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QUALITY ASSURANCE/QUALITY CONTROL DOCUMENTATION SERIES	
TITLE	**CALIBRATION OF OPTICAL MONITORING SYSTEMS**
TYPE	**STANDARD OPERATING PROCEDURE**
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AUTHORIZATIONS		
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1.0	Added responsibilities/equipment/methods.	October 1996	
1.1	Updated computer equipment / added auto cal'n	March 2005	

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1.0 PURPOSE AND APPLICABILITY

This standard operating procedure (SOP) outlines the steps for calibration of optical monitoring instruments operated according to IMPROVE Protocol. Optical monitoring instruments are calibrated periodically to verify an instrument's performance, assure quality data capture, and minimize data loss by measuring an instrument's output in response to well-defined and controlled operating conditions.

The two types of optical monitoring instruments currently operating in the IMPROVE visibility monitoring network are ambient nephelometers and transmissometers. Calibration of ambient nephelometers is required under any of the following circumstances:

- Upon acceptance testing of a new instrument.
- Upon installation in the field.
- Prior to any corrective action, service, or maintenance to any portion of the instrument that would change the instrument's response to specified input conditions.
- At weekly intervals.

Calibration of transmissometers is required under the following circumstances:

- Upon acceptance testing of a new instrument.
- Upon installation in the field.
- Immediately following removal of the instrument from the field.
- Following any corrective action, servicing, or maintenance that could affect the instrument's operational performance.

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Nephelometer and transmissometer calibration results are used to:

- Convert raw measurement values to appropriate engineering units.
- Evaluate the instrument's performance and estimate the precision and accuracy of the instrument for specific operational periods.

The following technical instructions (TIs) provide detailed information regarding specific calibration procedures:

- TI 4200-2000 *Calibration of Optec NGN-2 Nephelometers -Type 1 (IMPROVE Protocol)*
- TI 4200-2000 *Calibration of Optec NGN-2 Nephelometers -Type 2 (IMPROVE Protocol)*
- TI 4200-2100 *Calibration of Optec LPV Transmissometers (IMPROVE Protocol)*
- TI 4200-2110 *Transmissometer Lamp Preparation (Burn-in) Procedures*

2.0 RESPONSIBILITIES

2.1 PROJECT MANAGER

The project manager shall:

- Verify that nephelometer calibrations are performed as required.
- Schedule transmissometer calibrations.
- Review all calibration results with the field specialist.
- Identify inconsistencies in calibration results and initiate corrective action as required.
- Review and approve all changes to calibration procedures.
- Review transmissometer lamp inventory and status records to ensure a sufficient number of burned-in lamps are available.
- Approve purchase orders for new lamps.

2.2 FIELD SPECIALIST

The field specialist shall:

- Perform all required field calibrations.
- Document calibration results on the appropriate form.
- Review all calibration results with the project manager.
- Identify inconsistencies in calibration results and initiate corrective action as required.
- Enter calibration results in the site-specific Quality Assurance Database.
- Prepare a site-specific calibration memo for each instrument prior to installing the instrument in the field.

2.3 INSTRUMENT TECHNICIAN

The instrument technician shall:

- Perform a nephelometer calibration during acceptance testing and laboratory maintenance.
- Maintain a printout of nephelometer calibration results.
- Enter the calibration results in the site-specific Quality Assurance Database.
- Prepare lamps for transmissometer calibration.

- Measure pre-calibration transmissometer lamp voltages.
- Assist the field specialist in analyzing inconsistencies in calibration results.
- Prepare purchase orders for new lamps.
- Perform lamp burn-in procedures.
- Maintain the lamp inventory and status records.
- Coordinate with Optec, Inc. for replacement of lamps.

2.4 SITE OPERATOR

The site operator shall:

- Perform a nephelometer calibration every week.
- Verify that the automatic calibration system is operating properly (if applicable).
- Record the results of the nephelometer calibration on the NGN-2 Nephelometer/ Meteorology Log Sheet.

3.0 REQUIRED EQUIPMENT AND MATERIALS

3.1 NEPHELOMETER CALIBRATION

Required equipment and materials to calibrate nephelometer systems include:

- Calibration span gas
- A pressure regulator and adjustable flowmeter
- Calibration gas hoses and fittings
- HP200LX palmtop computer with Datacomm software or, a laptop computer with HyperTerminal software
- Nephcom.dcf communication configuration file
- Computer-to-nephelometer support system interface cable
- Site maintenance forms
- Calibration forms
- TI 4200-2000, *Calibration of Optec NGN-2 Nephelometers -Type 1 (IMPROVE Protocol)*
- TI 4200-2000, *Calibration of Optec NGN-2 Nephelometers –Type 2 (IMPROVE Protocol)*

- TI 4100-3100, *Routine Site Operator Maintenance Procedures for Optec NGN-2 Nephelometer Systems – Type 1 (IMPROVE Protocol)*

- TI 4100-3105, *Routine Site Operator Maintenance Procedures for Optec NGN-2 Nephelometer Systems – Type 2 (IMPROVE Protocol)*

3.2 TRANSMISSOMETER CALIBRATION

Prior to calibrating a transmissometer, the lamps to be used with a specific instrument must be burned-in, to stabilize the lamp's filament position and light output. Required equipment and materials for burn-in includes:

- A supply of lamps
- Lamp ID labels
- Lamp burn-in fixture
- Power supply (13.8 VDC @ 25 amps)
- Documentation forms
- KimWipe tissues
- TI 4200-2110, *Transmissometer Lamp Preparation (Burn-in) Procedures*

Calibration of LPV-2 transmissometers is performed at the Fort Collins Transmissometer Calibration and Test Facility. Equipment and materials required at the facility include:

- Tracking transmissometer (LPV-2 transmissometer installed to monitor light transmission measurements over a path parallel and adjacent to the calibration path)
- Tracking nephelometer (NGN-2 nephelometer installed to monitor ambient scattering measurements adjacent to the calibration path)
- Campbell 21X dataloggers and storage modules
- Digital voltmeters (4 ½ digit)
- Neutral Density Filters (NDFs)
- Assorted calibration apertures
- Power supplies (12 volts DC)
- Cleaning supplies (for windows and transmissometer optics)
- Calibration documentation forms
- TI 4200-2100, *Calibration of Optec LPV Transmissometers (IMPROVE Protocol)*

Analysis and review of transmissometer calibration data requires the following computer system hardware and software:

- Pentium class computer system with VGA, 80 megabyte hard disk, and 64 megabytes of RAM.
- Microsoft Windows98 or Windows2000 operating system and compatible printer
- Campbell Scientific datalogger support software
- ARS calibration support software

4.0 METHODS

This section includes two (2) major subsections:

4.1 Nephelometer Calibrations
4.2 Transmissometer Calibrations

4.1 NEPHELOMETER CALIBRATIONS

Nephelometer calibration includes performing a clean air zero calibration and a span calibration. Calibration may be simple or complete:

- Simple calibration: A single zero and a single span value generally obtained by the site operator during routine servicing, or initiated by the datalogging and control subsystem on a weekly basis (if equipped with an automatic calibration system).
- Complete calibration: A series of zero and span values generally obtained during acceptance testing, installation, removal, laboratory servicing, or audit of the nephelometer by the field specialist or instrument technician.

4.1.1 Simple Calibration

Simple calibration of NGN-2 nephelometers occurs during any of the following checks:

- Site operator initiated zero and span checks performed weekly
- Remote, telephone modem initiated zero and span checks
- Field specialist initiated zero and span checks
- Automatic simple calibrations occur every seven days as scheduled by the site operator or field specialist (if equipped with an automatic calibration system)

Simple calibration of NGN-2 nephelometers includes:

- Clean air zero consisting of the average of 10 one-minute readings of particle-free air.
- Span consisting of the average of 10 one-minute readings of a span gas with known scattering properties.

The results of a simple calibration must be recorded on the appropriate documentation form and entered into the site-specific Quality Assurance Database.

4.1.2 Complete Calibration

Complete calibration of NGN-2 nephelometers are generally performed by the field specialist or instrument technician during servicing in the field or in the laboratory. Complete calibrations include:

- Nephelometer power-on self test (POST) information
- Twenty (20) 1-minute clean air zero readings
- Twenty (20) 1-minute span readings

The results of a complete calibration must be recorded on the appropriate calibration form and entered into the site-specific Quality Assurance Database.

4.1.3 Instrument Adjustment

Nephelometers must not be adjusted during calibration. Unadjusted calibration values are required for evaluating the performance and estimating the precision and accuracy of nephelometers. If the nephelometer cannot be calibrated, refer to the appropriate troubleshooting standard operating procedure and technical instruction.

4.2 TRANSMISSOMETER CALIBRATIONS

Transmissometer calibration includes pre-calibration preparation of lamps and the actual transmissometer calibration.

4.2.1 Lamp Preparation

Preparation of lamps prior to transmissometer calibration includes:

- Purchasing and visually inspecting lamps upon receipt
- Burning-in the lamps
- Visually inspecting burned-in lamps
- Documenting lamp voltage measurements of burn-in

4.2.2 Transmissometer Calibration

Transmissometer calibration includes pre-field and post-field calibration of an operational instrument, calibration of the audit instrument, and measuring window transmittances, including:

- Uniformity test of transmissometer receiver detector
- Calibration of transmissometer with the appropriate number of lamps for the defined operating period and sample frequency. Ten (10) lamps are calibrated for annual service intervals for instruments operating according to IMPROVE protocols.
- Measuring window transmittances.
- Processing preliminary calibration data.
- Documenting calibration configuration, weather and visibility conditions, and lamp voltage measurements on the calibration form.
- Quality assurance review of calibration data.
- Entry of calibration data into the Transmissometer Calibration Database.
- Calculation of site-specific calibration numbers for each lamp.
- Maintenance of calibration documentation.

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QUALITY ASSURANCE/QUALITY CONTROL DOCUMENTATION SERIES	
TITLE	**CALIBRATION OF OPTEC LPV TRANSMISSOMETERS (IMPROVE PROTOCOL)**
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AUTHORIZATIONS		
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1.1	Update format/lamp burn-in hours	October 1996	
2.0	Revised calibration procedures/ added LPV-3	March 2005	

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1.0 PURPOSE AND APPLICABILITY

This technical instruction (TI) describes calibration procedures for Optec LPV-2 and LPV-3 transmissometers operated in accordance with IMPROVE Protocol. The purpose of transmissometer calibration is to assure quality data capture and minimize data loss by:

- Performing pre-field calibrations prior to installing an operational instrument at a field site.
- Performing post-field calibrations immediately after an instrument is removed from a field site.
- Performing pre-audit and post-audit calibrations on the audit transmissometer, before and after it is used to perform a field audit of an operational transmissometer.
- Performing window transmittance measurements before and after the shelter windows are installed at the transmitter and receiver stations.

Calibration of LPV-2 and LPV-3 transmissometers is performed at the Fort Collins Transmissometer Calibration and Test Facility. Pre-field calibration is required prior to installing an instrument at a field site and includes a receiver detector uniformity check, calibration of lamps, and calculation of a calibration number for each lamp.

Post-field calibration is required after an instrument has been removed from field operation, but prior to any cleaning or servicing of the instrument. Post-field calibrations include a receiver detector uniformity check, calibration of lamps, and calculation of a lamp brightening factor for each lamp.

An audit transmissometer is used to perform on-site internal field audits of operational instruments during the annual site servicing visit (refer to Standard Operating Procedure (SOP) 4710, *Optec LPV Transmissometer Field Audit Procedures* and TI 4115-3000, *Annual Site Visit Procedures for Optec LPV Transmissometer Systems (IMPROVE Protocol)*). Audit instrument calibrations are performed prior to and after each use in the field. Calibration of the audit instrument includes pre-field and post-field receiver detector uniformity checks, pre-field and post-field calibrations of reference and audit lamps, and calculation of lamp-specific calibration numbers.

Window transmittance is an operational factor that is used in determining lamp-specific calibration numbers. Window transmittance measurements include initial calibration measurements performed prior to using the windows at a monitoring site, field verification measurements performed during the annual site visit (refer to TI 4115-3000), and final calibration measurements performed after the windows are removed from a monitoring site.

2.0 RESPONSIBILITIES

2.1 PROJECT MANAGER

The project manager shall:

- Schedule transmissometer calibrations.
- Review all calibration results with the field specialist.
- Identify inconsistencies in calibration results and initiate corrective action as required.
- Review and approve all changes to calibration procedures.

2.2 FIELD SPECIALIST

The field specialist shall:

- Perform all required field calibrations.
- Document calibration results on the appropriate calibration form.
- Review all calibration results with the project manager.
- Identify inconsistencies in calibration results and initiate corrective action as required.
- Enter calibration results into the instrument-specific Quality Assurance Database.
- Prepare a site-specific calibration memo for each instrument prior to installing the instrument in the field.

2.3 INSTRUMENT TECHNICIAN

The instrument technician shall:

- Prepare lamps for calibration following lamp burn-in procedures described in TI 4200-2100, *Transmissometer Lamp Preparation (Burn-in)*) *Procedures*.
- Measure pre-calibration lamp voltages following procedures described in TI 4110-3400, *Annual Laboratory Maintenance Procedures for LPV Transmissometer Systems (IMPROVE Protocol)*).
- Notify the field specialist when laboratory servicing of a transmissometer has been completed and the instrument is ready for calibration.
- Assist the field specialist in analyzing inconsistencies in calibration results.

3.0 REQUIRED EQUIPMENT AND MATERIALS

Calibration of LPV transmissometers is performed at the Fort Collins Transmissometer Calibration and Test Facility. Specific equipment and materials required at the facility include:

- Tracking transmissometer (LPV-2 transmissometer installed to monitor light transmission measurements over a path parallel and adjacent to the calibration path)
- Tracking nephelometer (NGN-2 nephelometer installed to monitor ambient scattering measurements adjacent to the calibration path)
- Campbell 21X dataloggers and storage modules
- Digital voltmeters (4 1/2 digit)
- Neutral density filters (NDFs)
- Assorted calibration apertures
- Power supplies (12 volts DC)
- Cleaning supplies (for windows and transmissometer optics)
- Calibration documentation forms
- TI 4200-2100, *Calibration of Optec LPV Transmissometers (IMPROVE Protocol)*
- TI 4110-3400, *Annual Laboratory Maintenance Procedures for LPV Transmissometer Systems (IMPROVE Protocol)*

Analysis and review of transmissometer calibration data requires the following computer system hardware and software:

- Pentium class computer system with VGA and 80 megabyte hard disk and 64 megabytes of RAM
- Microsoft Windows98 or Windows2000 operating system and compatible printer
- Campbell Scientific datalogger support software
- ARS calibration support software

4.0 METHODS

To review descriptions of measurement techniques and system component functions of the LPV transmissometer, refer to SOP 4110, *Transmissometer Maintenance (IMPROVE Protocol).*

Calibration of the LPV transmissometer determines the irradiance from the transmitter lamp that would be measured by the receiver if the optical sight path between the two units allowed 100% transmission. The LPV transmissometer (all components) must be calibrated as a unit. Each lamp will have its own calibration number for use at a specific site with a specific transmissometer system. Receiver computers are individually calibrated during annual servicing (see TI 4110-3400 *Annual Laboratory Maintenance Procedures for LPV Transmissometer Systems (IMPROVE Protocol)*) and may be interchanged during emergency maintenance or for use with the audit instrument. Operation of an instrument with a receiver computer other than the one used at calibration requires recalculation of calibration numbers, but the instrument does not require recalibration. No other system component, including lamps, may be interchanged with another transmissometer without recalibration.

