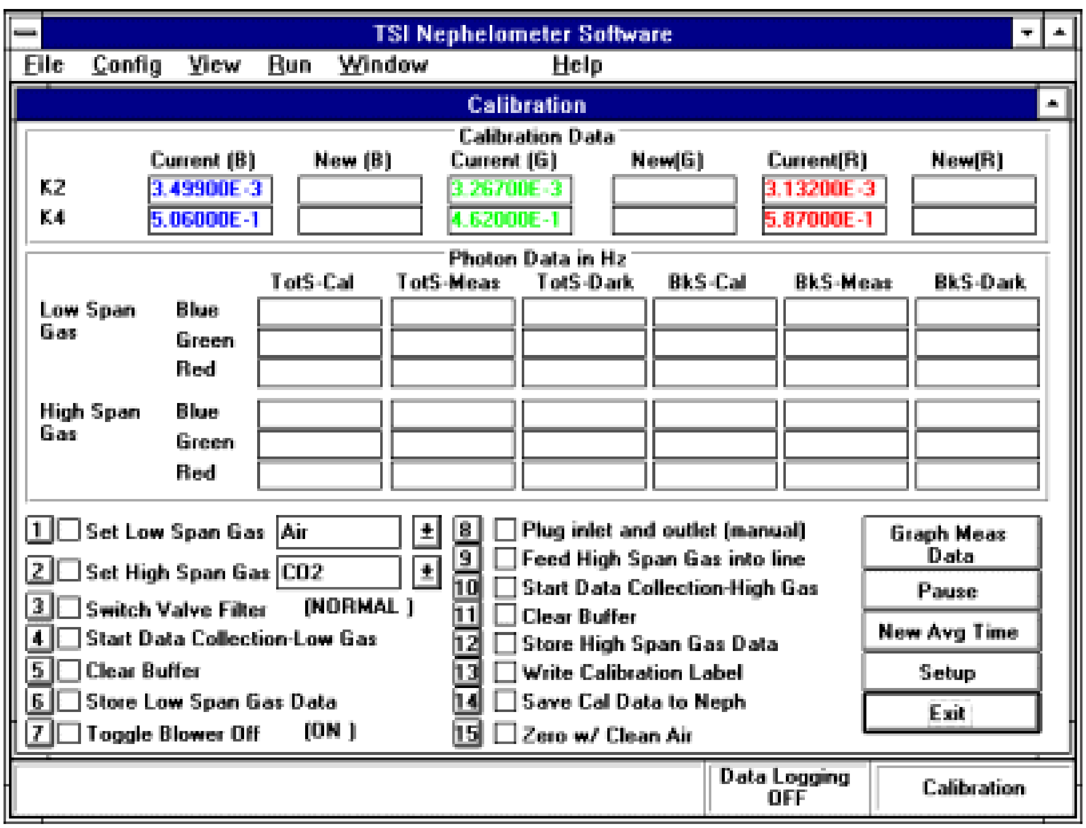


Figure 5-29
The Nephelometer Calibration Data Display

The information displayed on the Calibration Data screen is the same as that described in Chapter 4, “Performing Calibration,” and you use the same procedure for calibration.

- ❑ The top section of the window shows the current calibration settings stored in the Nephelometer and any new calibration settings not yet saved to the Nephelometer.
- ❑ The middle section of the window shows calibration data in frequency (Hz) for low span and high span gas in each wavelength (blue, green, and red). Calibration data is displayed for both total scatter and backscatter modes.
- ❑ The bottom section of the window lists the steps you will use to calibrate the Nephelometer. Perform each step in the order given. As you complete each step, select the button for the appropriate step. A check (√) is displayed next to the button as it is selected or executed.

Calibration allows you to easily calibrate the Nephelometer using two span gases and compare the results between air (low span) and CO_2 (high span).

You should calibrate the Nephelometer before an intensive experiment, calibrate periodically to verify no drift has occurred, calibrate if the reference chopper is dirty or scratched, or if you clean the chopper as part of periodic maintenance.

The Graph Meas Data button lets you observe (graphically) the low span or high span data as calibration is under way. This allows you to see graphically the low span gas purged and replaced by the high span gas.

The Pause button lets you stop data collection during calibration. The button then displays “Continue.” Select **Continue** to restart the data collection.

The New Avg Time button is available on this display to let you set/reset a new averaging time without going to the Nephelometer Setup display. This allows you to select a lower averaging time to have a better response time in viewing the low span gas being purged and replaced by the high span gas.

Note: *If the averaging time is changed to a low number (such as 5 sec) to view purging, be sure to change the averaging time back to a higher number (default is 300 sec). Otherwise, a low averaging time may generate very noisy data and result in bad calibration.*

Before calibration, use the Setup button to set up selected calibration parameters (Figure 5-30). From the Calibration Parameter display you can set up Calibration Points, Calibration Constants and PMT Voltages you want to use and enter a Calibration Label String.

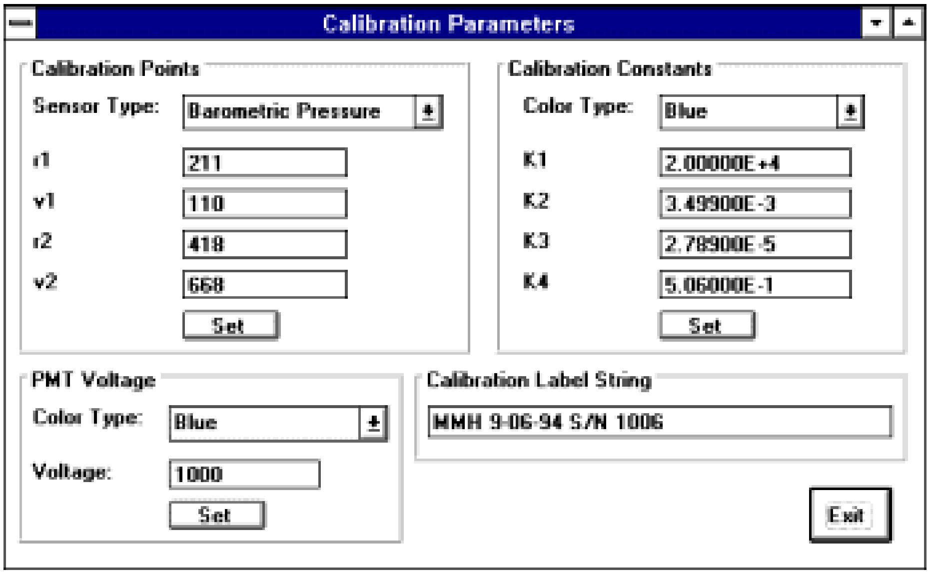


Figure 5-30
Calibration Parameters Setup Screen

Table 5-6 describes each of the parameters you can set. After entering values for each device/parameter type, you must press the Set button for the new values to be stored.

Table 5-6
Calibration Parameters

Parameter	Description
Calibration Points	These parameters let you calibrate the four internal sensors by entering low and high calibration points.
Sensor Type	Select **Barometric Pressure**, **Inlet Temperature**, **Relative Humidity**, or **Sample Temperature**.
r1	Sets the low value of raw A/D converter bits.
v1	Sets the data value (actual value × 10) for low scale calibration point.
r2	Sets the high value of raw A/D converter bits.
v2	Sets the data value (actual value × 10) for high scale calibration point.
Calibration Constants	These parameters let you enter calibration constants for each of the detector wavelengths.
Color Type	Select **Blue**, **Green**, or **Red**
K1	Sets the photon count input pulse width (dead time).
K2	Sets the total scatter calibration of the reference chopper in units of inverse meters.
K3	Sets the Rayleigh scatter of air at 273 °K and 1013.25 mb.
k4	Sets the backscatter calibration of the reference chopper in units of inverse meters.
PMT Voltage	These parameters set the voltage that drives each photomultiplier tube.
Color Type	Select **Blue**, **Green**, or **Red**.
Voltage	Sets the voltage level applied to the photomultiplier (0-1200).
Calibration Label String	Enter text to describe the calibration parameters, for example: Last Calibration 12/25/94. Up to 80 characters.

Select the **Exit** button when you are finished with the Calibration Parameters display.

Hardware Setup

Set up the gas before begin you begin calibration. Gas should be approximately room temperature as it reaches the Nephelometer. One way to ensure this is to use a 6- to 9-meter (20- to 30-foot) length of 6-mm (¼-in.) diameter tubing from the CO_2 tank to the Nephelometer. (The length of the tubing affects the temperature of the CO_2.)

Caution
Use calibration gases only in a well-ventilated area or exhaust the gases outside. Many gases used for calibration can cause asphyxiation if used in a confined area.

Note: *If you are using air as the low span gas and CO_2 as the high span gas, perform the calibration steps in the order given. If you are using a gas other than air as the low span gas (like helium), refer to calibration process given at the end of this procedure.*

Table 5-7
Calibration Procedure

Step	Explanation
1. Set Low Span Gas	Select the low span gas. Air is the default. The following types of gas can be selected from the list menu: air, CO_2, CCl2F2, SF6, R22, He and Ar.
2. Set High Span Gas	Select a high span gas, or a gas with a higher scattering coefficient than the low span gas, CO_2 is the default. The following types of gas can be selected from the list menu: air, CO_2, CCl2F2, SF6, R22, He and Ar.
3. Switch Valve Filter	Select to switch the filtered air valve to the zero (closed) position and to switch the large white HEPA filter in-line with the air inlet. When you select step 3, a blanking time begins. The blanking time is the time it takes the filtered air valve to move to the zero position plus the time it takes to purge the Nephelometer with filtered air. The blanking time is set using the Configure Nephelometer Parameters window or the STB command (see Chapter 6).

(continued)

Table 5-7
Calibration Procedure (*continued*)

Step	**Explanation**
4. Start Data Collection-Low Gas	Select to begin low span gas data collection. After you select step 4, data collection begins after the blanking time described in step 3. The low span gas area of the calibration screen is updated, but not the high span area. If you want to observe the filtered air purge, select New Avg Time to select a smaller averaging time of 5 seconds. The number in the Meas field should fluctuate, not rise and fall. When the Meas field is stable, select New Ave Time to select a 300-second averaging time and proceed to step 5.
5. Clear Buffer	Select to clear the Nephelometer internal buffers of the data collected during step 4. Wait at least 300 seconds, then proceed to step 6.
6. Store Low Span Gas Data	Select to store in the software, the 300-seconds of low span gas data collected in step 5. Selecting step 6 causes the low span gas area of the calibration screen to freeze and low span data is no longer updated.
7. Toggle Blower To Off (OFF)	Select to turn off the blower. High span gas should be regulated at the source. ***Note:*** *Step 7 can also be used to toggle on the blower.*
8. Plug inlet & outlet (manual)	Remove the top cover of the Nephelometer using the procedure in Chapter 8. Plug the aerosol inlet and outlet of the Nephelometer (Figure 4-19).
9. Feed High Span Gas into line (manual)	Remove the tubing from the inlet of the blue DQ filter and connect the tubing from the high span gas to either the inlet tubing or to the inlet block (Figure 4-19). Turn on the gas until the flowrate is approximately 5 lpm. You should feel gas exiting through the DQ filter in the opposite direction of the arrow on the filter. Proceed to step 10.

continued)

Table 5-7
Calibration Procedure (*continued*)

Step	**Explanation**
10. Start Data Collection-High Gas	Select to begin high span gas data collection. The high span gas area of the calibration screen is updated, but not the low span area. If you want to observe the high span gas purge, select New Avg Time to select smaller averaging time of 5 seconds. The number in the Meas field should fluctuate, not rise and fall. When the Meas field is stable with minimal fluctuation, select New Avg Time to select a 300-second averaging time and proceed to step 11.
11. Clear Buffer	Select to clear the Nephelometer internal buffers of the data collected during step 10. Remain at this step for at least 300 seconds, then proceed to step 12.
12. Store High Span Gas Data	Select to store to the software the 300 seconds of high span gas data collected in step 11. Selecting step 12 causes the high span gas area of the calibration screen to freeze and high span data is no longer updated. ***Note:*** *At this time, new calibration constants (K2 and K4) are calculated and the top section of the screen is updated. If the new constants are not satisfactory, you can recalibrate without changing the constants, as long as you do* not *perform step 14.*
13. Write Calibration Label	Select to write an identifying label for the calibration performed. The label can include the serial number of the Nephelometer, the calibration date, the low span and high span gases used, and the initials of the person performing the calibration.

(continued)

Table 5-7
Calibration Procedure (*continued*)

Step	**Explanation**
14. Save Cal Data (K2 & K4) to Neph	If the new K2 and K4 calibration constants are satisfactory, select 14 to write the new K2 and K4 constants to the Nephelometer. After selecting step 14, **1.** Remove the high span gas and the inlet and outlet plugs from the Nephelometer. **2.** Reconnect the DQ filter to the inlet block, with the arrow of the filter pointing *away* from the inlet block. **3.** Replace the top cover of the Nephelometer, attaching the cover with the four screws. **4.** Select 7 to toggle on the blower and to purge the Nephelometer of high span gas. ***Note:*** *To allow the Nephelometer to be completely purged of high span gas, wait at least 600 seconds with the blower on before proceeding to step 15.*
15. Zero w/Clean Air	*Optional*—Select to purge the Nephelometer with clean air and to perform a zero background measurement.

(continued)

Table 5-7
Calibration Procedure (*continued*)

Step	**Explanation**
If you are using a low span gas other than air, perform the calibration steps in this order:	**1.** See step 1. **2.** See step 2. **3.** See step 3. **7.** See step 7. **8.** See step 8. **9.** Remove the tubing from the inlet of the blue DQ filter and connect the tubing from the low span gas to either the inlet tubing or to the inlet block (Figure 4-19). Turn on the gas until the flowrate is approximately 5 lpm. You should feel gas exiting through the DQ filter in the opposite direction of the arrow on the filter. **4.** See step 4. **5.** See step 5. **6.** See step 6. **9.** See step 9. **A.** See step 10. **B.** See step 11. **C.** See step 12. **D.** See step 13. **E.** See step 14. **F.** See step 15.

Select **Exit** when calibration is complete.

Data Collection

Choose the **Data Collection** command from the Run menu to begin collecting data from the Nephelometer.

Note: *You can collect data without logging it to a file. If you start Data Collection without specifying a file in which to log data, no data is logged. To log data, choose Log Data from the File menu and enter the name of the file in which you want to collect data.*

When you select **Data Collection**, four windows are opened and minimized (Figure 5-31). Each window represents one of the following commands of the View menu: Data, Graph, Photon Frequency and Neph State. Refer to the description of each of these commands, above. You can maximize (restore) these icons to view the data being collected or check Nephelometer status.

To verify that data collection is underway, look in the lower right corner of the display. It should indicate Polled.

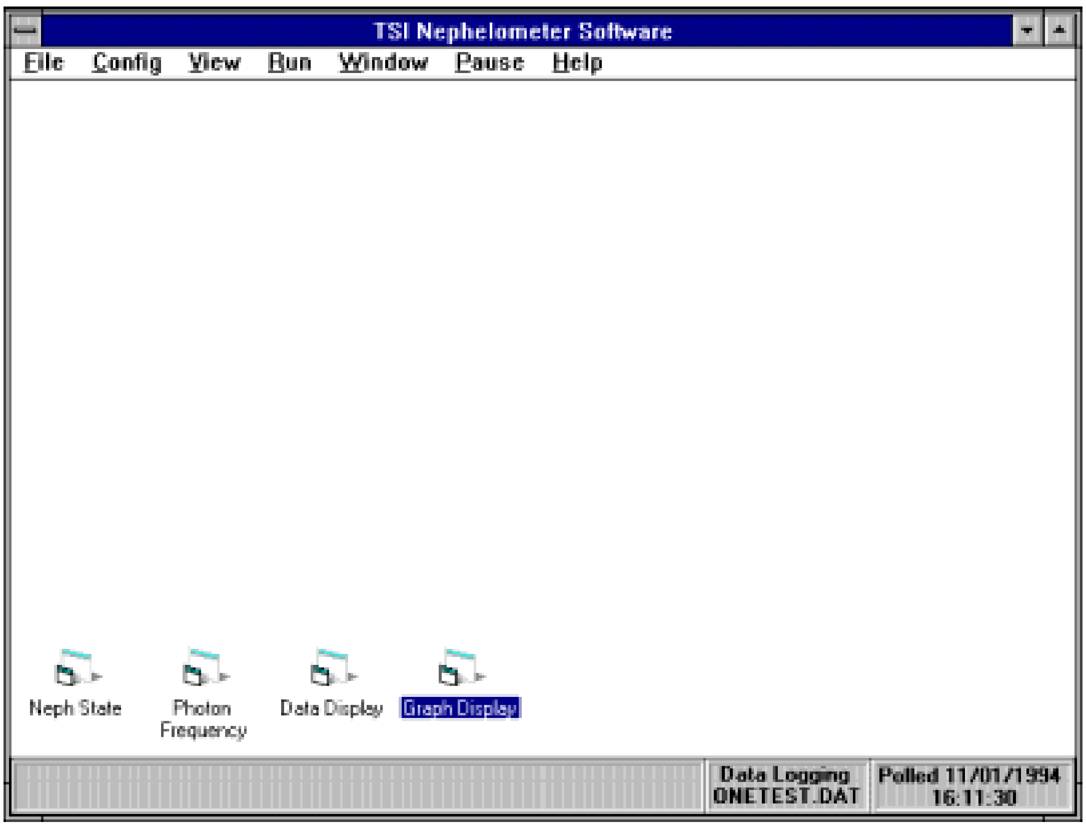


Figure 5-31
Selecting Data Collection from the Run Menu

To stop data collection, select **Data Collection** from the Run menu again.

Data files can become quite large if you have a short averaging time and allow data to accumulate over a long period of time. As a rule or thumb, do not allow files to get much larger than 450 kbytes.

Terminal Mode

Choose the **Terminal Mode** command from the Run menu to issue serial data commands directly to the Nephelometer (Figure 5-32).

You may want to use this method of controlling the Nephelometer during troubleshooting.

The serial data commands are described in Chapter 6. Refer to it for details.

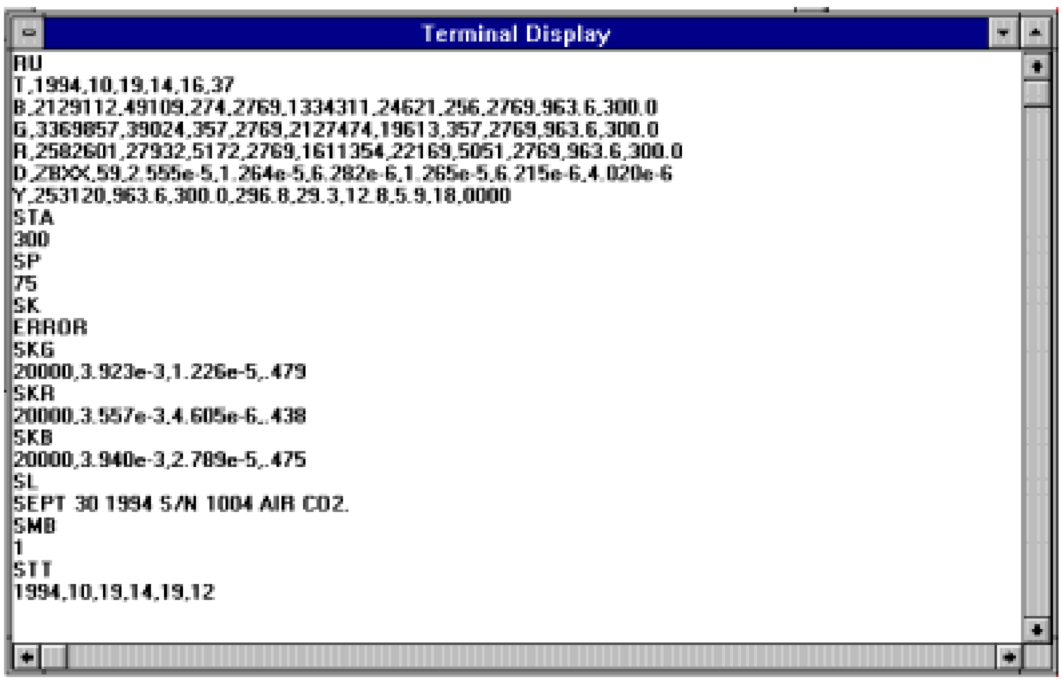


Figure 5-32
Select Terminal Mode to Issue Serial Data Commands to the Nephelometer

To issue a command, type the command and press **<Enter>**. The Nephelometer responds with the information requested, an **OK** acknowledgment, or an **ERROR** acknowledgment.

Using the Window Menu

The Window menu commands help you organize the open windows or arrange icons in open windows.

The commands available under this menu (Cascade, Tile, and Arrange Icons) are standard Windows commands. Please refer to your Windows documentation for complete information.

Using the Pause/Resume Menu

The Pause/Resume menu toggles data collection on and off. After you begin data collection (select the **Data Collection** command from the Run menu), data is collected from the Nephelometer. To stop data collection temporarily without quitting data collection, select **Data Collection** from the Pause menu.

When you select to pause, the menu name changes to "Resume," so when you want to start collecting data again, select **Data Collection** from the Resume menu. Data collection then continues and data is logged to the same log file as before.

Using the Help Menu

The Help menu commands provide access to the program help database. This help function is patterned after Windows Help, so if you are familiar with Help in Windows, you should find this function easy to use. If you are unfamiliar with Windows Help, review your Windows documentation.

Help is context sensitive. If you select Help anywhere in the program, you will find help for the area you are currently using. For example, if you press **<F1>,** while you are in the Terminal screen, the Help screen that details the serial data commands will appear.

Contents

Choose the Contents command from the Help menu to view the contents of online help (Figure 5-33). To select the relevant help topic, click on the keyword. You can select any word or group of words that are underlined (in green color).

***Note**: You can open help contents anytime by pressing the <**F1**> key.*

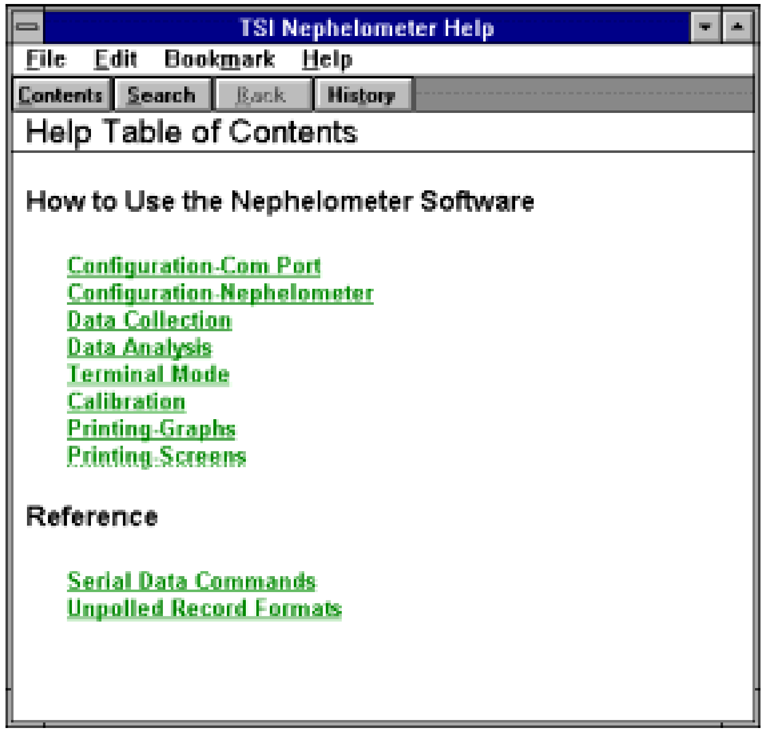


Figure 5-33
The Help Contents Display Provides a List of Help Topics

About

Choose the **About** command from the Help menu to display the version level and copyright notice for this Windows-based Nephelometer program (Figure 5-34).

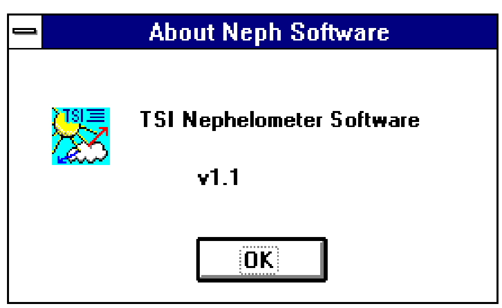


Figure 5-34
About Shows the Current Version of Your Software and the Copyright Notice

CHAPTER 6

Using Serial Data Commands

This chapter contains information you need if you are writing your own software for a computer or data acquisition system. The main sections are:

- Pin connectors
- Baud rate
- Parity
- Command definitions, syntax and examples, as well as input and troubleshooting directions.

Note: *If you are using the software that TSI provides, refer to Chapter 4, "Using Nephelometer Software."*

Pin Connectors

The Nephelometer has a single 9-pin, D-subminiature connector port on the back panel labeled COM PORT (Figure 6-1). This communication port is configured at the factory to work with RS-232 type devices. Table 6-1 gives the signal connections.

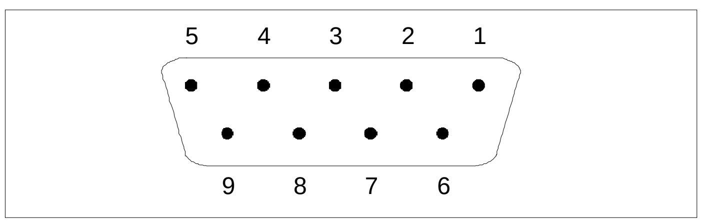


Figure 6-1
COM PORT Pin Designations

Table 6-1
Signal Connections for RS-232 Configurations

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

Baud Rate

The baud-rate setting is the rate of communication in terms of bits per second (baud).The Nephelometer uses a baud rate setting of 9600. For proper communications, make sure that all software used with the instrument is also set at this rate.

Parity (8-Bits Even)

Parity is the additional bit that accompanies the seven data bits to confirm that they are transmitted correctly. It is set so that the number of "1" bits (high) in a transmitted character is always an even number. The Nephelometer uses even parity as the only setting.

Commands

The Nephelometer uses an ASCII-based communications protocol that utilizes the RS-232 port of a computer to transmit commands in the form of strings.

The four types of commands are:

- Set commands, which set all the operating parameters for the Nephelometer
- Action commands, which control mechanical components of the Nephelometer
- Read (polled) commands, in which the Nephelometer sends data in response to a specific request from the computer
- Unpolled commands, in which the Nephelometer automatically outputs data records at specific intervals.

No line feed characters are transmitted. Either the requested data or an "OK" is returned if the command is understood. The word “ERROR” is returned if the command is not understood or if the command has an invalid parameter.

Table 6-2 gives a quick reference of all the serial commands. Command definitions, syntax, and examples begin after Table 6-2. Directions for inputting commands and troubleshooting commands are given at the end of this section.

Table 6-2
Serial Commands

Set Commands

SA	Set Analog output range **SA***cm,v,b.bbbe-b*
SB	Set the analog output channel **SB***c,t*
SC	Set Calibration points **SC***xr1,v1,r2,v2*
SD	Set Data Delimiter **SD***x*
SK	Set K calibration constants **SK***caaaaa,b.bbbe-b,c.ccce-c,ddde-d*
SL	Set calibration Label string
SMB	Set Mode for Backscatter shutter **SMB**z
SMZ	Set Mode for autoZero baseline measurement **SMZ***v*
SP	Set lamp Power **SP***www*
STA	Set Time for Averaging **STA***tttt*
STB	Set Time to Blank valve **STB***ttt*
STP	Set autozero Period **STP***tttt*
STT	Set Time and date **STT***yyyy,mm,dd,hh,nn,ss*
STZ	Set Time for autoZero measurement **STZ***tttt*
SV	Set Voltage on the photomultiplier tube **SV***cbbb*
SX	Set eXternal host analog value **SX***vvv*
SZ	Set Zero baseline (background) **SZ***cx.xxxe-x,y.yyye-y,r.rrre-r*

Action Commands

B	Blower control **B***xxx*
F	Fan control **F***c*
H	Heater control **H***c*
L	Lamp control **L***c*
PD	Power Down
PU	Power Up
V	Valve position **V***c*
Z	Zero command

Read (Polled) Commands

RA	Read raw Analog bit values
RB	Read Barometric pressure
RD	Read scatter Data
RF	Read status Flags
RI	Read Inlet temperature
RL	Read Lamp voltage and current
RN	Read Noise (sensitivity) level
RO	Read accumulated On time of Nephelometer
RP	Read all Photon counts (for blue, green, and red)
RPG	Read Photon counts for Green
RR	Read Relative Humidity
RS	Read Sample temperature
RT	Read Time and date
RU	Read all enabled Unpolled records
RV	Read firmware Version
RX	Read auXiliary PROGRAMMABLE I/O input port
RY	Read AuxiliarY data record
RZ	Read Zero background data record

Unpolled Commands

UB	Unpolled operation Begins
UD	Unpolled Data record
UE	Unpolled mode Ends
UP	Unpolled Photon counts **UP***n*
UT	Unpolled Time and date
UY	Unpolled AuxiliarY status data record
UZ	Unpolled Zero background data record

Set Commands

Set commands allow you to set up operating parameters for the Nephelometer. If a set command is sent with no parameter, the current parameter is echoed.

***Note**: Some of the commands directly affect or are affected by other commands. Refer to other commands where indicated.*

SA **see also SB SX RX**	Set Analog output range SA sets the range scales of the PROGRAMMABLE I/O (BNC) port. Ranges may be set for relative humidity, barometric pressure, sample and inlet temperatures, and scattering values. **SA***cm,v,b.bbbe-b* where: *c* = analog output R for relative humidity P for barometric pressure T for sample and inlet temperatures S for scattering *m* = data value represented by zero (0) volts output For R, the integer relative humidity in percent (0 - 99) For P, the integer pressure in mbar (0–1199) For T, the integer temperature in K (0–399) For S, the absolute value of the scattering coefficient exponent (integer 4–10). All scattering channels share the same range. *v* = data value represented by full scale output (BNC = 5 volts) For R, the integer relative humidity in percent (1 - 100) For P, the integer pressure in mbar (1–1200) For T, the integer temperature in K (1–400) For S, the integer number of volts per decade of scattering (1–10 acceptable) ***Note:*** For SAR, SAP, and SAT commands, *v* must be greater than *m*. *b.bbbe-b* = offset value added to the scattering data so that negative scattering values are allowed (0.000e-11 to 9.999e-3). This parameter is only used with the SAS command.

(continued on next page)

(continued)

SA	**Examples**
	To set the barometric pressure output to 0.0 volts at zero (0) pressure, and 5.0 volts (BNC) at 1200 mb pressure:
	`SAP0,2400`
	To set the sample temperature output to 0.0 volts at 220 K, and 5.0 volts BNC at 320 K:
	`SAT220,320`
	To set the scattering outputs range to 0.0 volts at $10^{-7}m^{-1}$, and to 5.0 volts analog at $10^{-2}m^{-1}$ (offset by $1.0e\text{-}7m^{-1}$):
	`SAS7,2,1.00e-7`

SB **see also** **SA** **SX** **RX**	Set the analog output channel SB maps an analog data type to a hardware output on the PROGRAMMABLE I/O (BNC) connector. **SB***c*,*t* where: *c* = analog channel number 0 = PROGRAMMABLE I/O port *t* = analog data type 0 = external host analog value (set by the SX command) 1 = Barometric pressure 2 = Sample temperature 3 = Blue σsp 4 = Green σsp 5 = Red σsp 6 = Blue σbsp 7 = Green σbsp 8 = Red σbsp 9 = Relative humidity 10 = Inlet temperature

(continued on next page)

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SB	The following is the factory default configuration:
	
	Channel — Type
	0 — 9 (Relative humidity)
	
	Examples
	To make channel 0 computer controlled:
	`SB0,0`
	Note: *T*he SX command automatically achieves the same results as SB0,0.
	
	To assign Barometric Pressure to channel 0:
	`SB0,1`
	
	To echo the channel 1 assignment:
	`SB1`

continued on next page

SC **see also** **RA** **RB** **RI** **RR** **RS**	Set Calibration points SC allows you to calibrate the four internal sensors by entering low and high calibration points. **SC***xr1,v1,r2,v2,*

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SC	**Examples**
	To set the inlet temperature calibration at 0 bits to 0 K and at 38991 bits to 297.9 K:
	`SCI0,0,38991,2979`
	To set the barometric pressure calibration at 15359 bits to 126.6 mb, and at 55291 bits to 994.4 mb:
	`SCP15359,1266,55291,9944`
	To set the relative humidity calibration at 250 bits to 12.0% and at 645 bits to 96.8%:
	`SCR250,120,645,968`
	To set the sample temperature calibration at 0 bits to 0 °, and at 39175 bits to 297.9 °:
	`SCS0,0,39175,2979`
	To echo the current inlet temperature calibration:
	`SCI`

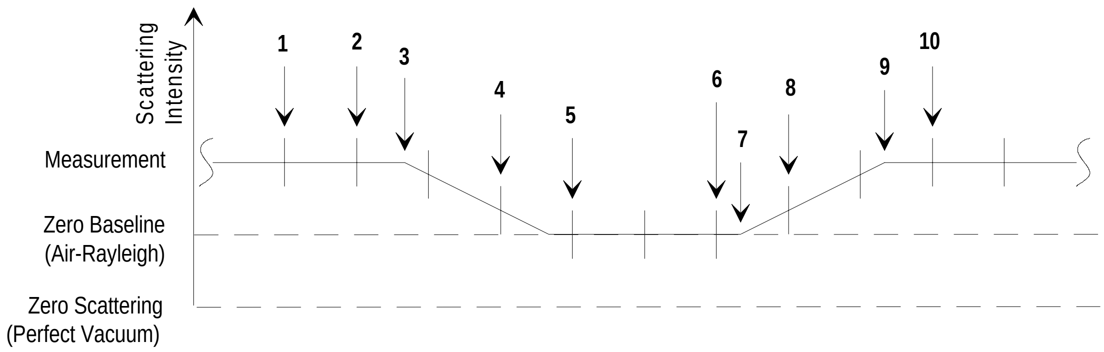
SD	Set Data Delimiter SD sets the character used to delimit data in the output responses. **SD***x*

SK	Set K calibration constants SK allows you to enter calibration constants for each of the detection colors (blue, green, and red). **SK***caaaaa,b.bbbe-b,c.ccce-c,ddde-d*

SL	Set calibration Label string
	
	SL enters an ASCII calibration string into the Nephelometer, where the string is up to 80 characters terminated with a carriage return.
	
	Examples
	To enter the string "Last calibration 12/25/93" :
	`SLLast Calibration 12/25/93`
	
	To echo the calibration string:
	`SL`

SMB	Set Mode for Backscatter shutter
	
	SMBz
	where:
	z = backscatter mode (0 or 1)
	0 sets the Nephelometer to measure only in total scatter mode, where the backscatter shutter is parked in total scatter position.
	1 enables operation of the backscatter shutter, where both total scatter and backscatter are measured.
	