All calibrations are performed at the Fort Collins Transmissometer Calibration and Test Facility. This facility, located at Colorado State University's Christman Field, includes sheltering and all support equipment required to conduct operational transmissometer calibrations. Test facility instrumentation includes a datalogging system, a tracking transmissometer (to monitor relative changes in visibility along the calibration sight path during calibrations), an NGN-2 nephelometer (to produce b_{scat}, meteorological instrumentation), electronic test equipment, and other support systems. The calibration path (the distance between transmitter and receiver during calibration) is 0.3 km. At this distance, the atmospheric transmission can be estimated with a high degree of accuracy for use in calculating the calibration number. A precision (2.74% transmission), high-quality, neutral density filter installed on the photometer and a 101.51 mm calibration aperture on the receiver telescope reduce the transmitted light intensity to a level well below the receiver detector saturation level. The increased light gathering capability of the receiver telescope operating near full aperture (110.0 mm) reduces the effects of turbulence on the transmissometer calibration measurements. As a result, transmissometer calibrations can be performed over a wide range of visibility conditions.

Because lamp brightness is dependent on lamp voltage, the lamp voltage is measured in the laboratory prior to calibration, at the test facility during calibrations, and in the laboratory following calibration. Lamp voltages are required for LPV-2 instruments only; LPV-3 instruments contain circuitry that maintain a constant lamp voltage. A shift in lamp voltage (LPV-2) may indicate damage to the lamp or a malfunction of the lamp control circuitry. To facilitate lamp voltage measurements, the transmitter control cable for each instrument provides a 4-wire lamp connection at the transmitter lamp housing. Two wires provide power to the lamp directly from the transmitter control box. The other two wires (the measurement pigtail) provide a non-current carrying connection from the lamp connections to a voltmeter or datalogger. This arrangement permits lamp voltage to be measured independent of the power cable voltage drop between the control box and the transmitter.

During annual laboratory servicing of the transmissometer, the receiver detector alignment is adjusted for maximum output (refer to TI 4110-3400, *Annual Laboratory Maintenance Procedures for LPV Transmissometer Systems (IMPROVE Protocol)*. Detector alignment is performed on an optical bench which provides a short (18-20 inches) separation between the light source and the receiver detector. To ensure that the detector alignment is valid over a longer path, a detector uniformity test is performed at the field test facility as the first step in performing any calibration.

This section includes four (4) major subsections:

4.1 Pre-Field Calibration
4.2 Post-Field Calibration
4.3 Audit Instrument Calibration
4.4 Window Transmittance Measurements

4.1 PRE-FIELD CALIBRATION

IMPROVE transmissometers are generally serviced and calibrated once per year. Pre-field calibration of a transmissometer is required prior to operating the instrument at a monitoring site and includes the following procedures:

- Burn-in of transmissometer lamps
- Measurement of pre-calibration lamp voltages
- Setup of instrumentation at the field calibration facility
- Measurement of receiver detector uniformity
- Calibration of ten (10) transmissometer lamps
- Measurement of pre-field lamp voltages
- Preliminary processing of calibration data
- Quality assurance review of calibration data
- Entry of calibration data into the Transmissometer Calibration Database
- Calculation of site-specific pre-field calibration numbers for each lamp
- Maintenance of pre-calibration documentation

The following subsections provide detailed instructions for performing the pre-field calibration procedures listed above.

4.1.1 Lamp Burn-In

All transmissometer lamps require a 72-hour burn-in cycle prior to being assigned to an operational instrument. The burn-in cycle is performed in the laboratory to stabilize the filament position and reduce the incidence of premature lamp failure in the operational network. Procedures for lamp burn-in are described in TI 4200-2110, *Transmissometer Lamp Preparation (Burn-in) Procedures*.

4.1.2 Pre-Calibration Lamp Voltages

Service procedures for the LPV transmissometer (see TI 4110-3400, *Annual Laboratory Maintenance Procedures for Optec LPV Transmissometer Systems (IMPROVE Protocol)*) include lamp voltage measurements. Following instrument servicing, lamp voltages are measured after each lamp has operated for five minutes. These laboratory measurements are documented on the Transmissometer Lamp Voltage Measurements Log (Figure 4-1).

OPTEC LPV-2 TRANSMISSOMETER
TRANSMITTER LAMP VOLTAGE MEASUREMENTS RECORD

Instrument Number: _____
Date: _____
Technician: _____

LAMP VOLTAGE MEASUREMENTS

Lamp #	Setup Voltage		Pre-Cal Voltage	Install Voltage	Post-Cal Voltage
	Initial	Final			

TRANSMITTER TEST POINT VOLTAGES - LAMP #: _____

	T1	T2	T3	T4
SETUP				
PRE-CAL				
POST-CAL				

Lampvolt.log (8/96)

Figure 4-1. Transmissometer Lamp Voltage Measurements Log.

4.1.3 Calibration Instrumentation Setup

Prior to going out to the test facility, visibility conditions should be verified. For pre-field calibrations, the b_{ext} values should be below 0.30 or greater than 81 miles. If conditions decline above 0.030 during the calibrations the process should be stopped and resumed during more stable conditions.

The Calibration Setup Checklist/Documentation Form (Figure 4-2) must be used to document the test facility instrumentation configuration for all transmissometer calibrations. This form presents the major setup tasks in the order they are to be performed. All items are to be documented as they are completed. The following task descriptions are presented in the order they appear on the form.

LIST LPV NUMBERS — List the tracking LPV number and each path's LPV number (A and B) that will be used.

CALIBRATION TYPE / PATH DESIGNATION — Indicate the type of calibration(s) to be performed with this configuration for each path selected.

TRANSMITTER SETUP / PATH DESIGNATION — The transmitter setup procedures described below apply to both the calibration and tracking transmitters.

- Remove the transmitter shelter windows. All test facility calibrations are performed with the windows removed.
- Clean the transmitter projection lens with Kimwipes and isopropyl alcohol. Use canned air to remove any remaining lint or dust particles.
- A test lamp for use during calibration transmitter setup is provided in the calibration transmitter shelter. Install this lamp and record the lamp number on the setup form.

  The tracking transmitter lamp is normally left installed in the transmitter between calibrations. If the lamp is not installed, or if it burns out, a replacement lamp (stored in the tracking transmitter lamp case) should be installed. Record the lamp number for the lamp actually used on the setup form.
- Check the alignment of the transmitter.
- Connect the pigtail cable from the side of the transmitter telescope to the 21X datalogger. Lamp voltage readings can be monitored on location 1 (*61A). Check the date and time of the datalogger to make sure it is correct.

CALIBRATION SETUP CHECKLIST/DOCUMENTATION FORM
OPTEC LPV-2 TRANSMISSOMETER

Technician _____ Date _____

Tracking LPV # _____ Path A LPV # _____

Path B LPV # _____

PATH A CALIBRATION TYPE

☐ Detector Uniformity ☐ Pre-Field/Site _____ ☐ Audit Instrument
☐ Other (Describe) ☐ Post-Field/Site _____ ☐ Window Transmittance

PATH B CALIBRATION TYPE

☐ Detector Uniformity ☐ Pre-Field/Site _____ ☐ Audit Instrument
☐ Other (Describe) ☐ Post-Field/Site _____ ☐ Window Transmittance

TRANSMITTER SETUP

	Path A	Tracking	Path B
Window Removed	☐	☐	☐
Transmitter Lens Inspected	☐	☐	☐
Transmitter Lens Cleaned	☐	☐	☐
Test Lamp Installed	☐	☐	☐
Test Lamp #	_____	_____	_____
Transmitter On	☐	☐	☐
Transmitter Aligned	☐	☐	☐
Storage Module In Place	☐	☐	☐
Storage Module #	_____	_____	_____
Data Logger Time & Date Verified (Standard Time)	☐	☐	☐
Cycle Switch (STD = 1)	_____	_____	_____
Integration Switch (STD = 64)	_____	_____	_____

RECEIVER SETUP

	Path A	Tracking	Path B
Window Removed	☐	☐	☐
Receiver Lens Inspected	☐	☐	☐
Receiver Lens Cleaned	☐	☐	☐
Full Aperture STD for all telescopes	☐	☐	☐
Other (in mm)			
NDF Cleaned and In Place	☐	☐	☐
NDF # Installed	_____	_____	_____
Telescope Focused and Aligned	☐	☐	☐
Gain Switch (STD = 100)	_____	_____	_____
A1 Switch (STD = C)	_____	_____	_____
A2 Switch (STD = CR)	_____	_____	_____
Cycle Switch (STD = Continuous)	_____	_____	_____
Integration Switch (STD = 1 Minute)	_____	_____	_____

RECEIVER DATA LOGGER SETUP

☐ Data Logger Operation Verified ☐ Storage Module In Place
☐ Data Logger Time & Date Verified Storage Module # _____
(Standard Time)

NEPHELOMETER DATA LOGGER SETUP

☐ Nephelometer Operation Verified ☐ Data Logger Operation Verified
☐ Data Logger Time & Date Verified ☐ Storage Module In Place
(Standard Time) Storage Module # _____

O:\project\Improve4\Forms\Cal Setup Checklist.doc

Figure 4-2. Calibration Setup Checklist/Documentation Form.

TRANSMITTER SETUP / PATH DESIGNATION (continued)

- Connect a storage module to the datalogger and record the module's serial number on the setup form. The storage module will be used to collect 1-minute average lamp volt readings during the calibration.

- Turn on the 12 VDC power supply and the transmitter control box. Verify that the lamp also turns on and that the chopper blade is turning. Align the transmitter telescope on the center of the corresponding receiver window.

TRANSMITTER CONTROL BOX SWITCH SETTINGS

For the LPV-2 instruments, the CYCLE and INTEG switches must be set for continuous operation prior to initiating a calibration. To access these switches, the cover of the control box must be removed. The locations of the two switches are shown in Figure 4-3, Transmitter Configuration Switch Locations (LPV-2 Transmissometer). The switch position labels on the CYCLE switch are in hours (except for the 20-minute position). The INTEG switch position labels are in minutes. Both switches are pc-board mounted dip switches and should be adjusted using the small plastic tipped adjustment tool in the transmitter shelter tool kit. The correct switch positions for continuous operation are indicated by the arrows in Figure 4-3. After the switches have been set, reset the transmitter control box by depressing the RESET switch.

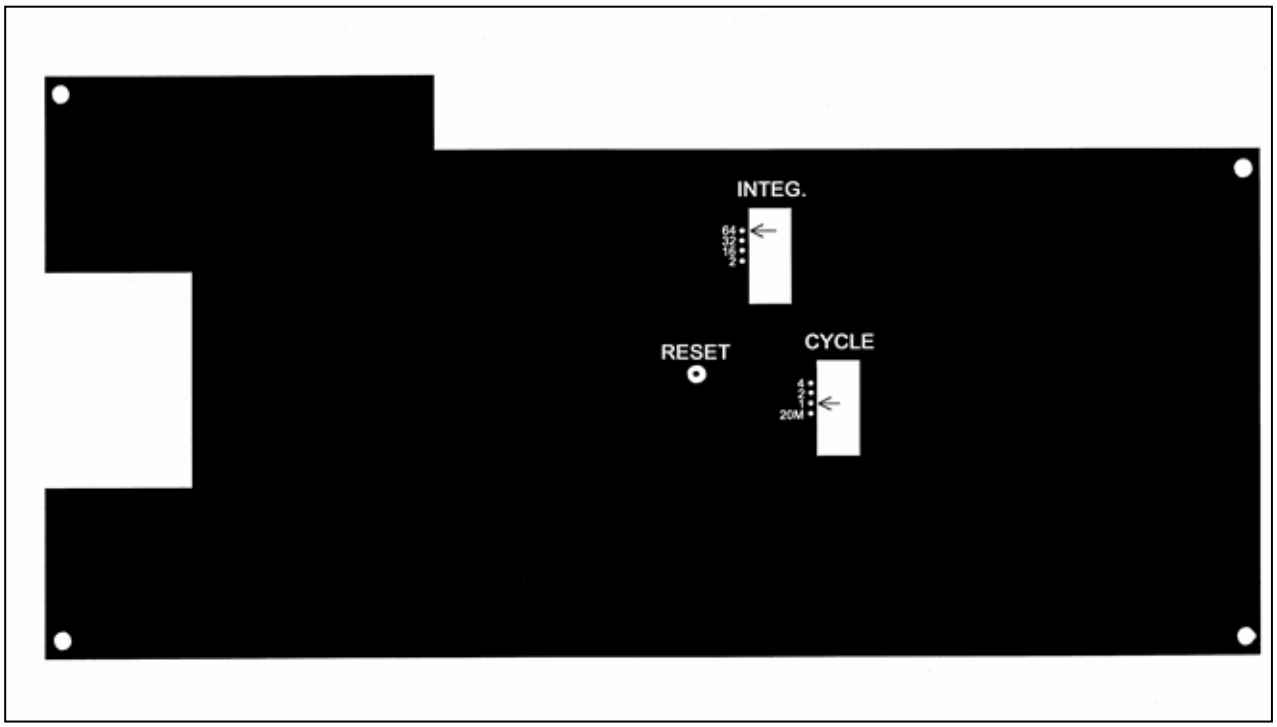


Figure 4-3. Transmitter Configuration Switch Locations (LPV-2 Transmissometer).

TRANSMITTER CONTROL BOX SWITCH SETTINGS (continued)

For LPV-3 instruments, the CYCLE and INTEG must also be set for continuous operation prior to calibration. To access these switches push the **Mode** button on top of the transmitter housing unit when the lamp is off, or push both the **Mode** and **Select** buttons if the lamp is on, until the ready prompt is displayed (see Figure 4-4).

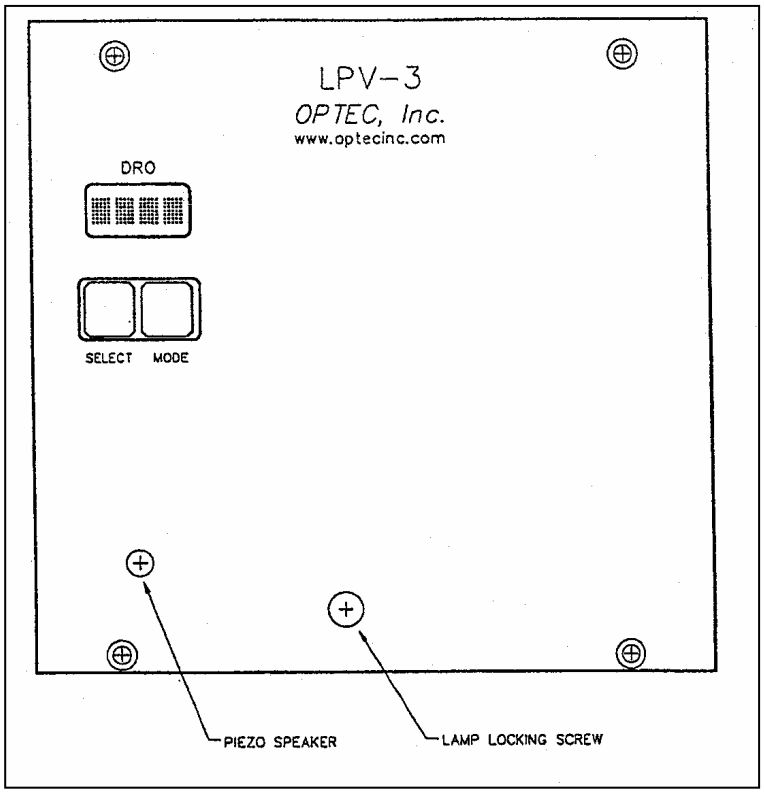


Figure 4-4. Transmitter Configuration Switch Locations (LPV-3 Transmissometer).