	Examples
	To measure only the total scatter:
	`SMB0`
	
	To enable the backscatter shutter, measuring total scatter and backscatter:
	`SMB1`
	
	To echo the backscatter mode:
	`SMB`

SMZ
 	
see also STB STP STZ SZ V Z
	Set Mode for autoZero baseline measurement
	
	SMZ sets the method used to zero baseline drift using filtered air. See Figures 6-2 and 6-3.
	***Note**: The duration of zero is set by the STZ command.*
	
	SMZ*v*
	where:
	v = autozero mode (0 to 24)
	0 = manual mode where a zeroing of the baseline only occurs when a Z command is given.
	1 = normal mode where an autozero is performed at intervals set by the STP command.
	2 - 24 = air-chop mode, which is similar to normal mode (1), except that the last "*v*" measured autozero baselines are averaged together.
	
	Examples
	To set the autozero mode to air-chop, with a baseline zero value based on the average of the last twelve readings:
	`SMZ12`
	
	To echo the autozero mode:
	`SMZ`



1-2 Nephelometer responses in unpolled mode are sent at the rate set by the averaging time (STA).
2 Unpolled response of data taken between times 1 and 2.
3 Beginning of zero baseline measurement cycle. Measurement data is suspended and valve is rotated to filtered air position to begin purging the Nephelometer.
4 Unpolled report containing data accumulated during the purge time. This data is taken during the transition from normal measurement to clean filtered air and can be discarded.
5 Zero baseline measurement begins. Transition data is cleared and filtered air data is accumulated.
6 Last unpolled report of accumulated data taken during the filtered air measurement.
7 Zero baseline measurement is stopped and the valve is rotated to normal measurement position. The value is stored internally and used for air-Rayleigh subtraction on subsequent measurements.
8 Unpolled report of current (or air-chopped sum) zero baseline value.
9 Normal measurement is reactivated. When operating in air-chop mode, the zero baseline value used is the average of the last measurement and any previous measurements as set by the SMZ command.
10 Unpolled report of measured data. This report contains the data between times 2 and 3 and times 9 and 10.

Figure 6-2
Timelines for Data Measurement

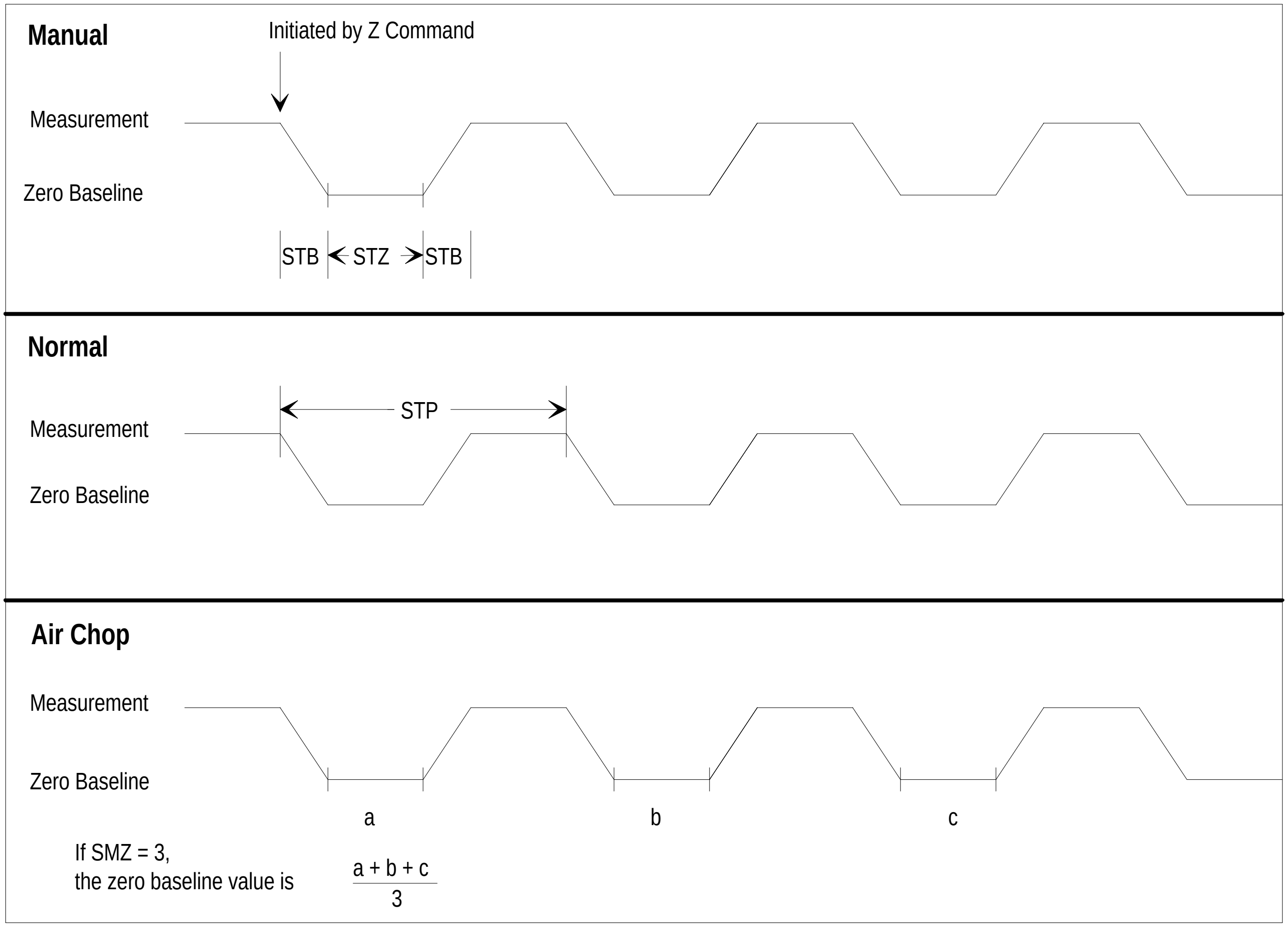


Figure 6-3
Comparison of Manual, Normal, and Air Chop Modes

SP **see also** **F** **L**	<u>S</u>et lamp <u>P</u>ower SP sets the input power of the lamp. **SP***www* where: *www* = watts (0 to 150) **Examples** To set the input lamp power to 75 watts: SP75 To echo the lamp power setting: SP

STA

Set Time for Averaging

STA sets the running average length, in seconds, over which the sample is measured. STA also affects the time between unpolled reports. See Figure 6-2.

STA*tttt*
where:
tttt = averaging time (1 - 9960 seconds)

Internally, the Nephelometer uses a sliding average called "boxcar," where the latest value bumps the earliest value from the average. Up to 300 values can be stored in each boxcar. The following shows averaging time versus boxcar size:

Averaging Time	Boxcar Size
1 to 300 seconds	1 second
302 to 600 seconds	2 seconds
603 to 900 seconds	3 seconds
906 to 1800 seconds	6 seconds
1810 to 3000 seconds	10 seconds
3020 to 6000 seconds	20 seconds
6030 to 9000 seconds	30 seconds
9060 to 9960 seconds	60 seconds

Note: *Averaging time entered must be an integer multiple of the boxcar size for the range in which the averaging time falls. If not, the Nephelometer will use the next smaller valid averaging time.*

Read commands RD and RP report new data only as it changes in the running average. Using the information above, if the averaging time is set to 3600 seconds, the RD and RP will reflect a change every 20 seconds. The analog outputs are also updated once each boxcar.

Examples

To set the averaging time to 60 seconds:

```
STA60
```

To echo the averaging time:

```
STA
```

STB see also SMZ STP STZ SZ V Z	Set Time to Blank valve
	
	STB sets the blanking time, in seconds, when the valve is switching. This includes the turning time of the valve as well as the purge time of the Nephelometer. During the STB interval, no data is taken. See Figures 6-2 and 6-3.
	
	STB*ttt*
	where:
	ttt = blanking time (5 - 999 seconds)
	Note: *The STB value must be less than (STP - STZ)/2*
	
	Examples
	To set the blanking time to 30 seconds:
	`STB30`
	
	To echo the blanking time:
	`STB`

STP see also SMZ STB STZ SZ V Z	Set autozero Period
	
	STP sets the time, in seconds, between autozeros. The value set with this command is only used if the Nephelometer autozero mode is normal or air-chop (SMZ > 0). See Figures 6-2 and 6-3.
	
	STP*tttt*
	where:
	tttt = the range (10 - 9999 seconds)
	
	Note: *The STP value must be greater than 2(STB) + STZ.*
	
	Examples
	To set the time between autozeros to 3600 seconds:
	`STP3600`
	
	To echo the autozero period:
	`STP`

STT	Set Time and date
	
	STT sets the time and date of the Nephelometer's internal clock.
	
	STT*yyyy,mm,dd,hh,nn,ss*
	where:
	yyyy is the year (1994 - 2999)
	mm is the month (1 - 12)
	dd is the date (1 - 31)
	hh is the hour (0 - 23)
	nn is the minute (0 - 59)
	ss is the second (0 - 59)
	
	Examples
	To set the internal clock to December 7, 1994, 10 pm.:
	`STT1994,12,7,22,0,0`
	
	To echo the internal clock time and date:
	`STT`

STZ
 	
see also SMZ STB STP SZ V Z
	Set Time for autoZero measurement
	
	STZ sets the time, in seconds, the Nephelometer spends measuring filtered air during a zero baseline measurement. See Figures 7-1 and 7-2.
	
	STZ*tttt*
	where:
	tttt = the range (1 - 9999 seconds)
	
	Note: *The STZ value must be less than STP - 2(STB).*
	
	Examples
	To set the zero baseline measurement to 300 seconds:
	`STZ300`
	
	To echo the zero baseline measurement:
	`STZ`

SV	Set Voltage on the photomultiplier tube
	
	SV sets the voltage that drives the photomultiplier tube (PMT). This voltage has an effect on the PMT's gain and noise level.
	
	SV*cbbb*
	where:
	c = color channel
	B= blue
	R = red
	G = green
	bbb = voltage level applied to the PMT (0 -1200)
	
	Examples
	To set the blue channel PMT to 850 volts:
	`SVB850`
	
	To echo the red channel PMT voltage:
	`SVR`

SX
 	
see also SA SB RX
	Set eXternal host analog value
	
	SX sets the external host analog value to a specified voltage. This value appears on the PROGRAMMABLE I/O hardware output (factory default) and can be configured with the SB command.
	
	SX*vvv*
	where:
	vvv = output voltage in millivolts (0 - 5000 mv for Programmable I/O (BNC)
	
	Examples
	To set the external host analog value to 2.50 volts:
	`SX2500`
	
	To set the external host analog value to 5.0 volts:
	`SX5000`
	
	Note: *Auxiliary Programmable I/O will read maximum (5 volts).*
	
	To echo the auxiliary PROGRAMMABLE I/O output:
	`SX`

SZ **see also** **SMZ** **STB** **STP** **STZ** **V** **Z**	Set Zero baseline (background) SZ allows you to externally set zero baseline (background) values, normally measured during an autozero measurement. SZ also clears previous zero data taken in air-chop mode. In air-chop mode, the supplied values are first in the running average of zero baseline values.

Action Commands

Action commands control mechanical components of the Nephelometer. If you enter an action command without a parameter, the mechanical state is echoed back.

B	Blower control
	
	B*xxx*
	where:
	xxx = value between 0 and 255, 0 turns the blower off; 255 represents full power.
	
	Example
	To set the blower to one-half power:
	`B128`
	
	To echo the blower power:
	`B`

F **see also L SP**	Fan control **F***c* where: *c* = 1 or 0. 1 turns the cooling fan on; 0 turns the cooling fan off. ***Note***: *Turning off the fan also reduces the lamp power to zero.*

H	Heater control **H***c* where: *c* = 1 or 0. 1 activates the heater control. The heater then operates to maintain the sample temperature at or above the inlet temperature. 0 turns the heater control off.

L **see also F SP**	Lamp control **L***c* where: *c* = 1 or 0 1 turns the lamp on to the power set by the SP command; 0 turns the lamp off.

PD	Power Down PD places the Nephelometer in a minimum power ("sleep") mode. When the PD command is given, this sequence occurs: 1. Lamp power off. 2. Heater power off (if on). 3. Chopper and shutter motors stop. 4. Valve switched to filtered air position (zero). 5. After a 5 second delay, fan power off. 6. Blower power off. **PD**

PU	Power Up PU is the only command accepted after a PD (Power Down) command. When the PU command is given, the hardware is restored to the operating state present before the PD command was given. When the PU command is given, this sequence occurs: 1. Blower power on 2. Fan power on. 3. Lamp power on. 4. Chopper and shutter motors on. 5. Heater power on (if on before the PD command). 6. Ten seconds after the PU command is given and after the heater has stabilized, the Nephelometer begins an autozero measurement and resumes operation in normal mode. If the Nephelometer was in manual mode before the PD command, the valve remains in the filtered air position. **PU**

V **see also SMZ STB STP STZ SZ Z**	<u>V</u>alve position **V***c* where: *c* = N for <u>N</u>ormal position and Z for <u>Z</u>eroing position (filtered air) VN changes the position of the valve to the normal measurement position. VN clears the averaged measured scattering values, but zero scattering values are not adjusted. VZ overrides the autozero mode and the average measured scattering values are cleared. ***Note:*** A "FAULT" message (instead of "ERROR") is returned after the V command if the valve position is not completed within 10 seconds. **Example** To echo the current position of valve NORMAL, ZERO, or FAULT: V

Z **see also SMZ STB STP STZ SZ V**	<u>Z</u>ero command Z causes the Nephelometer to perform a zero baseline measurement. In air-chop mode, the zero baseline measurement is averaged with the previous baseline data as defined in the SMZ command. **Z**

Read Commands (Polled)

Read commands are polled, which means the Nephelometer sends data in response to a specific request from the computer

Note: *Some of the commands directly affect or are affected by other commands. Refer to other commands where indicated.*

RA	Read raw Analog bit values RA allows the reading of pressure, sample temperature, inlet temperature, and relative humidity in analog bit value format. **RA** **Example** **Response** RA 26539,13245,13456,980

RB	Read Barometric pressure (mbar) **RB** **Example** **Response** RB 1013.2

RD	Read scatter Data The response to the RD command is in the Data Record (D). See the "Unpolled Record Formats" section in this chapter. **RD**

RF

Read status Flags

RF returns a four-character hexadecimal value representing the state of the Nephelometer. The values for the sixteen flags are as follows:

Bit Position	0 (Normal)	1(Fault)
0000 0000 0000 0001	Lamp at power	Not within 10% of SP setting
0000 0000 0000 0010	Valve Ok	Valve fault
0000 0000 0000 0100	Chopper Ok	Chopper fault
0000 0000 0000 1000	Shutter Ok	Shutter fault
0000 0000 0001 0000	Heater Ok or inactive	Heater active but not stabilized
0000 0000 0010 0000	Pressure within range	Pressure out of range
0000 0000 0100 0000	Sample Temp within range	Sample Temp out of range
0000 0000 1000 0000	Inlet temp within range	Inlet temp out of range
0000 0001 0000 0000	RH within range	RH out of range
0000 0010 0000 0000	Unused	
0000 0100 0000 0000	Unused	
0000 1000 0000 0000	Unused	
0001 0000 0000 0000	Unused	
0010 0000 0000 0000	Unused	
0100 0000 0000 0000	Unused	
1000 0000 0000 0000	Unused	

RF

Examples	**Responses**
RF	0002 indicates all flags are normal and the valve is in an unknown position.
RF	0080 indicates the measured inlet temperature is out of range, possibly due to improper calibration or sensor failure.

RI

Read Inlet temperature (K)

RI

Example	**Response**
RI	295.4

RL

Read Lamp voltage and current (volts and amps)

RL

Example	**Response**
RL	12.5,4.1 indicates the lamp is operating at 12.5 volts and 4.1 amps.

RN **see also SP STA SV**	Read Noise (sensitivity) levels Read noise levels based on photon counting statistics. This command requires clean filtered air and varies with the lamp power (SP), averaging time (STA), and PMT voltages (SV). **RN** **Example** **Response** RN ????.

RO	Read accumulated On time of Nephelometer (not including power down time) **RO** **Example** **Response** RO 3425,48 indicates the Nephelometer has been on for 3425 hours and 48 minutes.

RP	Read all Photon counts (for blue, green, and red) **RP** **Examples** **Response** RP B, G, or R photon count records. See the Photon Count Records in the "Unpolled Record Formats" section of this chapter.

RPG	Read Photon counts for Green (only) **RPG** **Example** **Response** RPG See the Photon Count Records in the "Unpolled Record Formats" section of this chapter.

RR	Read Relative Humidity (0 - 99.9%) **RR** **Example** **Response** RR 15.6

RS	Read Sample temperature (K) **RS** **Example** **Response** RS 298.0
RT	Read Time and date **RT** **Example** **Response** RT See the Time Record (T) in the "Unpolled Record Formats" section of this chapter.
RU	Read all enabled Unpolled records **RU** **Example** **Response** RU This command will send all unpolled records that have been enabled with the corresponding unpolled command.
RV	Read firmware Version **RV** **Example** **Response** RV Version 1.3 July 4, 1994
RX **see also** **SA** **SB** **SX**	Read auXiliary PROGRAMMABLE I/O input port (millivolts) **RX** **Example** **Response** RX 2543 (indicating an input voltage of 2.543 volts)
RY	Read AuxiliarY data record **RY** **Example** **Response** RY See the Status Record (Y) in the "Unpolled Record Formats" section of this chapter.

RZ	Read Zero background data record **RZ** **Example** **Response** RZ See the Zero Background Data Record (Z) in the "Unpolled Record Formats" section of this chapter

Unpolled Commands

Use unpolled commands to cause the Nephelometer to automatically output data records at specific intervals. In unpolled mode, 0 disables a record and 1 enables the record. During unpolled operation, records that have been enabled are sent at the end of each averaging time.

Note: *UE is the only command allowed during unpolled operation. All other commands receive a "no response."*

UB	Unpolled operation Begins The only command accepted after UB is UE. **UB**

UD	Unpolled Data record UD0 disables the record; UD1 enables a record to be sent at the end of each averaging time. See Data Record (D) in the "Unpolled Record Formats" section of this chapter.

UE	Unpolled mode Ends UE is the only command allowed during unpolled operation. All other commands receive a "no response." **UE**

UP	Unpolled Photon counts **UP***n* where: *n* = 0, 1, or 3 0 = disabled 1 = sends photon counts for green channel only 3 = sends all three photon count records (blue, green, and red) See Photon Count Records in the "Unpolled Record Formats" section of this chapter.

UT	Unpolled Time and date UT1 enables the T record sent at the end of each averaging time; UT0 disables the record. See Time Record (T) in the "Unpolled Record Formats" section of this chapter.

UY	Unpolled AuxiliarY status data record UY1 enables the record sent at the end of each averaging time; UY0 disables the record. See Auxiliary Status Record (Y) in the "Unpolled Record Formats" section of this chapter.

UZ	Unpolled Zero background data record UZ1 enables sending of the zero background data record one time after the end of a zero background measurement. UZ0 disables sending of the zero background data record. See Zero Background Data Record (Z) in the "Unpolled Record Formats" section of this chapter.

Unpolled Record Formats

The following are examples of unpolled record formats. These records are shown with the data delimiter set to space (SD1). Delimiters other than a space, cause the record to be packed with no added white space.

Time Record (T)

```
T YYYY MM DD HH NN SS
```

where:

T = Time record
YYYY = Year
MM = Month
DD = Day
HH = Hour
NN = Minute
SS = Second

Photon Count Records (B, G, and R)

```
B CCCCCCCCC SSSSSSSSS DDDDDD RRRRR LLLLLLLL MMMMMMMMM NNNNNN VVVVV PPPP.P TTT.T
```

where:

B	=	Photon count record for B , R or G (Blue, Red, or Green)
CCCCCCCCC	=	Photon counts from calibrator (total scatter)
SSSSSSSSS	=	Photon counts from measure (total scatter)
DDDDDD	=	Photon counts from dark
RRRRR	=	Revolutions of chopper for total scatter measurement
LLLLLLLL	=	Photon counts from calibrator(unused backscatter cycle)
MMMMMMMMM	=	Photon counts from measure (backscatter)
NNNNNN	=	Photon counts from dark (backscatter cycle)
VVVVV	=	Revolutions of chopper for backscatter measurement
PPPP.P	=	Pressure in millibar
TTT.T	=	Sample temperature in degrees K

***Notes**: In total scatter only mode L, M and N are set to 0 and RR reflects revolutions of the calibrator.*

It is possible that for averaging times in excess of 1000 seconds, the photon count data will overflow the space delimited fixed format. In this case the format is extended to include the required extra digits.

Data Record (D)

```
D wxyz TTTT +B.BBBe-B +G.GGGe-G +R.RRRe-R +A.AAAe-A +B.BBBe-B +C.CCCe-C
```

where:

D	=	Total scatter data record
w	=	Current mode. N if in normal measurement mode, Z if in Zero mode; B if in blanking mode
x	=	T if in total scatter mode; B if in backscatter mode
y	=	X Currently unused
z	=	X Currently unused
TTTT	=	Time remaining in current state
+B.BBBe-B	=	Scattering coefficient in blue
+G.GGGe-G	=	Scattering coefficient in green
+R.RRRe-R	=	Scattering coefficient in red
+A.AAAe-A	=	Scattering coefficient in blue (backscatter)
+B.BBBe-B	=	Scattering coefficient in green (backscatter)
+C.CCCe-C	=	Scattering coefficient in red (backscatter)

Note: *In normal mode the Rayleigh scattering signal is subtracted to give the scattering coefficient, whereas in zero mode it is not. In blanking mode the scattering coefficients retain their value from the previous mode.*

Auxiliary Status Record (Y)

```
Y 9999999 PPP.P TTT.T III.I RR.R VV.V AA.A BBBB FFFF
```

where:

Y	=	Auxiliary status record
9999999	=	Sensitivity based on green channel (proton frequency)
PPPP.P	=	Barometric pressure (mbar)
TTT.T	=	Sample temperature (degrees K)
III.I	=	Inlet temperature (degrees K)
RR.R	=	Relative humidity (%)
VV.V	=	Lamp voltage
AA.A	=	Lamp current
BBBB	=	BNC input voltage (millivolts)
FFFF	=	Status flags (hex)

Zero Background Data Record (Z)

```
Z +B.BBBe-B +G.GGGe-G +R.RRRe-R +A.AAAe-A +B.BBBe-B +C.CCCe-C
   +D.DDDe-D +E.EEEe-E +F.FFFe-F
```

where:

Z	=	Zero background record
+B.BBBe-B	=	Scattering value from last zero (blue)
+G.GGGe-G	=	Scattering value from last zero (green)
+R.RRRe-R	=	Scattering value from last zero (red)
+A.AAAe-A	=	Scattering value from last zero (blue backscatter)
+B.BBBe-B	=	Scattering value from last zero (green backscatter)
+C.CCCe-C	=	Scattering value from last zero (red backscatter
+D.DDDe-D	=	Rayleigh scattering value from last zero (blue)
+E.EEEe-E	=	Rayleigh scattering value from last zero (green))
+F.FFFe-F	=	Rayleigh scattering value from last zero (red)

T, B, G, R, D, Y and Z Records

(Shown in order of data transmitted)

```
T 1994 12 31 23 59 59
B 999999999 999999999 999999 10990 99999999 999999999 999999 10991 1013.7 299.7
G 999999999 999999999 9999999 10990 9999999 999999999 999999 10991 1013.7 299.7
R 999999999 999999999 9999999 10990 9999999 999999999 999999 10991 1013.7 299.7
D NTXX 9999 +1.111e-1 +2.222e-2 +3.333e-3 +4.444e-4 +5.555e-5 +6.666e-6
Y 9999999 222.2 333.3 444.4 55.5 66.6 77.7 8888 9999
Z +1.111e-1 +2.222e-2 +3.333e-3 +4.444e-4 +5.555e-5 +6.666e-6 +7.777e-7 +8.888e-8
       +9.999e-9
```

How to Input Commands and Troubleshoot the Results

Use the following information as a guide to inputting software commands and for troubleshooting possible problems.

Input Guidelines

- ❑ Input all alpha characters as capital letters (SMZ, *not* smz).
- ❑ Separate parameters with commas, not spaces.
- ❑ If you are in a command string, use the <Backspace> key to back up and make changes. Do *not* use <arrow> keys.
- ❑ At the end of a command string, press <Enter> to complete the string.

Troubleshooting Input

Use Table 6-3 as a troubleshooting guide.

Table 6-3
Troubleshooting Software Commands

Symptom	Possible Problem	Refer to
"Error" message after pressing <Enter>	• An invalid command; command does not exist. • An invalid parameter, which includes too many parameters or a parameter that is out-of-range. • Incorrect syntax	• Table 6-3??? in this section. • The command showing the range and an example. • "Input Guidelines" in this section.
No response after pressing <Enter>	• In unpolled mode • Serial cable • Incorrect COM port • Incorrect baud rate • RS232 chip on the Nephelometer • Nephelometer is locked up • In power down mode (PD command)	• Use the UE command to exit unpolled mode. Reenter the command if an "OK" is returned. • Check the cable and the cable connection. See Chapter 2, "Unpacking and Setting Up the Hardware." • Check the COM port specified in the software. • Software must be set at 9600 baud. Also check computer hardware. • Contact TSI. Refer to Chapter 9, "Contacting Customer Service." • Remove power from the Nephelometer, then apply power to the instrument. If the problem continues, contact TSI. • Enter the PU (power up) command to start the Nephelometer. Reenter the command if an "OK" is returned.

CHAPTER 7
Theory of Operation

This chapter contains the theory of operation for the Model 3550/3560 Series Integrating Nephelometer with these main sections:

- History
- Theory of Integration
- Signal Processing
- Detection Optics
- Calibration
- Theory of Wavelength

History

> ***Note:*** Background information for this section has been taken from the paper: "Three-Wavelength Nephelometer Suitable for Aircraft Measurement of Background Aerosol Scattering Coefficient," Bodhaine, Ahlquist, & Schnell, *Atmospheric Environment*, Vol 25A, No 10, pp 2268-2276, 1991.

The integrating Nephelometer has been used extensively for measurement of the aerosol light scattering/extinction coefficient (σ_{sp}) and visual range in ground-based and airborne applications. The technique of nephelometery was begun by Beuttell and Brewer in 1949, refined by Crosby and Koerber in 1963, and improved by Charlson and Ahlquist in 1967. Multiwavelength nephelometers, predecessors of the TSI nephelometers, were developed beginning in 1969. The high-sensitivity integrating nephelometer (Figure 7-1) was standardized and commercialized by TSI in 1993 by incorporating design improvements and technology advances developed over more than two decades.

The integrating nephelometer is a high-sensitivity device capable of detecting the scattering properties of aerosol particles. The nephelometer detects by measuring the light scattered by the aerosol and then subtracting light scattered by the walls of the measurement chamber, light scattered by the gas, and electronic noise inherent in the detectors.

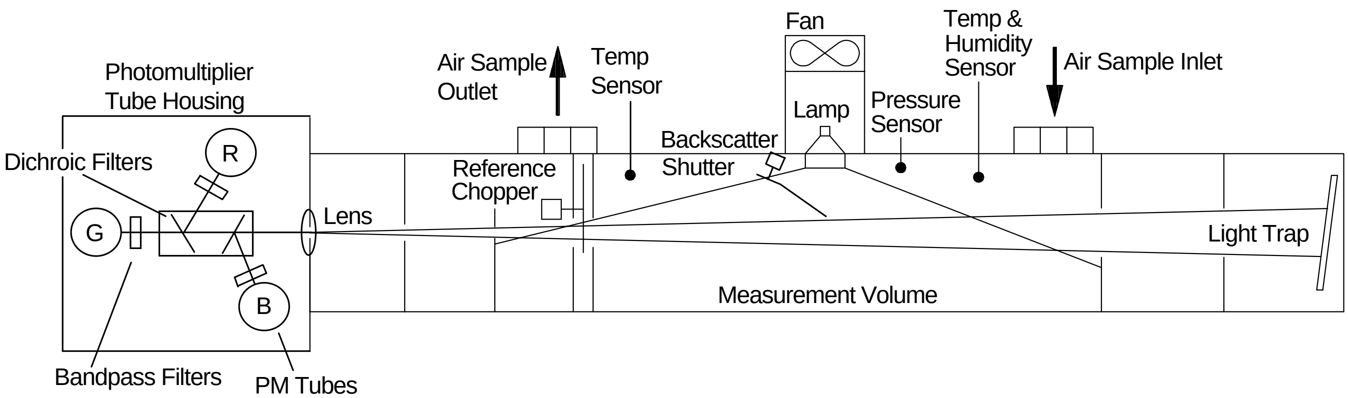


Figure 7-1
Nephelometer Schematic

The three-color detection version of the TSI nephelometers detects scattered light intensity at three wavelengths. Normally the scattered light is integrated over an angular range of 7–170° from the forward direction. But with the addition of the backscatter shutter feature to the Nephelometer, this range can be adjusted to either 7–170° or 90–170° to give total scatter and backscatter signals. This provides additional useful information about the particle scattering behavior.

Construction

The integrating nephelometer is constructed primarily of aluminum parts for purposes of rigidity, ruggedness, and weight. The main body of the nephelometer consists of 10 cm diameter thin walled aluminum tubing, which is approximately 90 cm long. Aperture plates are set along the axis of the tube, held and spaced by 8 cm diameter tubing. Receiving optics are located at one end of the main tube with a light trap located at the other end to provide a very dark reference against which to view the light scattered by particles and gas.

A 75 watt quartz-halogen lamp, with a built-in elliptical reflector, provides illumination for the aerosol. The reflector focuses the light onto one end of an optical pipe where the light is carried into the internal cavity of the instrument. The optical pipe is used to thermally isolate the lamp from the sensing volume.

The output end of the optical light pipe is an opal glass diffuser that acts as a cosine (Lambertian) light source. Within the measuring volume, the first aperture on the detection side of the instrument limits the light integration to angles greater than 7°, measured from the horizontal at the opal glass. On the other side, a shadow plate limits the light to angles less than 170°. The measurement volume is defined by the intersection of this light with a viewing volume cone defined by the second and fourth aperture plates on the detection side of the instrument. The fourth aperture plate incorporates a lens to collimate the light scattered by aerosol particles so that it can be split into separate wavelengths.

The nephelometer uses a reference chopper to calibrate scattered signals. The chopper makes a full rotation 23 times per second. The chopper consists of three separate areas labeled: signal, dark, and calibrate (Figure 7-2).

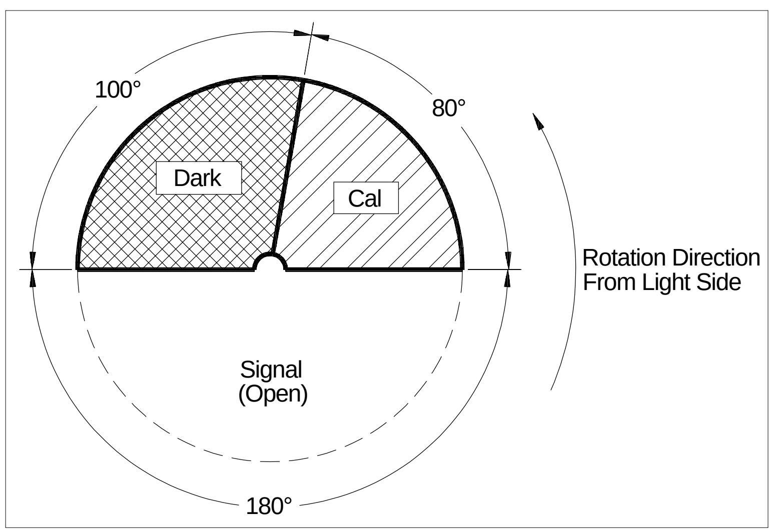


Figure 7-2
Reference Chopper Zones

The signal section covers 180° and simply allows all light to pass through unaltered. The dark section covers 100° and is a very black background that blocks all light. This section provides a measurement of the photomultiplier tube (PMT) background noise. The third section, calibrate, covers 80°. The light source directly illuminates this section providing a measure of lamp stability over time. To reduce the lamp intensity to a level that will not saturate the photomultiplier tubes, the calibrate section incorporates a neutral density filter that blocks approximately 99.9% of the incident light.

To subtract the light scattered by the gas portion of the aerosol, a high-efficiency particulate air (HEPA) filter is switched periodically in line with the inlet. This allows compensation for changes in the background scattering of the nephelometer, and in gas composition that will affect Rayleigh scattering of air molecules with time. The HEPA filter is switched into line using an automated valve, activated by a gear motor and positioned, using an optical position sensor. When the HEPA filter is not in line with the inlet, a small amount of filtered air leaks through the light trap to keep the apertures and light trap free of particles. A smaller HEPA filter allows a small amount of clean air to leak into the sensor end of the chamber between the lens and second aperture. This keeps the lens clean and confines the aerosol light scatter to the measurement volume only.

Theory of Integration

The property of interest in using the integrating nephelometer is usually the extinction of light over a short distance. Light extinction is caused by the properties of both light absorption and light scattering caused by air or other gas and by the particles within the gas. The total extinction coefficient, σ, is the sum of these properties. The effect is generally described by the Beer-Lambert law:

$$I/Io = e^{(-\sigma_{ext}\, x)} \qquad \text{[equation 7-1]}$$

where:

$\sigma_{ext} = \sigma_{scat} + \sigma_{abs} = ln(I/Io)/x$
x = distance in meters (length of light path)
I = intensity of light after distance
Io = intensity of incident light

σ_{scat} and σ_{abs} are called the scattering and absorption coefficients and are described by:

$$\sigma_{scat} = \sigma_{rg} + \sigma_{sp} \quad \text{[equation 7-2]}$$

$$\sigma_{abs} = \sigma_{ag} + \sigma_{ap} \quad \text{[equation 7-3]}$$

where:
σ_{rg} = term for Rayleigh scattering
σ_{sp} = term for scattering by particles
σ_{ag} = term for absorption by gases
σ_{ap} = term for absorption by particles

The integrating nephelometer measures the σ_{scat} term and generates the σ_{sp} term by subtracting the σ_{rg} term from σ_{scat} using (equation 7-2).

Since it is often assumed that $\sigma_{sp} \rangle \sigma_{ap}$ or that $\sigma_{sp} \rangle\rangle \sigma_{ap}$ for areas other than those having high concentrations of soot particles, the measure of σ_{sp} often gives a good estimate of the aerosol contribution to σ_{ext}. Also, σ_{ag} is usually negligible.

The basic geometry of the TSI integrating nephelometer was first described by Beuttel and Brewer (1949). Since this geometry integrates the intensity of the scattered light over close to 4π steradians, it gives a good approximation of the scattering component of extinction, σ_{sp}. Figure 7-3 shows a schematic of this geometry which results in the integration of the angular scattering function, $\beta(\phi)$, such that the sensor detects the flux B due to the light source with intensity Io located at a distance y from the detector axis:

$$B = {Io}/{y} \int_{\phi_1}^{\phi_2} \beta(\phi) \sin\phi \, d\phi \quad \text{[equation 7-4]}$$

Since the nephelometer has a Lambert (cosine ϕ) source, and if we make the assumption that $\phi_1 \approx 0$ and that $\phi_1 \approx \pi$, then:

$$B \approx (Io / y) * (\sigma_{scat} / 2\pi) \qquad \text{[equation 7-5]}$$

These equations are derived formally by Middleton (1958) and by Butcher and Charlson (1972).

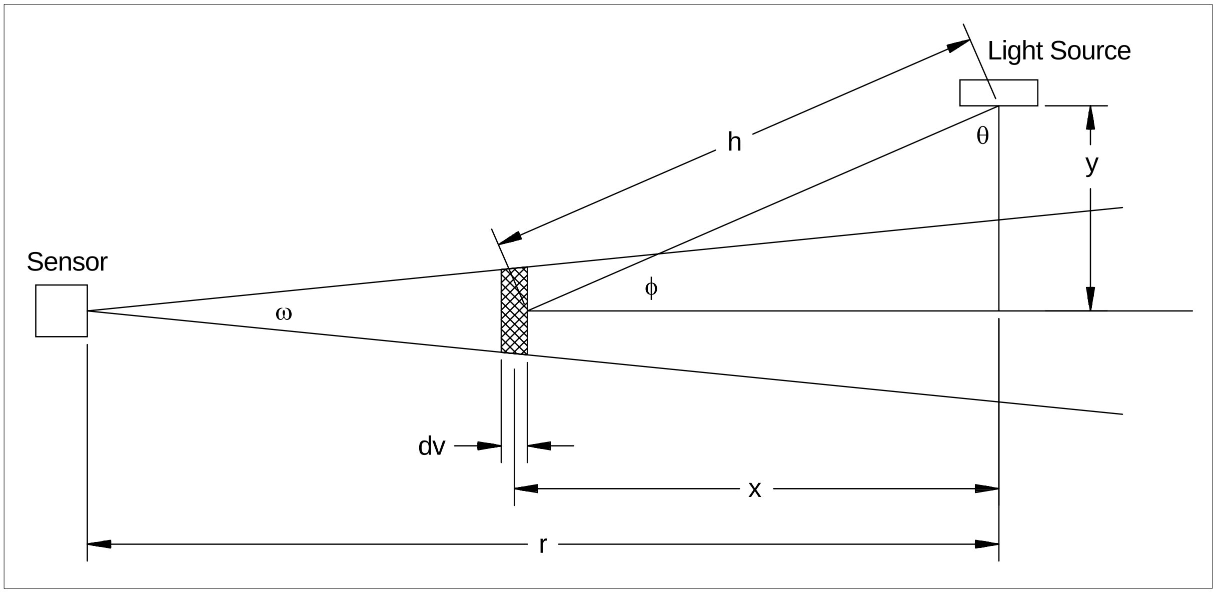


Figure 7-3
Nephelometer Geometry

Theory of Wavelength Dependence

The theory of wavelength dependence of light scattering is simple to define in the broad sense, and has substantial detail in application. The simple explanation is that smaller particles scatter differently than larger particles which results in different amounts of scattering at different wavelengths.

Light scattered by particles less than 0.05 µm is described in relatively simple terms by Rayleigh's theory. Particles larger than 10 µm must be described by geometric optics. Particles between these sizes can be analyzed using the much more complicated Mie scattering theory. The scattering of these particles is complicated because the size of particle and the wavelength of light have the same order of magnitude.

However, if we consider a polydisperse aerosol, which is usually the case for atmospheric aerosols, the wavelength dependence in the Mie region is dictated entirely by the size distribution and can be analyzed in a simpler fashion than the full blown Mie theory.

All materials have a describing characteristic called the index of refraction (m). This is the ratio of the speed of light in a vacuum (c) to the speed of light in a particular material (V_p).

$$m = \frac{c}{V_p}$$

[equation 7-6]

$c \cong 3 \times 10^{10}$ cm/s, is the speed of light in a vacuum.

The scattering of particles is governed by the ratio of the particle size (d) to the wavelength of light (λ). This dimensionless number is called the size parameter a.

$$a = (\pi * d)/\lambda$$

[equation 7-7]

As can be seen from the equation, for a << 1 particles are in the Rayleigh region and for a ≅ 1 they are in the Mie region.

Rayleigh's equation is as follows:

$$I(\theta) = \frac{I_o \pi^4 d^6 (m^2 - 1)^2}{8 R^2 \lambda^4 (m^2 + 2)^2} (1 + \cos^2 \theta) \qquad d < 0.05 \mu m$$

[equation 7-8]

Where m is the index of refraction and R is the distance of the particle, at angle θ, from the light.

It is already evident even for the case of Rayleigh scattering that particle size relative to wavelength is a key concern.

A simple description of the way that particle size distribution controls the wavelength dependence of σ_{sp} for a $\cong$ 1 can be stated, starting with the empirical observation that σ_{sp} for atmospheric aerosols is often close to a power-law function of wavelength:

$$\sigma_{sp} = C \lambda^{-å} \qquad \text{[equation 7-9]}$$

where:

C = a quantity describing the amount of scattering
$å$ = Angstrom exponent

The number distribution of atmospheric aerosol often can be crudely described as a power-law function of size:

$$dN/d\log r = c\, r^{-\beta} \qquad \text{[equation 7-10]}$$

where:

N = number concentration
r = particle radius
c = related to total concentration
β = slope of the number distribution on a log-log plot.

If this is approximately true, which is usually the case for a $\cong$ 1, then it can be shown that:

$$å = \beta - 2 \qquad \text{[equation 7-11]}$$

Thus, what controls $\mathring{a}$ is the slope of the number distribution; in other words the relative amounts of fine and course particles. Typically values of $\mathring{a}$ for gases are very nearly 4, for urban aerosols are on the order of 2, for rural haze 1–2, and close to 0 for very course aerosols like wind blown dust or sea salt. For large values of $\mathring{a}$, there will be a large difference in scattering at different wavelengths and for small values of $\mathring{a}$, for example near 0, scattering at different wavelengths are nearly equal.

Because the Model 3550/3560 Series Nephelometers can calculate the logarithm of σ_{sp} as an analog output, a simple numerical exercise yields the quantity $\mathring{a}$:

since

$$\sigma_{sp} = C\lambda^{-\mathring{a}}$$

$$\log \sigma_{sp} = \log C - \mathring{a} \log \lambda \qquad \text{[equation 7-12]}$$

so taking the derivative ($d\log C = 0$)

$$d\log \sigma_{sp} = -\mathring{a}\ d\log \lambda \qquad \text{[equation 7-13]}$$

Since the Nephelometer measures at different specific wavelengths, we can approximate the derivative with a finite difference:

$$\dot{a} \cong \frac{\Delta \log \sigma_{sp}}{\Delta \log \lambda} = \frac{\log \sigma_{sp}(\lambda_2) - \log \sigma_{sp}(\lambda_1)}{\log \lambda_2 - \log \lambda_1} \qquad \text{[equation 7-14]}$$

Why measure $\mathring{a}$?

One of the main reasons to measure σ_{sp} is to quantify and understand how it governs the transfer of light through the air. Examples are the partial transmission of sunlight to the earth's surface, transmission of lasers or other light beams horizontally or the appearance of haze in front of distant vistas. Because σ_{sp} is a function of wavelength, λ, different amounts of blue versus red light are transmitted. Usually, atmospheric aerosols scatter more blue light than green or red light, that is σ_{sp} for blue light is greater than σ_{sp} for green light etc. However since å is variable and visible light spans quite a range of wavelengths (roughly 400–700 nm) it is necessary to know $\mathring{a}$ in order to quantify the transmission of all the wavelengths.

Measurement of *å* also provides a continuous record of variations in the size distribution via estimation of variations of β.

In conclusion for $a \ll 1$, e.g., for $\lambda = 0.6$ µm, $d \ll 0.1$ µm, the Rayleigh theory is typically valid. The intensity of the Rayleigh scatter is proportional to the sixth power of the particle diameter and inversely proportional to the fourth power of the incident wavelength.

For $\alpha \cong 1$, where the particle diameter and the wavelength are of the same magnitude, say 0.1–1 µm, atmospheric aerosol scattering can often be described by a simple power-law function, which is governed solely by the slope of the number distribution of the aerosol on a log-log plot.

Signal Processing

This section describes the microprocessors and equations used in the Nephelometer firmware to calculate various scattering coefficients from the raw scatter data and calibration data.

Description

All electronics are located inside the nephelometer. Two microprocessors are used to control all functions. A Motorola 68HC711D3 microprocessor is used to control the brushless DC motors used to spin the reference chopper and optional backscatter shutter. A Motorola 68HC16Z1 microprocessor is used to control all other signal processing and input/output operations. All setup and configuration is done through the serial interface to an external computer with all parameters stored in the Nephelometer's battery-backed-up RAM.

Equations/Calculations

This section contains firmware and calibration equations for the Nephelometer.

Firmware Calculations

The Nephelometer calculations begin with the raw signals received from the photomultiplier tubes (PMT) for each color, for each section of the reference chopper and for each rotation of the backscatter shutter. Therefore, there are eighteen values. In addition, the number of cycles of the chopper are given for each color. This is the data that is sent from the nephelometer as raw count data. Examples are shown in Table 7-1.

Table 7-1
Examples of Raw Count Data

Color	Total Scatter				Backscatter			
	Calibrate	**Signal**	**Dark**	**Cycles**	**Calibrate**	**Signal**	**Dark**	**Cycles**
Blue	523939	12691	28	693	413847	6350	16	693
Green	1022163	12185	52	693	807927	6146	27	693
Red	514975	5271	1038	693	401071	3835	1021	693

These values are the raw photon counts for each portion of the reference chopper for each color. Since the angular width of each portion of the chopper is different, the values are normalized for gate width and number of cycles during the measurement. This converts the photon counts to cycles/second (Hz) using the equation:

$$C_s = (360*C*S)/(G*N) \quad \text{[equation 7-15]}$$

where: C_s = scaled count rate (Hz)
C = raw photon count rate
S = speed of reference chopper (22.994 RPS)
G = gate width in degrees
40° for calibrate section
140° for signal section
60° for dark section
N = number of revs in measurement

Notes: *The gate widths defined in equation 7-15 do* not *add up to 360° as one might imagine. This is because there is a 40° period between each of the sections to blank the overlap.*

The calibrate signal taken during the backscatter cycle is not *entirely used in the measurement cycle because the chopper is* not *illuminated during the backscatter cycle.*

Table 7-2 shows the comparisons between gate width and physical dimensions of the three sections.

Table 7-2
Comparisons Between Gate Width and Physical Dimensions

Shutter Area	**Gate Width [°]**	**Physical Width [°]**	**Blank Width [°]**
Calibrate	40	80	40
Signal	140	180	40
Dark	60	100	40
Total	240	360	120

Note: *Blank width is 20° at the beginning and 20° at the end of each gate.*

Next, each of the scaled count rates is corrected for dead time (due to photomultiplier pulse width) by the approximation:

$$F = C_s*(C_s*K_1 + 1) \qquad \text{[equation 7-16]}$$

where: K_1 = constant based on pulse width (picoseconds/counts)
C_s = scaled count rate (Hz)
F = corrected count rate (Hz)

When the numbers from the Table 7-1 are run through equation 7-15 and equation 7-16, the results are shown in Table 7-3.

Table 7-3
Counts Normalize to Photon Frequency (Hz)

Color	**Total Scatter**			**Backscatter**		
	Calibrate	**Signal**	**Dark**	**Calibrate**	**Signal**	**Dark**
Blue	156950	1083	6	123890	542	3
Green	307105	1040	10	242430	524	5
Red	154257	450	207	120056	327	203

Next, the nephelometer calculates averages of the data using a simple boxcar running average with up to 300 elements. Each of the eighteen values in Table 7-4 are averaged, depending on the averaging time selected.

Table 7-4
Boxcar Averages

Selected Boxcar Average	Seconds per Boxcar
1 to 300	1
302 to 600	2
603 to 900	3
906 to 1800	6
1810 to 3000	10
3020 to 6000	20
6030 to 9000	30
9060 to 18000	60

Next, the nephelometer uses the scaled and corrected count rates to calculate the raw scattering signals for each of the three colors. Periodically, the aerosol sampled by the nephelometer is filtered to determine the background scattering portion of the total scattered light. At all times, the nephelometer automatically monitors the temperature and pressure to allow correction of these environmental parameters. This is important since the Rayleigh scattering by gas molecules is dependent on temperature and pressure. Also, the user periodically performs a manual calibration with a span gas such as CO_2.

The nephelometer calculates two raw scattering signals: one for the aerosol and the other for filtered air:

$$B_f = K_2 * (S_f - D_f) / (C_f - D_f) \quad \text{[equation 7-17]}$$

where: B_f = filtered air raw scatter signal
K_2 = constant determined by span gas
C_f = calibrate (Hz) scaled count rate for filtered air
S_f = signal (Hz) scaled count rate for filtered air
D_f = dark (Hz) scaled count rate including the dark measured during total scatter and backscatter

$$B_a = K_2 * (S_a - D_a) / (C_a - D_a) \quad \text{[equation 7-18]}$$

where: B_a = aerosol raw scatter signal
K_2 = constant determined by span gas
C_a = calibrate (Hz) scaled count rate for aerosol
S_a = signal (Hz) scaled count rate for aerosol
D_a = dark (Hz) scaled count rate for aerosol

The Rayleigh scattering is calculated for the filtered air measurement and for the clean air using the equations including temperature and pressure:

$$R_f = (K_3 * P_f * T_s)/(T_f * P_s) \quad \text{[equation 7-19]}$$

where: R_f = filtered air Rayleigh scatter
K_3 = Rayleigh scatter of air for given color
P_f = pressure of filtered air
T_s = standard temperature (273.2 K)
T_f = temperature of filtered air
P_s = standard pressure (1013.3 mbar)

$$R_a = K_3 * (P_a / T_a) * (T_s / P_s) \quad \text{[equation 7-20]}$$

where: R_a = aerosol Rayleigh scatter
K_3 = Rayleigh scatter of air for given color
P_a = pressure of aerosol
T_a = temperature of aerosol
P_s = standard pressure (1013.3 mbar)
T_s = standard temperature (273.2 K)

These parameters allow us to calculate a variety of interesting numbers for each of the three colors:

$$W = B_f - R_f \quad \text{[equation 7-21]}$$

where: W = filtered air wall scatter
B_f = filtered air raw scatter signal
R_f = filtered air Rayleigh scatter

$$B_s = B_a - W \quad \text{[equation 7-22]}$$

where: B_s = total scatter (particles + Rayleigh)
B_a = aerosol raw scatter signal
W = filtered air wall scatter

$$\sigma_{sp} = B_s - R_a \quad \text{[equation 7-23]}$$

where: σ_{sp} = aerosol scatter
B_s = total scatter (particles + Rayleigh)
R_a = aerosol Rayleigh scatter

Equations 7-21, 7-22, and 7-23 can also be calculated for backscatter only by using the backscatter signal from Table 7-3 and multiplying all Rayleigh scatter by K_4.

Note: *W and R_a will be different for backscatter than for total scatter.*

Calibration Calculations

The previous equations use the four calibration factors: K_1, K_2, K_3, and K_4. These constants are obtained by calibration or measurement of the nephelometer.

The constant, K_1, is a one time calibration factor based on the measured pulse width of the photomultiplier tubes for each color. This parameter is set at the factory and used to correct for the dead time when a pulse is registered on the photomultiplier tube, preventing a second pulse from being registered.

K_2 is calculated during calibration using a equation similar to equation 7-8 and a table of wavelength-dependent, theoretical Rayleigh-scattering coefficients (from Table 2, Bodhaine, et. al.)

The constant K_3 represents the known scattering value for air at a standard temperature and pressure condition for the wavelength in question.

K_4 is a constant near 0.5 representing the ratio of Rayleigh backscatter to Rayleigh total scatter.

Calculation of K_2 using total scatter data (equations 7-22 and 7-23) can be expanded to:

$$\sigma_{sp} = B_l - W_t - R_l \qquad \text{[equation 7-24]}$$

For low span gas

$$\sigma_{sp_l} = B_l - W_t - R_l = K_2 \frac{S_l - D_l}{C_l - D_l} - K_{3_l} \frac{P_l}{T_l} \frac{T_s}{P_s} - W_t = 0$$

[equation 7-25]

For high span gas

$$\sigma_{sp_h} = B_h - W_t - R_h = K_2 \frac{S_h - D_h}{C_h - D_h} - K_{3_h} \frac{P_h}{T_h} \frac{T_s}{P_s} - W_t = 0$$

[equation 7-26]

where: B_l = low span gas raw scatter signal
B_h = high span gas raw scatter signal
R_l = low span gas Rayleigh scatter
R_h = high span gas Rayleigh scatter
W_t, W_b = wall scatter (total or backscatter)
C_l = low span gas calibration average scaled count rate
D_l = low span gas dark average scaled count rate
S_l = low span gas signal average scaled count rate
S_{lb} = low span gas backscatter signal average scaled count rate
P_l = low span gas calibration pressure
T_l = low span gas calibration temperature
K_{3_l} = low span gas scattering coefficients at standard pressure and temperature
C_h = high span gas calibration average scaled count rate
D_h = high span gas dark average scaled count rate
S_h = high span gas signal average scaled count rate
S_{hb} = high span gas backscatter signal average scaled count rate
P_h = high span gas calibration pressure
T_h = high span gas calibration temperature
K_{3_h} = high span gas scattering coefficients at standard pressure and temperature
P_s = standard pressure (273.2K)
T_s = standard temperature (1013.3 mbar)

Equations 7-25 and 7-26 are equal to zero because there are no particles present, and therefore, no scattering by particle (σ_{sp} = 0). Scattering is only from the wallscatter and the Rayleigh scatter of the gas.

We have two equations, two unknowns K_2 and W_t (wall). Subtract equation 7-25 from 7-26 to eliminate W_t.

To get:

$$K_2\left[\frac{S_h - D_h}{C_h - D_h} - \frac{S_l - D_l}{C_l - D_l}\right] - \frac{T_s}{P_s}\left[K_{3_h}\frac{P_h}{T_h} - K_{3_l}\frac{P_l}{T_l}\right]$$ [equation 7-27]

Solve for K_2:

$$K_2 = \frac{\frac{T_s}{P_s}\left[K_{3_h}\frac{P_h}{T_h} - K_{3_l}\frac{P_l}{T_l}\right]}{\frac{S_h - D_h}{C_h - D_h} - \frac{S_l - D_l}{C_l - D_l}}$$ [equation 7-28]

Generally, the low span gas in filtered air and the high span gas is CO_2 or CCl_2F_2.

K_4 can be calculated using the backscatter data and K_2 calculated from above.

$$\sigma_{sp_{lb}} = K_2\left(\frac{S_{lb} - D_l}{C_l - D_l}\right) - K_4 K_{3_l}\frac{P_l}{T_l}\frac{T_s}{P_s} - W_b = 0$$ [equation 7-29]

$$\sigma_{sp_{hb}} = K_2\left(\frac{S_{hb} - D_h}{C_h - D_h}\right) - K_4 K_{3_h}\frac{P_h}{T_h}\frac{T_s}{P_s} - W_b = 0$$ [equation 7-30]

Again, subtract equation 7-29 from 7-30 to eliminate W_b (wall). Solve for $K4$:

$$K_4 = \frac{K_2\left\{\left[\frac{S_{hb} - D_h}{C_h - D_h}\right] - \left[\frac{S_{lb} - D_l}{C_l - D_l}\right]\right\}}{\frac{T_s}{P_s}\left[\frac{P_h}{T_h}K_{3_h} - \frac{P_l}{T_l}K_{3_l}\right]}$$ [equation 7-31]

Detection Optics

The detection optics depend on the model of the nephelometer. The single wavelength unit (TSI Models 3551/61) consists of a broadband-coated 400 mm focal-length lens used to collimate the diverging light defined by apertures in the body of the instrument. This light is then passed through a 40 nm bandpass filter centered at 550 nm before entering a photomultiplier tube (green channel).

The three wavelength instrument (TSI Models 3553/63) contains the same lens as the single wavelength device. From the lens, the scattered light is separated by dichroic filters to three bandpass filters and separate photomultiplier tubes. The first wavelength is reflected by a color splitter that passes 500-800 nm light and reflects 400–500 nm light, through a 40 nm bandpass filter, centered at 450 nm, into a photomultiplier (blue channel). Light that passes through the first color splitter is split again by a filter that passes 500–600 nm light and reflects 600–800 nm light, through a 40 nm bandpass filter centered at 700 nm to a PMT (red channel). The light that passes through both color splitters (500-600 nm) continues to a 40 nm bandpass filter, centered at 550 nm and a PMT (green channel).

Calibration

The Nephelometer is a photon counting instrument. Particles and gas molecules scatter photons that are detected and counted using highly sensitive photomultiplier tubes. These photon counts are converted into counting frequencies and correlated to light scattering coefficients using calibration constants. These constants are determined by filling the nephelometer's interior measurement volume with two span gases, one at a time, that have largely different scattering coefficients and measuring a few key parameters. By measuring the photon frequency, temperature, and pressure for each span gas measurement, and knowing the scattering coefficient for each of the span gases at a known temperature and pressure (e.g., STP), and using two simple equations, the calibration constants are easily calculated. For more detail on the calculations see "Calibration Calculations" earlier in this chapter.

CHAPTER 8

Performing Maintenance

Use the procedures in this chapter to maintain the Model 3550/3560 Series Integrating Nephelometer. Most maintenance procedures do not have specific time guidelines, but should be performed based on software or hardware failures, degradation in overall performance, or as a result of the special environments in which the Nephelometer may be used.

Table 8-1 gives an overview of the procedures in this chapter. The organization of the table reflects the order in which the procedures are presented.

Table 8-1
Maintenance Overview

Maintenance Procedure	Perform:
With the top and bottom covers on:	
Calibrate the Nephelometer	Periodically, or if the reference chopper is dirty or scratched.
Clean or replace the fan filters	If a visual check shows the filters are clogged.
With the top cover off:	
Replace the main microprocessor EPROM	As part of a firmware update.
Replace the motor control microprocessor	As part of a firmware update.
Replace the lamp	If there is a status failure in the software, or periodically based on the power rating and the hours of use.
Replace the aerosol filters	Periodically, or if there is a significant drop in pressure.
Clean the light pipe lens	As needed, depending on the cleanliness of the environment in which the Nephelometer is operated.
Check for leaks	If the instrument is disassembled and is to be used in a low pressure environment.
With the top and bottom covers off:	
Clean the reference chopper	If the calibrate signal changes dramatically while using the lamp at a constant power.
Clean the light pipe outlet and the backscatter shutter	As needed, depending on the cleanliness of the environment in which the Nephelometer is operated.
Clean the flocked paper	If the background signal rises over time.
With the photomultiplier tube (PMT) cover off:	
Replace PMTs	If a failure occurs.
Check, clean, or replace bandpass filters	Periodically, or if using in a high-humidity environment.
Clean the lens	If there is an overall reduction in the signal of all three wavelengths over time.

Removing Nephelometer Covers: Top, Bottom, and PMT

This section give instructions for removing Nephelometer top, bottom or PMT covers, necessary for most maintenance or hardware troubleshooting procedures (Figure 8-1).

Note: *The steps needed to remove covers are also included, when appropriate, in each maintenance procedure.*

Figure 8-1
Nephelometer Showing Top, Bottom, and PMT Covers

Removing the Top Cover

To remove the top cover of the Nephelometer:

1. Remove power from the Nephelometer and from any instruments connected to the Nephelometer.
2. Loosen the four screws fastening the Nephelometer cover and remove the cover (Figure 8-2).

Caution
To avoid damage to the electronic circuitry, use electrostatic discharge (ESD) precautions when removing the top or bottom Nephelometer cover:
❑ Use only a table top with a grounded conducting surface.
❑ Wear a grounded, static-discharging wrist strap.

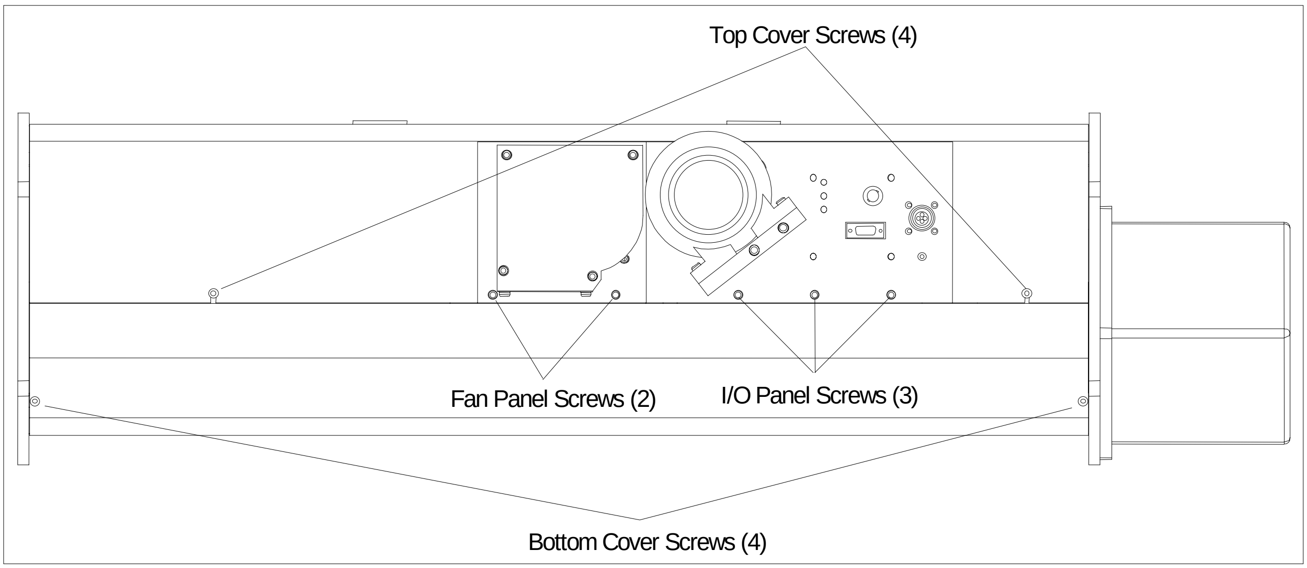


Figure 8-2
Top Cover Screws, Bottom Cover Screws, Fan Cover Screws, and I/O Panel Screws

Removing the Bottom Cover

To remove the bottom cover of the Nephelometer:

1. Remove power from the Nephelometer and from any instruments connected to the Nephelometer.
2. Remove the top cover using the procedure in this section.

Caution
To avoid damage to the electronic circuitry, use electrostatic discharge (ESD) precautions when removing the top or bottom Nephelometer cover:
❑ Use only a table top with a grounded conducting surface.
❑ Wear a grounded, static-discharging wrist strap.

3. The bottom cover of the Nephelometer is pliable and fits very tightly around the bottom of the instrument. Remove the bottom cover in one of two ways:

- ❑ The more difficult method is to pry off the bottom cover without removing the I/O panel and the fan panel. Unscrew the four bottom cover screws (Figure 8-2). *Carefully* remove the bottom cover, working alternately at both ends. Pry the edges of the cover apart, and ease the cover away from the body of the Nephelometer.
- ❑ The easier method takes more time. After removing the I/O panel, the fan panel and the end plate, slide the bottom cover off the body of the instrument. Using Figure 8-2 as a reference:

  a. Unscrew the three screws securing the I/O panel to the backbone, loosen the panel, and let the panel hang over the side of the instrument.

  b. Unscrew the two screws securing the fan panel to the backbone, loosen the panel, and let the panel hang over the side of the instrument.

  c. Unscrew the three screws securing the end plate to the inlet section of the instrument and remove the end plate.

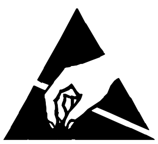
  d. Unscrew the four bottom cover screws, and *carefully* slide the cover off the end of the instrument.

Note: *Attach the bottom cover of the Nephelometer reversing the steps in step 3 of this procedure. Remember that the cover is pliable and fits tightly around the bottom of the instrument.*

Removing the PMT Cover

To remove the PMT cover:

1. Remove power from the Nephelometer and from any instruments connected to the Nephelometer.
2. Unscrew the four screws attaching the PMT cover to the sensor and remove the cover (Figure 8-3).



Caution
To avoid damage to the electronic circuitry, use electrostatic discharge (ESD) precautions when removing the Nephelometer cover: ❑ Use only a table top with a grounded conducting surface. ❑ Wear a grounded, static-discharging wrist strap.

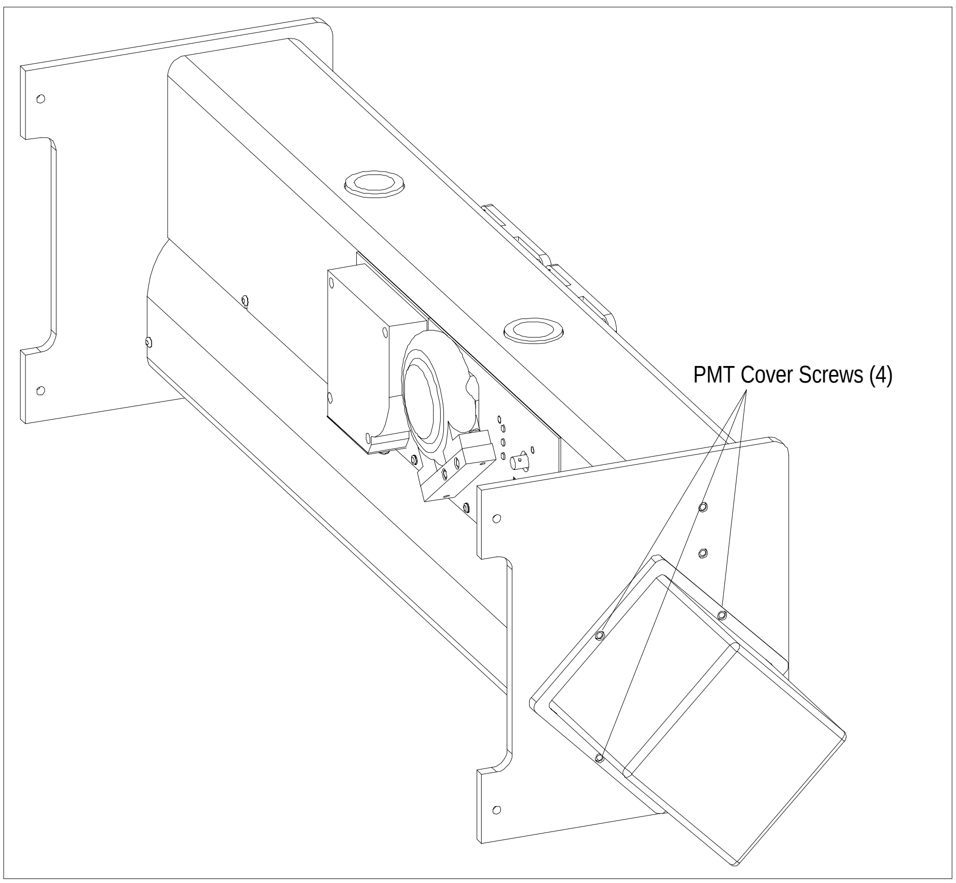


Figure 8-3
PMT Cover

Calibrating the Nephelometer

Calibrate the Nephelometer before an intensive experiment, calibrate periodically to verify no drift has occurred, calibrate if the reference chopper is dirty or scratched, or if you clean the chopper as part of periodic maintenance.

Perform calibration using TSI software. The "Calibration" option under the Main Menu screen allows you to easily calibrate the Nephelometer using two span gases, comparing the results between air (low span) and CO_2 (high span).

Refer to the "Performing Calibration" section in Chapter 4. Hardware setup instructions are included as part of the calibration process.

Cleaning Fan Filters

The Nephelometer circuitry is cooled by a fan, which has two fan filters located on the outside of the Nephelometer (Figure 8-4). Running the fan with clogged filters can significantly reduce the life of the lamp.

If power is applied to the Nephelometer and the lamp is working properly, but you cannot see light (at any angle) coming through the filters, the foam inserts are clogged and should be cleaned or replaced.

Note: *You can clean fan filters while power is applied to the Nephelometer.*

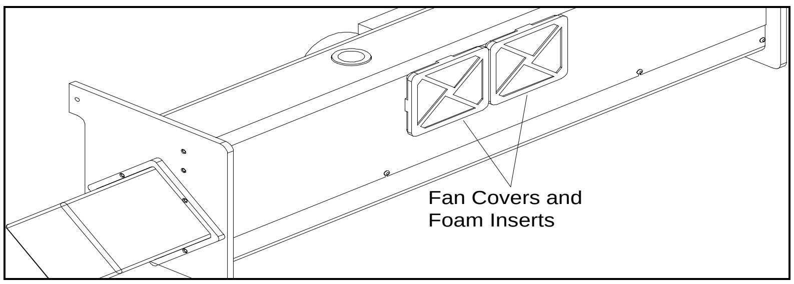


Figure 8-4
Fan Covers and Foam Inserts

Tools and Parts
You need a vacuum or a compressed air source, and if you replace the foam inserts, TSI P/N 1602071. One set of foam inserts is included in the accessory kit.

1. Snap off the fan covers and remove the open-cell foam inserts from the covers (Figure 8-4).
2. To clean the foam inserts, use a vacuum to remove accumulated dirt or a compressed air source to blow away the dirt.

   Note: *Cleaning solvents will dissolve the foam inserts.*
3. Replace the foam inserts in the fan covers and snap the fan covers back in place.

Replacing the Main Microprocessor EPROM

The Nephelometer sensor contains a 68HC16Z1 main microprocessor that controls signal processing and input/output operations. The main microprocessor has separate battery-backed-up RAM-storage and EPROM chip.

Over time, TSI may update the firmware to enhance the performance of the Nephelometer. Updating the main microprocessor firmware requires replacing a separate EPROM chip on the digital PC board.

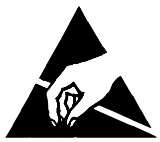
Note: *Replacing an electronic chip should only be performed by someone who is technically qualified and who is familiar with the operation of the Nephelometer.*

Tools and Parts
You need a Phillips-head screwdriver, a replacement chip, a small flat screwdriver, a static-discharging wriststrap, and an antistatic mat.

To replace the main microprocessor EPROM:

1. Apply power to the Nephelometer and start the Nephelometer software (Chapter 4).
2. Select "Configuration Menu" from the Main Menu.
3. Select "Read Config. Data from Nephelometer" from the Configuration Menu screen.
4. After data is read from the Nephelometer, select "Save Config. Data to Disk File" from the Configuration Menu screen.
5. After data is saved, select "Print Config. Data" from the Configuration Menu screen to make a hard copy of the data record.
6. Confirm that data was written and saved to the NEPHCNFG.DAT file and exit the software.
7. Remove power from the Nephelometer and from any instruments connected to the Nephelometer.

8. Loosen the four screws fastening the Nephelometer top cover and remove the cover (Figure 8-5).



Caution
To avoid damage to the electronic circuitry, use electrostatic discharge (ESD) precautions when removing the Nephelometer cover: ❑ Use only a table top with a grounded conducting surface. ❑ Wear a grounded, static-discharging wrist strap.