Once the ready prompt is displayed select **Y** to change parameters. Select Integration Time in Minute will appear on the screen. By pushing the Select button the current integration time will be shown. Push the **Mode** button until 64 is shown. Once 64 is selected, push the **Select** button again to save the setting. Return to the Select Integration Screen. Push the **Mode** button to select the Cycle screen. Push the **Select** button again to show the current cycle. Push the **Mode** button to select continuous mode. Pushing the Select button saves the setting and returns to the Select Cycle Screen. Push the **Mode** button 5 more times to reach the Run screen. Push the **Select** button for Yes, and the instrument returns to normal operation.

RECEIVER SETUP

The receiver setup procedures described below apply to both the calibration and tracking receivers.

- Remove both receiver shelter windows.
- Inspect and clean the receiver telescope objective lens with Kimwipes and isopropyl alcohol. Use canned air to remove any remaining lint or dust particles.
- Detector uniformity checks are normally performed with the receiver telescope at full aperture. If the raw readings at full aperture are greater than 975, install the 101.51 mm calibration aperture prior to performing the detector uniformity check.
- Prior to initiating an instrument calibration, the 101.51 mm calibration aperture should be installed on the tracking receiver telescope.
- Remove the neutral density filter (NDF) from the airtight filter storage container. Clean both surfaces of the NDF with Kimwipes and alcohol and use canned air to remove any remaining lint or dust particles. Install the NDF in the receiver photometer.
- When a transmissometer is operating at a monitoring site, the receiver telescope is focused at infinity. During calibration, the calibration receiver telescope focus should be adjusted to 0.3 km, the length of the sight path. To refocus the receiver telescope, loosen the thumbscrew that secures the objective lens and rotate the objective lens clockwise (viewed from the front of the telescope) until the transmitter lamp is sharply focused. The tracking receiver telescope is normally left focused at 0.3 km, but the focus should always be verified during receiver setup. After focusing, the receiver telescope should be aligned to place the transmitter lamp in the center of the alignment reticle.

RECEIVER COMPUTER SWITCH SETTINGS

There are five front panel switches on the receiver computer that must be set and the settings documented prior to beginning a calibration. All IMPROVE network instruments should be calibrated with the switches set to the standard settings specified on the setup form. When calibrating non-IMPROVE instruments requiring non-standard switch settings, note the switch setting actually used on the setup form. The tracking instrument setup always uses the standard settings.

RECEIVER DATALOGGER SETUP

Calibration data (1-minute averaged raw readings from both the calibration receivers and the tracking receiver) are collected by a Campbell 21X datalogger and SM 192 or 716 solid state storage module. Proper operation of the datalogger components must be verified prior to performing a calibration.

- The datalogger will date- and time-stamp each data record written to the storage module. Verify that the time and date shown on the datalogger are correct. If incorrect, reset the date and time following the procedures described in TI 4250-2000, *Servicing and Calibration of Campbell 21X Dataloggers*.

The 1-minute raw readings from the datalogger (locations 1, 2, and 3) should agree (within ± one count) with the receiver computer display.

- Connect a storage module to the datalogger and record the storage module serial number on the setup form.

NEPHELOMETER DATALOGGER SETUP

Check the operation of the nephelometer, it should be set on continuous mode, outputting a reading (b_{scat}) every 2 minutes. The nephelometer door should be open, fan running, and solenoid and lamp on.

- Check the light trap.
- Check and replace if necessary the clean air filter.
- Prior to calibrating the lamps, perform a span/zero calibration on the nephelometer.
- Check the nephelometer datalogger for correct date and time and operation.
- Check the datalogger for correct output of meteorology values such as air temperature, relative humidity, wind speed and wind direction.
- Note the serial number of the storage module in place.

4.1.4 Receiver Detector Uniformity

Prior to performing a detector uniformity field check, the Calibration Setup Checklist/Documentation Form must have been completed in accordance with the procedures described in Section 4.1.3, Calibration Instrumentation Setup.

The detector uniformity check is performed by comparing lamp irradiance measurements obtained with the receiver telescope misaligned so that the transmitter lamp image appears at

four specified locations near the outer edge of the receiver telescope alignment reticle, with lamp irradiance measurements obtained with the receiver telescope properly aligned. The Detector Uniformity Field Check Form (Figure 4-5) includes a diagram indicating five alignment points. A measurement sequence consists of 1-minute averaged raw readings from each position, beginning with position 1. this sequence of five 1-minute readings is repeated five times. The Campbell 21X datalogger is used as a voltmeter, providing increased resolution and accuracy over the receiver computer display. All data are recorded on the field check form. Specific procedures for performing the detector uniformity field check are as follows:

- Document the test configuration on the Detector Uniformity Field Check Form.
- Set the datalogger to monitor channels 1 and 3.
- Align the receiver telescope at position 1.
- Turn the receiver computer ON (initiating a 1-minute measurement).
- After one minute, record on the field check form: 1) the 1-minute averaged raw reading (as shown on the datalogger display) as the position 1 reading, and 2) the time (hours:minutes) the reading was taken.
- Turn the receiver computer OFF, realign the receiver telescope at each successive position (2-5) and repeat the previous two steps.
- Perform the previous four steps (which comprise one complete measurement sequence) four additional times (providing five measurement sequences at each of the five telescope alignment positions).

Detector uniformity is determined by calculating the mean and standard deviation of the five 1-minute readings obtained at each alignment position and comparing the mean values for positions 2 through 5 to the mean value for position 1. The standard deviation values provide a measure of the stability of the visibility conditions during this test. Detector uniformity is considered acceptable when the mean values for positions 2 through 5 are equal to the position 1 mean values with a tolerance of +0.25% / -1.0%. These calculations are initially performed at the test facility using a scientific calculator. The calculated means, standard deviations, and percent deviation of the mean values are recorded on the field check form. After returning to the office, the measurement data are entered into the detector uniformity worksheet (included with the ARS calibration software) and the means and standard deviations described above are recalculated as a check on the manually calculated values. (See Figure 4-6).

Technician:_______________ Date:__________
LPV#:__________

DETECTOR UNIFORMITY FIELD CHECK
OPTEC LPV-2 TRANSMISSOMETER

TEST CONFIGURATION

Lamp #: ________ Aperture: ________ Gain Setting: ________

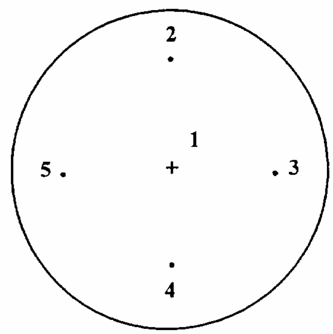
Position	Reading	Time
1		:
2		:
3		:
4		:
5		:

Position	Reading	Time
1		:
2		:
3		:
4		:
5		:

Position	Reading	Time
1		:
2		:
3		:
4		:
5		:

Position	Reading	Time
1		:
2		:
3		:
4		:
5		:

Position	Reading	Time
1		:
2		:
3		:
4		:
5		:



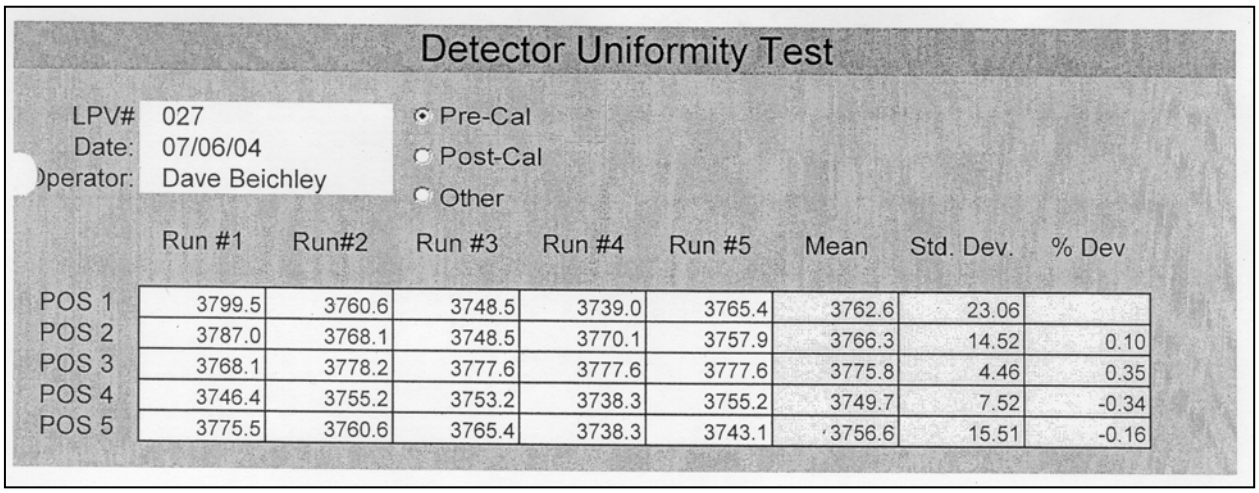
Position	Mean	Standard Deviation
1		
2		
3		
4		
5		

Position	Deviation from Position 1 Mean
2	
3	
4	
5	

COMMENTS:______________________________

(4.37 1/94)

Figure 4-5. Detector Uniformity Field Check Form.



Detector Uniformity Test

LPV# 027
Date: 07/06/04
Operator: Dave Beichley

Pre-Cal
Post-Cal
Other

	Run #1	Run#2	Run #3	Run #4	Run #5	Mean	Std. Dev.	% Dev
POS 1	3799.5	3760.6	3748.5	3739.0	3765.4	3762.6	23.06	
POS 2	3787.0	3768.1	3748.5	3770.1	3757.9	3766.3	14.52	0.10
POS 3	3768.1	3778.2	3777.6	3777.6	3777.6	3775.8	4.46	0.35
POS 4	3746.4	3755.2	3753.2	3738.3	3755.2	3749.7	7.52	-0.34
POS 5	3775.5	3760.6	3765.4	3738.3	3743.1	3756.6	15.51	-0.16

Figure 4-6. Detector Uniformity Test Screen.

4.1.5 Lamp Calibration

Ten (10) uncalibrated transmissometer lamps (1 primary reference lamp, 1 on-site reference lamp, 6 operational lamps, and 2 spare lamps) are assigned to each transmissometer during annual laboratory servicing (see TI 4110-3400, *Annual Laboratory Maintenance Procedures for LPV Transmissometer Systems (IMPROVE Protocol)*). During calibration, the primary reference lamp is calibrated three times (at the beginning, in the middle, and at the end of the calibration). All other lamps are calibrated once.

Procedures for performing and documenting lamp calibrations are as follows:

COMPLETE SETUP FORM	Complete the Calibration Setup Checklist/Documentation Form as described in Section 4.1.3, Calibration Instrumentation Setup.
COMPLETE CALIBRATION DATA FORM	Use the Optec LPV Transmissometer Calibration Data Form, Figure 4-7, to document test facility weather and visibility conditions, preliminary support equipment measurements, calibration type, and lamp-specific calibration parameters.
PHOTOGRAPH SITE	Photographic documentation is required at the start and finish of a calibration. Three views are photographed from the northwest corner of the transmitter compound. Each view, the approximate bearing from the transmitter compound, and the lens used for photographing the view are presented in Figure 4-8, Test Facility Photographic Documentation.

Technician: _____ Date: _____

Tracking LPV#:_____ Calibration LPV #: _____

CALIBRATION DATA

OPTEC LPV-2 TRANSMISSOMETER

TEST SITE CONDITIONS

Weather _____

Visibility _____ Estimated b_{ext} _____

☐ Initial Photo Documentation Completed Time_____:_____ ☐ Final Photo Documentation Completed Time_____:_____

METEOROLOGICAL PARAMETERS

	Air Temperature	Relative Humidity	Wind Speed	Wind Direction	Solar Radiation
START OF CALIBRATION					
MIDDLE OF CALIBRATION					
END OF CALIBRATION					

CALIBRATION INSTRUMENT - Transmitter Test Point Measurements

Reference Lamp # _____ TI _____ T2 _____ T3 _____ T4 _____ T5 _____

TRACKING INSTRUMENT - Transmitter Measurements

CALIBRATION TYPE:

Tracking Lamp #_____ Lamp Hours: ON _____ OFF _____ ☐ Pre-Field ☐ Audit Instrument

Lamp Voltage: Start _____ Finish _____ ☐ Post-Field ☐ Test Instrument

CALIBRATION TEST SEGMENTS LOG

☐ Lamp voltage datalogger connected to transmitter measurement pigtail

☐ Datalogger ground connected to negative T5 terminal on control box

Lamp #	Alignment	Start Time	End Time	Lamp Voltage	b_{scat}	Comments
		:	:			
		:	:			
		:	:			
		:	:			
		:	:			
		:	:			
		:	:			
		:	:			
		:	:			
		:	:			
		:	:			
		:	:			
		:	:			

caldata.frm (2/95)

Figure 4-7. Optec LPV-2 Transmissometer Calibration Data Form.

Description: Toward Engineering Research Center centered on upper south end of Soldier Canyon Dam.

Bearing 250°

Lens Size: 135 mm

Description: Toward north centered on horizon halfway between the Ideal Cement Plant and Rawhide Power Plant.

Bearing 10°

Lens Size: 50 mm

Description: Toward north centered on Rawhide Power Plant.

Bearing 15°

Lens Size: 135 mm

Figure 4-8. Test Facility Photographic Documentation.

MEASURE TRANSMITTER VOLTAGES

For LPV-2 instruments, transmitter test point voltages are measured on the printed circuit board inside the calibration transmitter control box and documented on the lamp calibration data form. Connect the negative (ground) lead of the voltmeter to the negative (black) terminal of the external T5 jack located on the side of the transmitter control box (see Figure 4-9, Transmitter Control Circuit Component Layout). Note that the calibration instrument test point voltages are measured only during the first (reference lamp) calibration segment. The tracking instrument lamp voltage is measured during the first and last calibration segments.

For LPV-3 instruments, the lamp mode should be set on medium intensity. This is accomplished using the Select and Mode buttons on top of the transmitter housing unit. Select lamp mode display and choose the mode the lamp should be in (low, medium, high). Once the mode is selected and saved, the mode must never change until the next servicing.

RECORD PARAMETERS

Meteorological parameters are logged by the nephelometer datalogger at the transmitter compound and should be recorded at the start, middle, and end of the calibration.

DOCUMENT LAMP HOURS

The tracking instrument lamp hours and lamp voltage should be documented at the start (during the first calibration segment) and finish (during the final calibration segment) of the calibration. Lamp hours are logged on a DC timer located in the tracking instrument transmitter shelter and connected to the transmitter control box. If a new lamp is installed in the tracking transmitter, the DC timer should be reset to zero.

- Lamps are calibrated by serial number (ascending order). The lamp with the lowest serial number is always designated as the reference lamp and is used for repeat calibrations as defined by the type of calibration.

- Turn the transmitter power switch OFF prior to installing or removing a lamp.