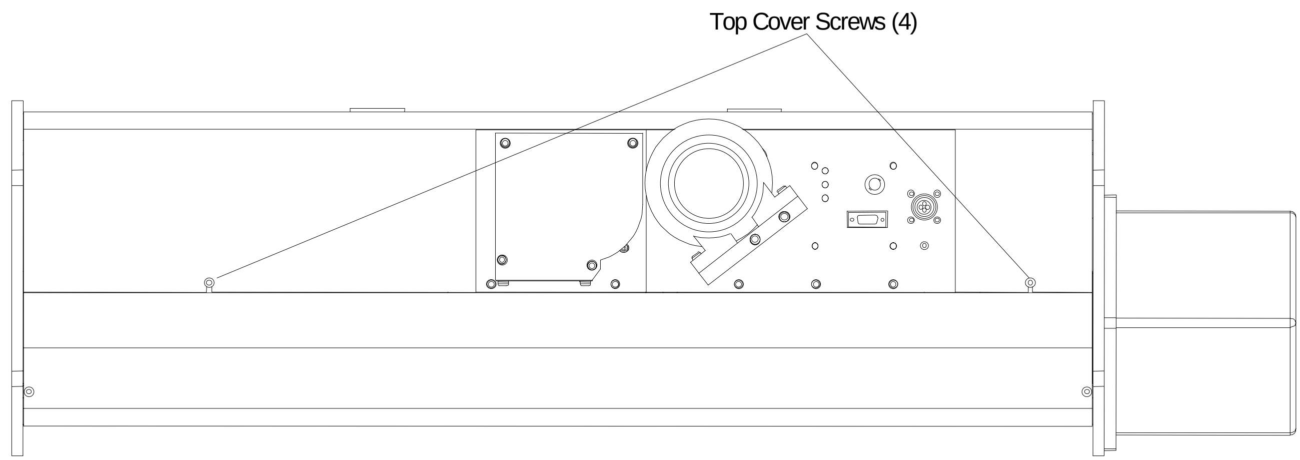


Figure 8-5
Top Cover Screws

9. Locate the main microprocessor EPROM on the digital circuit board (Figure 8-6). Remove the main microprocessor EPROM by inserting the tip of a small flat screwdriver under the short side of the chip and *gently* twisting.

10. Remove the new chip from the static protective wrapper.

11. Align the new chip in the socket, making sure notch in the microprocessor EPROM matches the position in Figure 8-6. Apply pressure to the center of the chip until it snaps down into the socket. Press *firmly* to make sure it is seated properly and ***check to see that there are no bent or unseated pins***.

12. Apply power to the Nephelometer and observe the LEDs: POWER lights when power is applied, VALVE lights as the valve turns, and STATUS lights when the Nephelometer is ready for operation.

Note: *If the LEDs do* not *function, remove power from the Nephelometer and make sure the chip is seated correctly.*

13. Remove power from the Nephelometer, and replace the top cover, attaching the cover with the four screws.

14. Apply power to the Nephelometer and start the Nephelometer software.

15. Select "Configuration Menu" from the Main Menu.

16. Select "Read Config. Data from Disk File" from the Configuration Menu screen.

17. After data is read from the Nephelometer, select "Write Config Data to Nephelometer" from the Configuration Menu screen.

18. After data is written, press <Esc> to go to the Main Menu and choose "Data Collection" to verify that the Nephelometer is operating properly.

Replacing the Motor Control Microprocessor

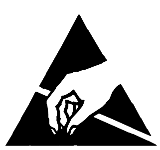
The Nephelometer sensor contains an HC711D3 microprocessor that controls the motor functions of the calibrator and backscatter shutters. Over time, TSI may update the firmware to enhance the performance of the Nephelometer. Updating the firmware may require replacing the motor microprocessor chip on the digital PC board.

Note: *Replacing an electronic chip should only be performed by someone who is technically qualified and who is familiar with the operation of the Nephelometer.*

Tools and Parts
You need a Phillips-head screwdriver, a replacement chip, a 44-pin chip extractor (provided with the replacement chip), a static-discharging wriststrap, and an antistatic mat.

To replace the microprocessor:

1. Remove power from the Nephelometer and from any instruments connected to the Nephelometer.
2. Loosen the four screws fastening the Nephelometer top cover and remove the cover (Figure 8-5).



Caution
To avoid damage to the electronic circuitry, use electrostatic discharge (ESD) precautions when removing the Nephelometer cover: ❑ Use only a table top with a grounded conducting surface. ❑ Wear a grounded, static-discharging wrist strap.

3. Locate the motor microprocessor chip on the digital circuit board (Figure 8-6). Use the 44-pin chip extractor to remove the chip.

4. Remove the new chip from the static protective wrapper.

5. Align the new chip in the socket, making sure the clipped corner of the motor microprocessor matches the position in Figure 8-6. Apply pressure to the center of the chip until it snaps down into the socket. Press *firmly* to make sure it is seated properly and check to see that there are no bent or unseated pins.

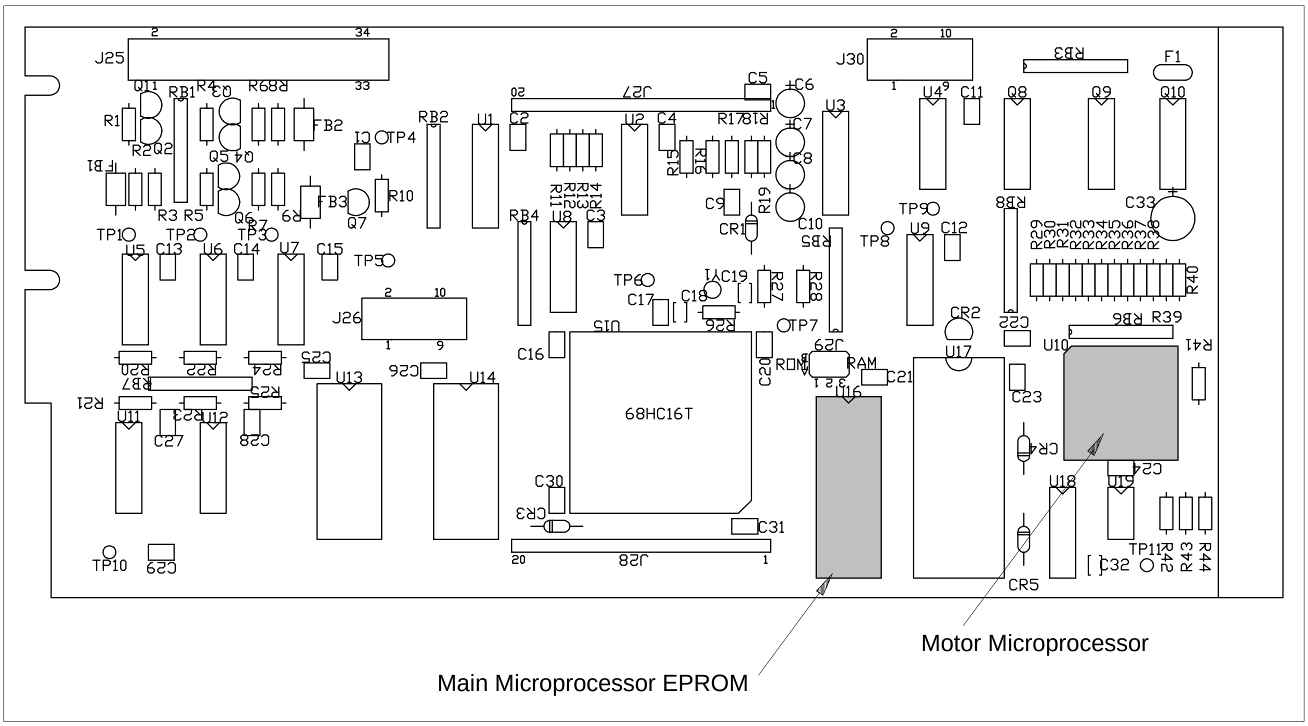


Figure 8-6
Microprocessor and EPROM Locations on the Digital Circuit Board

6. Apply power to the Nephelometer and observe the LEDs: POWER lights when power is applied, VALVE lights as the valve turns, and STATUS lights when the Nephelometer is ready for operation.

   Note: *If the LEDs do* not *function, remove power from the Nephelometer and make sure the chip is seated correctly.*

7. Remove power from the Nephelometer, and replace the top cover, securing the cover with the four screws.

Replacing the Lamp

The lamp is a projector-type halogen bulb with a built-in elliptical dichroic mirror. The lamp is rated at 75 watts with a recommended maximum of 12 volts. The lamp has an estimated life of 2000 hours of continuous operation at the maximum power (75 watts).

Tools and Parts
You need a Phillips-head screwdriver and a replacement lamp (P/N 2201111). A replacement lamp is included in the accessory kit.

1. Remove power from the Nephelometer and from any instruments connected to the Nephelometer.
2. Loosen the four screws fastening the Nephelometer top cover and remove the cover (Figure 8-7).

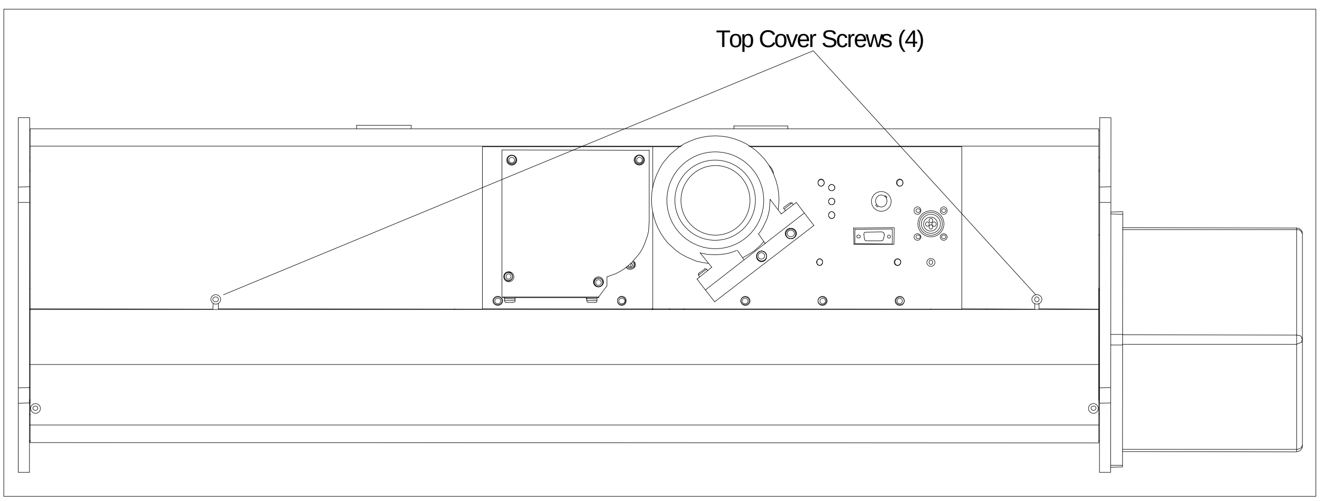


Figure 8-7
Top Cover Screws

3. Unscrew the two screws attaching the lamp shield. Remove the shield, supporting the shield so that it does not hang by the sensor wires (Figure 8-8).

Caution

Lamp and shield at high temperatures, which can cause burns.

To avoid personal injury, disconnect power to the Nephelometer and allow the halogen lamp and the lamp shield to cool before handling.

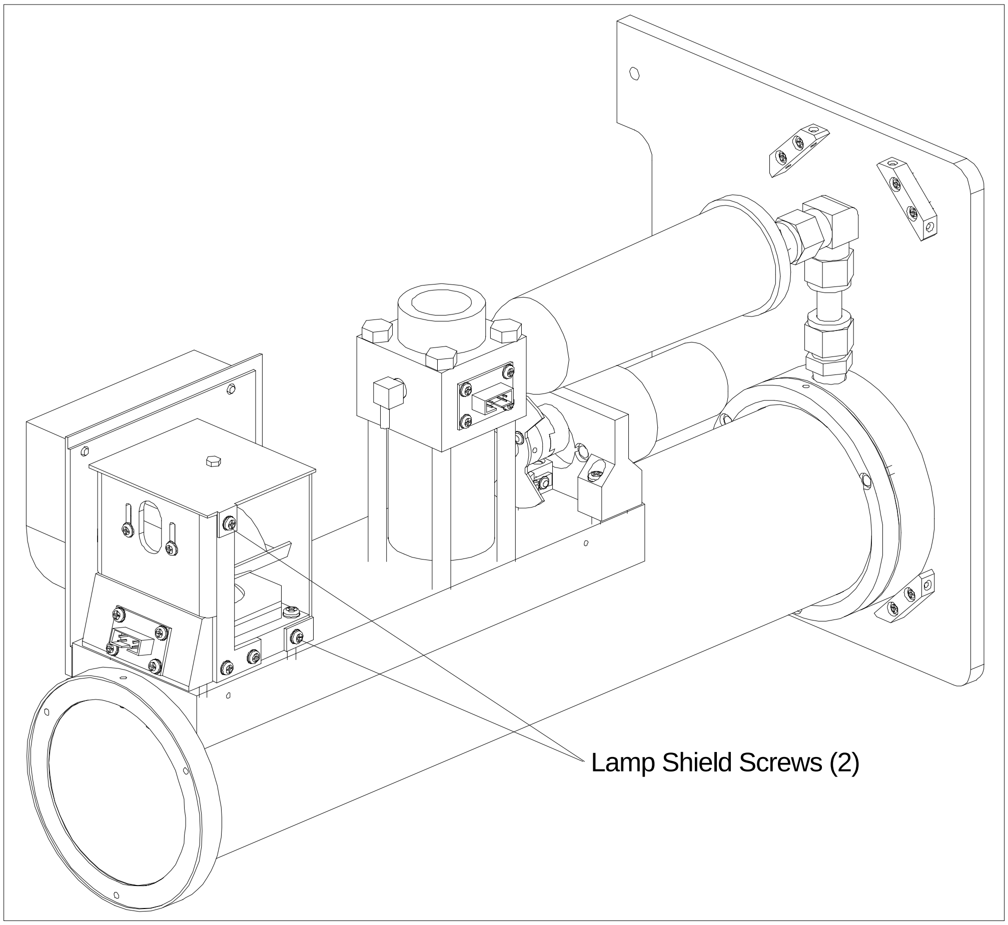


Figure 8-8
Lamp Shield

4. Allow the lamp to cool and push up the lamp lever to force the lamp from the socket.
5. Plug in a new lamp and push down the lamp lever to secure the lamp.
6. Replace the lamp shield and attach the shield with the two screws.
7. Replace the Nephelometer top cover and attach with the four screws.
8. After applying power to the Nephelometer, check the operation of the lamp either by observing the light inside the sensor or by selecting “Data Collection” from the Main Menu of the TSI software.

Replacing Aerosol Filters

The Nephelometer has two aerosol filters:

- ❑ A large white HEPA filter that can be switched into the inlet to filter all sample air coming into the sensor.
- ❑ A small blue DQ filter that is used to purge a small flow of clean air into the light pipe apertures. This airflow keeps the lens clean.

There is no software indication or error message if either filter is not functioning. However, if there is a significant increase in pressure drop through the filter from the time you set up Nephelometer to the present, check the white HEPA filter and fittings to see if the inlet flow is blocked.

Replace the white HEPA filter every six months of operation and replace the blue DQ filter every 12 months. If the Nephelometer is sampling very dirty aerosols, shorten these times. If the Nephelometer is sampling very clean aerosols, extend the times.

Tools and Parts
You need a Phillips-head screwdriver, adjustable wrench, small needle-nose pliers, RTV silicone sealer, and replacement filters, white HEPA: TSI P/N 1602051, and blue DQ: TSI P/N 1602080. Replacement filters are included in the accessory kit.

To replace the white HEPA filter or the blue DQ filter:

1. Remove power from the Nephelometer and from any instruments connected to the Nephelometer.
2. Loosen the four screws fastening the top cover of the Nephelometer and remove the cover (Figure 8-9).

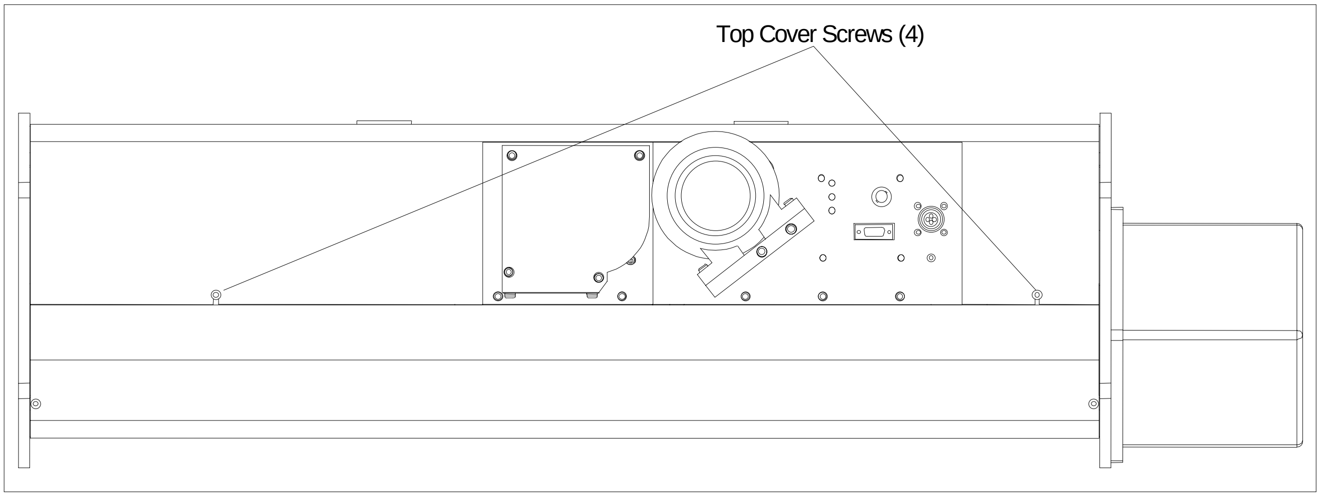


Figure 8-9
Top Cover Screws

3. To replace the white HEPA filter:
   a. Loosen the end plate by removing the two bottom cover screws (Figure 8-10).
   b. Unscrew the three screws fastening the end plate and remove the end plate.

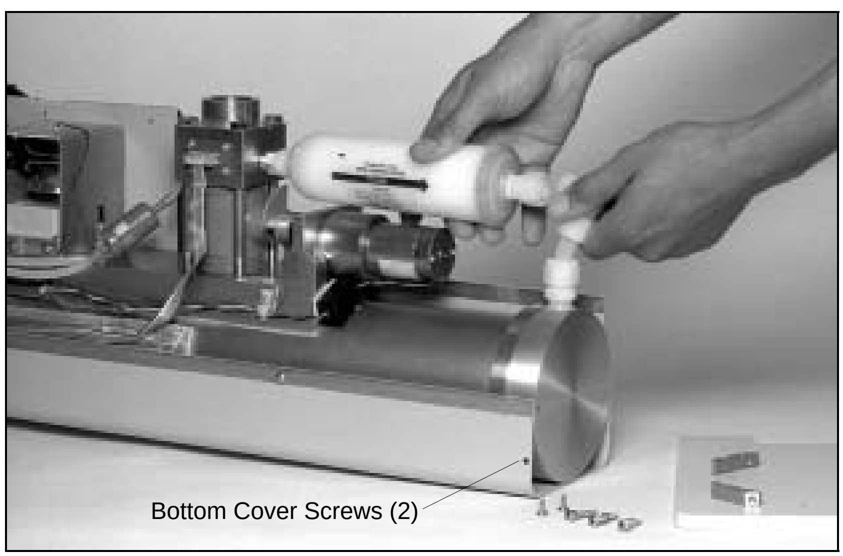


Figure 8-10
Bottom Cover Screws Securing End Plate

c. Use an adjustable wrench to remove the nylon nut connecting the elbow fitting to the filter outlet (Figure 8-11).

d. Pull back on the elbow to separate the elbow fitting from the filter.

e. Unscrew the filter from the brass fitting on the inlet block (Figure 8-11).

f. Coat the threads on the brass fitting on the inlet block with RTV silicone sealer.

g. Making sure the arrow on the new filter is pointing away from the inlet block, screw the new filter into the brass fitting on the inlet block (Figure 8-11).

h. Remove the nylon fitting from the old filter, coat the threads of the fitting with RTV silicone sealer, and screw the nylon fitting into the outlet of the new filter.

i. Use the nylon nut to attach the elbow fitting to the outlet of the filter.

j. Reattach the end plate using the three screws.

k. Replace the two bottom cover screws.

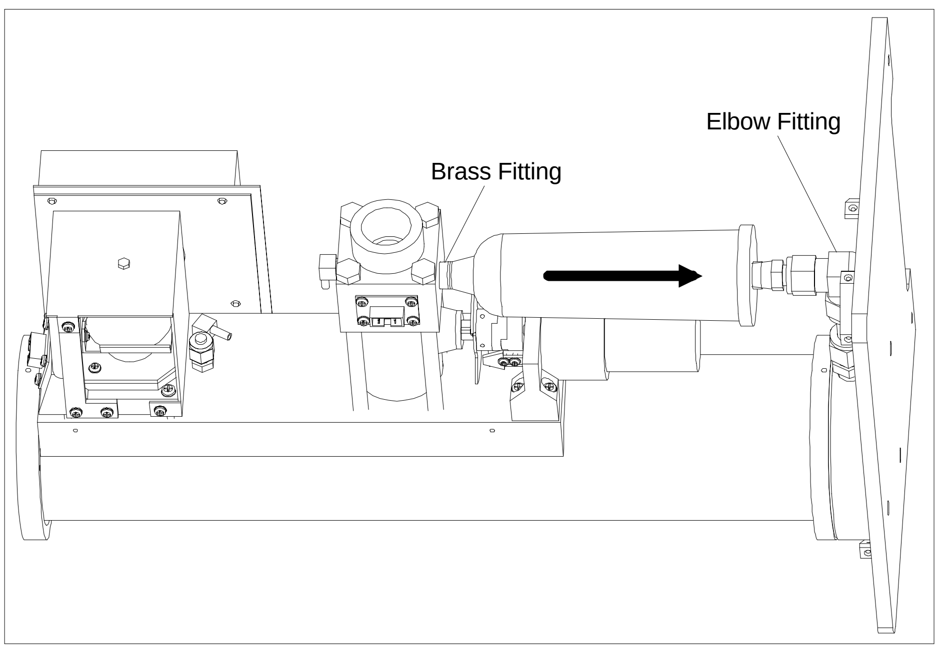


Figure 8-11
White HEPA Filter

4. To replace the blue DQ filter:

   a. Remove the ⅛ in. ID silicone tubing from both ends of the blue filter (Figure 8-12).

   b. Making sure the arrow of the new filter is pointing away from the inlet block, install the new DQ filter, reattaching the silicone tubing.

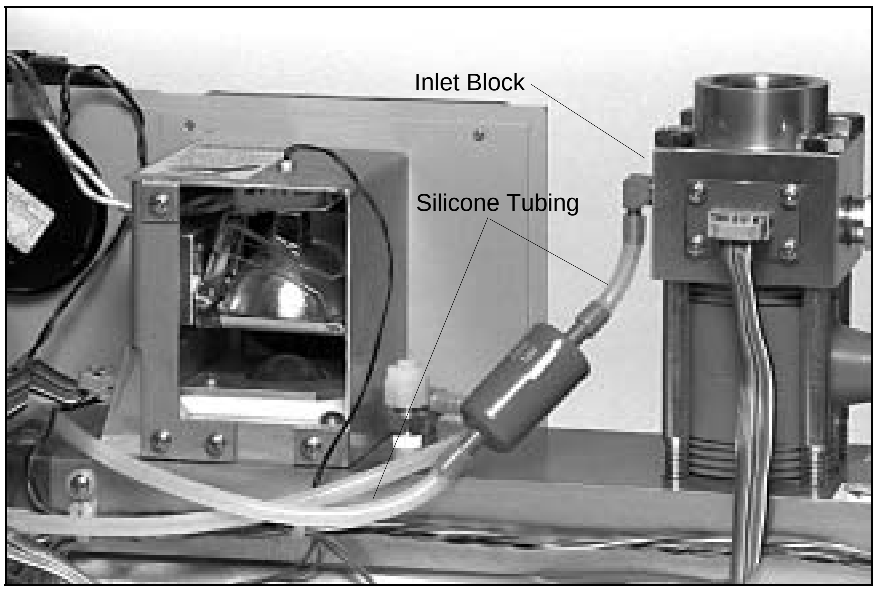


Figure 8-12
Blue DQ Filter

5. Replace the top cover of the Nephelometer and attach with the four screws.

Cleaning the Light Pipe Lens

The light pipe is a solid glass rod that transfers light from the lamp to the measurement volume, providing a thermal break between the lamp and the measurement volume. The light pipe lens, which receives a high volume of cooling air, may require frequent cleaning.

Tools
You need a Phillips-head screwdriver, soft cloth, cotton swabs, isopropyl alcohol, and O-ring grease.

1. Remove power from the Nephelometer and from any instruments connected to the Nephelometer.
2. Loosen the four screws fastening the top cover of the Nephelometer and remove the cover (Figure 8-13).

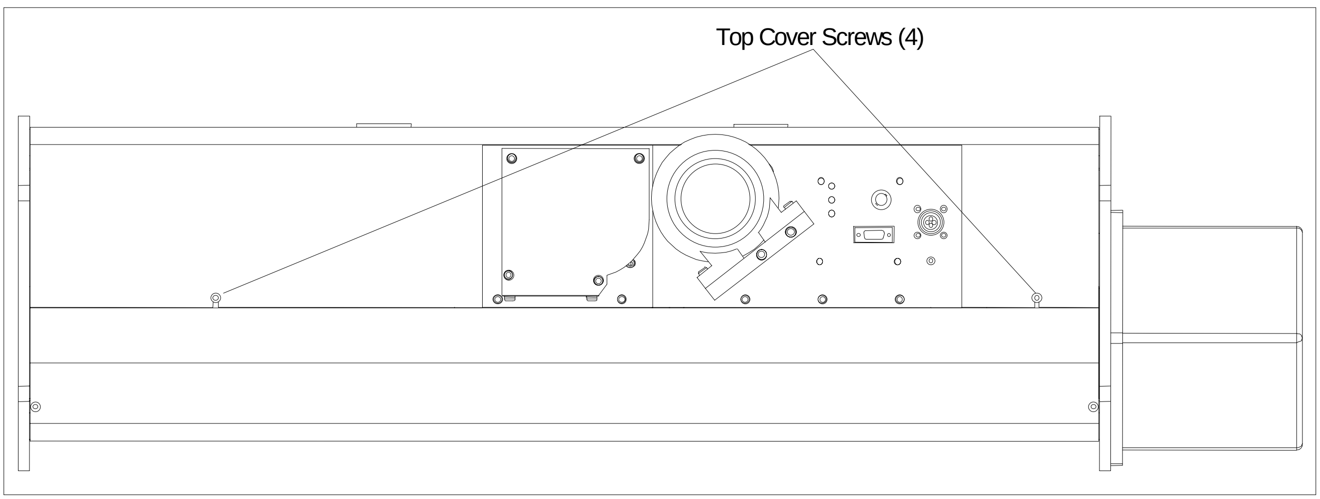


Figure 8-13
Top Cover Screws

3. Unscrew the two screws attaching the lamp shield (Figure 8-14). Remove the shield, supporting the shield so that it does not hang by the sensor wires.

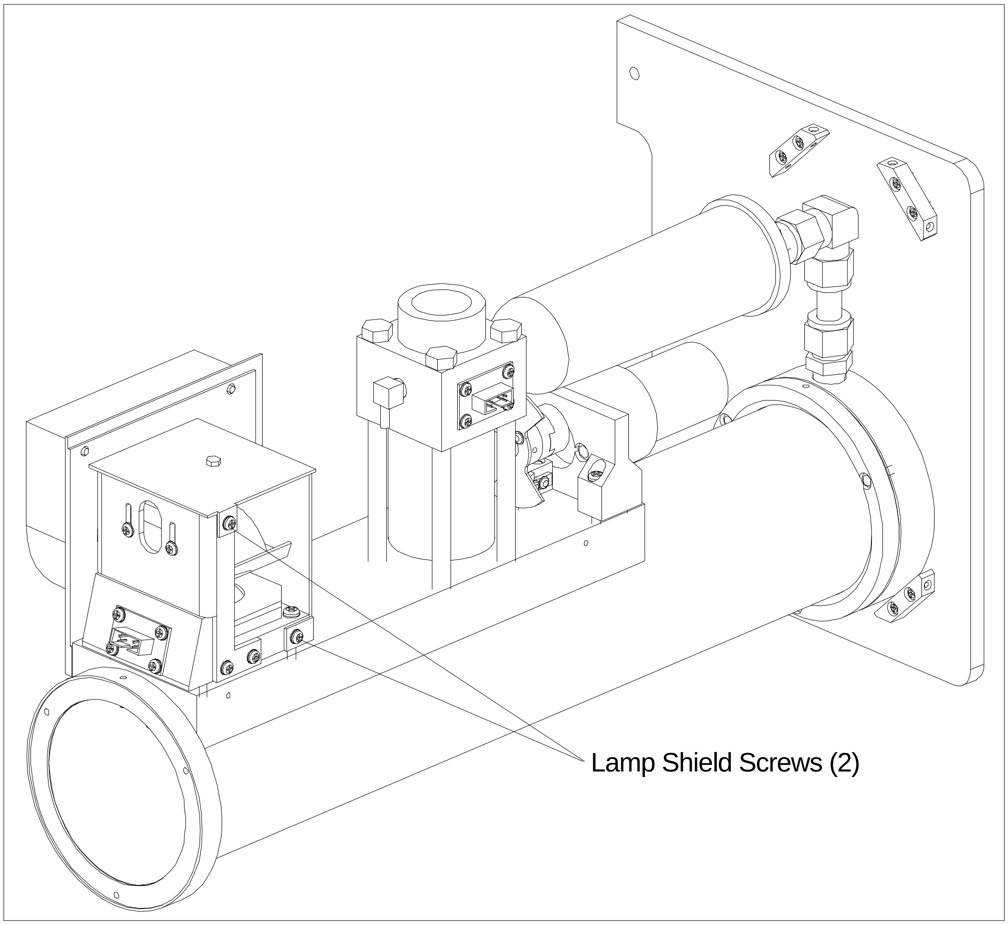


Figure 8-14
Lamp Shield

4. Allow the lamp to cool and push up the lamp lever to force the lamp from the socket.

C a u t i o n
Lamp and shield at high temperatures, which can cause burns.
To avoid personal injury, disconnect power to the Nephelometer and allow the halogen lamp and the lamp housing to cool before handling.

5. Locate the light pipe lens below the lamp socket. Use the cotton swab and alcohol to clean the lens (Figure 8-15).

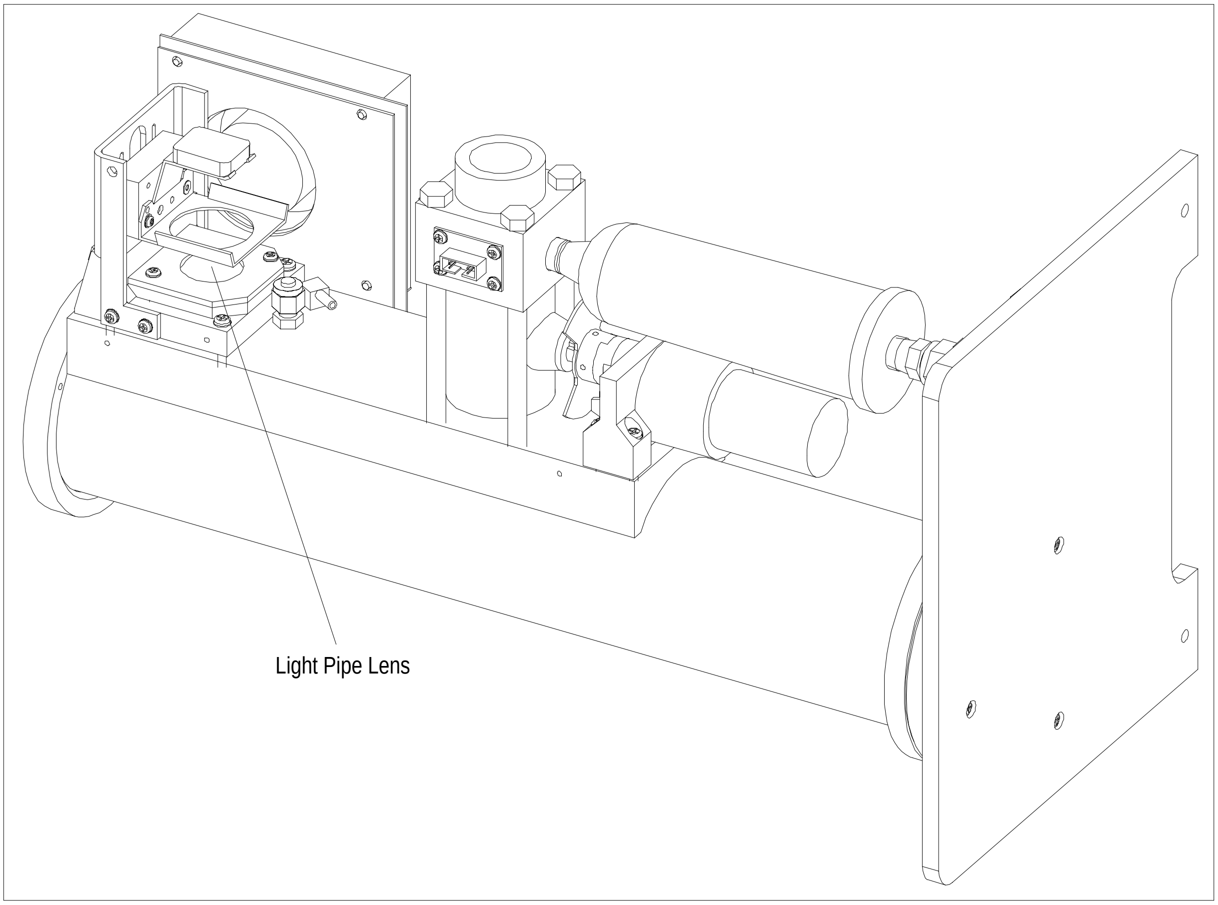


Figure 8-15
Light Pipe Lens

6. Plug in the lamp and push down the lamp lever to secure the lamp.
7. Replace the lamp shield securing it with the two screws.
8. Replace the top cover of the Nephelometer and attach with the four screws.
9. After applying power to the Nephelometer, check the operation of the lamp either by observing the light inside the sensor or by typing the RF command on the computer and checking the status flags (see “Read Commands” in Chapter 6).

Checking for Leaks

This section describes procedures for checking the vacuum integrity of the Nephelometer.

Tools needed
A vacuum pump (capable of 18 in. Hg vacuum), manometer or vacuum gauge, leak check solution (bubble solution) pump capable of 5 psi pressure, 1” NPT plugs.