MEASURE AND RECORD LAMP VOLTAGES

For LPV-2 instruments, at the end of each calibration segment, measure and record the lamp voltage. Prior to initiating the first calibration segment, connect the lamp voltage datalogger to the transmitter cable measurement pigtail (located at the transmitter telescope end of the transmitter cable). Connect the red and black banana jacks to the side of the transmitter telescope's corresponding color connections. Connect the other end of the cable to the datalogger. Press ***6A1** to display the lamp voltage on the datalogger. All lamp voltages are obtained using this measurement configuration and recorded on the calibration data form (Figure 4-7).

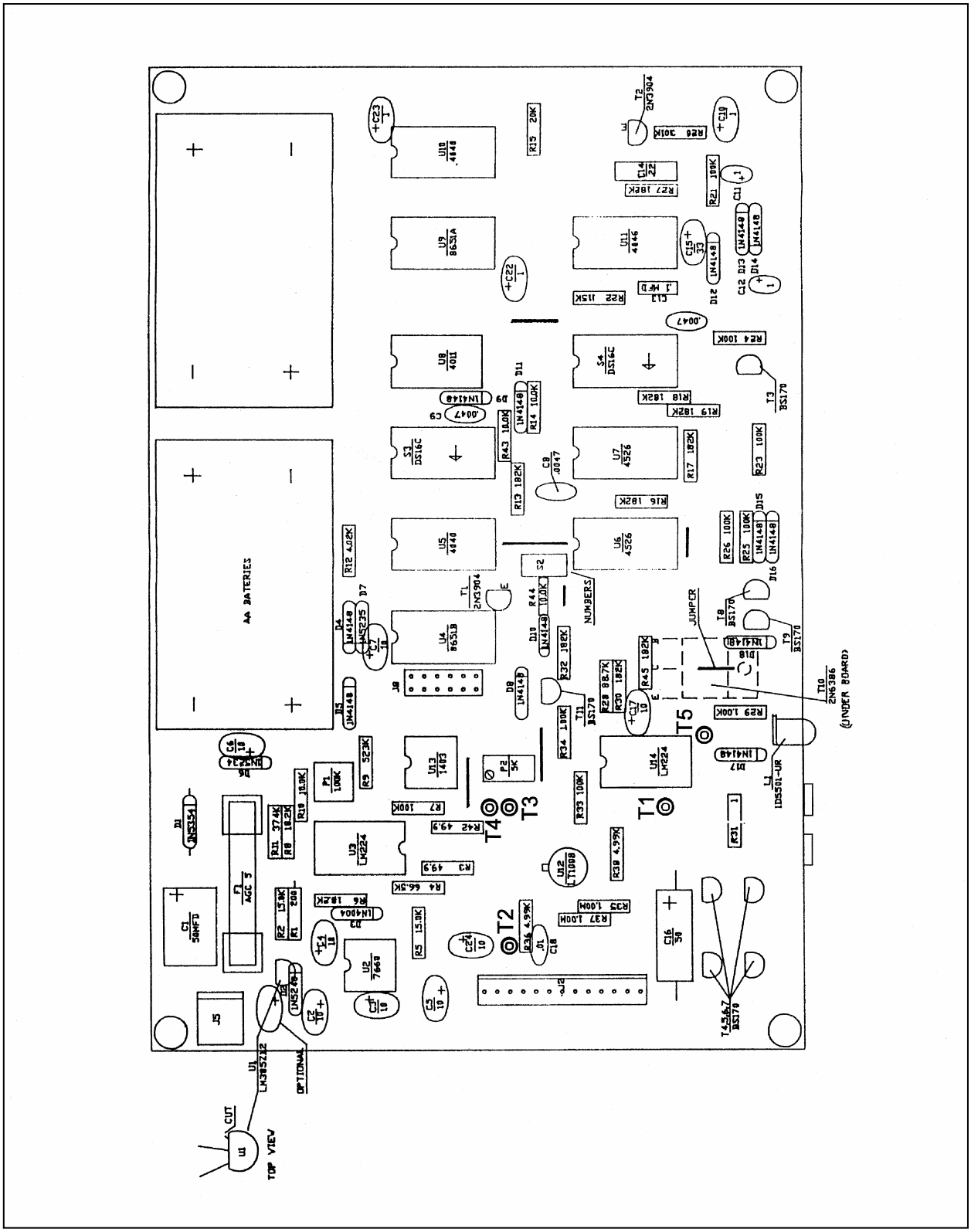


Figure 4-9. Transmitter Control Circuit Component Layout.

To initiate a calibration, remove the test lamp from the calibration transmitter (after turning the transmitter off) and install the reference lamp for use. The reference lamp should be cleaned with the microfiber cleaning cloth located in the transmitter shelter. Measure and record the lamp voltage after the lamp has been operating for about five minutes. For each calibration segment (10-15 uninterrupted, 1-minute readings from a single lamp), perform and document the following procedures:

INSTALL LAMP	Visually inspect and clean each lamp before installing the lamp in the transmitter. Clean the lamp with the microfiber cleaning cloth located in the transmitter shelter. Inspect the lamp to make sure there are no spots on the bulb or damage to the filament. Be sure the lamp is fully inserted into the lamp socket. Check the telescope alignment and correct if necessary. **CAUTION:** Transmissometer lamps are fragile and should be handled with great care. Dropping the lamp case or the lamp can result in a broken or damaged filament, even though the bulb does not appear broken.
TURN TRANSMITTER ON	Turn the transmitter power switch ON and document the calibration start time. Watch the lamp voltage as the lamp comes up to full power. Verify that the lamp voltage begins to stabilize near the standard operating voltage (approximately 5.5 volts). Each lamp should operate for approximately 10-15 minutes.
DOCUMENT LAMP VOLTAGE	The lamp voltage should be documented at the end of each calibration segment. Compare this lamp voltage with previously measured values as shown on the Transmitter Lamp Voltage Measurements Log included in the Instrument History Notebook. If the values differ by more than 30 mV, the lamp should be removed, reinserted, and the calibration segment restarted.
OBTAIN b_{SCAT}	Obtain the current test facility b_{scat} reading from the datalogger at the nephelometer test area.
TURN TRANSMITTER OFF	After the lamp has operated long enough for the receiver to collect 10-15 uninterrupted, 1-minute readings, turn the transmitter power off, document the end time, and check the telescope alignment. If the alignment is correct, remove the lamp from the transmitter. Let the lamp cool before reinserting the lamp into the lamp storage case. If the alignment is not correct, realign and retest the lamp.
DOCUMENT OBSERVATIONS	Document any unusual observations, changes in conditions, or other factors that might influence the calibration results.
REPEAT	Repeat these procedures for all lamps.
VERIFY OPERATION	At 45-minute intervals, verify receiver and datalogger operation.

4.1.6 Measurement of Pre-Field Lamp Voltages

When the calibrated instrument is returned to the laboratory, pre-field lamp voltages are measured for all lamps and recorded on the Lamp Voltage Measurement Record as described in Section 4.1.2, Pre-Calibration Lamp Voltages and TI 4110-3400, *Annual Laboratory Maintenance Procedures for LPV Transmissometer Systems (IMPROVE Protocol)*).

4.1.7 Preliminary Processing of Calibration Data

Prior to final review of the calibration data, the raw data must be transferred from the datalogger storage module to a computer data file and processed to present the data in a summarized format. Procedures for performing these tasks are as follows:

DOWNLOAD CALIBRATION DATA

Use the Campbell datalogger support software and the Campbell storage module interface to download calibration data from the SM192 storage modules to a calibration data file. For transmitter lamp voltage storage modules, the naming convention for downloaded files is LV*mmddyyx*, where LV denotes lamp voltage, *mm* the month, *dd* the day, *yy* the year, and *x*, a letter indicating the site path used (A, B, or X=tracking path).The files are placed in the ARS computer network directory O:/trans/IMP_OP/lampvolt.

For receiver raw data storage modules, the naming convention for downloaded files is R*mmddyyx.xxx*, where R denotes receiver, *mm* the month, *dd* the day, *yy* the year, *x* the path (A, B, or X), and *xxx* the instrument number. The receiver file is open in a general software editor such as Notepad or Ultraedit. The last three columns designate the receiver raw readings from the three different paths (A, B, X). Columns 4 and 5 are the columns that are used in processing. Column 4 designates the instrument that is being calibrated and Column 5 is the tracking instrument raw counts. To create a file for the B path, remove Column 4 from the original files. Cut and paste Column 6 in place of Column 4. Perform a Save As and rename the file in the same manner substituting a B for the path and Path B's instrument number for the file extension. An example receiver raw data file is provided as Figure 4-10.

File: O:\TRANS\IMP OP\R110204A.021 11/3/2004, 10:01:40AM

Array ID	Julian Day	Time	Path A Raw C	Tracking Raw C	Path B Raw Counts
01+0104.	02+0307.	03+1152.	04+3748.9	05+1294.5	06+5249.3
01+0104.	02+0307.	03+1153.	04+3732.6	05+7763.5	06+4805.6
01+0104.	02+0307.	03+1154.	04+3747.6	05+7783.2	06+5058.6
01+0104.	02+0307.	03+1155.	04+3692.9	05+7794.8	06+5080.3
01+0104.	02+0307.	03+1156.	04+3700.7	05+7774.4	06+5151.0
01+0104.	02+0307.	03+1157.	04+3703.4	05+7824.0	06+5151.3
01+0104.	02+0307.	03+1158.	04+3707.5	05+7767.6	06+4929.8
01+0104.	02+0307.	03+1159.	04+3715.7	05+7716.0	06+3835.2
01+0104.	02+0307.	03+1200.	04+3715.4	05+7774.5	06+4583.6
01+0104.	02+0307.	03+1201.	04+3720.8	05+7769.7	06+4707.9
01+0104.	02+0307.	03+1202.	04+3705.5	05+7789.4	06+4745.2
01+0104.	02+0307.	03+1203.	04+3705.5	05+7715.4	06+4605.6
01+0104.	02+0307.	03+1204.	04+3598.2	05+7767.7	06+.67929
01+0104.	02+0307.	03+1205.	04+3715.0	05+7765.0	06+.67929
01+0104.	02+0307.	03+1206.	04+3711.0	05+7755.5	06+.67923
01+0104.	02+0307.	03+1207.	04+3724.9	05+7777.2	06+.67923
01+0104.	02+0307.	03+1208.	04+3704.9	05+7750.0	06+.67923
01+0104.	02+0307.	03+1209.	04+3713.0	05+7761.6	06+.67917
01+0104.	02+0307.	03+1210.	04+3715.8	05+7771.8	06+68.597
01+0104.	02+0307.	03+1211.	04+3725.3	05+7786.7	06+.67917
01+0104.	02+0307.	03+1212.	04+3717.1	05+7772.5	06+.67917
01+0104.	02+0307.	03+1213.	04+3703.2	05+7747.4	06+.67912
01+0104.	02+0307.	03+1214.	04+3710.0	05+7769.1	06+.67912
01+0104.	02+0307.	03+1215.	04+3730.1	05+7737.9	06+9972.2
01+0104.	02+0307.	03+1216.	04+3721.9	05+7730.4	06+.67912
01+0104.	02+0307.	03+1217.	04+3727.4	05+7764.4	06+4308.0
01+0104.	02+0307.	03+1218.	04+3708.3	05+7813.3	06+4333.1
01+0104.	02+0307.	03+1219.	04+3712.1	05+7759.0	06+4339.5
01+0104.	02+0307.	03+1220.	04+3702.6	05+7786.1	06+4332.7
01+0104.	02+0307.	03+1221.	04+3698.5	05+7744.7	06+4300.1
01+0104.	02+0307.	03+1222.	04+3690.7	05+7775.9	06+4311.0
01+0104.	02+0307.	03+1223.	04+3700.9	05+7783.4	06+4317.4
01+0104.	02+0307.	03+1224.	04+3730.1	05+7768.5	06+4335.1
01+0104.	02+0307.	03+1225.	04+3692.8	05+7798.4	06+4317.4
01+0104.	02+0307.	03+1226.	04+3710.1	05+7748.8	06+4320.1
01+0104.	02+0307.	03+1227.	04+3700.6	05+7717.6	06+4319.8

Figure 4-10. Example Transmissometer Receiver Raw Data File.

GENERATE CALIBRATION REPORT

Use the ARS calibration support software for preliminary processing of downloaded data files. This software reads each valid record from the data file and calculates the mean value, the 95% confidence interval (CI), and the ratio of the CI to the mean for raw readings measured by both the calibration and tracking instruments during each individual lamp calibration segment. A preliminary calibration report (see Figure 4-11, Example Test Site Calibration Report) is generated and includes:

- Calibration parameters
- Estimated b_{ext}
- The neutral density filter (NDF) transmittance used
- Comments describing weather and visibility
- Lamp numbers used
- Calibration lamp voltages

GENERATE CALIBRATION REPORT (continued)

- Calibration instrument – calculated mean raw readings and CI/mean for each calibration lamp
- Tracking instrument – calculated mean raw readings and CI/mean for tracking lamp during each calibration segment
- Ratio of the tracking instrument mean to the calibration instrument mean for each calibration segment
- b_{scat} reading from the nephelometer for each lamp that was calibrated and only comments for the individual runs

Air Resource Specialists **Bulber Lamp Calibration**

Test Site Information

Calibration Date: **07/06/04B**
Operator: **Dave Beichley**
Cal. Type: **PRE**
Bext.: **0.025**
Instrument: **027**
CG: **100**
CA: **110.03**
CP: **0.300**
NDF Transmittance: **0.009717188**

Tracking Instrument Lamp no. **3259** ON Hours: **129.4** OFF Hours: **133.6**

Data File: **o:\trans\imp_op\R070604B.027**

Comments: **Mostly clear, slight breeze, warm. Visibility excellent, good detail on foothills and R**

Weather Information

Start	AT = 21°C	RH = 49%	WS = 5.8mph	WD = 144
Middle	AT = 22°C	RH = 44%	WS = 7.9mph	WD = 169
End	AT = 24°C	RH = 38%	WS = 7.4mph	WD = 127

Calibration Results

Lamp #	Lamp Voltage	RAWcal Mean	CI/ RAWcal Mean	Rawtrk Mean	CI/ Rawtrk Mean	Rawtrk Mean/ Rawcal Mean	Comments
2552	5.332	374.8	0.29	785.9	0.20	0.4769	.028 Site Ref
3079	5.562	388.4	0.22	786.5	0.25	0.4939	.027
3080	5.489	378.0	0.33	786.9	0.26	0.4804	.026
3081	5.540	381.5	0.25	787.9	0.40	0.4842	.024
3082	5.598	387.8	0.26	783.6	0.28	0.4948	.027
3418	5.608	413.9	0.31	784.8	0.22	0.5274	.024
2552	5.337	375.9	0.20	788.1	0.19	0.4770	.017 Site Ref
3419	5.546	399.5	0.24	785.3	0.30	0.5087	.027
3420	5.522	407.1	0.30	787.8	0.26	0.5168	.021
3421	5.579	410.6	0.20	785.5	0.23	0.5227	.019
3422	5.506	421.2	0.27	784.9	0.30	0.5366	.024
2552	5.336	376.3	0.29	784.0	0.22	0.4800	.029 Site Ref

Figure 4-11. Example Test Site Calibration Report.