To check if the instrument has a leak:

1. Remove the blower from the instrument and plug the lower connection port.
2. Connect a vacuum pump and vacuum gauge to the inlet.
3. Draw the pressure down to about 18 in. Hg below atmospheric pressure.
4. Wait for about ten minutes for any pressure/temperature changes with the instrument.
5. Record the reading on the vacuum gauge.
6. Wait five minutes and record again.
7. If the gauge has dropped by more than 0.2 in. Hg in five minutes, there is probably a leak.

To check for leaks:

1. Make sure that the vacuum system itself does not leak.
2. Remove the top and bottom covers from the instrument.
3. Connect the pump in place of the vacuum pump and pressurize the instrument to ***no more than*** 5 psi.
4. Drip bubble solution over all silicone sealed joints or O-ring joints until the leak is found.
5. Repair/replace seals or O-ring as needed.
6. Retest with vacuum as described above.
7. Reassemble covers.

Cleaning the Reference Chopper

The reference chopper contains three areas: one area provides a signal from light scattered by an aerosol, one area provides an indication of the lamp power, and one area provides a measure of the PMT dark current.

Make sure the chopper is operating properly and clean the calibrate portion of the chopper if, over time, the calibrate signal from the Nephelometer rises (from light scattered by dirt) or falls (from light blocked by dirt) significantly using the same lamp power.

Note: *Recalibrate the Nephelometer after you clean the reference chopper. Refer to Chapter 4, "Using Nephelometer Software (DOS)," for the calibration procedure using TSI software commands.*

Tools and Parts
You need a Phillips-head screwdriver, isopropyl alcohol, and cotton swabs.

1. Remove power from the Nephelometer and from any instruments connected to the Nephelometer.

2. Loosen the four screws fastening the top cover of the Nephelometer and remove the cover (Figure 8-16).

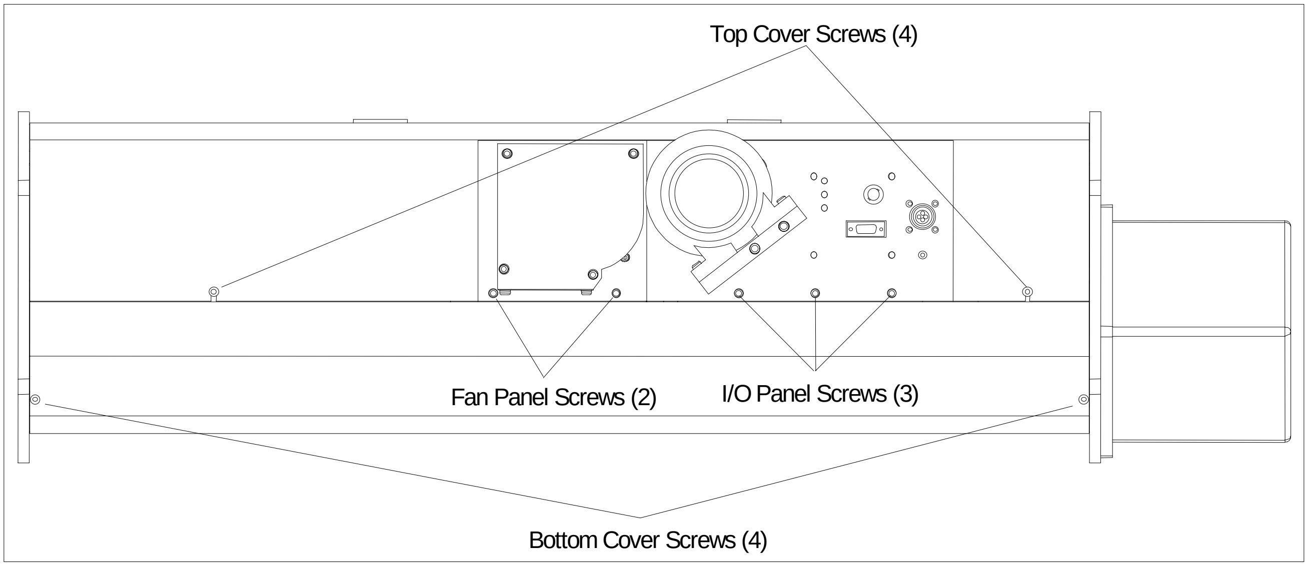


Figure 8-16
Top Cover Screws, Bottom Cover Screws, Fan Cover Screws, and I/O Panel Screws

3. The bottom cover of the Nephelometer is pliable and fits very tightly around the bottom of the instrument. Remove the bottom cover in one of two ways:

- ❑ The more difficult method is to pry off the bottom cover without removing the I/O panel and the fan panel. Unscrew the four bottom cover screws (Figure 8-16). *Carefully* remove the bottom cover, working alternately at both ends. Pry the edges of the cover apart, and ease the cover away from the body of the Nephelometer.
- ❑ The easier method takes more time. After removing the I/O panel, the fan panel and the end plate, slide the bottom cover off the body of the instrument. Using Figure 8-16 as a reference:

  a. Unscrew the three screws securing the I/O panel to the backbone, loosen the panel, and let the panel hang over the side of the instrument.

  b. Unscrew the two screws securing the fan panel to the backbone, loosen the panel, and let the panel hang over the side of the instrument.

c. Unscrew the three screws securing the end plate to the inlet section of the instrument and remove the end plate.

d. Unscrew the four bottom cover screws, and *carefully* slide the cover off the end of the instrument.

4. If the Nephelometer is resting on its feet, support the underside of the instrument.

5. Loosen the two screws attached to the analog and digital circuit boards (Figure 8-17).

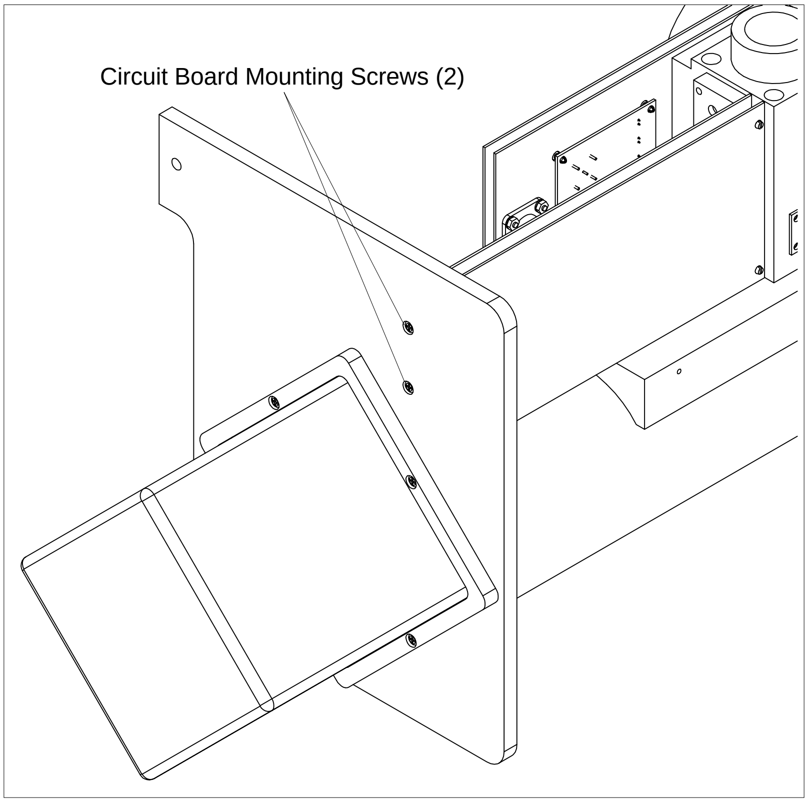


Figure 8-17
Circuit Board Mounting Screws

6. Disconnect the J25 connector attaching a wide ribbon cable from the PMT box to the digital circuit board.

7. Remove the three screws attaching the PMT end plate to the outlet section of the Nephelometer (Figure 8-17a).

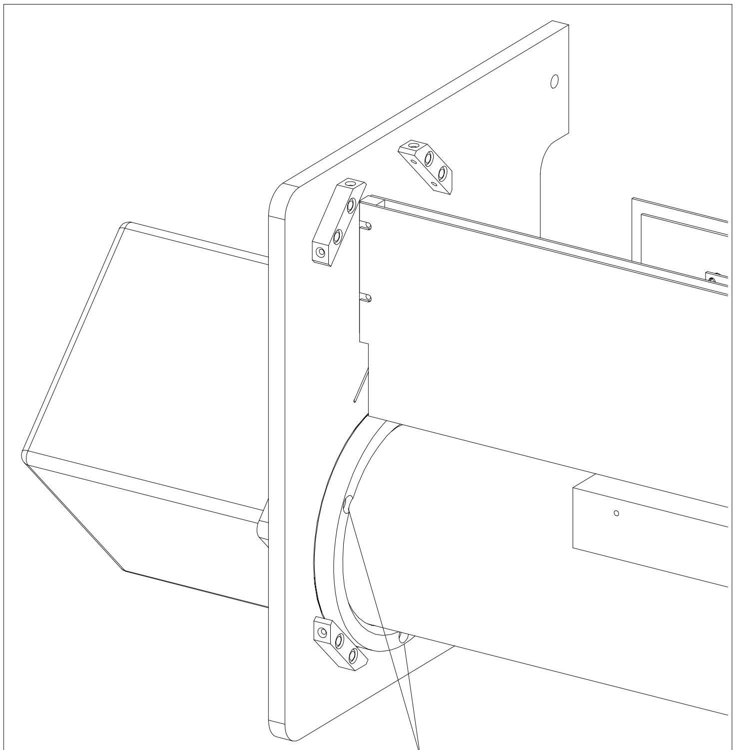


Figure 8-17a
PMT End Plate Screws

8. Using one hand to hold the PMT box, use the other hand to slide the aperture assembly from the outlet section of the Nephelometer.

Note: *Be careful not to let the inner tube drag inside the outer tube and scrape the paint.*

9. Set the aperture assembly on a flat surface, PMT end down (Figure 8-18).

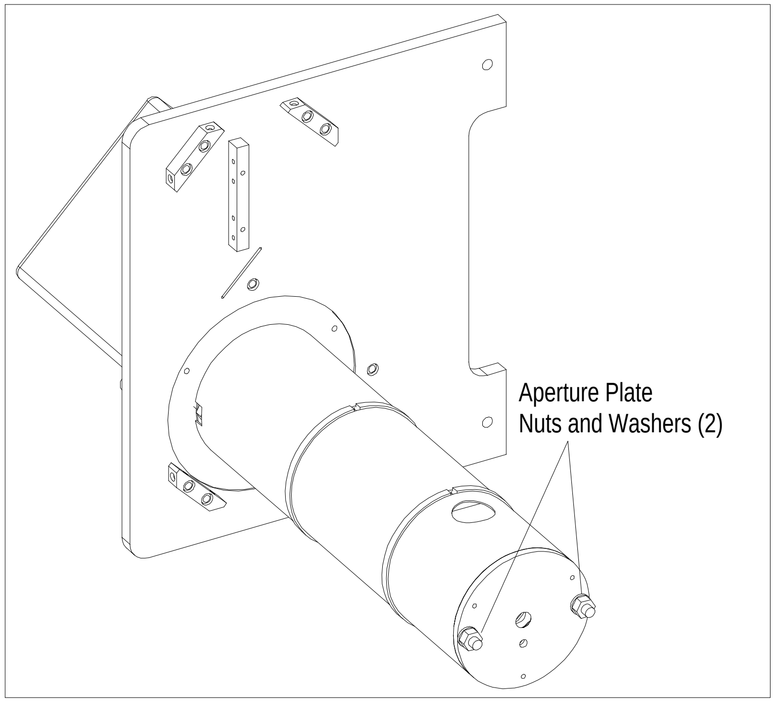


Figure 8-18
Aperture Assembly

10. Using an adjustable wrench, remove the two nuts and washers attaching the plate to the aperture assembly (Figure 8-18).

11. The aperture plate fits snugly. As you remove the plate, disconnect the motor connector (J13) from the circuit board.

12. To access the reference chopper:

a. Set the plate assembly, circuit board side up, on a flat surface (Figure 8-19).

b. Remove the three screws and washers attaching the circuit board and plate 1 to plate 2 (Figure 8-19).

c. Separate plate 1 and circuit board from plate 2 and turn plate 1 so that the shutter is facing you (Figure 8-20).

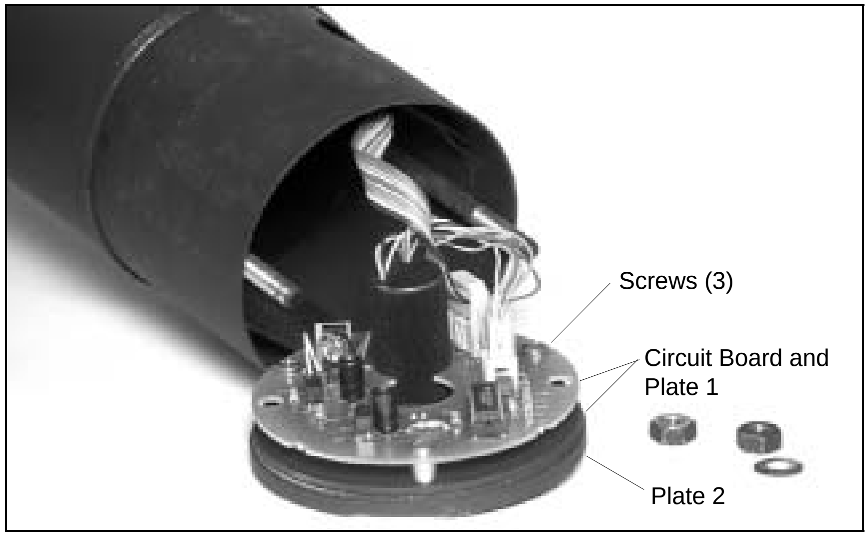


Figure 8-19
Aperture Plates and Circuit Board

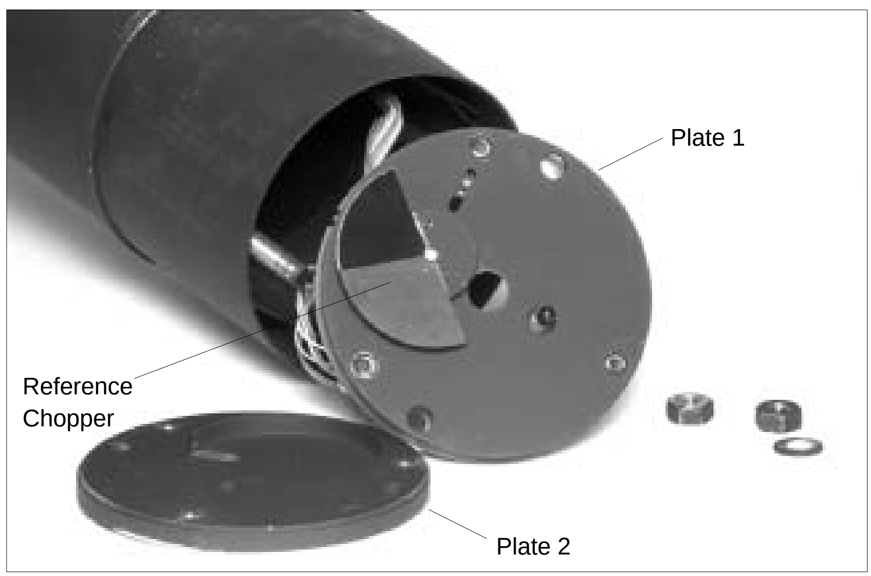


Figure 8-20
Reference Chopper

13. Use a cotton swab and alcohol to clean *only* the frosted or reflective aluminum surfaces of the reference chopper.

    Note: *Although TSI recommends isopropyl alcohol to clean the chopper, alcohol will remove black paint from components.*

14. ***Optional***

    If you need better access to the frosted surface of the reference chopper, loosen the screw in the counterweight and remove the chopper from plate 1.

    Note: *If you remove the reference chopper from plate 1, reattach the chopper by placing two sheets of paper as a spacer between the chopper and plate 1 so the hub of the chopper is very close to plate 1 without touching. Then tighten the setscrew and remove the paper. Make sure the chopper turns freely.*

15. Use the three screws and washers to reattach the circuit board and plate 1 to plate 2. Using a cotton swab, turn the chopper by the hub or plate to make sure that the chopper does not come in contact with any plate surface.

16. Reconnect the motor connector (J13) to the circuit board and seat the plate assembly in the aperture assembly.

    Note: *Make sure the motor connector cable does not block an aperture inside the aperture assembly.*

17. Reattach the two nuts and washers securing the aperture plate to the aperture assembly.

18. Reinsert the aperture assembly into the outlet end of the Nephelometer being careful not to bend the flocked paper insert in the middle of the Nephelometer sensor.

19. Reattach the PMT end plate with the three screws.

20. Reattach the analog and digital circuit boards to the end plate using the two screws (Figure 8-17).

21. Attach the bottom cover of the Nephelometer reversing the steps in step 3 of this procedure. Remember that the cover is pliable and fits tightly around the bottom of the instrument.

22. Replace the top cover of the Nephelometer and attach with the four screws.

23. Recalibrate the Nephelometer after you clean the reference chopper. Refer to Chapter 4, "Using Nephelometer Software (DOS)," for the calibration procedure using TSI software commands.

Cleaning the Light Pipe Outlet and the Backscatter Shutter

The light pipe is a solid glass rod that transfers light from the lamp to the measurement volume, providing a thermal break between the lamp and the measurement volume. The backscatter shutter, easily accessed while you are cleaning the outlet to the light pipe, collects dust when it is spinning in backscatter mode.

Tools
You need a Phillips-head screwdriver, soft cloth, cotton swabs, isopropyl alcohol, and O-ring grease.

1. If you are going to clean the outlet of the light pipe and the backscatter shutter, park the shutter in "Sleep" mode using the PD software command (refer to the "Action Commands" in Chapter 6).

Note: *The PD command positions the backscatter shutter so that you can remove the lamp base assembly from the Nephelometer without damaging the shutter.*

2. Remove power from the Nephelometer and from any instruments connected to the Nephelometer.

3. Loosen the four screws fastening the top cover of the Nephelometer and remove the cover (Figure 8-21).

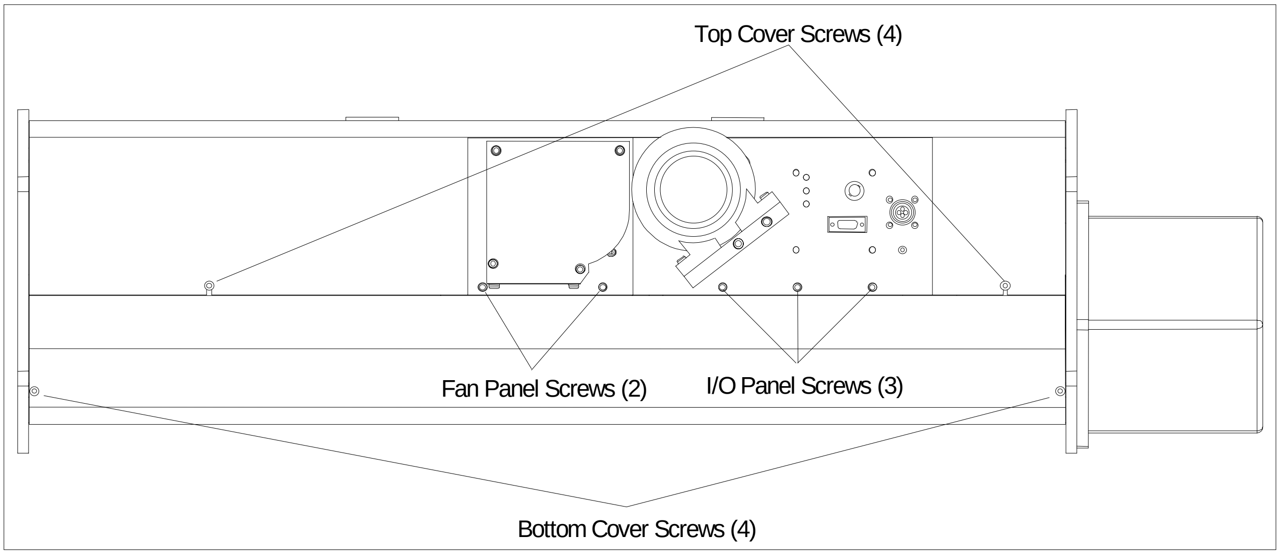


Figure 8-21
Top Cover Screws, Bottom Cover Screws, Fan Cover Screws, and I/O Panel Screws

4. Unscrew the two screws attaching the lamp shield (Figure 8-22). Remove the shield, supporting the shield so that is does not hang by the sensor wires.

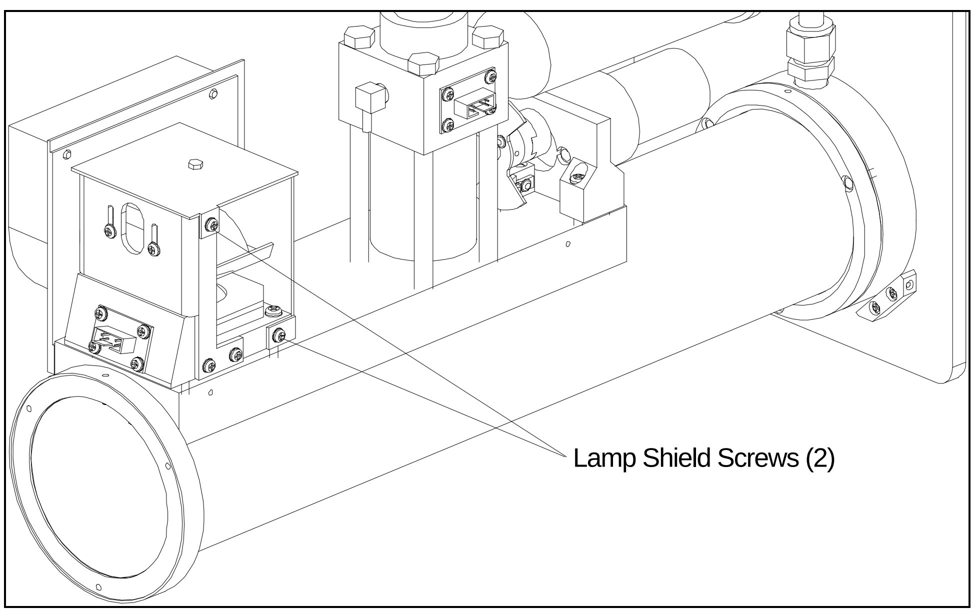


Figure 8-22
Lamp Shield

5. The bottom cover of the Nephelometer is pliable and fits very tightly around the bottom of the instrument. Remove the bottom cover in one of two ways:

- ❑ The more difficult method is to pry off the bottom cover without removing the I/O panel and the fan panel. Unscrew the four bottom cover screws (Figure 8-21). *Carefully* remove the bottom cover, working alternately at both ends. Pry the edges of the cover apart, and ease the cover away from the body of the Nephelometer.
- ❑ The easier method takes more time. After removing the I/O panel, the fan panel and the end plate, slide the bottom cover off the body of the instrument. Using Figure 8-21 as a reference:

  a. Unscrew the three screws securing the I/O panel to the backbone, loosen the panel, and let the panel hang over the side of the instrument.

  b. Unscrew the two screws securing the fan panel to the backbone, loosen the panel, and let the panel hang over the side of the instrument.

  c. Unscrew the three screws securing the end plate to the inlet section of the instrument and remove the end plate.

  d. Unscrew the four bottom cover screws, and *carefully* slide the cover off the end of the instrument.

6. Using Figure 8-23 as a reference:

   a. Remove the connector for the lamp on the analog board.

   b. Remove the ribbon cable connector from the inlet block.

   c. Remove the motor controller ribbon cable connector from the lamp block.

   d. Disconnect these sensor connectors (as marked): 1 (lamp temperature), 2 (valve position), 3 (valve motor), 4 (heater), and 6 (fan).

   e. Disconnect the blue DQ filter silicone tubing at the elbow connector on the backbone and at the elbow connector on the inlet.

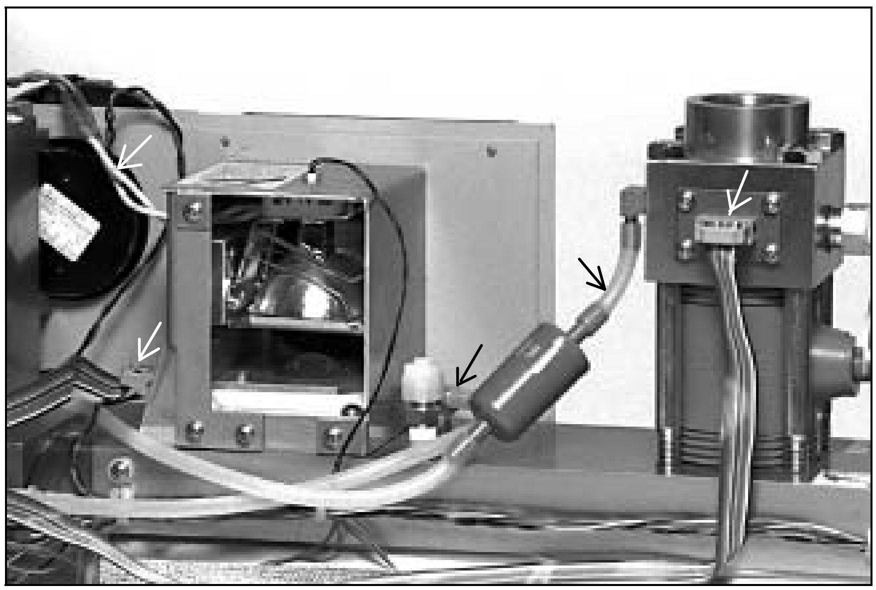


Figure 8-23
Disconnect Connectors and Tubing

7. To separate the Nephelometer inlet section from the outlet section, loosen the three screws attaching the two sections to each other (Figure 8-24) and *carefully* pull the sections apart (Figure 8-25). The flocked paper insert will be visible.

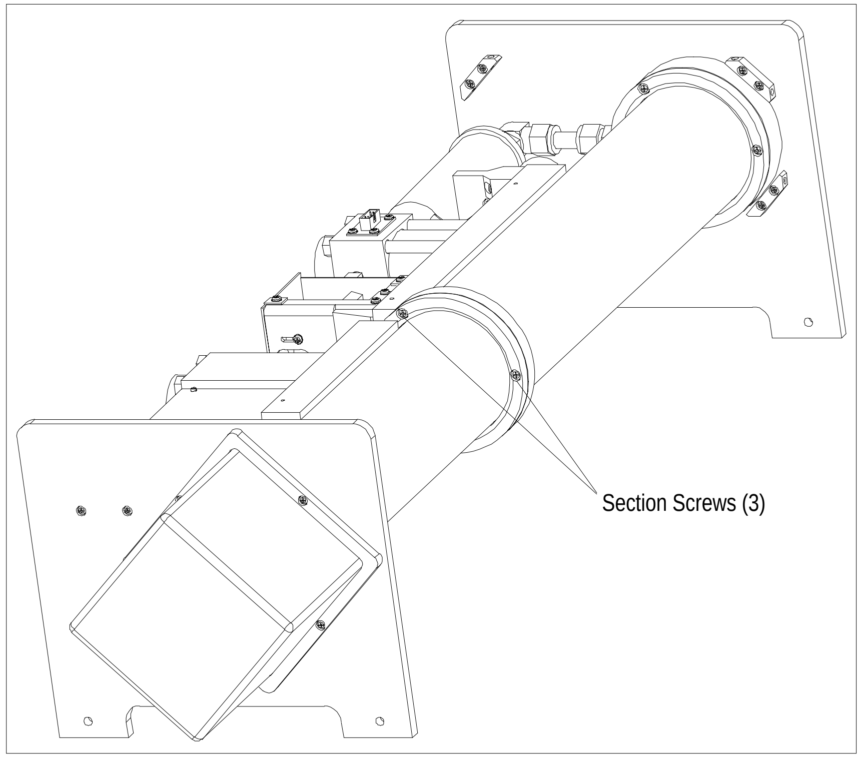


Figure 8-24
Nephelometer Sections Together

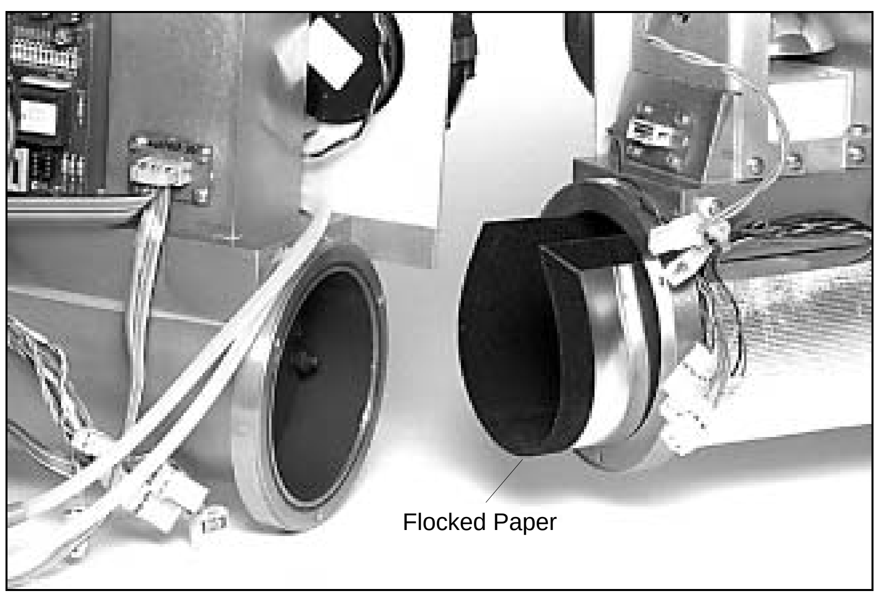


Figure 8-25
Nephelometer Sections Apart

8. To clean the light pipe outlet:

a. Unscrew the four screws, one on each corner, on the aluminum lamp base. Two of the screws are recessed (Figure 8-26).

b. Check to make sure the backscatter shutter is located underneath the light pipe. If not, rotate the shutter with your fingers.

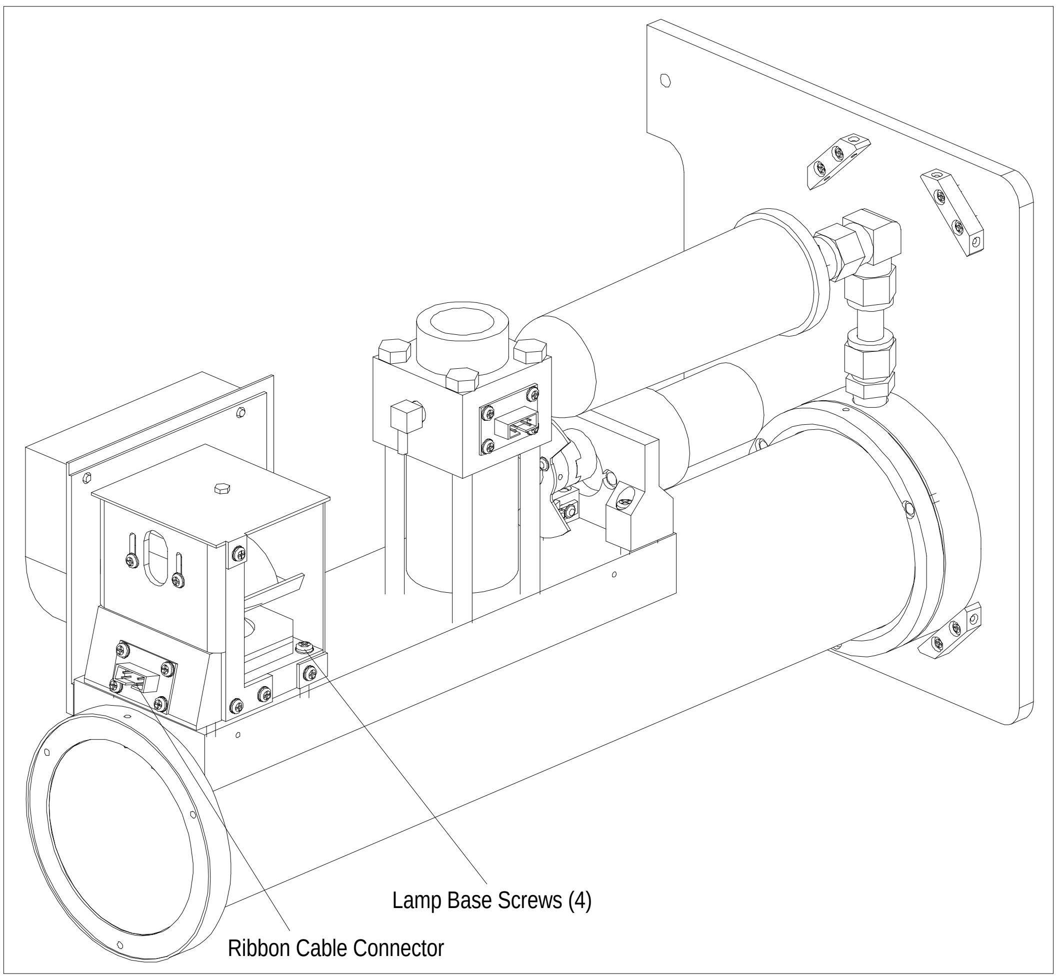


Figure 8-26
Lamp Base

c. Using one hand to support the backscatter shutter from below, use the other hand to *carefully* remove the lamp base assembly, angling the assembly as you pull it out of the sensor body (Figure 8-27).

Note: *Be careful not to catch the shadow lightstop plate on the backbone.*

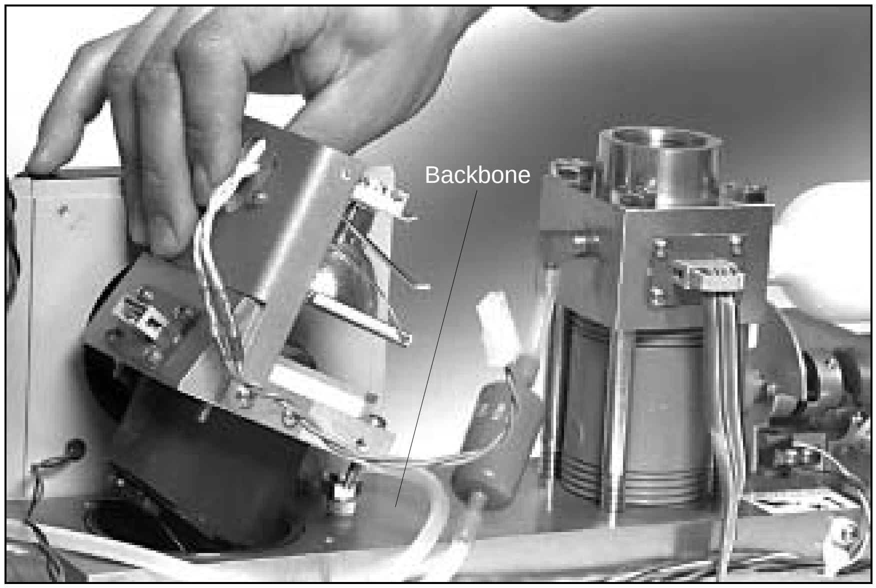


Figure 8-27
Removing the Lamp Base Assembly From the Sensor

d. Locate the light pipe outlet on the underside of the lamp base assembly (Figure 8-28). Use a cotton swab and alcohol to clean the outlet, making sure the swab does *not* touch black components.