4.1.8 Quality Assurance Review of Calibration Data

After all calibration data have been collected, the field specialist and the project manager review the data to verify that all procedures have been followed, that specific measurement relationships are satisfied, and that the data appear reasonable. Specific procedures for performing this review are as follows:

REVIEW SETUP FORM	Review the Calibration Setup Checklist/Documentation Form. Verify that all required information has been properly documented.
REVIEW LAMP VOLTAGE LOG	Review the Transmissometer Lamp Voltage Measurements Log. Verify that lamp voltages recorded to date do not vary by more than 30 mV.
REVIEW DETECTOR UNIFORMITY CHECK	Review the detector uniformity check. Verify that the maximum deviation of peripheral alignment measurements from centered alignment measurements is +0.25% / -1.0%.
REVIEW CALIBRATION REPORT	Review the Test Site Calibration Report (Bulber Lamp Calibrations) for the ten (10) lamp final calibration. (see Figure 4-11). The CI/mean is a measure of the stability of the visibility conditions over the time period during which each lamp was calibrated and should be less than 0.5% for both the calibration instrument and the tracking instrument. If the CI/mean is 0.5% or greater, the data are reviewed to determine if the high CI/mean is due to a single bad measurement. Individual bad measurements can be removed from the data, and the calculations and statistics can be regenerated. The number of data points used for individual lamp calibrations should be at least 10 readings. If the CI/mean exceeds 0.5% for several lamps, the calibration must be repeated. The ratio of the tracking mean to the calibration mean should not change by more than 1% for repeat calibrations of a specific lamp. This ratio is used to compare repeat calibrations performed over a wide range of visibility conditions.

4.1.9 Entry of and Normalization of Calibration Data Into the Calibration Database

When the quality review of the calibration data is completed, the preliminary calibration report (Bulber Lamp Calibration Report) is then accepted (Figure 4-12) in which the preliminary data is automatically entered into the calibration database. When the quality assurance review of the calibration data is complete, the data from the ten (10) lamp final calibration are normalized and entered into the Transmissometer Calibration Database. ARS calibration support software is used in performing both of these functions.

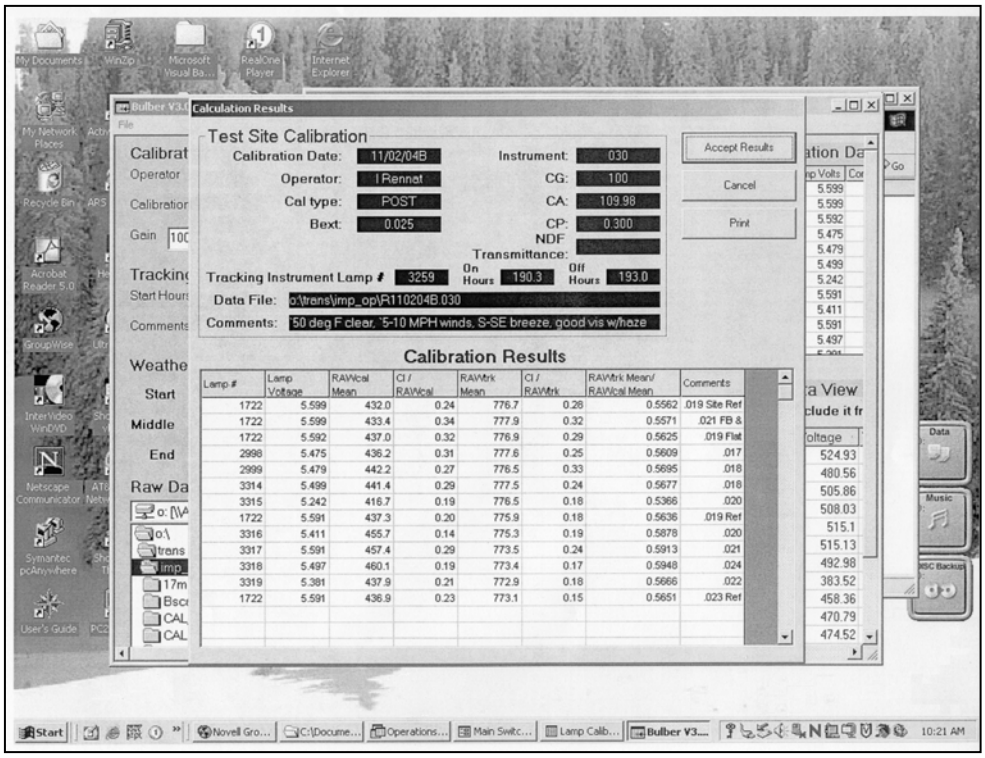


Figure 4-12. Transmissometer Calibration Database Screen.

The calibration data are normalized to a b_{ext} of .020. The normalization process includes the following steps:

- In the calibration database, select the normalized form (Figure 4-13). Enter the calibration date and run ID (designated site path "A" or "B").

- Select and enter the highest average raw tracking reading from the 10 lamp runs using the Bulber lamp calibration report. Take the corresponding b_{scat} value and add .005 for b_{abs} (absorption) to get the total b_{ext} value and enter it on the normalized calibration form.

- Select the calculated button to run the normalization. A normalized calibrations raw reading report will be calculated and entered into the database. Print a copy of the report for the individual instrument logbooks.

Figure 4-14 is an example of a Normalized Calibration Raw Readings Report (Normalized Data Report).

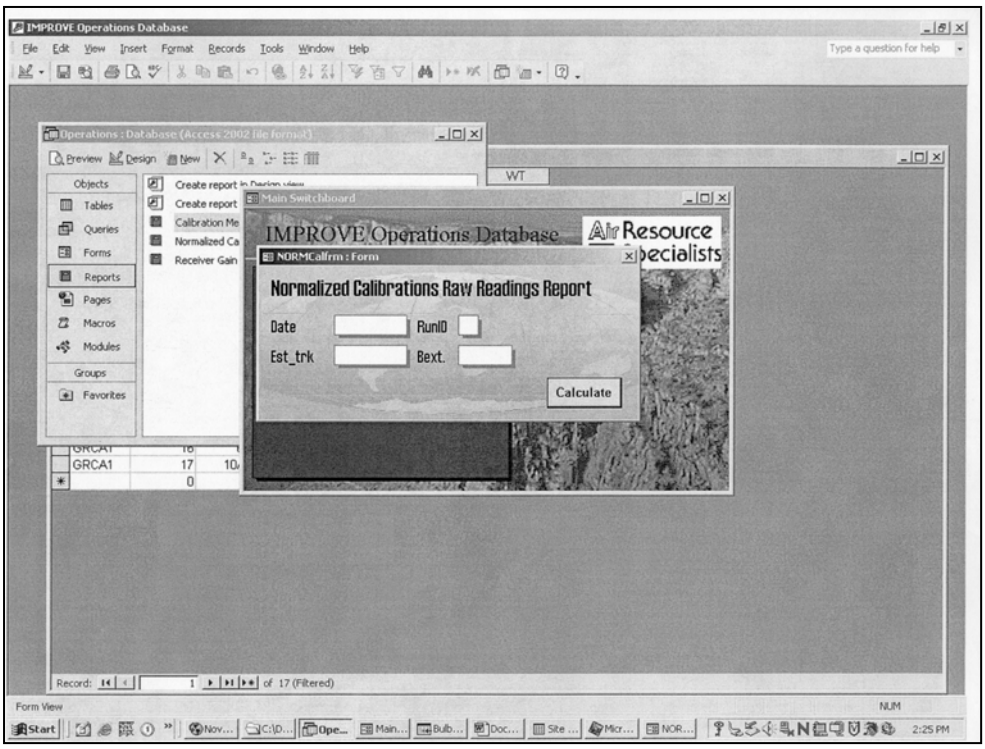


Figure 4-13. Normalized Calibrations Form Screen in the Transmissometer Calibration Database.

Normalized Calibrations Raw Readings Report

Thursday, July 08, 2004

Cal_Date	*7/6/2004*	***Est_Bext***	*0.022*
RunID	*B*	***EstTrk***	*788.100*
Cal_Type	*PRE*	***NormTrk***	*788.6*
LPV_No	*027*		

Lamp #	*Lamp Voltage*	*RAWcal Mean*	*RAWtrk Mean*	*RawCal Mean/ RawTrk Mean*	*NORMcal*
2552	5.332	374.8	785.9	.4769	376.1
2552	5.337	375.9	788.1	.4770	376.1
2552	5.336	376.3	784.0	.4800	378.5
3079	5.562	388.4	786.5	.4939	389.4
3080	5.489	378.0	786.9	.4804	378.8
3081	5.540	381.5	787.9	.4842	381.8
3082	5.598	387.8	783.6	.4948	390.3
3418	5.608	413.9	784.8	.5274	415.9
3419	5.546	399.5	785.3	.5087	401.2
3420	5.522	407.1	787.8	.5168	407.5
3421	5.579	410.6	785.5	.5227	412.2
3422	5.506	421.2	784.9	.5366	423.2

Figure 4-14. Example Normalized Calibration Raw Readings Report.

4.1.10 Calculation of Site-Specific Pre-Field Calibration Numbers

When a transmissometer is selected for installation at a specific monitoring location, ARS calibration support software is used to enter site-specific operating parameters into lamp-specific data records for the instrument. Site-specific calibration numbers are calculated for each lamp and a calibration memo detailing the calibration parameters, site parameters, and calibration results is generated. Operational parameters are entered into the database via the Site Configuration Table (see Figure 4-15). Specific information added to the database includes:

- Site ID – Enter the 5-character site abbreviation for the operational site.
- Configuration number – Configuration number for the new site parameter.
- Date installed – the installation date should be entered after the instrument is installed and operational parameters such as window transmission, working gain, and working aperture have been updated to reflect changes occurring at installation.
- LPV number - The instrument number of the LPV that will be installed.
- Working Path – Enter the site path length in kilometers, with a resolution of 0.1 meters (e.g., 5.4339 km). The site path length is precisely measured and documented as described in TI 4070-3010, *Installation and Site Documentation for Optec LPV Transmissometer Systems (IMPROVE Protocol).*
- Working aperture – If the receiver telescope is being operated at full aperture, enter the aperture as documented during annual servicing (refer to TI 4110-3400, *Annual Laboratory Maintenance Procedures for LPV Transmissometer Systems (IMPROVE Protocol).* If a reduced aperture is required at a specific site, enter the aperture diameter as marked on the aperture ring.
- Window Transmission – Measured window transmittance (both windows combined) is typically around 80% (0.800) with a resolution of 0.1% (0.001). If new windows are being installed, enter the WT value measured at the test facility (refer to Section 4.4, Window Transmittance Measurements). If the windows currently in use the site are to be used, use the WT value currently in use for these windows. Window transmittance measurements are performed on-site during each annual site visit as described in SOP 4710, *Transmissometer Field Audit Procedures*. The WT value in the database should be updated and the calibration numbers recalculated using the on-site WT measurement.

Site Configurations 11/12/2004

SiteID	Config_No	Date_Installed	LPV_No	WP	WA	WT
GRCA1	1	4/20/1999	029	5.7904	110.03	.8100
GRCA1	2	9/27/2000	036	5.7904	110.03	.8100
GRCA1	3	9/27/2000	992	5.7904	84.95	1.0000
GRCA1	4	9/27/2000	992	5.7904	116.80	1.0000
GRCA1	5	9/20/2001	004	5.7904	116.80	.8100
GRCA1	6	9/20/2001	992	5.7904	101.50	1.0000
GRCA1	7	9/20/2001	992	5.7904	84.95	1.0000
GRCA1	8	9/20/2001	992	5.7904	116.80	1.0000
GRCA1	9	10/21/2002	003	5.7904	116.81	.8100
GRCA1	10	10/21/2002	992	5.7904	116.78	1.0000
GRCA1	11	10/21/2002	992	5.7904	84.95	1.0000
GRCA1	12	10/1/2003	007	5.7904	109.98	.8100
GRCA1	13	10/1/2003	991	5.7904	110.00	1.0000
GRCA1	14	10/1/2003	991	5.7904	84.97	1.0000
GRCA1	15	6/8/2004	991	5.7904	110.00	1.0000
GRCA1	16	6/8/2004	991	5.7904	84.97	1.0000
GRCA1	17	10/19/2004	013	5.7904	110.06	.8100

Figure 4-15. Example Site Configuration Table.

Site-specific calibration numbers for audit instrument used to perform the audit on-site are also entered into the site configuration table. Once the site configuration table is entered a calibration memo can be made for the site and instrument. Select Calculate Cal Number/Cal Memo from the IMPROVE operations database main menu (Figure 4-16). Within the table enter the date of the calibration and the RUN ID (path used A or B). With this information the table will automatically pull up parameters from the database:

LPV # - the instrument that was calibrated
CP - the calibration path (0.3 km)
CA - the calibration aperture (usually the full aperture of the instrument)
CG - the calibration gain that was used (usually 100)
FT - the filter transmittance of the neutral density filter that was used
bext - the bext the calibration was normalized to