Note: *Although TSI recommends isopropyl alcohol to clean the outlet, alcohol removes black paint from components.*

e. Use a soft dry cloth to clean the backscatter shutter. If necessary, use a soft cloth and a mild detergent solution followed by a soft dry cloth.

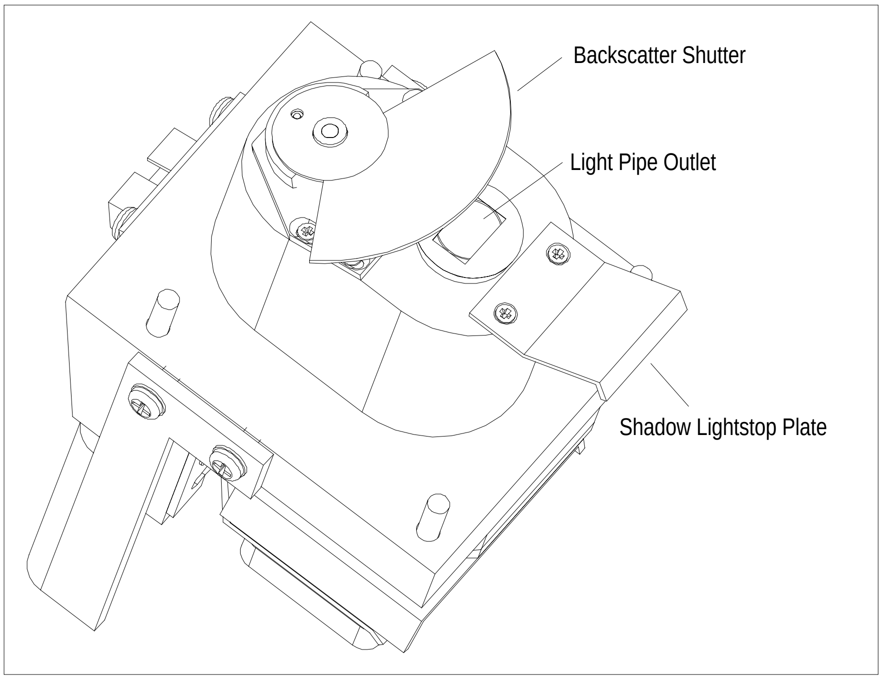


Figure 8-28
Light Pipe Outlet and Backscatter Shutter

f. Grease the O-ring on the backbone of the sensor (Figure 8-29) and replace the O-ring.

g. Rotate the backscatter shutter so it is positioned under the light pipe and *gently* reinsert the lamp base assembly, at an angle, into the sensor.

h. Tighten the four screws, one at each corner of the aluminum lamp base.

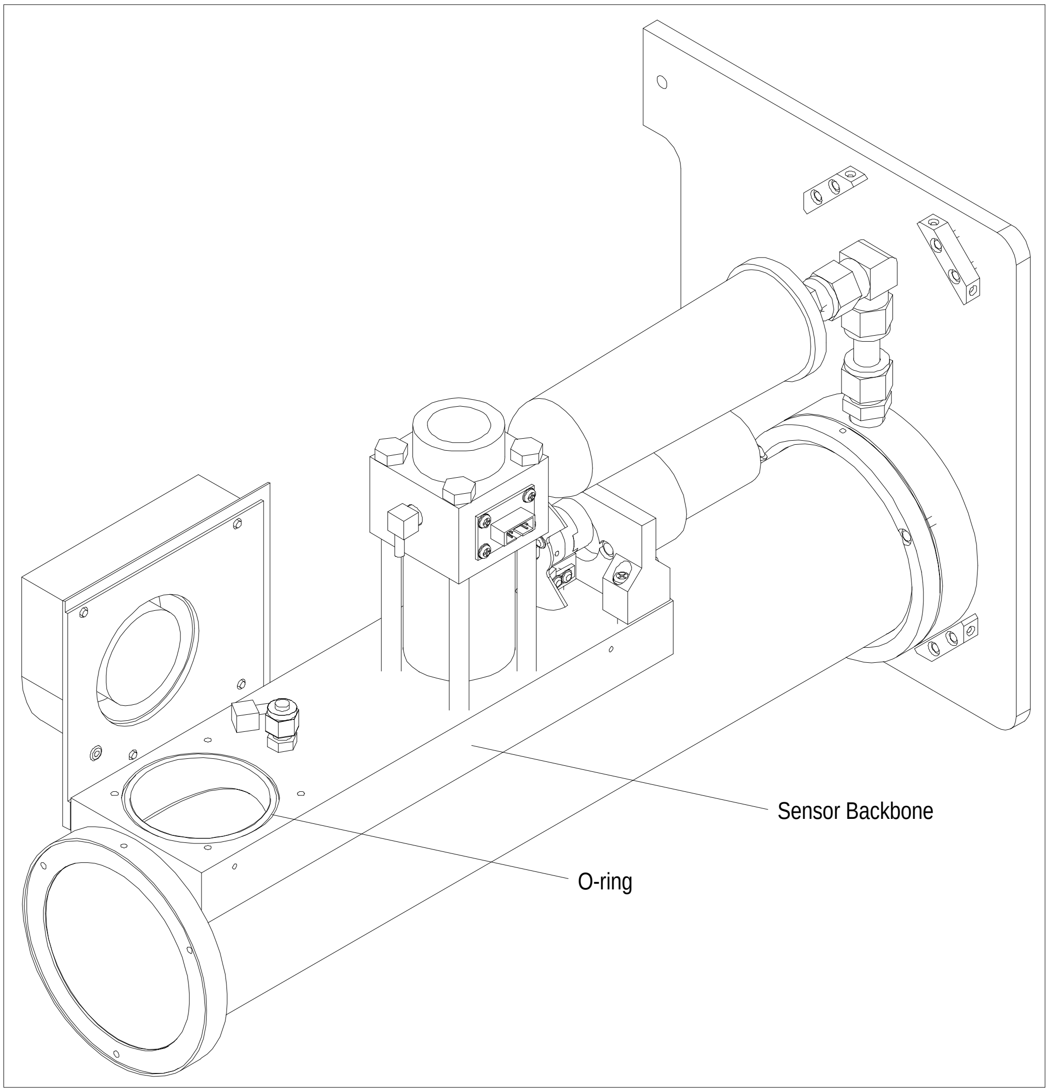


Figure 8-29
O-ring on the Sensor Backbone

9. Put a light coating of grease on the O-ring between the Nephelometer inlet and outlet sections and replace the O-ring in the groove (Figure 8-25).
10. Use the three screws to attach the Nephelometer outlet to the inlet.

11. Using Figure 8-23 as a reference:

a. Attach the connector for the lamp to the analog board.

b. Attach the ribbon cable connector to the inlet block.

c. Attach the motor controller ribbon cable connector to the lamp block.

d. Connect these sensor connectors (as marked): 1 (lamp temperature), 2 (valve position), 3 (valve motor), 4 (heater), and 6 (fan).

e. Connect the blue DQ filter silicone tubing at the elbow connector on the backbone and at the elbow connector on the inlet.

12. Attach the bottom cover of the Nephelometer reversing the steps in step 5 of this procedure. Remember that the cover is pliable and fits tightly around the bottom of the instrument.

13. Replace the top cover of the Nephelometer and attach with the four screws.

Cleaning the Flocked Paper

Black flocked paper inside the main tube has a direct effect on the amount of wallscatter light. If the paper collects dust, more light is scattered, affecting counts from the wall.

Tools and Parts
You need a Phillips-head screwdriver, a vacuum or a compressed air source, and O-ring grease.

1. Remove power from the Nephelometer and from any instruments connected to the Nephelometer.
2. Loosen the four screws fastening the top cover of the Nephelometer and remove the cover (Figure 8-30).

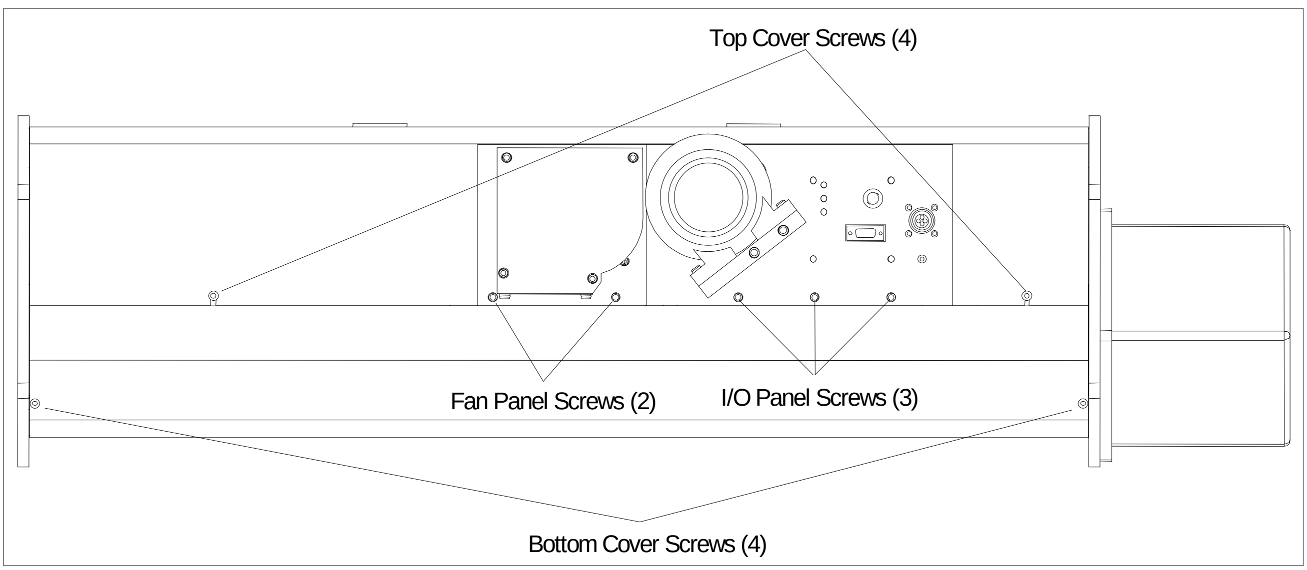


Figure 8-30
Top Cover Screws, Bottom Cover Screws, Fan Cover Screws, and I/O Panel Screws

3. The bottom cover of the Nephelometer is pliable and fits very tightly around the bottom of the instrument. Remove the bottom cover in one of two ways:

- ❑ The more difficult method is to pry off the bottom cover without removing the I/O panel and the fan panel. Unscrew the four bottom cover screws (Figure 8-30). *Carefully* remove the bottom cover, working alternately at both ends. Pry the edges of the cover apart, and ease the cover away from the body of the Nephelometer.
- ❑ The easier method takes more time. After removing the I/O panel, the fan panel and the end plate, slide the bottom cover off the body of the instrument. Using Figure 8-30 as a reference:

   a. Unscrew the three screws securing the I/O panel to the backbone, loosen the panel, and let the panel hang over the side of the instrument.

   b. Unscrew the two screws securing the fan panel to the backbone, loosen the panel, and let the panel hang over the side of the instrument.

   c. Unscrew the three screws securing the end plate to the inlet section of the instrument and remove the end plate.

   d. Unscrew the four bottom cover screws, and *carefully* slide the cover off the end of the instrument.

4. If the Nephelometer is resting on its feet, support the underside of the instrument.

5. Using Figure 8-31 as a reference:

   a. Remove the connector for the lamp on the analog board.

   b. Remove the ribbon cable connector from the inlet block.

   c. Remove the motor controller ribbon cable connector from the lamp block.

   d. Disconnect these sensor connectors (as marked): 1 (lamp temperature), 2 (valve position), 3 (valve motor), 4 (heater), and 6 (fan).

   e. Disconnect the blue DQ filter silicone tubing at the elbow connector on the backbone and at the elbow connector on the inlet.

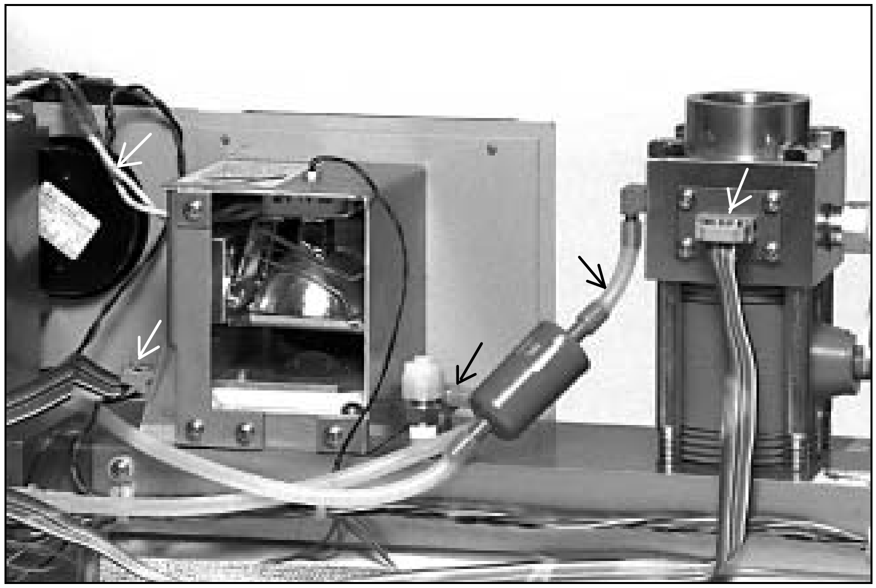


Figure 8-31
Disconnect Connectors and Tubing

6. To separate the Nephelometer inlet section from the outlet section, loosen the three screws attaching the two sections to each other (Figure 8-32) and *carefully* pull the sections apart (Figure 8-33). The flocked paper will be visible.

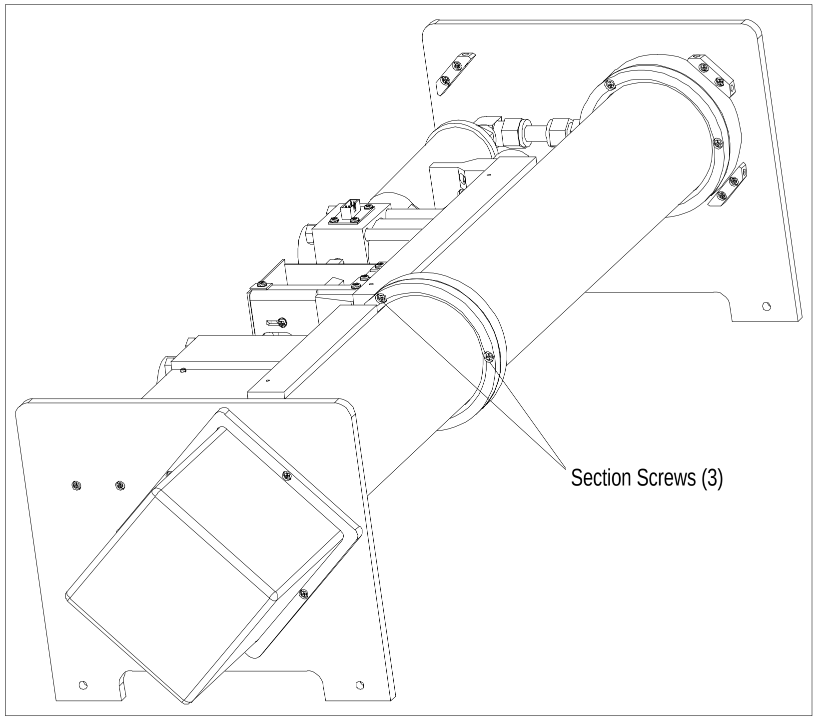


Figure 8-32
Nephelometer Sections Together

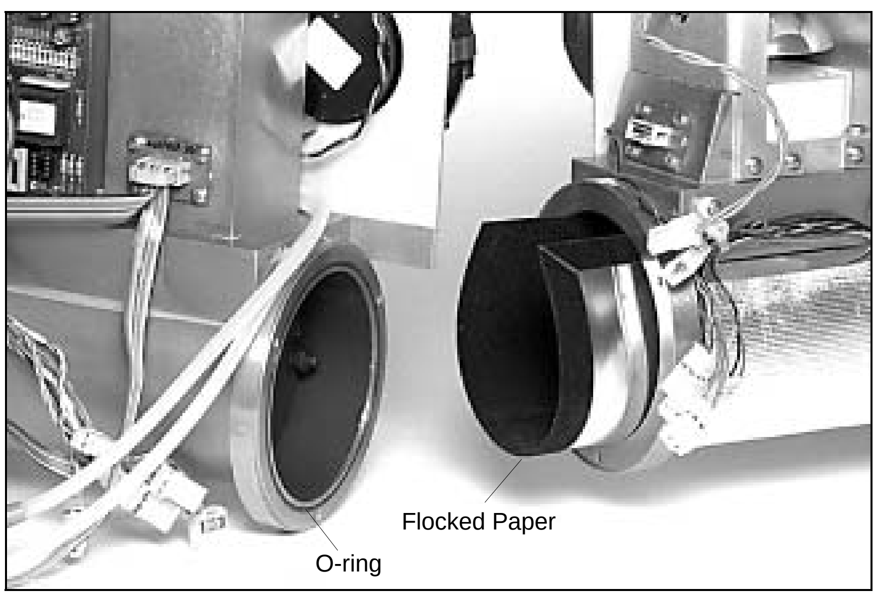


Figure 8-33
Nephelometer Sections Apart

7. Pull the flocked paper from the outlet section (Figure 8-34).

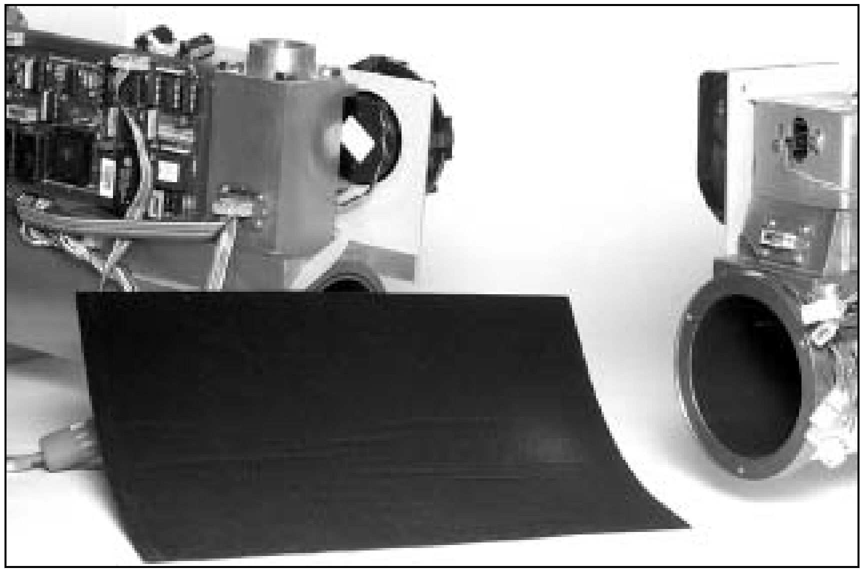


Figure 8-34
Flocked Paper Outside the Nephelometer

8. To clean the flocked paper, use a vacuum to take up or a compressed air source to blow away the dirt.

   Note: *If the paper has bald patches, it should be replaced. Contact TSI for assistance.*

9. Put a light coating of grease on the O-ring between the Nephelometer inlet and outlet sections and replace the O-ring in the groove (Figure 8-33).

10. *Carefully* reinstall the flocked paper, fitting the paper around the PMT aperture plate in the outlet section of the Nephelometer.

11. Use the three screws to attach the Nephelometer outlet section to the inlet section.

12. Using Figure 8-31 as a reference:

    a. Attach the connector for the lamp to the analog board.

    b. Attach the ribbon cable connector to the inlet block.

    c. Attach the motor controller ribbon cable connector to the lamp block.

d. Connect these sensor connectors (as marked): 1 (lamp temperature), 2 (valve position), 3 (valve motor), 4 (heater), and 6 (fan).

e. Connect the blue DQ filter silicone tubing at the elbow connector on the backbone and at the elbow connector on the inlet.

13. Attach the bottom cover of the Nephelometer reversing the steps in step 3 of this procedure. Remember that the cover is pliable and fits tightly around the bottom of the instrument.

14. Replace the top cover of the Nephelometer and attach with the four screws.

Replacing a Temperature or Humidity Sensor

The Nephelometer has two built-in temperature sensors and a humidity sensor. The sensors are mounted on PC boards to make service easy. Although the sensors are rugged, they may have to be replaced sometime during the life of the instrument. The first temperature sensor is located at the inlet of the instrument. The second temperature sensor and the humidity sensor are located near the outlet, on the same PC board.

Tools and Parts
You need a Phillips-head screwdriver, a replacement sensor mounted on its PC board, and O-ring grease.

1. Remove power from the Nephelometer and from any instruments connected to the Nephelometer.

2. Loosen the four screws fastening the top cover of the Nephelometer and remove the cover (Figure 8-35).

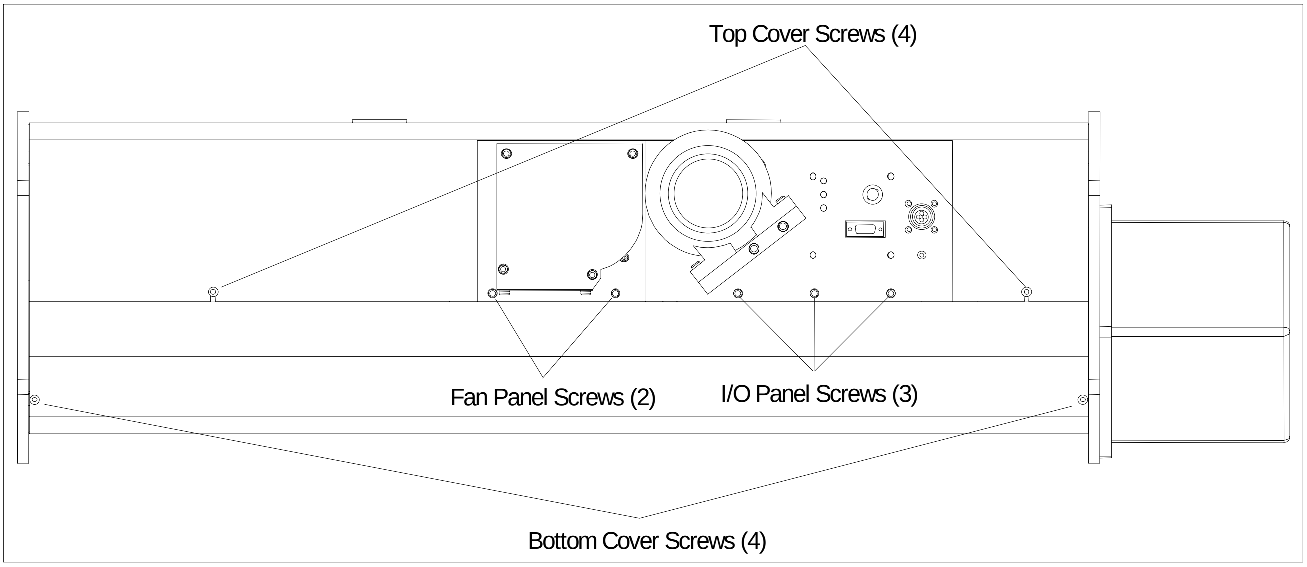


Figure 8-35
Top Cover Screws, Bottom Cover Screws, Fan Cover Screws, and I/O Panel Screws

3. Disconnect the ribbon cable from the appropriate sensor (Figure 8-36).

4. Remove the four screws from the appropriate PC board and remove the sensor assembly.

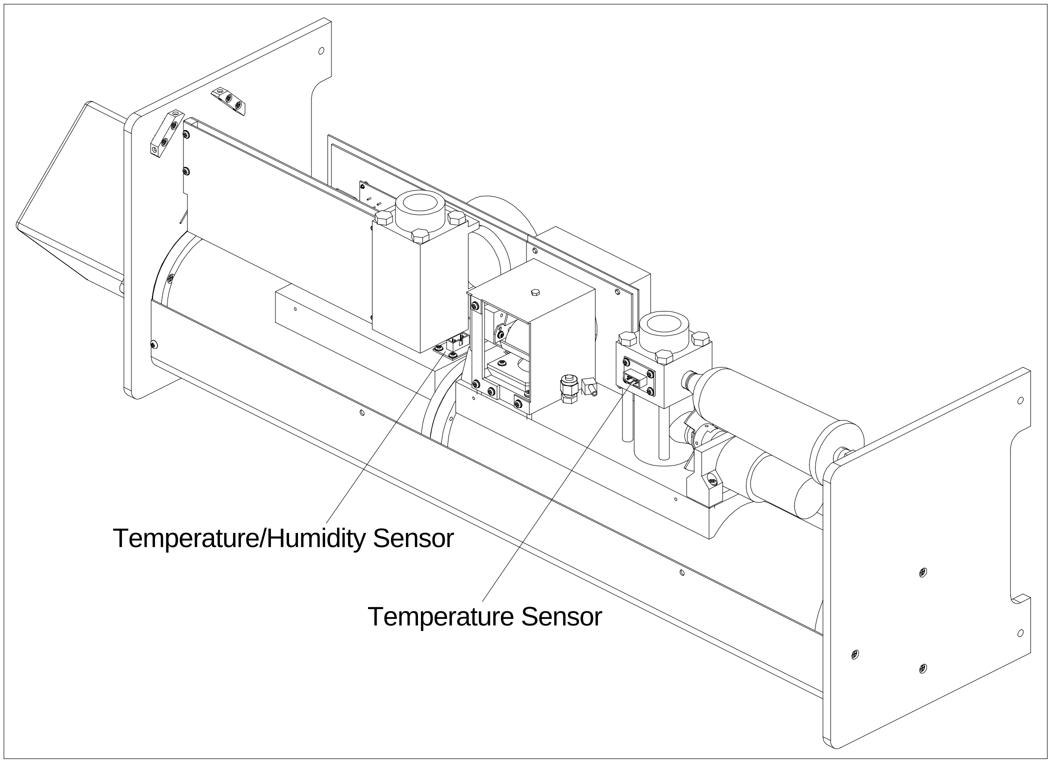


Figure 8-36
Humidity and Temperature Sensor Locations

5. Lightly grease the sealing O-ring if necessary.

6. Replace the sensor assembly with the replacement sensor.

7. Replace the four screws.

8. Replace the cover and run the Nephelometer software to verify that the sensor is operating correctly.

9. Calibrate the sensor, if needed (refer to SC command in Chapter 6).

Replacing a Photomultiplier Tube

As a photomultiplier tube (PMT) ages, it becomes less sensitive. You may find that you can compensate for the gain by increasing the voltage. At this time, there is no data on life expectancy of a PMT or how the tube may be affected by different environments. If there is a substantial increase in dark current (see the RP command under "Read Commands" in Chapter 6), replace the PMT.

Notes: *Replacing a PMT should only be attempted by someone who is technically qualified and who is familiar with the operation of the Nephelometer.*

Tools and Parts

You need a Phillips-head screwdriver and a replacement PMT:

- Blue PMT R1527P TSI P/N 3009004
- Green PMT R1527P TSI P/N 3009004
- Red PMT R2949 TSI P/N 3009005

W A R N I N G

High voltages that can shock or burn.

The box that houses the photomultiplier tubes (PMT) contains a high voltage source. Components within this box should only be serviced by a qualified technician. Disconnect all power to the Nephelometer and contact TSI personnel before disassembling the PMT box.

C a u t i o n

Light sensitive components.

To avoid damage to the photomultiplier tubes (PMT), remove power from the Nephelometer and open the PMT box in subdued lighting. Exposing the photomultiplier tubes to direct light may affect tube performance.

1. Remove power from the Nephelometer and from any instruments connected to the Nephelometer.

2. Unscrew the four screws attaching the PMT cover to the sensor and remove the cover (Figure 8-37)

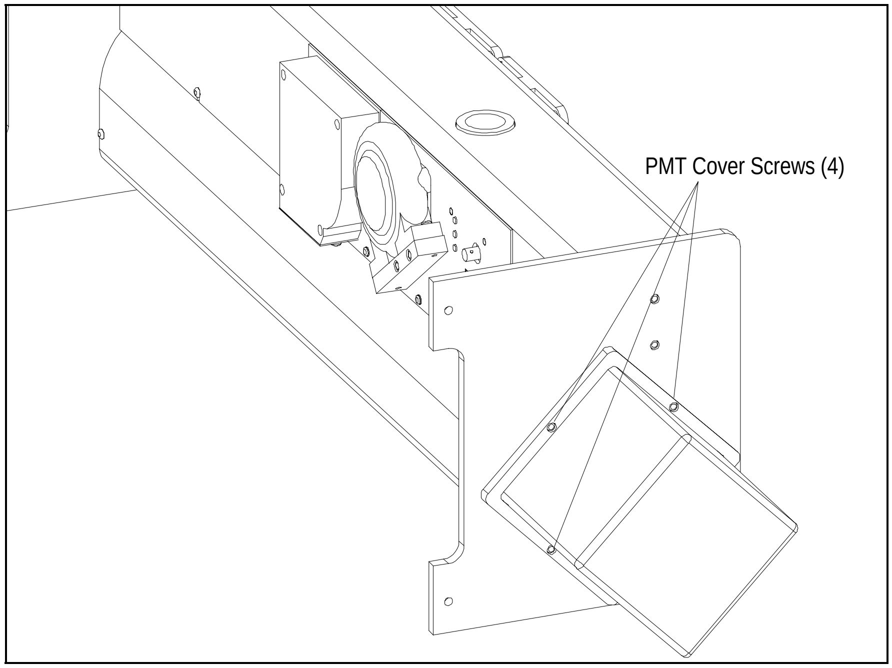


Figure 8-37
PMT Cover

3. Each PMT fits inside a magnetic shield (Figure 8-38). To remove the shield and PMT, support the sensor frame with one hand and use your other hand to *gently* rock the shield from side to side as you pull it from its socket.

5. To remove the PMT from the shield, loosen the three setscrews at the base of the shield (Figure 8-38) and withdraw the tube.

6. *Carefully* insert a new PMT into the shield. Position the tube so that the light-sensing portion (criss-crossed wires) of the tube faces the slotted opening on the shield. *Gently* tighten the three setscrews so that the end of the tube is ⅛ in. from the end of the shield.

Notes: *If the tube is not inserted far enough, the setscrews will touch glass and may shatter the tube when they are tightened.*

Tighten the setscrews only enough to support the tube. If you overtighten the screws you may crack the plastic base.

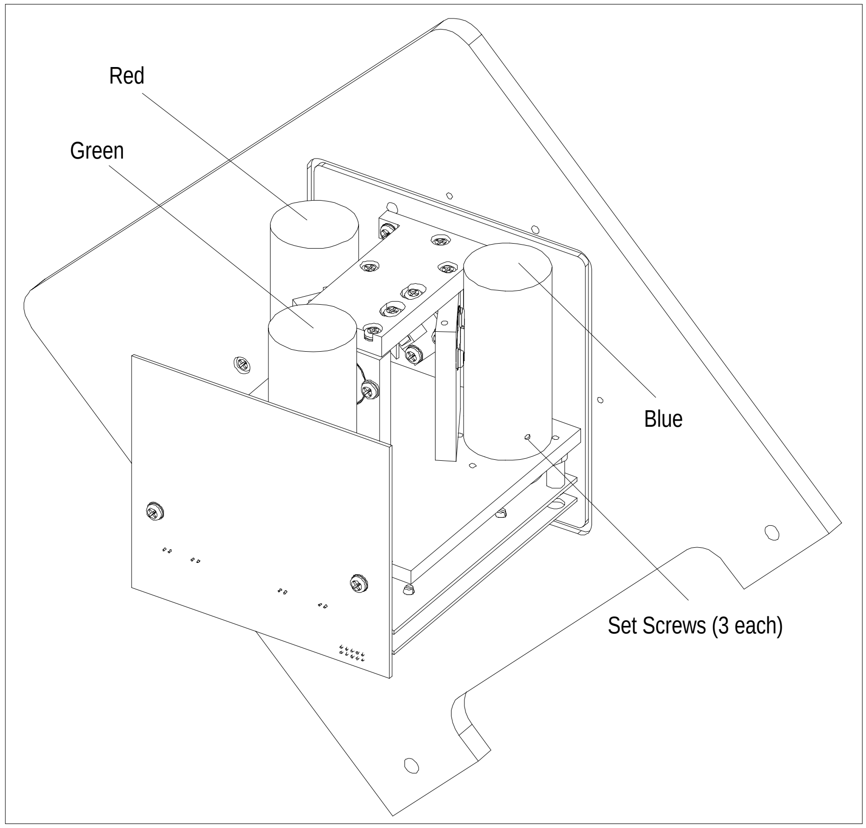


Figure 8-38
Red, Blue and Green PMTs with Setscrews

7. Plug the tube into the socket, noting the alignment of the center pin of the tube into its mating socket.
8. Replace the PMT cover and attach with the four screws.

Checking, Cleaning, and Replacing Bandpass Filters

Three bandpass filters are centered at 450 nm (blue), 550 nm (green), and 700 nm (red) wavelengths. Although located within a protective can, the filters may need periodic cleaning if they accumulate dust or dirt. In addition, exposure to high humidity can attack the coatings on the filters causing them to cloud.

Tools and Parts
You need a Phillips-head screwdriver, an S-shaped Phillips-head screw driver, and a bandpass filter:

- Blue filter P/N 2502486
- Green filter P/N 2502485
- Red filter P/N 2502487

WARNING

High voltages that can shock or burn.

The box that houses the photomultiplier tubes (PMT) contains a high voltage source. Components within this box should only be serviced by a qualified technician. Disconnect all power to the Nephelometer and contact TSI personnel before disassembling the PMT box.

Caution

Light sensitive components.

To avoid damage to the photomultiplier tubes (PMT), remove power from the Nephelometer and open the PMT box in subdued lighting. Exposing the photomultiplier tubes to direct light may affect tube performance.

1. Remove power from the Nephelometer and from any instruments connected to the Nephelometer.
2. Remove the PMT cover by unscrewing the four screws attaching the cover to the sensor (Figure 8-39).