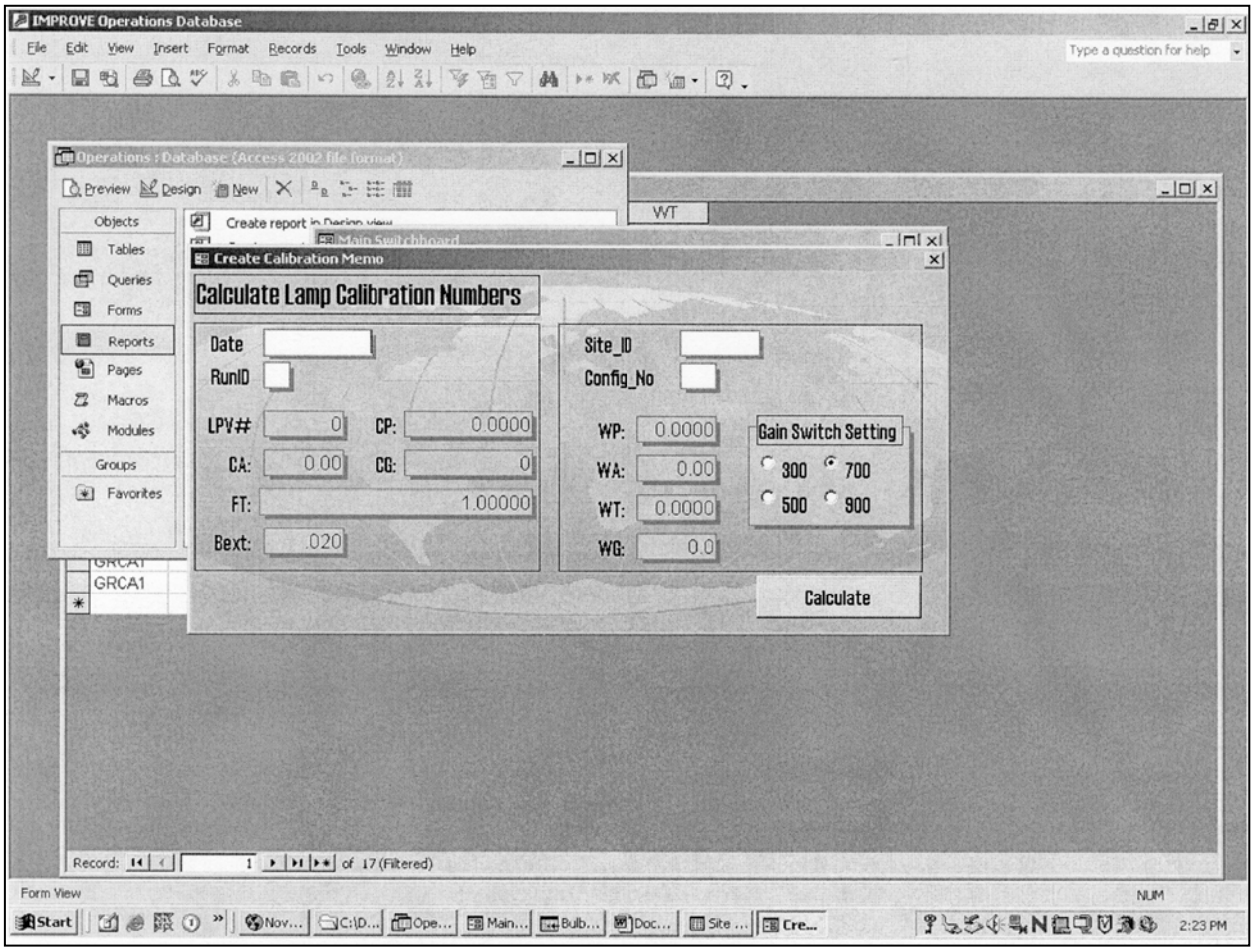


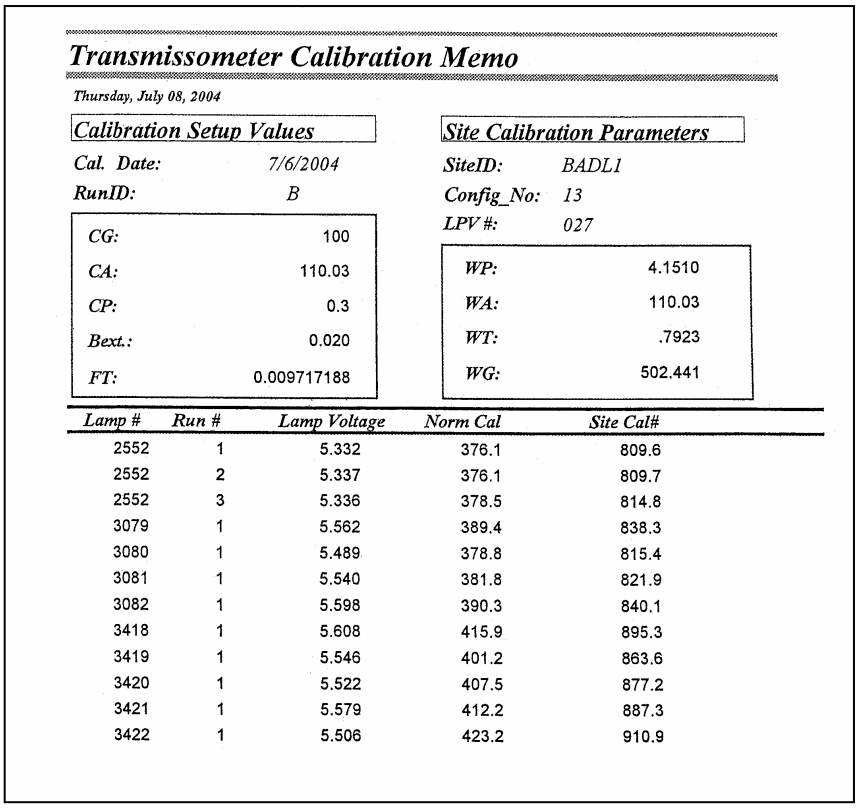
Figure 4-16. Calculate Lamp Calibration Numbers Screen.

On the other side of the table enter the site ID (5-character) and the configuration number made in the site configuration table. With this information the cal memo table will automatically update the site-specific parameters from the Site Configuration Table:

WP - the working path of the site
WA - the working aperture of the instrument to be used
WT - the window transmittance of the windows on site
WG - the working gain that will be set on the receiver computer

You can select the gain that fits the site the best. The highest gain should be used to yield the highest calibration numbers possible. The higher the calibration number the better the resolution. However, calibration numbers cannot be over 1,000 or else the receiver computer will overrange. Click the **Calculate** button and the calibration memo will be created. If the calibration numbers are below 975 and are at the highest range the calibration memo can be printed and used. The final calibration numbers will be saved in lamp calibration table of the database.

An example calibration memo is shown as Figure 4-17. The calibration numbers are calculated using the calibration equation described below.



Transmissometer Calibration Memo

Thursday, July 08, 2004

Calibration Setup Values	
Cal. Date:	*7/6/2004*
RunID:	*B*
CG:	100
CA:	110.03
CP:	0.3
Bext.:	0.020
FT:	0.009717188

Site Calibration Parameters	
SiteID:	*BADL1*
Config_No:	*13*
LPV #:	*027*
WP:	4.1510
WA:	110.03
WT:	.7923
WG:	502.441

Lamp #	*Run #*	*Lamp Voltage*	*Norm Cal*	*Site Cal#*
2552	1	5.332	376.1	809.6
2552	2	5.337	376.1	809.7
2552	3	5.336	378.5	814.8
3079	1	5.562	389.4	838.3
3080	1	5.489	378.8	815.4
3081	1	5.540	381.8	821.9
3082	1	5.598	390.3	840.1
3418	1	5.608	415.9	895.3
3419	1	5.546	401.2	863.6
3420	1	5.522	407.5	877.2
3421	1	5.579	412.2	887.3
3422	1	5.506	423.2	910.9

Figure 4-17. Example Calibration Memo.

Calibration data are used to calculate the individual calibration numbers and are located in the IMPROVE operations database. Lamp-specific calibration data to be entered into the database via this screen include:

$$\text{Calibration \#} = (CP/WP)^2 * (WG/CG) * (WA/CA)^2 * (1/FT) * WT * (1/T) * CR$$

Where:

CP = calibration path length, 0.300 km
WP = working path length, 0.500 to 10.000 km
(5.000 km for standardized site)

WG = working gain, nominal values are 100, 300, 500,700, or 900
CG = calibration gain, nominal values are 100, 300, 500, 700, or 900

WA = working aperture, approximately 110.00 mm
CA = calibration aperture, 101.51 mm

FT = calibration filter (NDF) transmittance, approximately 1.00% or 0.01
WT = total window transmittance for the operational system (typically 80% or 0.800)
(1.000 for audit instruments)

T = estimated atmospheric transmittance for the calibration path ($T=e^{-bext*CP}$)
CR = normalized average of 10-12 readings over the calibration path

The standardized calibration number is used in calculating lamp brightening and varies from instrument to instrument, but typically is in the range 500-700 for pre-field calibrations.

For audit instrument calibrations, calibration numbers are calculated in the same manner. The raw readings from the test facility calculated in Bulber for preliminary calibration numbers. These new numbers are automatically transferred to the IMPROVE Operation Database. Next the averaged raw readings are normalized to a b_{ext} of 0.020. For site-specific audits the site configuration table must be updated for the audit instrument that will be used at the particular site. Afterwards, a calibration memo can be run to generate calibration numbers for the instrument for a particular site.

4.1.11 Maintenance of Calibration Documentation

All calibration documentation is maintained in the ARS Data Collection Center in instrument-specific notebooks. Following completion of all pre-field calibration procedures, the following documentation is transferred to the Data Collection Center:

- Transmissometer Lamp Voltage Measurements Log
- Calibration Setup Checklist/Documentation Form
- Detector Uniformity Field Check Form and Calculation Sheet
- Optec LPV Transmissometer Calibration Data Form
- Test Site Calibration Data Report (Bulber Lamp Calibration
- Normalized Calibrate Raw Readings Report
- Transmissometer Calibration Memo
- Test facility photographic documentation

Data Collection Center staff distribute calibration documentation as required.

4.2 POST-FIELD CALIBRATION

Post-field calibration of a transmissometer is required after the instrument is removed from a monitoring location, and includes the following procedures:

- Setup of instrumentation at the field calibration facility
- Measurement of receiver detector uniformity
- Calibration of ten (10) transmissometer lamps

- Measurement of post-calibration lamp voltages
- Preliminary processing of calibration data
- Quality assurance review of calibration data
- Entry of calibration data into the transmissometer Calibration Database
- Maintenance of post-calibration documentation

The following subsections provide detailed instructions for performing the post-field calibration procedures listed above. Many of the post-field calibration procedures parallel pre-field calibration procedures described in Section 4.1.

4.2.1 Calibration Instrumentation Setup

Setup and documentation for all post-field calibrations are performed using the Calibration Setup Checklist/Documentation Form and follow the detailed procedures described in Section 4.1.3.

4.2.2 Receiver Detector Uniformity

Detector uniformity checks are an integral part of all post-field calibrations and are performed according to the detailed procedures described in Section 4.1.4.

4.2.3 Lamp Calibration

Post-field calibration of LPV transmissometers is performed according to the detailed procedures for pre-field calibrations described in Section 4.1.5. Exceptions to these procedures are:

- The number of lamps calibrated differs. Of the nine (9) transmissometer lamps initially sent to a field site, lamp breakage and failure often will reduce the number of lamps returned for post-calibration. All lamps returned with an operational instrument and the primary reference lamp must be post-field calibrated so that the lamp brightening characteristics can be measured and added to the lamp brightening database.

- Additional procedures are required for quantifying the affects of optical interference related to the transmissometer telescopes (receiver and/or transmitter). To start the post-calibration procedure, the instrument is calibrated as is using the site reference. After each 10-15 calibration run each of the optical surfaces are cleaned and another calibration procedure is performed. The cleaning of the optical surface should follow the order as follows:

  - Receiver objective lens
  - Transmitter objective lens
  - Transmitter condensing lens
  - Transmitter flat lens

  Once the optical surfaces have been cleaned the rest of the lamps can be post-calibrated with the site reference lamp calibrated again in the middle and at the end.

4.2.4 Measurement of Post-Calibration Lamp Voltages

When the post-field calibration is complete and the instrument is returned to the laboratory, post-field lamp voltages are measured for all lamps and recorded on the transmissometer Lamp Voltage Measurements Log as described in TI 4110-3400, *Annual Laboratory Maintenance Procedures for LPV Transmissometer Systems (IMPROVE Protocol)*).

4.2.5 Preliminary Processing of Calibration Data

Prior to final review of the calibration data, the raw calibration data must be transferred from the datalogger storage module to a computer data file and processed to present the data in a summarized format. Procedures for performing these tasks are described in Section 4.1.7.

4.2.6 Quality Assurance Review of Calibration Data

After all calibration data have been collected, the field specialist and project manager review the data to verify that all procedures have been followed, that specific measurement relationships are satisfied, and that the data appear reasonable. Specific procedures for performing this review are as follows:

REVIEW SETUP FORM	Review the Calibration Setup Checklist/Documentation Form. Verify that all required information has been properly documented.
REVIEW LAMP VOLTAGE LOGS	Review Transmissometer Lamp Voltage Measurements Logs. Verify that lamp voltages for the primary and on-site reference lamps have not varied by more than 30 mV between calibrations.
REVIEW DETECTOR UNIFORMITY CHECK	Review the detector uniformity check. Verify that the maximum deviation of peripheral alignment measurements from centered alignment measurements is +0.25% / -1.0%.
REVIEW CALIBRATION REPORT	Review the Test Site Calibration Report. The CI/mean is a measure of the stability of the visibility conditions over t he time period during which each lamp was calibrated and should be less than 0.5% for both the calibration instrument and the tracking instrument. If the CI/mean is 0.5% or greater, the data are reviewed to determine if the high CI/mean is due to a single bad measurement. If the CI/mean exceeds 0.5% for several lamps, the calibration must be repeated. The ratio of the tracking mean to the calibration mean should not change by more than 1% for repeat calibrations of a specific lamp. This ratio is used to compare repeat calibrations performed over a wide range of visibility conditions.

4.2.7 Entry of Calibration Data Into the Calibration Database

After the quality assurance review of the calibration data is complete, the data from the post-field calibration are automatically entered into the Transmissometer Calibration Database. ARS calibration support software is used in performing both of these functions following the procedures described in Section 4.1.9.

4.2.8 Maintenance of Calibration Documentation

All calibration documentation is maintained in the ARS Data Collection Center. Following completion of all post-field calibration procedures, the following documentation is transferred to the Data Collection Center:

- Transmissometer Lamp Voltage Measurements Log
- Calibration Setup Checklist/Documentation Form
- Detector Uniformity Field Check Form and calculation sheet
- Optec LPV Transmissometer Calibration Data Form
- Test Site Calibration Data Report
- Normalized Calibration Raw Readings Report

Data Collection Center staff distribute calibration documentation as required.

4.3 AUDIT INSTRUMENT CALIBRATION

Calibration of the audit transmissometer is required prior to and following its use in performing a field audit, and includes the following procedures:

- Setup of instrumentation at field calibration facility
- Measurement of receiver detector uniformity
- Calibration of six (6) transmissometer lamps
- Preliminary processing of calibration data
- Quality assurance review of calibration data
- Entry of calibration data into the Transmissometer Calibration Database
- Calculation of site-specific audit calibration numbers for each lamp
- Maintenance of audit instrument calibration documentation

4.3.1 Calibration Instrumentation Setup

Setup and documentation for all audit instrument calibrations are performed using the Calibration Setup Checklist/Documentation Form and follow the detailed procedures described in Section 4.1.3.

4.3.2 Receiver Detector Uniformity

Detector uniformity checks are an integral part of all audit instrument calibrations and are performed according to the detailed procedures described in Section 4.1.4.

4.3.3 Lamp Calibration

Calibration of the LPV-2 audit transmissometer is performed according to the detailed procedures for pre-field calibrations described in Section 4.1.5. The only exception to these procedures is that six (6) lamps are calibrated for use with the audit instrument (a primary reference lamp, a traveling reference lamp, and four (4) audit lamps). The audit instrument is recalibrated following any field audit requiring shipment (air freight, UPS, FedEx, etc.) of the instrument.

4.3.4 Preliminary Processing of Calibration Data

Prior to final review of the calibration data, the raw calibration data must be transferred from the datalogger storage module to a computer data file and processed to present the data in a summarized format. Procedures for performing these tasks are described in Section 4.1.7.

4.3.5 Quality Assurance Review of Calibration Data

After all calibration data have been collected, the field specialist and project manager review the data to verify that all procedures have been followed, that specific measurement relationships are satisfied, and that the data appear reasonable. Specific procedures for performing this review are as follows:

REVIEW SETUP FORM	Review the Calibration Setup Checklist/Documentation Form. Verify that all required information has been properly documented.
REVIEW LAMP VOLTAGE LOGS	Review Transmissometer Lamp Voltage Measurements Logs. Verify that lamp voltages for the primary and on-site reference lamps have not varied by more than 30 mV between calibrations.
REVIEW DETECTOR UNIFORMITY CHECK	Review the detector uniformity check. Verify that the maximum deviation of peripheral alignment measurements from centered alignment measurements is +0.25% / -1.0%.
REVIEW CALIBRATION REPORT	Review the Test Site Calibration Report.

REVIEW CALIBRATION REPORT (continued)

The CI/mean is a measure of the stability of the visibility conditions over t he time period during which each lamp was calibrated and should be less than 0.5% for both the calibration instrument and the tracking instrument. If the CI/mean is 0.5% or greater, the data are reviewed to determine if the high CI/mean is due to a single bad measurement. Individual bad measurements can be removed from the data, and the calculations and statistics can be regenerated. The number of data points used for individual lamp calibrations should be at least 10 readings. If the CI/mean exceeds 0.5% for several lamps, the calibration must be repeated.

The ratio of the tracking mean to the calibration mean should not change by more than 1% for repeat calibrations of a specific lamp. This ratio is used to compare repeat calibrations performed over a wide range of visibility conditions.

COMPARE READINGS

Compare lamp-specific raw readings obtained during this calibration with readings obtained with the same lamps in recent audit instrument calibrations.

4.3.6 Entry and Normalization of Calibration Data Into the Calibration Database

After the quality assurance review of the calibration data is complete, data from the post-field calibration are normalized and entered into the Transmissometer Calibration Database. ARS calibration support software is used in performing both of these functions following the procedures described in Section 4.1.9.

4.3.7 Calculation of Site-Specific Audit Instrument Calibration Numbers

Audit calibration numbers are calculated using ARS calibration support software to enter site-specific operating parameters into lamp-specific data records for the instrument. Site-specific calibration numbers are calculated for each lamp and a calibration memo detailing the calibration parameters, site parameters, and calibration results is generated. Operational parameters are entered into the database via the Site Configuration Table (see Figure 4-15). Specific information added to the database includes:

- Site ID – Enter the 5-character site abbreviation for the operational site.
- Date installed – the installation date should be entered after the instrument is installed and operational parameters such as window transmission, working gain, and working aperture have been updated to reflect changes occurring at installation.
- LPV number - The instrument number of the LPV that will be installed.
- OP SITE – Enter the four (4) letter abbreviation for the operational site.

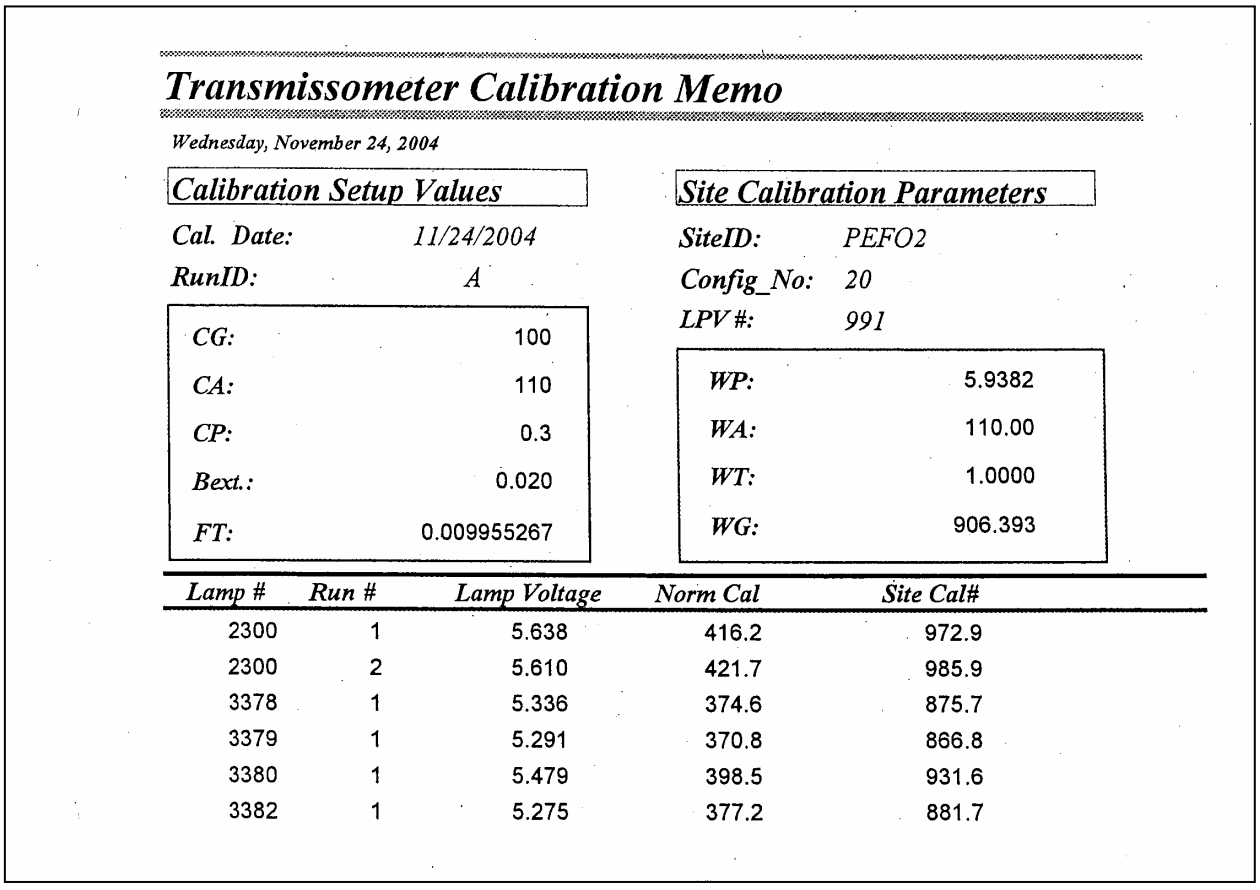
- Configuration number – Configuration number for the new site parameter.

- WORKING PATH – Enter the sight path length in km, with a resolution of 0.1 meters (e.g., 5.4339 km). The sight path length is precisely measured and documented as described in TI 4070-3010, *Installation and Site Documentation for Optec LPV Transmissometer Systems*. If a reduced aperture is required for operation of the audit instrument, enter the aperture diameter marked on the aperture ring.

- WORKING APERTURE – If the receiver telescope is being operated at full aperture, enter the aperture as documented during annual servicing (refer to the Transmissometer Servicing Checklist, TI 4110-3400). If a reduced aperture is required at a specific site, enter the aperture diameter as marked on the aperture ring.

- WINDOW TRANSMISSION – Refer to procedures described in Section 4.1.10.

An Audit Calibration Numbers Report is generated for both the instrument to be removed and the instrument to be installed. An example Audit Instrument Calibration Numbers Report is shown as Figure 4-18. The calibration numbers are calculated using the calibration equation described in Section 4.1.10.



Transmissometer Calibration Memo

Wednesday, November 24, 2004

Calibration Setup Values

Cal. Date:	11/24/2004
RunID:	A
CG:	100
CA:	110
CP:	0.3
Bext.:	0.020
FT:	0.009955267

Site Calibration Parameters

SiteID:	PEFO2
Config_No:	20
LPV #:	991
WP:	5.9382
WA:	110.00
WT:	1.0000
WG:	906.393

Lamp #	Run #	Lamp Voltage	Norm Cal	Site Cal#
2300	1	5.638	416.2	972.9
2300	2	5.610	421.7	985.9
3378	1	5.336	374.6	875.7
3379	1	5.291	370.8	866.8
3380	1	5.479	398.5	931.6
3382	1	5.275	377.2	881.7

Figure 4-18. Example Audit Instrument Calibration Numbers Report.

4.3.8 Maintenance of Calibration Documentation

All calibration documentation is maintained in the ARS Data Collection Center. Following completion of all post-field calibration procedures, the following audit instrument documentation is transferred to the Data Collection Center:

- Transmissometer Lamp Voltage Measurements Log
- Calibration Setup Checklist/Documentation Form
- Detector Uniformity Field Check Form and calculation sheet
- Optec LPV Transmissometer Calibration Data Form
- Test Site Calibration Data Report
- Normalized Calibration Raw Readings Report
- Audit Calibration Numbers Report

Data Collection Center staff distribute calibration documentation as required.

4.4 WINDOW TRANSMITTANCE MEASUREMENTS

Calibration of a window for use requires measurement of light loss as transmitted light passes through the window. Initial measurements of window transmittance are performed at the test facility and follow the basic measurement procedures described for other calibrations. Individual and combined transmittance is measured for the transmitter and receiver windows. The transmittance is determined by measuring the light received at the receiver with the windows in place and the windows removed. The ratio of the average readings with the windows in, to the average readings with the windows out, is the window transmittance. Procedures for performing test facility window transmittance measurements are as follows:

- Setup of instrumentation at field calibration facility
- Measurement of window transmittances
- Preliminary processing of calibration data
- Quality assurance review of calibration data
- Calculation of window transmittances

Window transmittance measurements are also performed during the annual site visit (refer to TI 4115-3000, *Annual Site Visit Procedures for Optec LPV Transmissometer Systems (IMPROVE Protocol)*).

4.4.1 Calibration Instrumentation Setup

Setup and documentation for window transmittance measurements are performed using the Calibration Setup Checklist/Documentation Form and follow the detailed procedures described in Section 4.1.3.

4.4.2 Window Transmittance Measurements

All windows are calibrated in pairs, one (1) transmitter window and one (1) receiver window. The procedures for performing and documenting window transmittance measurements are as follows:

DOCUMENT INFORMATION

Use the Window Transmittance Data Form (Figure 4-19) to document test facility weather and visibility conditions, preliminary support equipment measurements, window serial numbers, and measurement data.

MEASURE TRANSMITTANCES

Use the calibration transmitter with a test lamp to measure window transmittances.

- Do not initiate transmittance measurements until the lamp voltage has stabilized around 5.6 volts.
- Five measurement segments of 10-12 one-minute readings per segment are required for calibrating a pair of windows:

  Segment #1 Both windows out
  Segment #2 transmitter window in
  Segment #3 Both windows in
  Segment #4 Receiver window in
  Segment #5 Both windows out

OBTAIN b_{SCAT}

Obtain the current test facility b_{scat} reading from the datalogger located at the NGN-2 test area.

4.4.3 Preliminary Processing of Calibration Data

Prior to final review of the calibration data, the raw calibration data must be transferred from the datalogger storage module to a computer data file and processed to present the data in a summarized format. Procedures for performing these tasks are described in Section 4.1.7.

Technician: _____ **Date:** _____
Tracking LPV#: _____ **Transmitter Window #:** _____
Calibration LPV#: _____ **Receiver Window #:** _____

WINDOW TRANSMITTANCE DATA

TEST SITE CONDITIONS

Weather: _____

Visibility: _____

CALIBRATION INSTRUMENT – Transmitter Test Point Measurements

Test Lamp #	T1	T2	T3	T4	T5
_____	_____	_____	_____	_____	_____

TRACKING INSTRUMENT – Transmitter Measurements

Tracking Lamp #: _____ **Lamp Hours:** **ON** _____:_____ **OFF** _____:_____

WINDOW TRANSMITTANCE TEST SEGMENTS LOG

	Alignment	Start Time	End Time	Lamp Voltage	b_{scat}	Comments
No Windows		:	:			
Transmitter Window		:	:			
Both Windows		:	:			
Receiver Window		:	:			
No Windows		:	:			
		:	:			
		:	:			

wintran.frm (8/96)

Figure 4-19. Window Transmittance Data Form.

4.4.4 Quality Assurance Review of Calibration Data

After all calibration data have been collected, the field specialist and the project manager review data to verify that all procedures have been followed, that specific measurement relationships are satisfied, and that the data appear reasonable. Specific procedures for performing this review are as follows:

REVIEW SETUP FORM	Review the Calibration Setup Checklist/Documentation Form. Verify that all required information has been properly documented.
REVIEW CALIBRATION REPORT	Review the Test Site Calibration Report. The CI/mean is a measure of the stability of the visibility conditions over t he time period during which each lamp was calibrated and should be less than 0.5% for both the calibration instrument and the tracking instrument. If the CI/mean is 0.5% or greater, the data are reviewed to determine if the high CI/mean is due to a single bad measurement. If the CI/mean exceeds 0.5% for several lamps, the calibration must be repeated. Look for obvious inconsistencies. The raw readings should be approximately the same for segments #2 and #4 and segments #1 and #5. Raw readings for segments #2 and #4 should be about halfway between the segment #3 reading and the segment #1 or #5 reading.

4.4.5 Calculation of Window Transmittances

Data from the Test Site Calibration Report are used to calculate individual and combined window transmittances. A Window Transmittance Measurement Report is generated by the ARS calibration support software.

Raw readings and tracking mean to calibration mean ratios (see Section 4.1.7) for each measurement segment are entered into the calibration database using the Window Transmittance Measurements Data Entry Screen shown as Figure 4-20. Window transmittances are then calculated from raw readings and mean ratios. An example Window Transmittance Measurement Report is presented as Figure 4-21.

4.4.6 Maintenance of Window Transmittance Documentation

All window transmittance documentation is maintained in the ARS Data Collection Center. Following completion of window transmittance tests, the following documentation is transferred to the Data Collection Center:

- Window Transmittance Data Form
- Window Transmittance Measurements Report

Data Collection Center staff distribute window transmittance documentation as required.

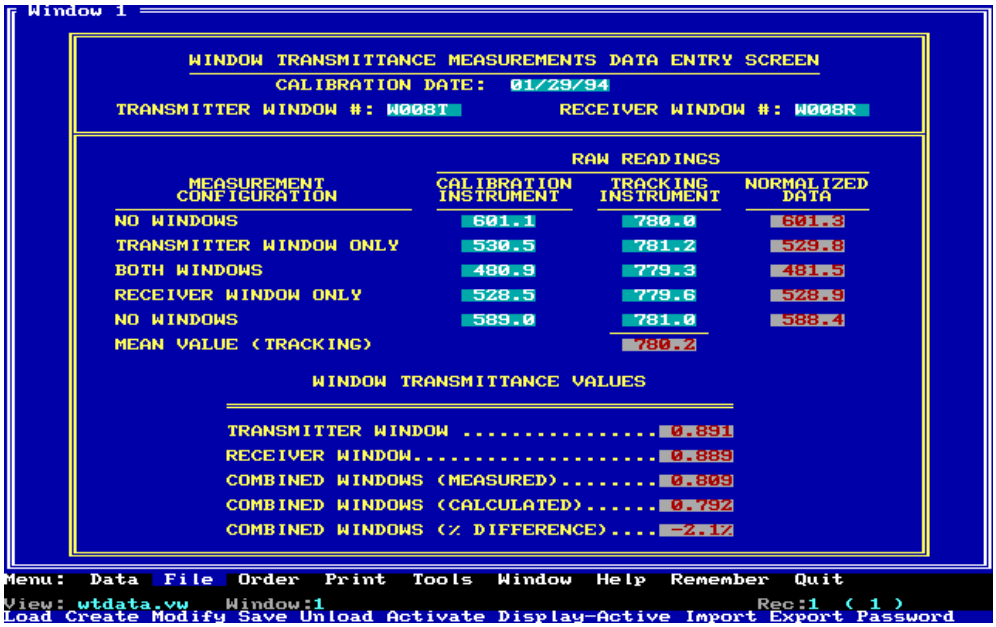


Figure 4-20. Window Transmittance Measurements Data Entry Screen.

WINDOW TRANSMITTANCE MEASUREMENTS DATA ENTRY SCREEN

CALIBRATION DATE: 01/29/94

TRANSMITTER WINDOW #: W008T **RECEIVER WINDOW #: W008R**

MEASUREMENT CONFIGURATION	RAW READINGS		
	CALIBRATION INSTRUMENT	TRACKING INSTRU-MENT	NORMAL-IZED DATA
NO WINDOWS	601.1	780.0	601.3
TRANSMITTER WINDOW ONLY	530.5	781.2	529.8
BOTH WINDOWS	480.9	779.3	481.5
RECEIVER WINDOW ONLY	528.5	779.6	528.9
NO WINDOWS	559.0	781.0	558.4
MEAN VALUE (TRACKING)		780.2	

WINDOW TRANSMITTANCE VALUES

TRANSMITTER WINDOW 0.914

RECEIVER WINDOW 0.912

COMBINED WINDOWS (MEASURED) 0.830

COMBINED WINDOWS (CALCULATED) 0.833

COMBINED WINDOWS (% DIFFERENCE) 0.4%

Figure 4-21. Window Transmittance Measurements Report.