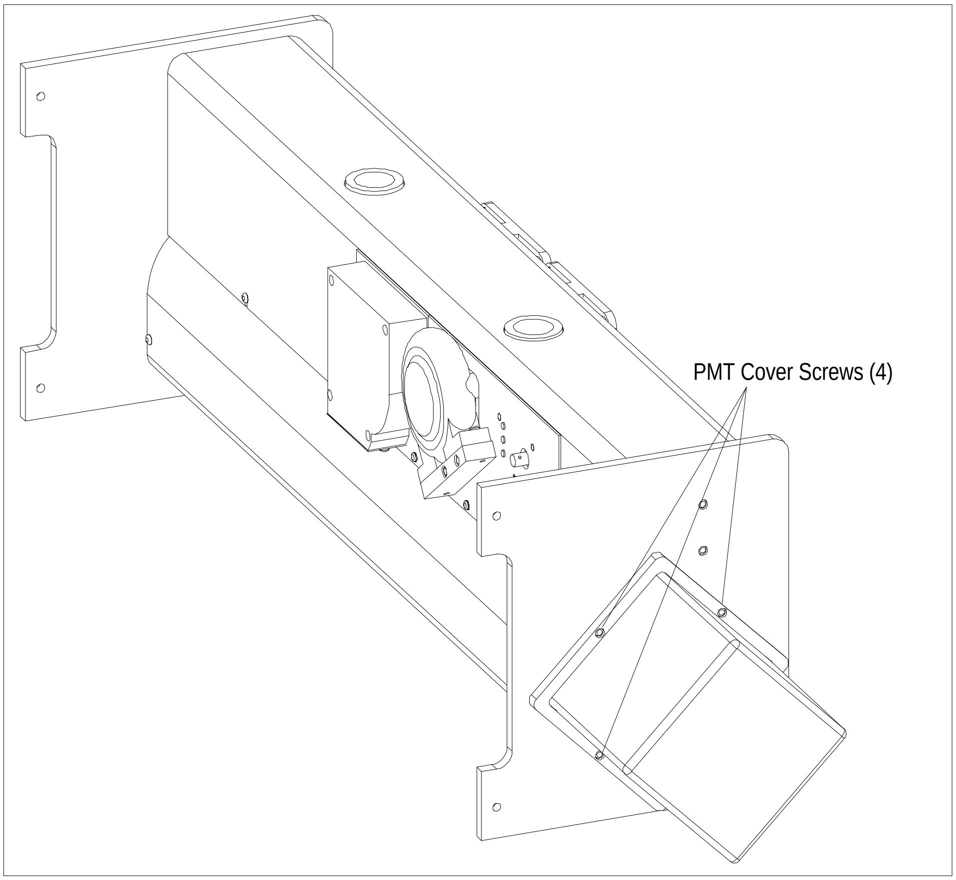


Figure 8-39
PMT Cover

3. To check the bandpass filters, you must remove the PMTs with their magnetic shields (Figure 8-40). To remove a shield and tube, support the sensor frame with one hand and use your other hand to *gently* rock the shield from side to side as you pull it from its socket.

4. Visually inspect the filter but *avoid* touching the filter with your fingers.

- ❑ If there is dust, use a lens cloth to remove the dust. If the filter looks clean and transparent, it does *not* need to be replaced. Go to step 7 of this procedure.
- ❑ If the filter is cloudy, remove the filter for a closer inspection. Go to step 5 of this procedure.

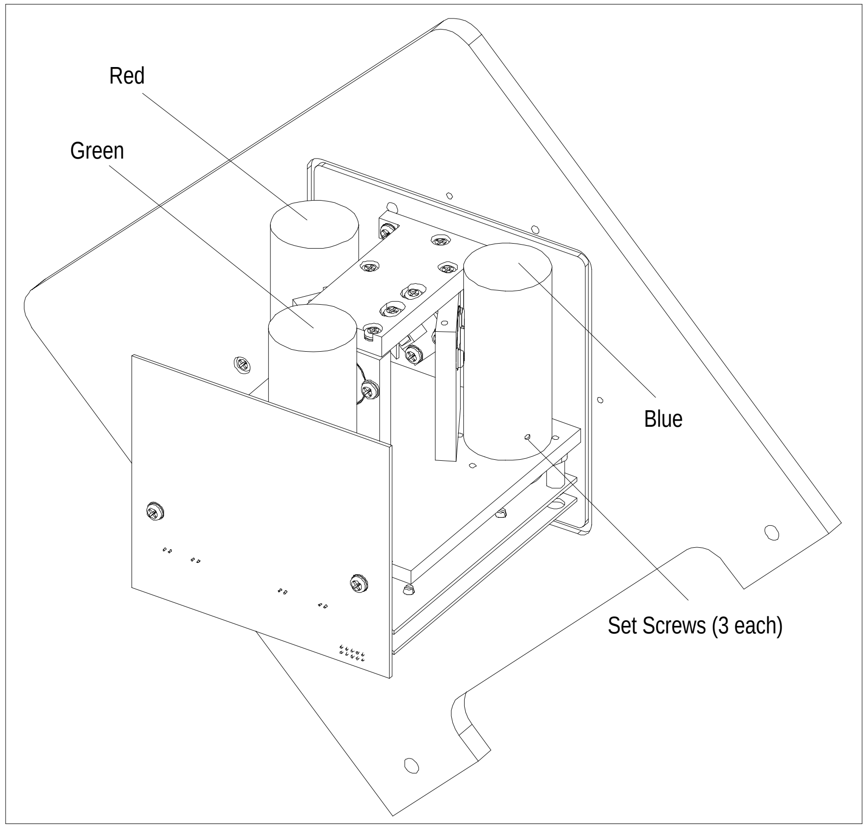


Figure 8-40
Red, Blue and Green PMTs with Setscrews

5. Use the S-shaped Phillips-head screwdriver to unscrew the two screws holding the filter in place, and remove the filter (Figure 8-41).
6. Hold the filter up to the light. If the filter is *not* transparent, or if there is clouding around the edges, replace the filter. Attach the new filter in the holder using the two screws and washers.
7. Plug the tube into the socket, noting the alignment of the center pin of the tube into its mating socket.
8. Replace the PMT cover and attach with the four screws.

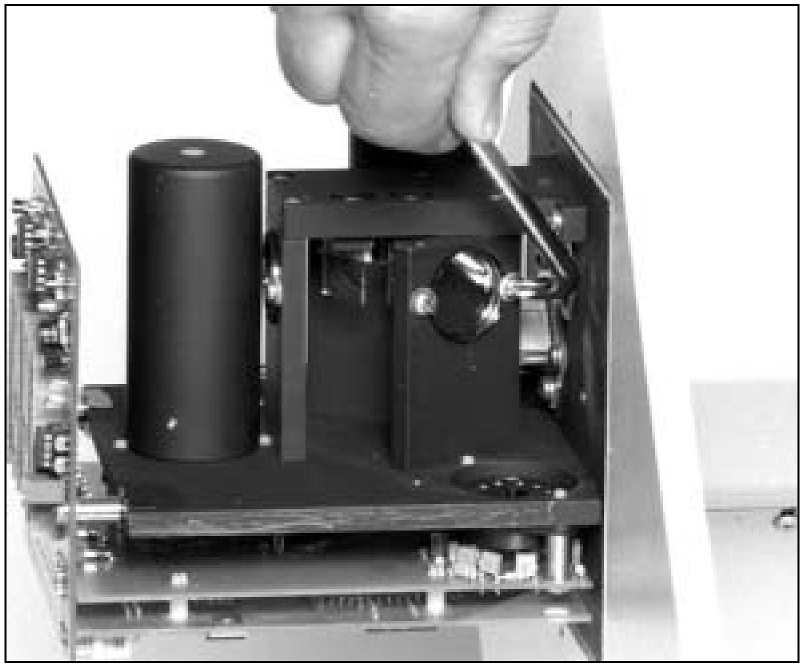


Figure 8-41
Bandpass Filter

Cleaning the Lens

The lens collimates light from apertures that define the viewing volume in the body of the instrument. The light is collimated before it is split into separate colors to ensure that each photomultiplier tube sees the same area of light scatter from the viewing volume.

Note: *Under normal circumstances, you do not have to periodically check or clean the lens. Check the lens if there is an overall reduction in the signal in all three wavelengths over time.*

Tools and Parts
You need a Phillips-head screwdriver, flashlight, lens cloth, and cotton swabs.

WARNING

High voltages that can shock or burn.

The box that houses the photomultiplier tubes (PMT) contains a high voltage source. Components within this box should only be serviced by a qualified technician. Disconnect all power to the Nephelometer and contact TSI personnel before disassembling the PMT box.

Caution

Light sensitive components.

To avoid damage to the photomultiplier tubes (PMT), remove power from the Nephelometer and open the PMT box in subdued lighting. Exposing the photomultiplier tubes to direct light may affect tube performance.

1. Remove power from the Nephelometer and from any instruments connected to the Nephelometer.
2. Remove the PMT cover by unscrewing the four screws attaching the cover to the sensor (Figure 8-42).

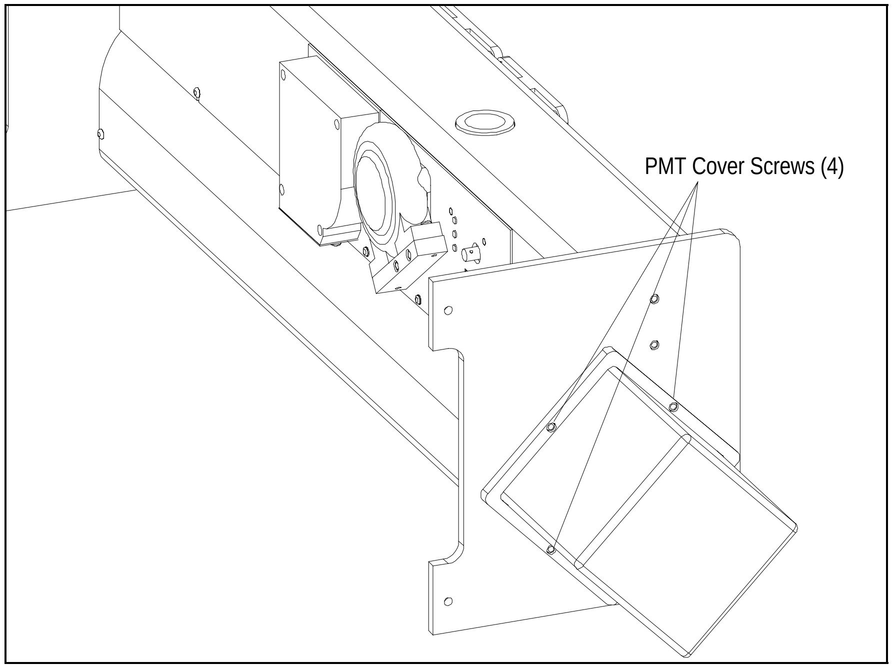


Figure 8-42
PMT Cover

3. To access the lens, you must remove the red PMT tube with its magnetic shield (Figure 8-43). To remove the tube, support the sensor frame with one hand and use your other hand to *gently* rock the shield from side to side as you pull the shield and tube from its socket.

Note: *If you need further access to the lens, you can remove the screw attaching the lens holder.*

4. Use a flashlight to inspect the lens for signs of dust.
5. If the lens is dusty, *carefully* clean the lens with a cotton swab you have covered with lens paper.

Note: *Although TSI normally recommends isopropyl alcohol to clean lenses, alcohol or acetone removes black paint from components.*

6. Replace the tube into its socket, noting the alignment of the center pin of the tube with its mating socket.
7. Replace the PMT cover and attach with the four screws.

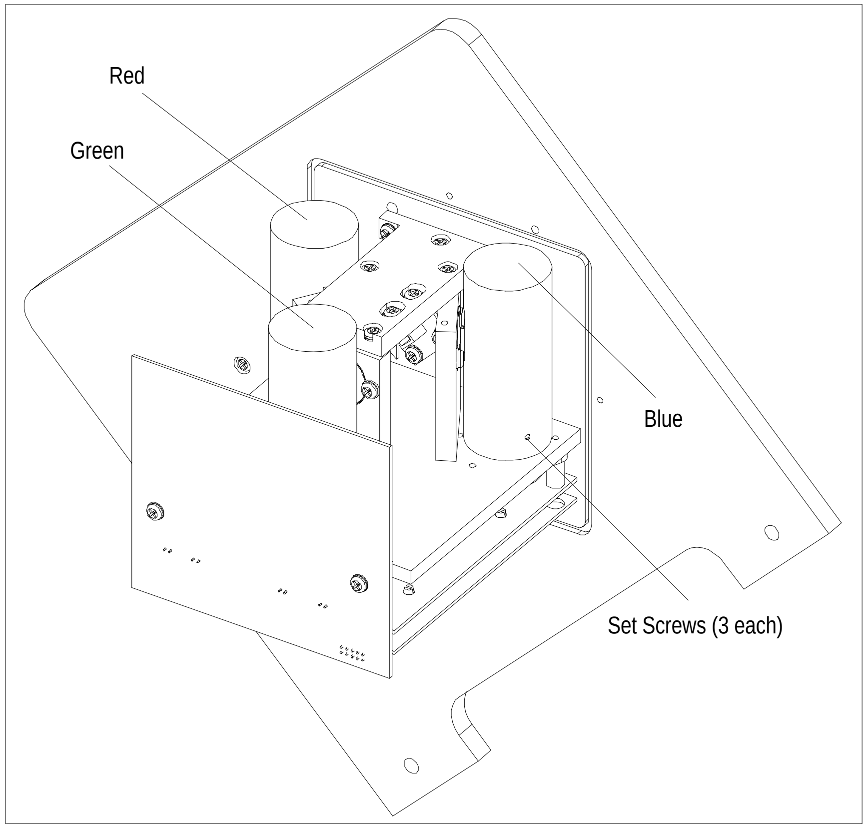


Figure 8-43
Red, Blue and Green PMTs with Setscrews

CHAPTER 9

Contacting Customer Service

This chapter gives directions for contacting people at TSI Incorporated for technical information and directions for returning the Model 3550/3560 Series Integrating Nephelometer for service.

Technical Contacts at TSI

- ❑ If you have any difficulty installing the Nephelometer, or if you have technical or application questions about this instrument, contact an applications engineer at TSI Incorporated, 1-800-678-2708 or (651) 490-2833.
- ❑ If the Nephelometer fails, or if you are returning it for service, contact TSI Particle Instrument Division, Customer Service, at 1-800-874-3893 (USA) or (651)-490-3893.

Returning the Nephelometer for Service

Call Customer Service 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 inlet and fan on the sensor to prevent debris from entering the instrument and ensure that the indicator lights and the connectors on the instrument back panel are protected.

APPENDIX A
Specifications

Table A-1 lists the specifications for the Nephelometer sensor and Table A-2 lists the power supply. These specifications are subject to change.

Table A-1
Specifications for the Nephelometer Sensor

Wavelengths	
Models 3551	550 nm (green)
Models 3563	450 nm (blue), 550 nm (green), and 700 nm (red/infrared)
Bandwidth	50 nm (all wavelengths)
Sensitivity at 30-sec averaging time (aerosol scattering coefficient, σ_{sp})	
Blue and green wavelengths	1.0×10^{-7} m^{-1}
Red/Infrared wavelength	3.0×10^{-7} m^{-1}
Averaging time	1 to 4096 sec (selectable)
Drift	$<2.0 \times 10^{-7}$ m^{-1} at 30-sec averaging time for up to one hour after filtered-air reference measurement for green wavelength
Optical background signal	
Blue and green wavelengths	$<5.0 \times 10^{-5}$ m^{-1}
Red/Infrared wavelength	$<1.0 \times 10^{-5}$ m^{-1}
Angular integration	7 to 170°
Backscatter shutter	Changes angular integration from 7 to 170° to 90 to 170° (Models 3561 and 3563 only)
Reference shutter	Allows measurement of light intensity of a reference object illuminated by main lamp or of photodetector's dark signal
Filtered air reference chopper	High-efficiency particle filter switches into sample air stream automatically on host computer demand or at intervals selected by user
Response time	<10 sec
Recommended flowrate	20 to 200 L/min
Inlet/Outlet Dimensions	25 mm diameter
Particle transport efficiency	>95% of unit-density particles from 0.05 to 5 µm in diameter

(continued)

Table A-1
Specifications for the Nephelometer Sensor (*continued*)

Temperature and pressure sensors...	Built-in sensors allow corrections for changes in the Rayleigh-scattering coefficient of air within sample volume
Humidity sensor...............................	Measures relative humidity of sample from 5 to 95% ±5%
Time and date	Provided by internal, real-time clock with battery backup
Vacuum integrity	<10 mm Hg/hr at a negative pressure of 700 mm Hg (not including optional blower)
Dimensions.......................................	1100 mm × 300 mm × 250 mm (43 in. × 12 in. × 10 in.)
Weight..	<18 kg (<40 lb)
Power requirements	Operates on 24.0 ±4.0 VDC at <5.0 A (125 W maximum), supplied by power supply (included)
Environmental conditions	Indoor use Altitude up to 2000 m (6500 ft) Ambient temperature 5–40°C Ambient humidity 0–90% RH noncondensing Overvoltage category II Pollution degree II

Table A-2
Specifications for the Power Supply

Output	24.0 ±4.0 VDC at <5.0 A
Dimensions.....................................	300 mm × 150 mm × 100 mm (12 in. × 8 in. × 5 in.)
Weight...	<5 kg (<11 lb)
Power requirements	85–260 VAC, 50–60 Hz at <100 W
Fuse *(not replaceable by user)* .... (*Internal—**not** accessible by operator*)	~F 7A FB/250V

APPENDIX B

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Prepared for
TSI Incorporated
by
Robert J. Charlson, Ph. D.

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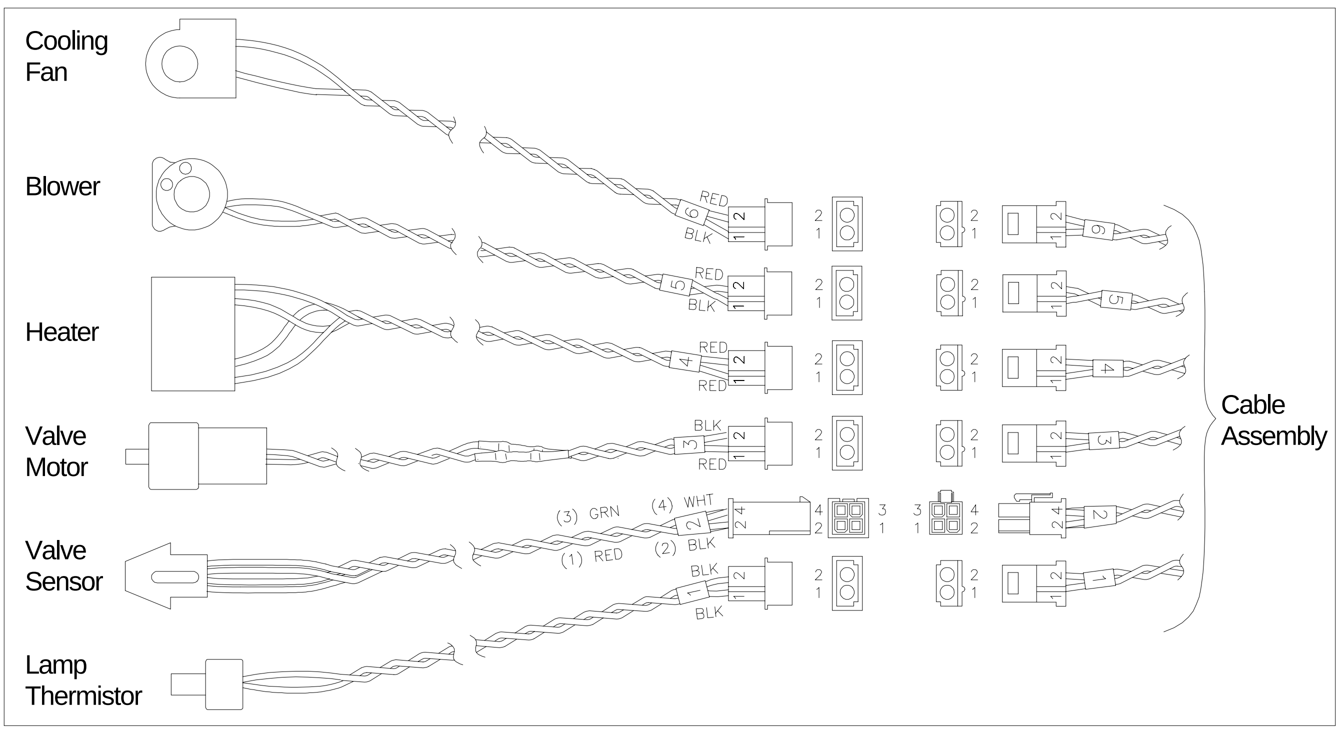
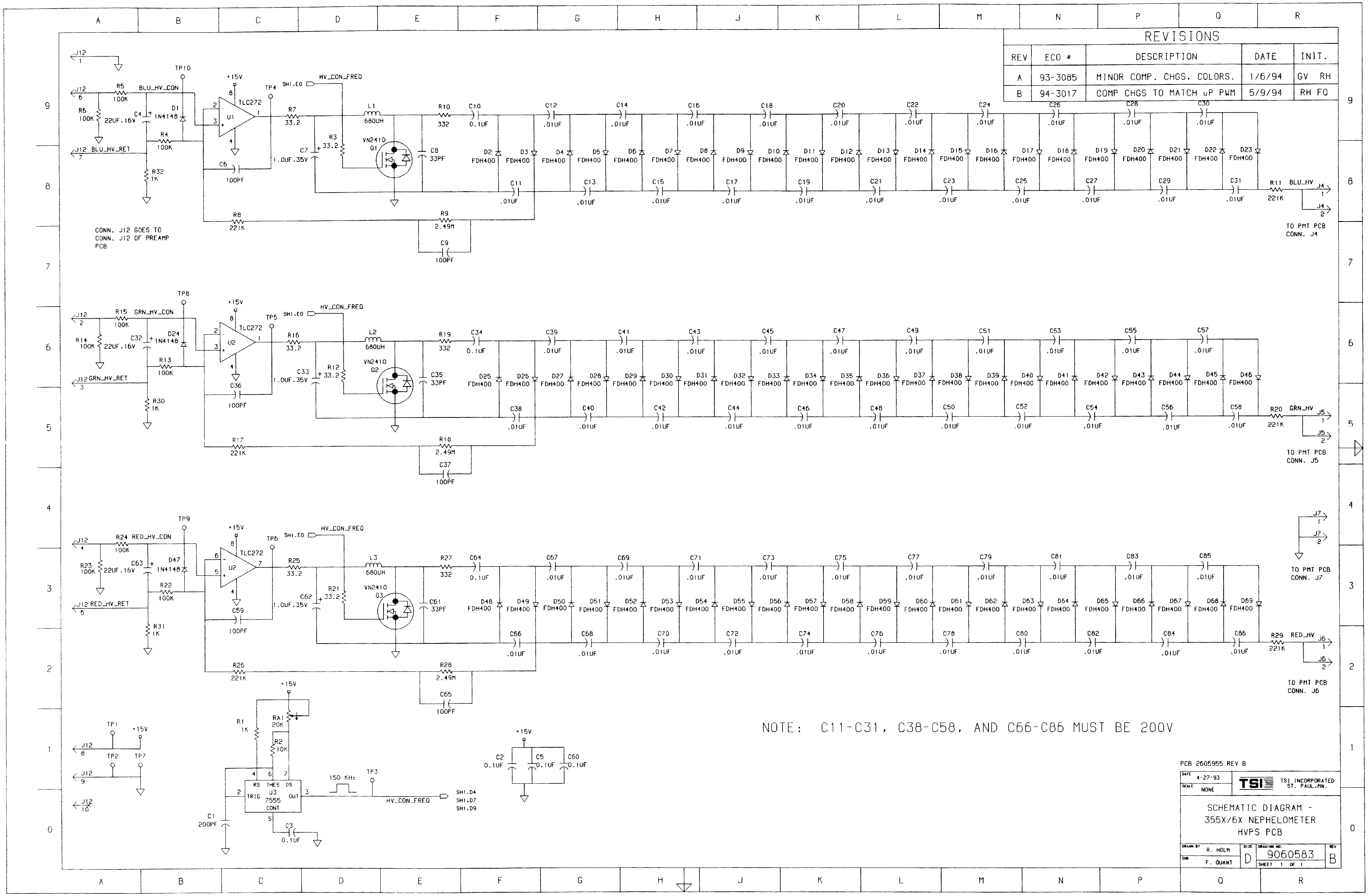
APPENDIX C
Schematics

This appendix contains the following drawing and schematics:

- Nephelometer sensor connectors
- 9060583, revision B, 1 sheet
- 9060584, revision B, 1 sheet
- 9060585, revision B, 4 sheets
- 9060586, revision A, 1 sheet
- 9060587, revision B, 1 sheet
- 9060601, revision D, 3 sheets





REVISIONS				
REV	ECO #	DESCRIPTION	DATE	INIT.
A	93-3085	MINOR COMP. CHGS. COLORS.	1/6/94	GV RH
B	94-3017	COMP CHGS TO MATCH uP PWM	5/9/94	RH FQ

NOTE: C11-C31, C38-C58, AND C66-C86 MUST BE 200V

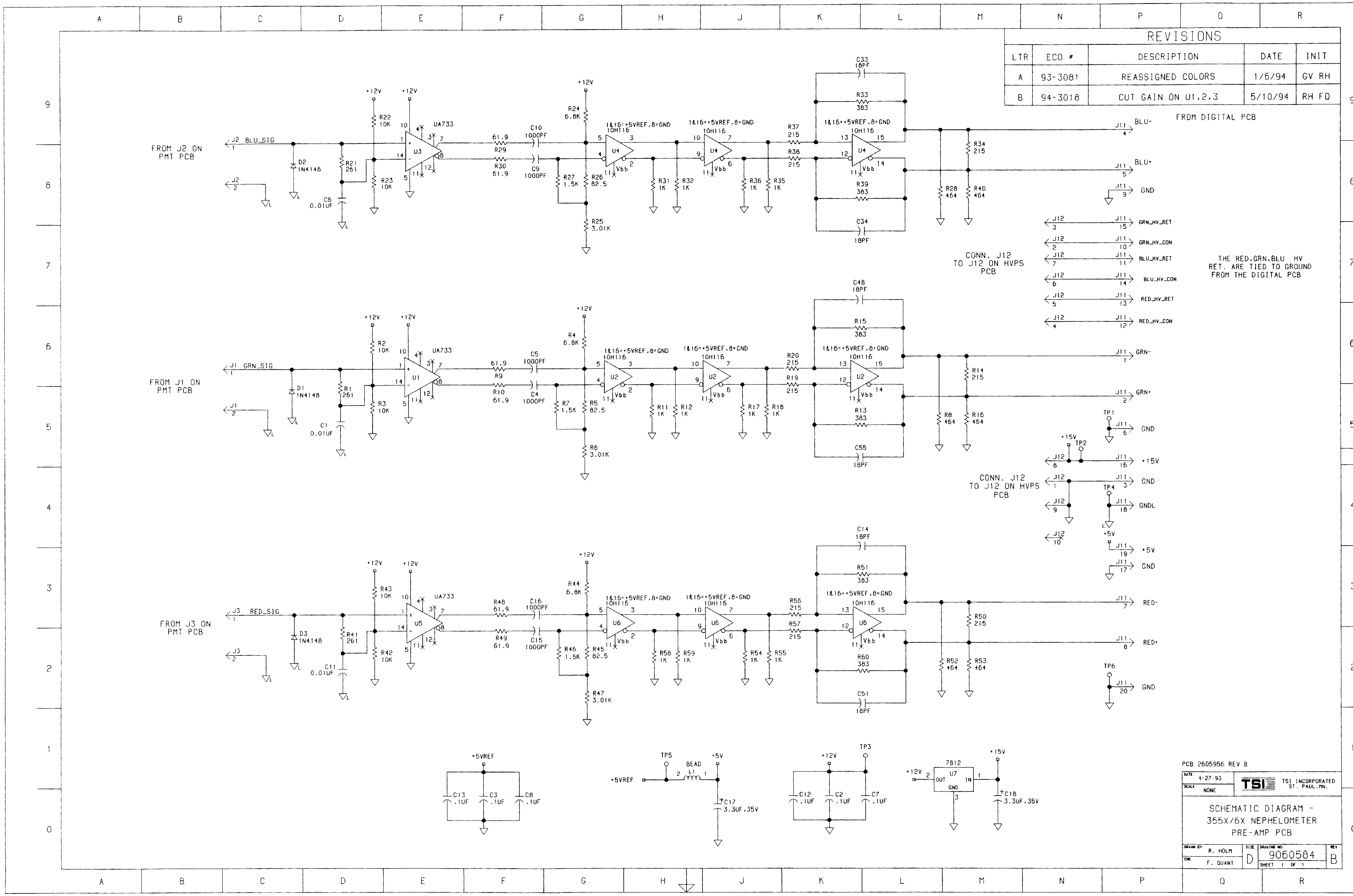
PCB 2605955 REV B

DATE 4-27-93
SCALE NONE

TSI INCORPORATED ST. PAUL, MN.

SCHEMATIC DIAGRAM -
355X/6X NEPHELOMETER
HVPS PCB

DRAWN BY R. HOLM
CHK F. QUANT
SIZE D
DRAWING NO. 9060583
SHEET 1 OF 1
REV B



REVISIONS

LTR	ECO #	DESCRIPTION	DATE	INIT
A	93-3081	REASSIGNED COLORS	1/6/94	GV RH
B	94-3018	CUT GAIN ON U1,2,3	5/10/94	RH FD

DATE 4-27-93
SCALE NONE

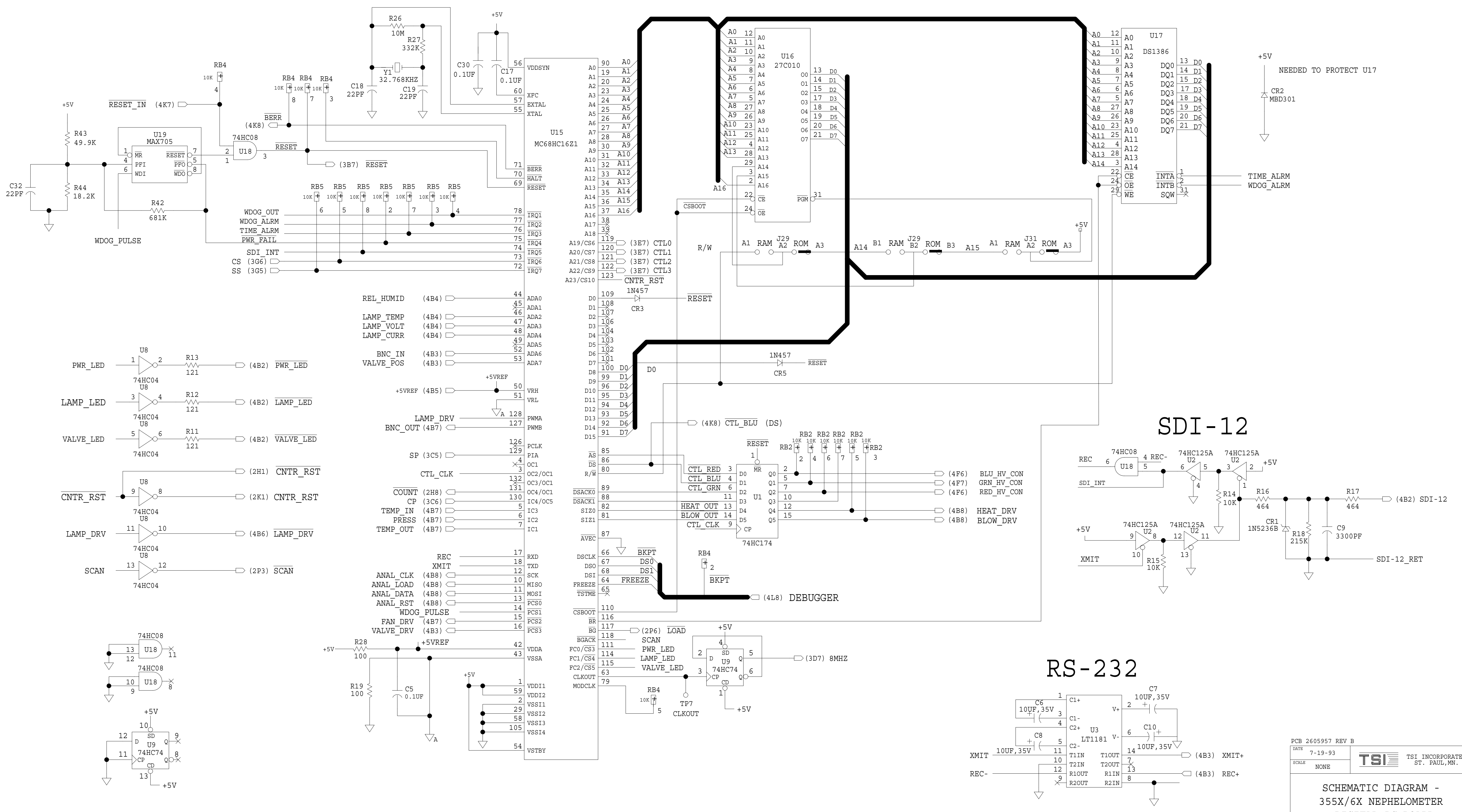
TSI INCORPORATED ST. PAUL, MN.

SCHEMATIC DIAGRAM - 355X/6X NEPHELOMETER PRE-AMP PCB

DRAWN BY R. HOLM
CHK F. QUANT
SIZE D
DRAWING NO. 9060584
REV B
SHEET 1 OF 1

REVISIONS

REV	ECO #	DESCRIPTION	DATE	APPROVED
A	93-3083	UPDATE;CHG NAME FR. MAIN	1/10/94	GV FQ
B	96-3020	ADDED TEST PINS CS & SS	1/9/97	TK



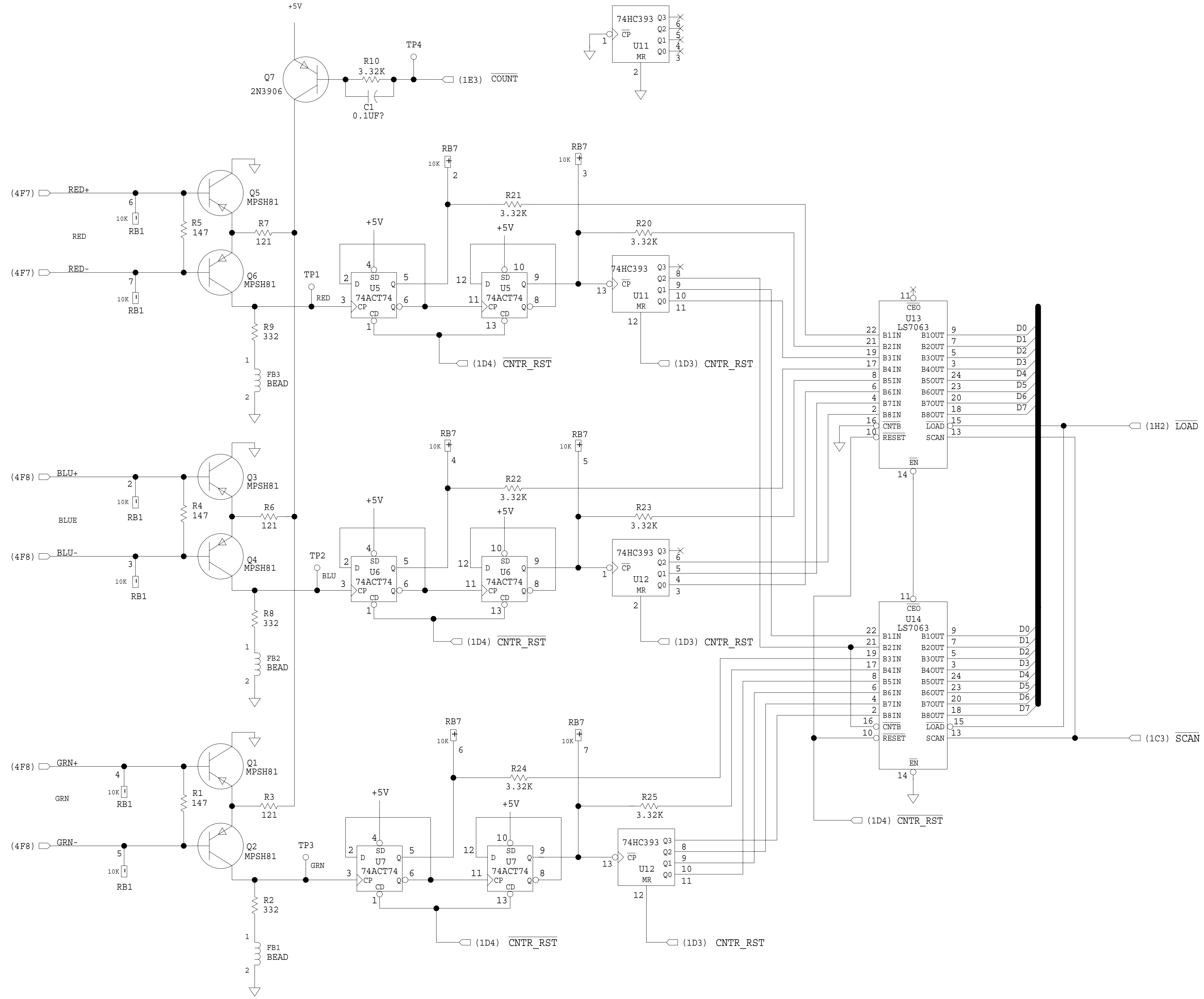
PCB 2605957 REV B

DATE	7-19-93
SCALE	NONE

TSI INCORPORATED
ST. PAUL,MN.

SCHEMATIC DIAGRAM -
355X/6X NEPHELOMETER
DIGITAL PC BOARD

DRAWN BY	SIZE	DRAWING NO.	REV
T.KERRICK	D	9060585	B
CHK R.HOLM 1258		SHEET 1 OF 4	



PCB 2605957 REV B

DATE 7-19-93

SCALE NONE

TSI INCORPORATED
ST. PAUL,MN.

SCHEMATIC DIAGRAM -
355X/6X NEPHELOMETER
DIGITAL PCB

DRAWN BY T.KERRICK

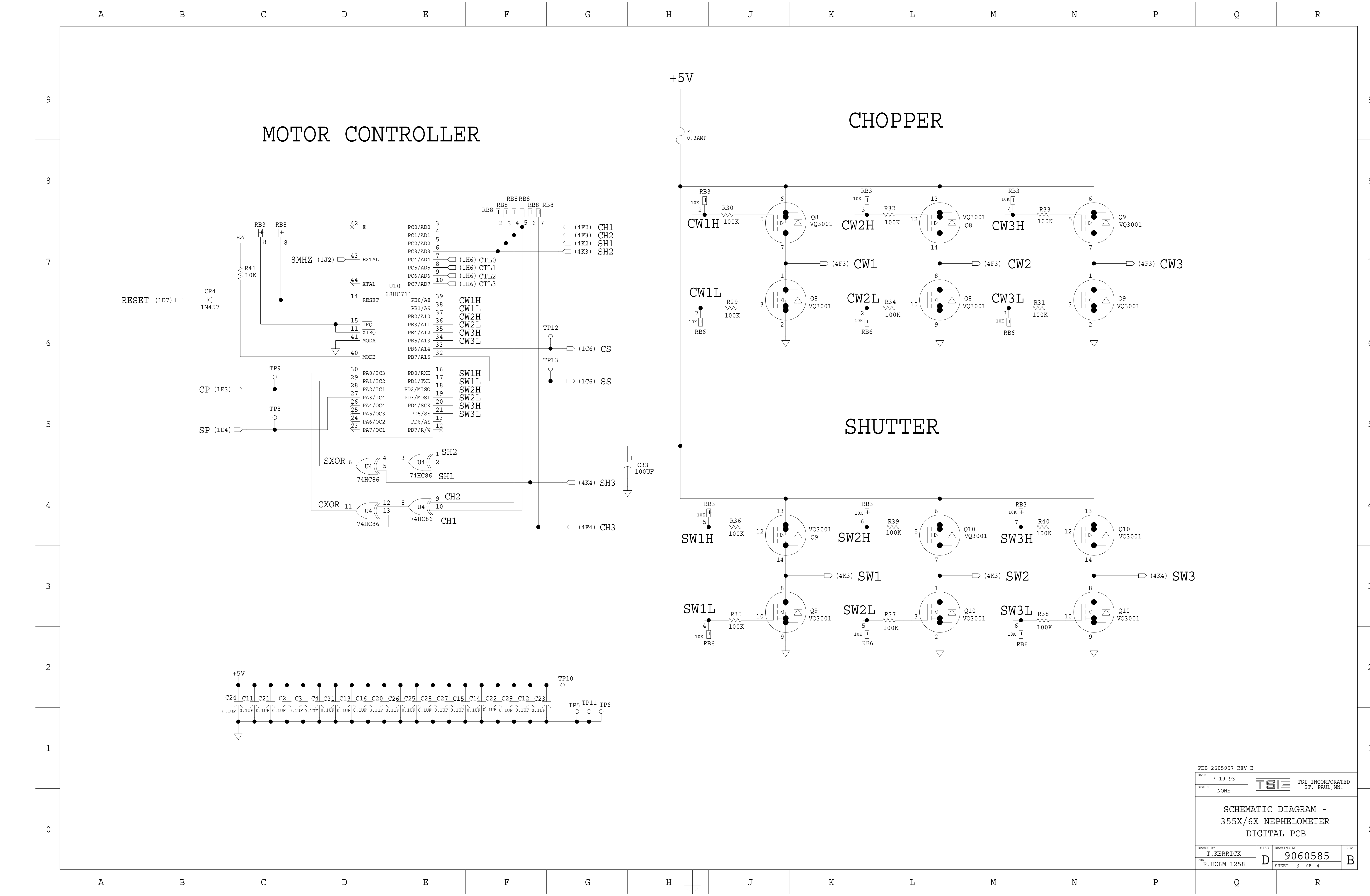
CHK R.HOLM 1258

SIZE D

DRAWING NO. 9060585

SHEET 2 OF 4

REV B



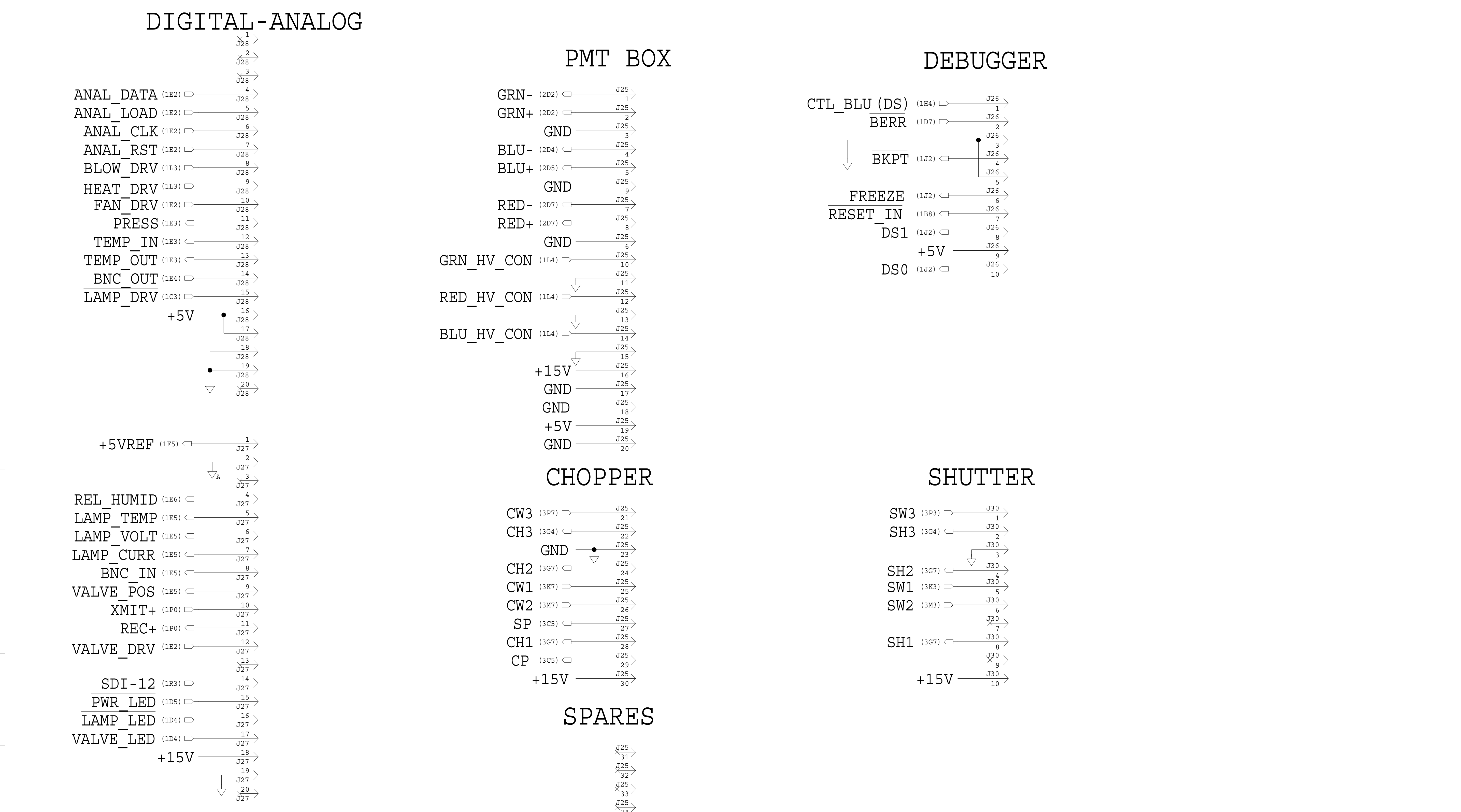
PDB 2605957 REV B

DATE	7-19-93
SCALE	NONE

TSI INCORPORATED
ST. PAUL, MN.

SCHEMATIC DIAGRAM -
355X/6X NEPHELOMETER
DIGITAL PCB

DRAWN BY	SIZE	DRAWING NO.	REV
T.KERRICK	D	9060585	B
CHK R.HOLM 1258		SHEET 3 OF 4	



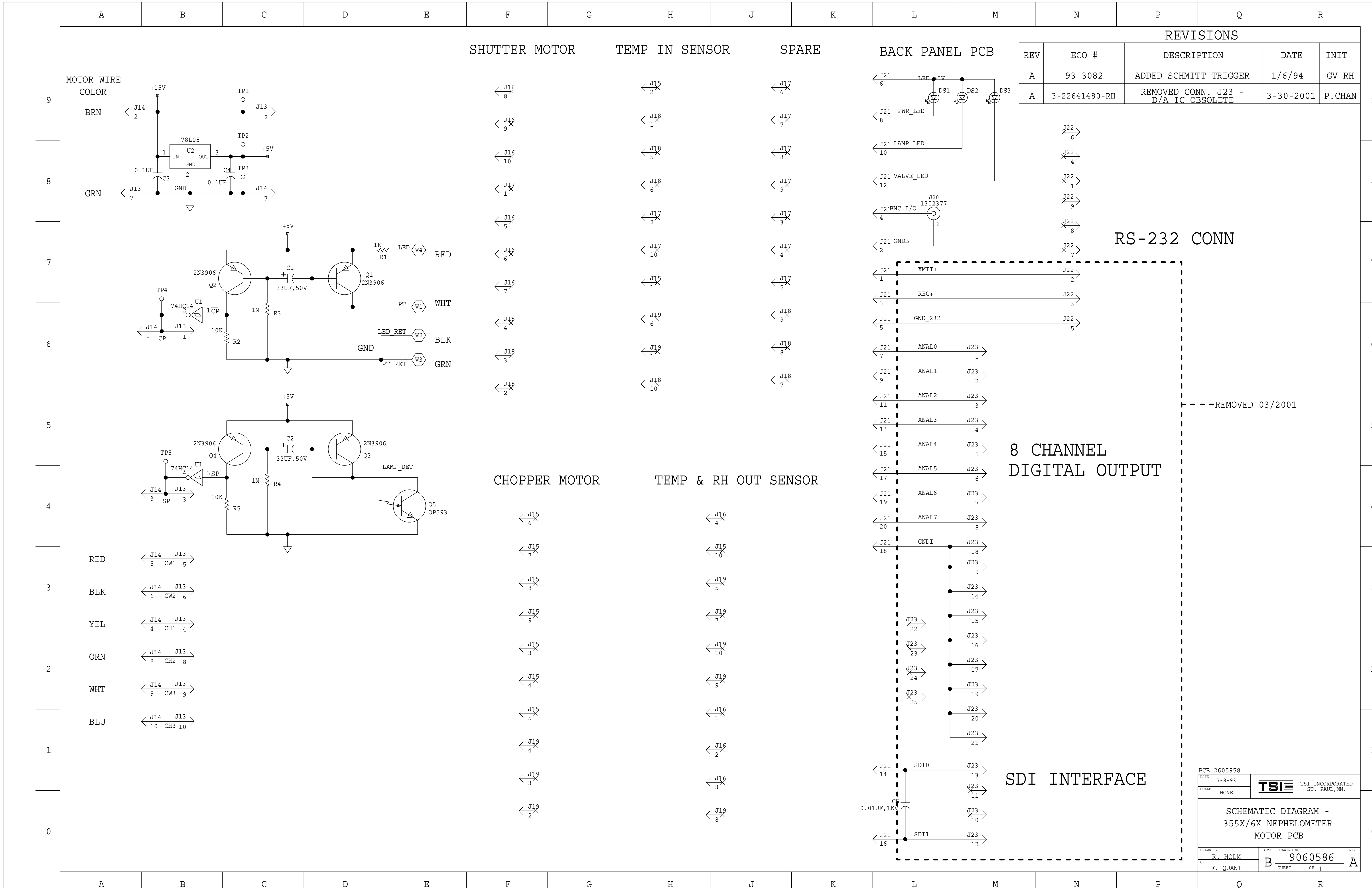
PCB 2605957 REV B

DATE 7-19-93 | SCALE NONE

TSI INCORPORATED
ST. PAUL,MN.

SCHEMATIC DIAGRAM -
355X/6X NEPHELOMETER
DIGITAL PCB

DRAWN BY T.KERRICK | CHK R.HOLM 1258 | SIZE D | DRAWING NO. 9060585 | SHEET 4 OF 4 | REV B



REVISIONS

REV	ECO #	DESCRIPTION	DATE	INIT
A	93-3082	ADDED SCHMITT TRIGGER	1/6/94	GV RH
A	3-22641480-RH	REMOVED CONN. J23 - D/A IC OBSOLETE	3-30-2001	P.CHAN

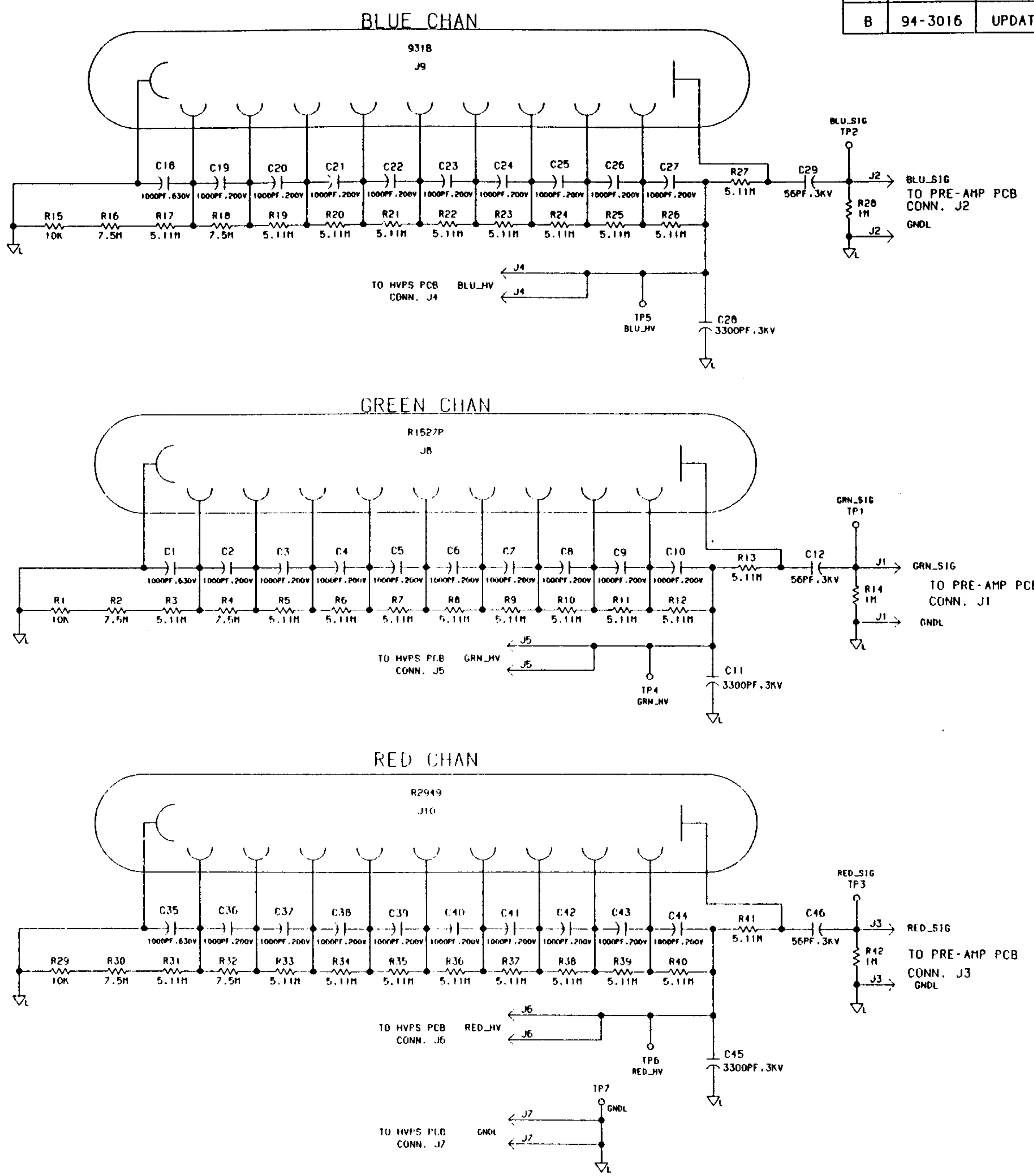
DATE	7-8-93
SCALE	NONE

TSI INCORPORATED
ST. PAUL,MN.

SCHEMATIC DIAGRAM -
355X/6X NEPHELOMETER
MOTOR PCB

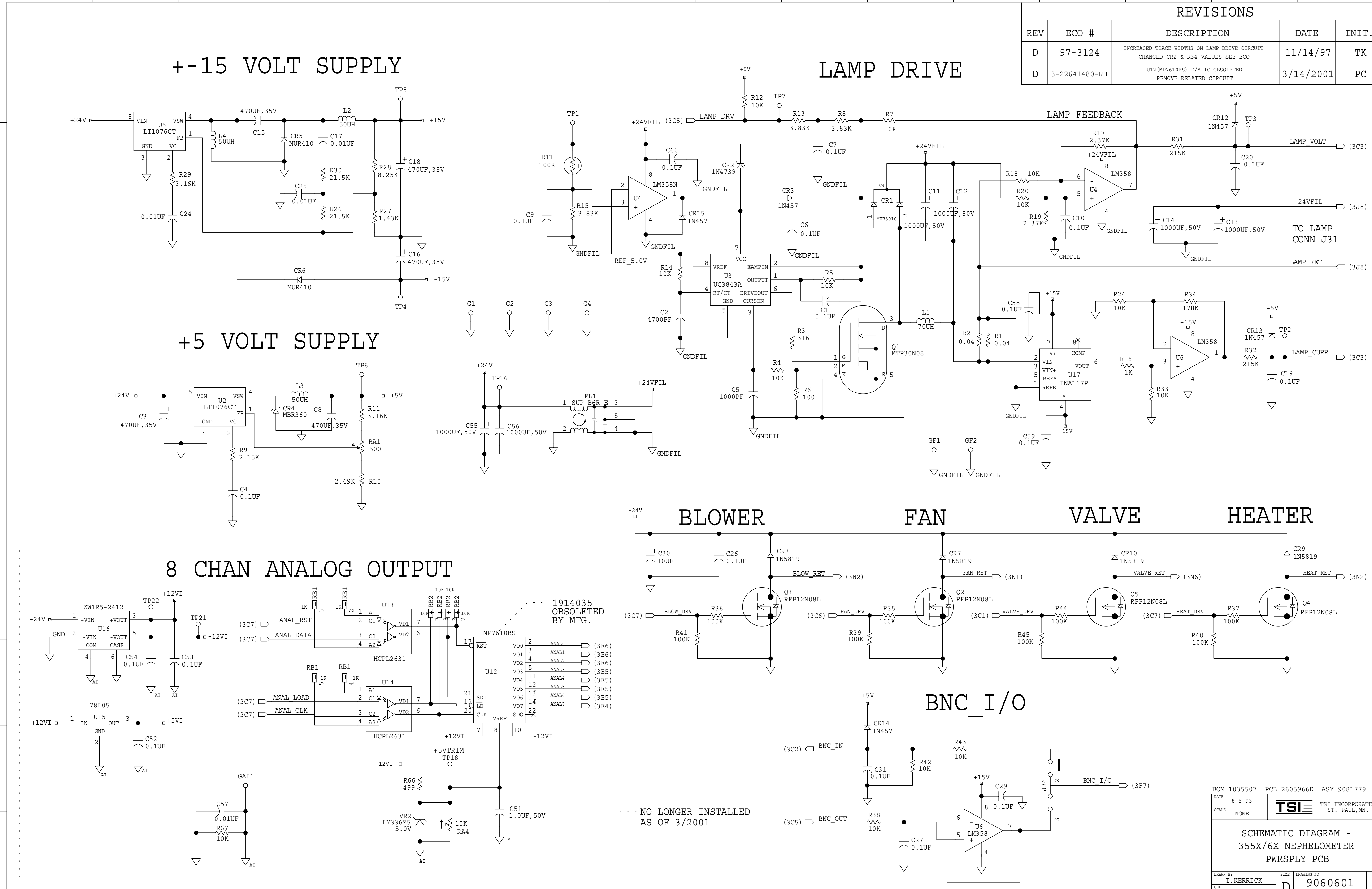
DRAWN BY	SIZE	DRAWING NO.	REV
R. HOLM	B	9060586	A
CHK F. QUANT		SHEET 1 OF 1	

REVISIONS				
LTR	ECO #	DESCRIPTION	DATE	INIT
A	93-3075	CORRECTED NET LABELING	1/6/94	GV RH
B	94-3016	UPDATED TO MATCH PCB REV	5/10/94	RH FQ



PCB 2605959 REV B

DATE 4-27-93	TSI INCORPORATED ST. PAUL, MN.
SCALE NONE	
SCHEMATIC DIAGRAM - PMT SOCKET PCB	
DRAWN BY R. HOLM	SIZE D
CHK F. QUANT	DRAWING NO. 9060587 SHEET 1 OF 1 REV B



REVISIONS

REV	ECO #	DESCRIPTION	DATE	INIT.
D	97-3124	INCREASED TRACE WIDTHS ON LAMP DRIVE CIRCUIT CHANGED CR2 & R34 VALUES SEE ECO	11/14/97	TK
D	3-22641480-RH	U12(MP7610BS) D/A IC OBSOLETED REMOVE RELATED CIRCUIT	3/14/2001	PC

BOM 1035507 PCB 2605966D ASY 9081779

DATE 8-5-93
SCALE NONE

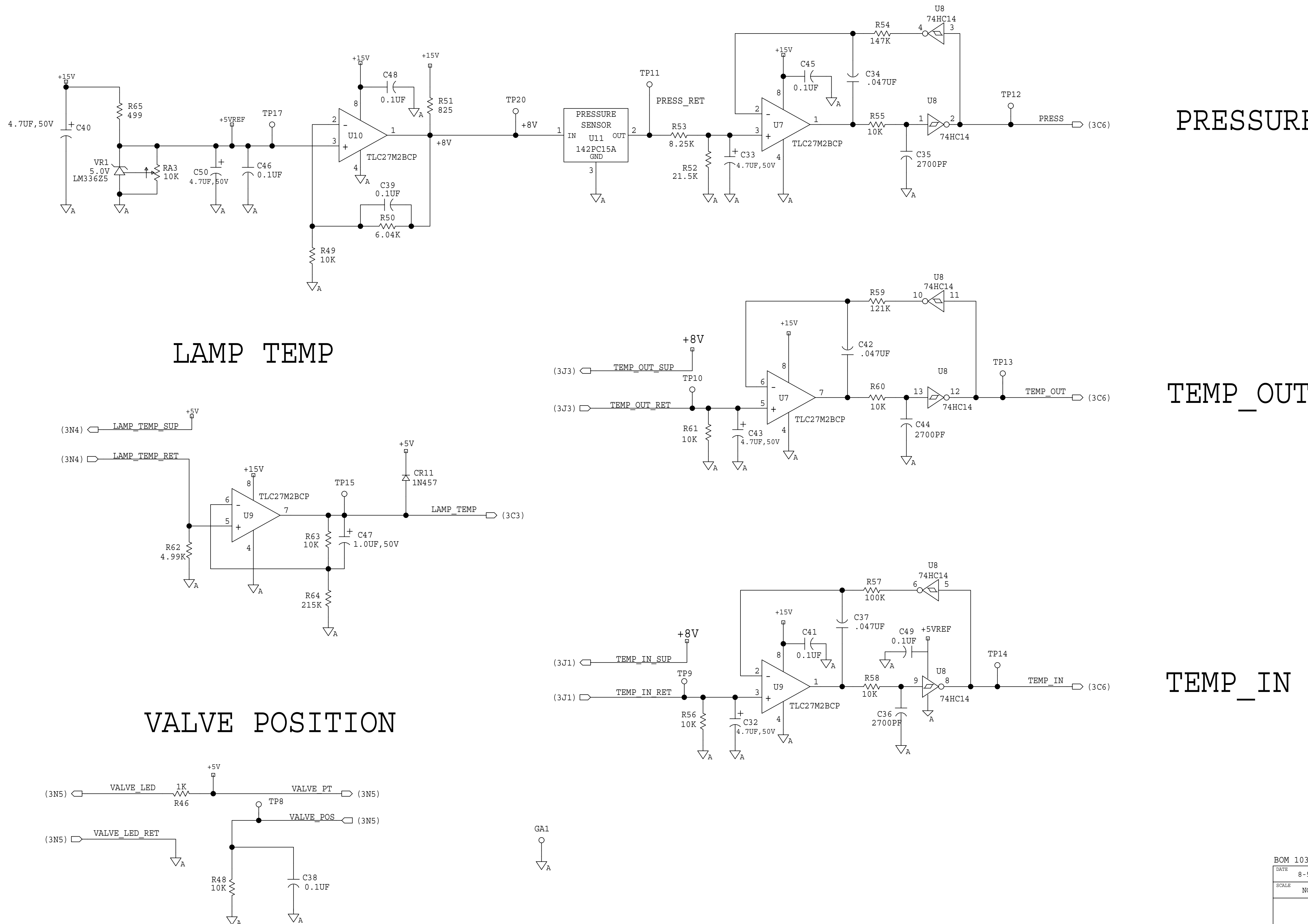
TSI INCORPORATED ST. PAUL, MN.

SCHEMATIC DIAGRAM - 355X/6X NEPHELOMETER PWRSPLY PCB

DRAWN BY T.KERRICK
CHK R.HOLM 1258
SIZE D
DRAWING NO. 9060601
REV D
SHEET 1 OF 3

REVISIONS

REV	ECO #	DESCRIPTION	DATE	INIT.
D	97-3124	INCREASED TRACE WIDTHS ON LAMP DRIVE CIRCUIT CHANGED CR2 & R34 VALUES SEE ECO	11/14/97	TK
D	3-22641480-RH	U12(MP7610BS) D/A IC OBSOLETED REMOVE RELATED CIRCUIT	3/14/2001	PC



BOM 1035507 PCB 2605966D ASY 9081779

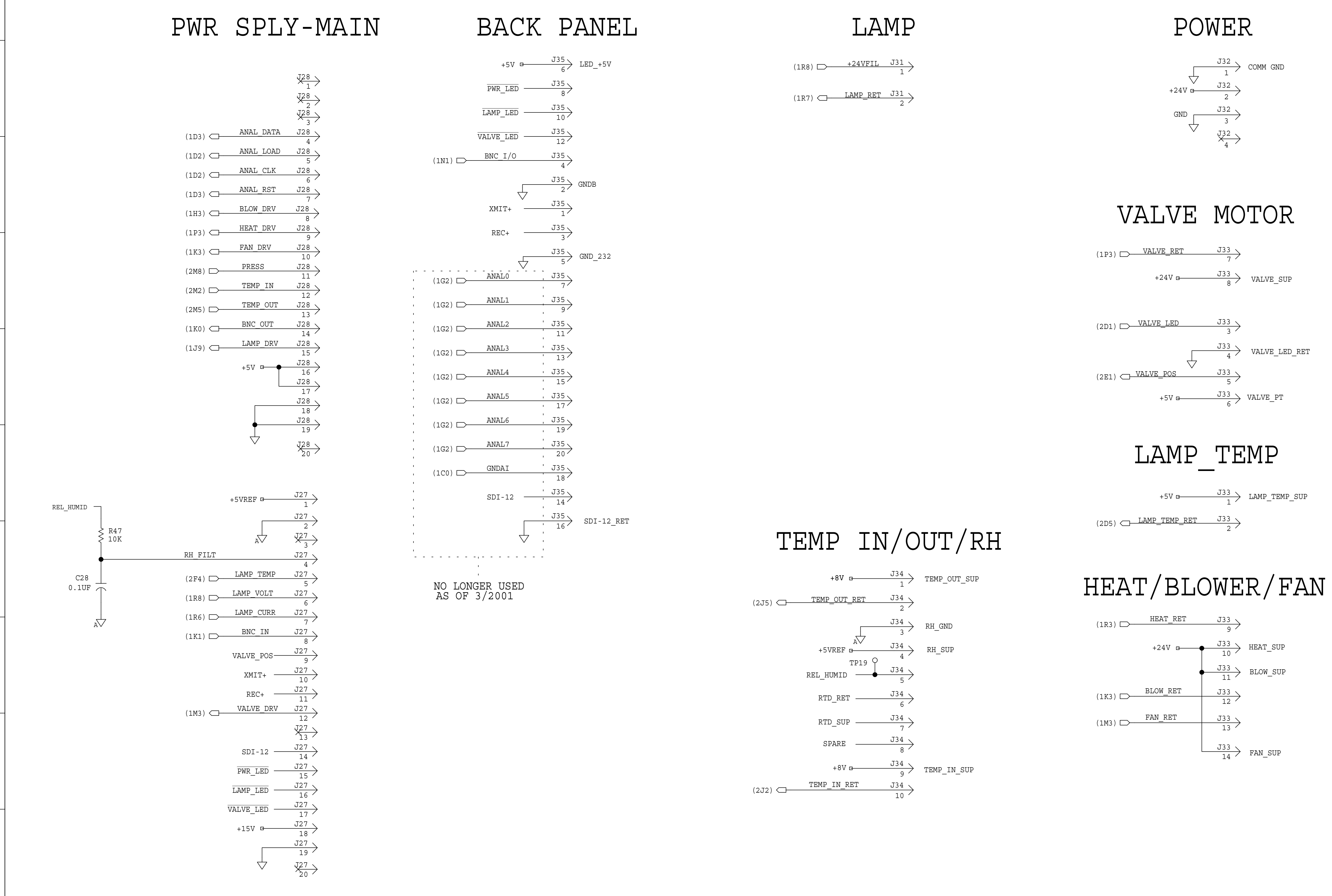
DATE	8-5-93
SCALE	NONE

TSI INCORPORATED ST. PAUL,MN.

SCHEMATIC DIAGRAM - 355X/6X NEPHELOMETER PWRSPLY PCB

DRAWN BY	SIZE	DRAWING NO.	REV
T.KERRICK	D	9060601	D
CHK R.HOLM 1258		SHEET 2 OF 3	

REVISIONS				
REV	ECO #	DESCRIPTION	DATE	INIT.
D	97-3124	INCREASED TRACE WIDTHS ON LAMP DRIVE CIRCUIT CHANGED CR2 & R34 VALUES SEE ECO	11/14/97	TK
D	3-22641480-RH	U12(MP7610BS) D/A IC OBSOLETED REMOVE RELATED CIRCUIT	3/14/2001	PC



BOM 1035507 PCB 2605966D ASY 9081779

DATE 8-5-93
SCALE NONE

TSI INCORPORATED ST. PAUL, MN.

SCHEMATIC DIAGRAM -
355X/6X NEPHELOMETER
PWRSPLY PCB

DRAWN BY T.KERRICK
CHK R.HOLM 1258
SIZE D
DRAWING NO. 9060601
SHEET 3 OF 3
REV D

APPENDIX D

Windows Program Files

The program files required for the Windows version of the Nephelometer software are described below.

Note: *In addition to these files, your directory will also contain data files and possibly other files.*

The .vbx and .dll files are support files required for program operation. The .vbx files are:

cmdialog.vbx
cschk.vbx
cscmd.vbx
cscombo.vbx
csdialog.vbx
csform.vbx
csgroup.vbx
csopt.vbx
csspin.vbx
cstext.vbx
graph.vbx
mscomm.vbx
ssdata2.vbx
threed.vbx

The .dll files are:

gswdll.dll
qpro200.dll
vbrun300.dll

The .exe files are required for program execution. The .exe files are:

gsw.exe	Required for graphical display.
nephmain.exe	The main execution file for the program.

The .dat files are data files. The only two data files provided with the program are:

nephcnfg.dat	The current Nephelometer configuration information.
rayscat.dat	
sample.dat	The sample log data file.

Reader's Comments

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 ______________________________ **P/N** ________ **Rev.** __

1. Was the manual easy to understand and use?

   ❑ Yes ❑ No

   Please identify any problem area(s) ______________________________

2. Was there any incorrect or missing information? (please explain) ______________________________

3. Please rate the manual according to the following features:

	Good	Adequate	Poor
Readability	❑	❑	❑
Accuracy	❑	❑	❑
Completeness (is everything there?)	❑	❑	❑
Organization (finding what you need)	❑	❑	❑
Quality and number of illustrations	❑	❑	❑
Quality and number of examples	❑	❑	❑

   Comments: ______________________________

4. Which part(s) of this manual did you find most helpful? ______________________________

5. Rate your level of experience with the product:

   ❑ Beginning ❑ Intermediate ❑ Expert

6. Please provide us with the following information:

   Name ______________________ Address ______________________

   Title ______________________

   Company ______________________