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QUALITY ASSURANCE/QUALITY CONTROL DOCUMENTATION SERIES	
TITLE	**TRANSMISSOMETER LAMP PREPARATION (BURN-IN) PROCEDURES**
TYPE	**TECHNICAL INSTRUCTION**
NUMBER	**4200-2110**
DATE	**FEBRUARY 1994**

AUTHORIZATIONS		
TITLE	NAME	SIGNATURE
ORIGINATOR	Mark Tigges	
PROJECT MANAGER	Mark Tigges	
PROGRAM MANAGER	David L. Dietrich	
QA MANAGER	Gloria S. Mercer	
OTHER		

REVISION HISTORY			
REVISION NO.	CHANGE DESCRIPTION	DATE	AUTHORIZATIONS
	Reviewed; no changes necessary.	February 1995	
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	Reviewed; no changes necessary.	October 1998	
	Reviewed; no changes necessary.	October 1999	
	Reviewed; no changes necessary.	October 2000	
	Reviewed; no changes necessary.	October 2001	
	-- continued --		

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REVISION HISTORY			
REVISION NO.	CHANGE DESCRIPTION	DATE	AUTHORIZATIONS
	Reviewed; no changes necessary.	October 2002	
0.2	Add packing in lamp “sleeves”	October 2003	
	Reviewed; no changes necessary.	October 2004	

TABLE OF CONTENTS

LIST OF FIGURES

1.0 PURPOSE AND APPLICABILITY

The purpose of this technical instruction (TI) is to describe the procedures for preparing a transmissometer lamp for calibration and operational use in the IMPROVE transmissometer network. The primary purpose of lamp preparation is to assure quality data capture through a transmissometer lamp burn-in procedure that will:

- Stabilize the operational characteristics of the lamps prior to performing pre-field lamp calibrations.
- Reduce infant mortality in operational lamps.

This TI describes all procedures required to perform and document transmissometer lamp preparation and burn-in and is referenced from Standard Operating Procedure (SOP) 4200, *Calibration of Optical Monitoring Systems*, and the following technical instructions:

- TI 4200-2100 *Calibration of Optec LPV-2 Transmissometers (IMPROVE Protocol)*
- TI 4110-3400 *Annual Laboratory Maintenance Procedures for Optec LPV-2 Transmissometer Systems (IMPROVE Protocol)*

2.0 RESPONSIBILITIES

2.1 PROJECT MANAGER

The project manager shall:

- Review lamp inventory and status records to ensure that a sufficient number of burned-in lamps are available to support transmissometer field operations.
- Approve purchase orders for new lamps.

2.2 INSTRUMENT TECHNICIAN

The instrument technician shall:

- Prepare purchase orders for new transmissometer lamps.
- Inspect all new transmissometer lamps when received at ARS.
- Prepare lamp ID labels for all new lamps received and maintain the Transmissometer Lamp Receiving Log.
- Perform the lamp burn-in procedures described in this TI.
- Maintain the lamp inventory and status records.
- Ensure that all burned-in lamps are identified properly and stored in a manner that will protect them from damage.
- Coordinate with Optec, Inc. for replacement of lamps that are received damaged or that fail during burn-in.

3.0 REQUIRED EQUIPMENT AND MATERIALS

Specific equipment and materials required for transmissometer lamp burn-in include:

- Supply of lamps
- Lamp ID labels
- Lamp burn-in fixture
- Power supply (13.8 VDC @ 25 amps)
- Lamp Burn-in Log Sheet
- Lamp inventory and status records
- KimWipe tissues

4.0 METHODS

Transmissometer lamps are purchased from Optec, Inc., Lowell, Michigan. When a lamp order is received, all lamps are visually inspected and lamp ID labels are placed on the base of each lamp. Lamps are then installed in the transmissometer lamp burn-in fixture (see Figure 4-1) for a burn-in cycle of 72 hours. The lamp burn-in fixture provides two (2) separate burn-in banks. Each burn-in bank permits up to six (6) lamps to be burned-in during a burn-in cycle. The burn-in control circuit switches power between the two banks at 15 minute intervals. With six lamps installed in each burn-in bank, each lamp is cycled through a 15-minute "on" period followed by a 15-minute "off" period twice an hour. This cycled burn-in technique closely replicates lamp operation in the field. The 72 hour burn-in cycle provides 144 lamp "on" cycles which is equivalent to 144 hours (6 days) of field operation. Once a lamp has been burned-in, the ID label is marked to indicate that the lamp is ready to be assigned to an operational instrument.

This section includes (2) major subsections:

4.1 Lamp Receiving and Preparation
4.2 Lamp Burn-in

4.1 LAMP RECEIVING AND PREPARATION

Specific procedures for receiving and preparing lamps for burn-in are described in the following subsections.

4.1.1 Documentation for Lamps Received

Optec inscribes a lamp serial number on each lamps' plastic base. Lamps are then individually packed in a sleeve made from pipe insulation labeled with the lamp serial number. The individual lamps in sleeves are packed 18 to a box, then packed into a larger box for shipment. Receiving procedures include:

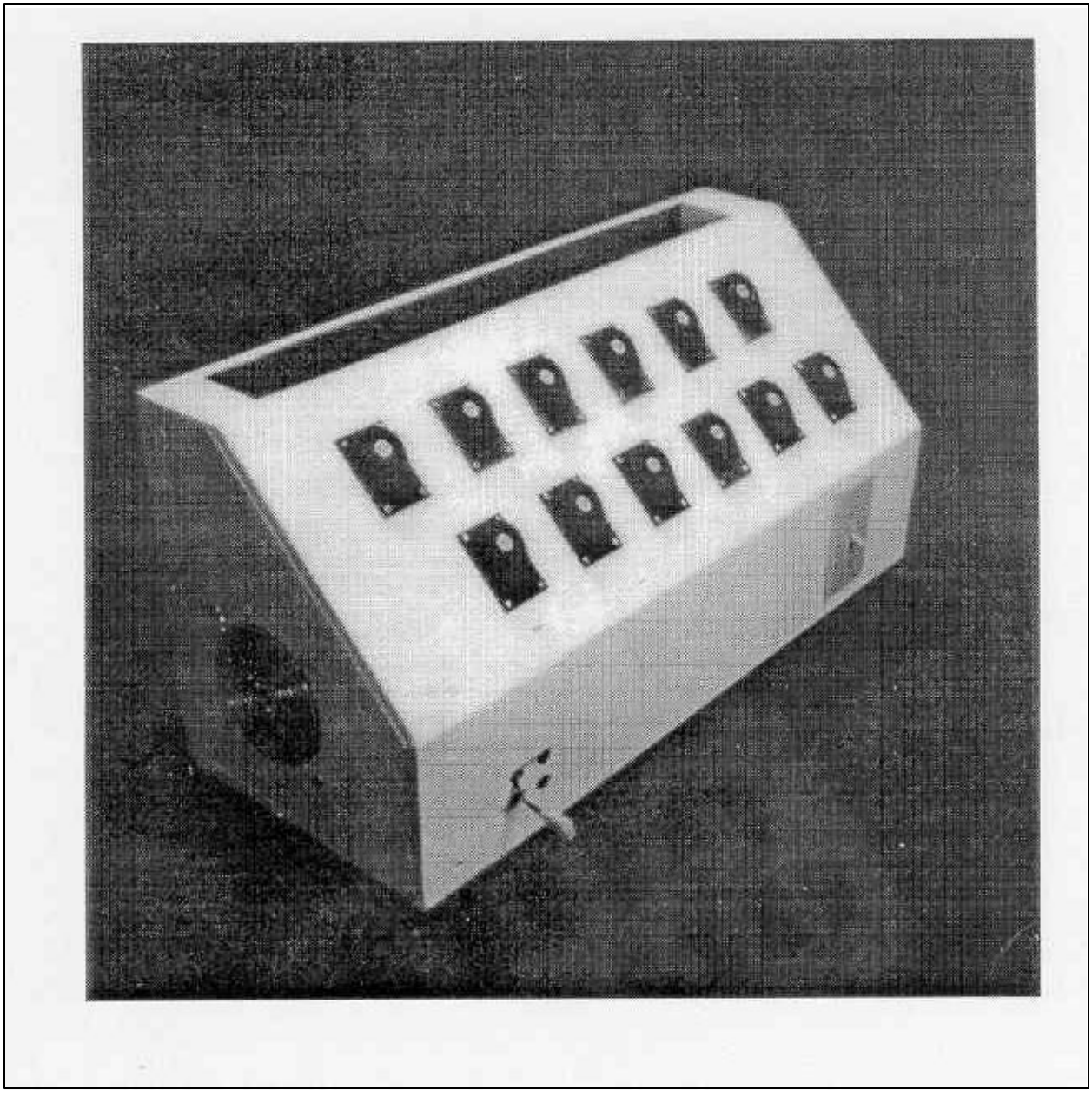

Figure 4-1. Transmissometer Lamp Burn-in Fixture.

CONFIRM NUMBER OF LAMPS	Confirm that the number of lamps received matches the number of lamps shipped (as documented on the packing list).
RECORD SERIAL NUMBERS	Using the Transmissometer Lamp Receiving Log (Figure 4-2), record the serial numbers (from the label on the lamp sleeves) of all lamps received.

4.1.2 Visual Inspection of Lamps

Lamp inspection procedures include:

PREPARE LABEL	The lamp serial number inscribed on the lamp base is difficult to see when the lamp is installed in a field instrument. Using the Transmissometer Lamp Receiving Log, prepare an ID label (1/2" diameter adhesive backed) with the lamp serial number for each lamp received.
VERIFY SERIAL NUMBER	Remove each lamp from its shipping box and verify that the serial number inscribed on the base matches the serial number on the sleeve. Apply the ID label to the base as shown in Figure 4-3.
INSPECT LAMP	As each lamp is removed, the lamp should be visually inspected. Lamp condition should also be documented on the Transmissometer Lamp Receiving Log. Typical flaws or lamp damage (examples shown in Figure 4-4) include the following: • Cracked or broken filament • Abnormalities in the shape, texture, clarity, or thickness of the glass bulb • Missing or damaged gold sleeves on lamp power pins • Bent, broken, or missing power pins
PLACE LAMP IN STORAGE	After a lamp has been visually inspected and the inspection results documented on the Transmissometer Lamp Receiving Log, place the lamp in the lamp storage drawer, ensuring that the plastic lamp holder is lined with a KimWipe tissue to prevent damage to the lamp bulb.

4.2 LAMP BURN-IN

Specific procedures for burning in lamps include:

CLEAN LAMPS	Select 12 lamps for burn-in. Clean each lamp with a microfiber optical cleaning cloth and insert into the 12 lamp sockets in the lamp burn-in fixture.
RECORD SERIAL NUMBERS	Record the lamp serial numbers on the Lamp Burn-in Log Sheet (Figure 4-5).

TRANSMISSOMETER LAMP RECEIVING LOG

Reference Purchase Order Number: _______ Quantity Received (Packing List): _________
Date Received: ______________ Quantity Received (ARS Count): __________

Lamp #	Condition	Lamp #	Condition

lamprec.log 8/96

Figure 4-2. Transmissometer Lamp Receiving Log.

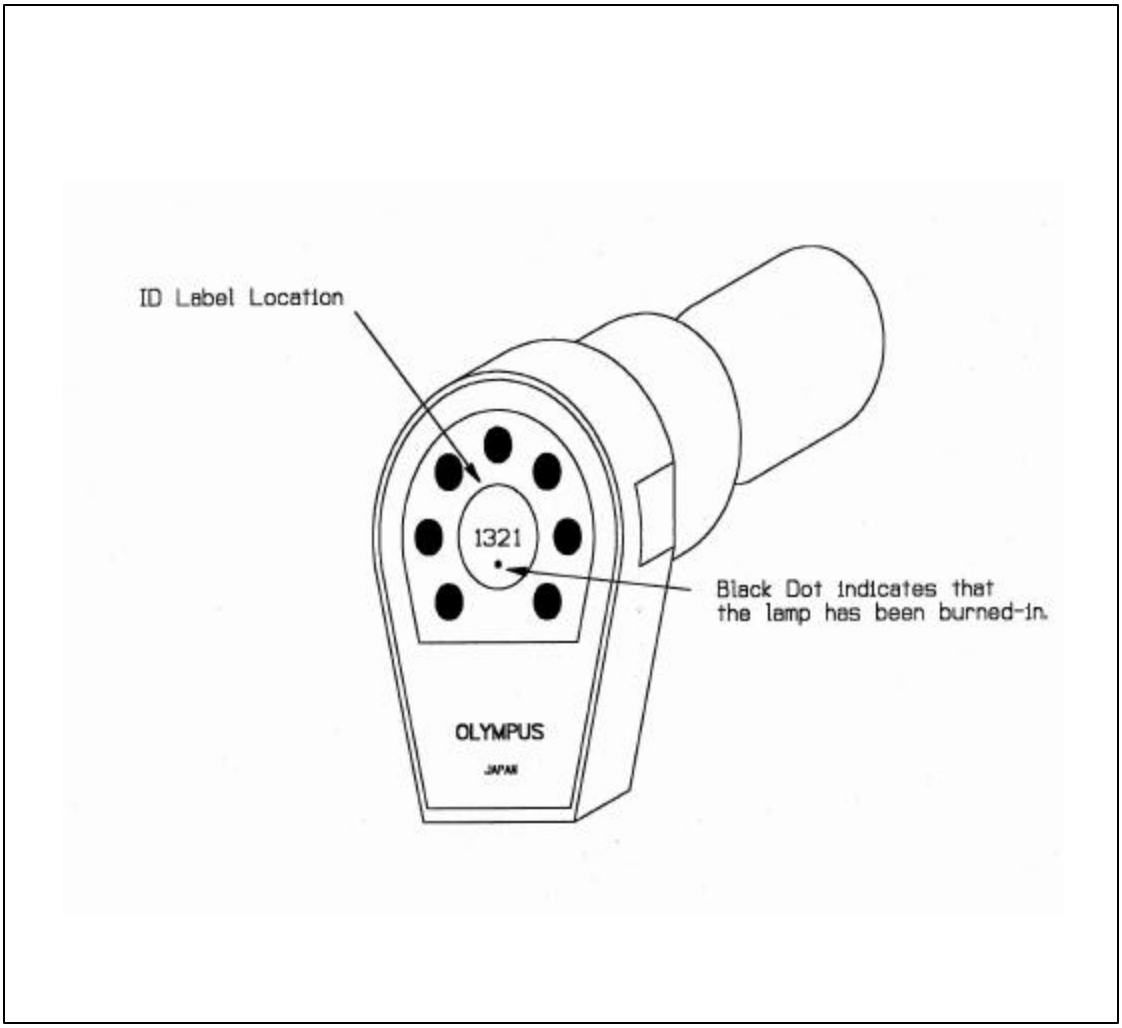

Figure 4-3. Placement of Lamp ID Label on Lamp Base.

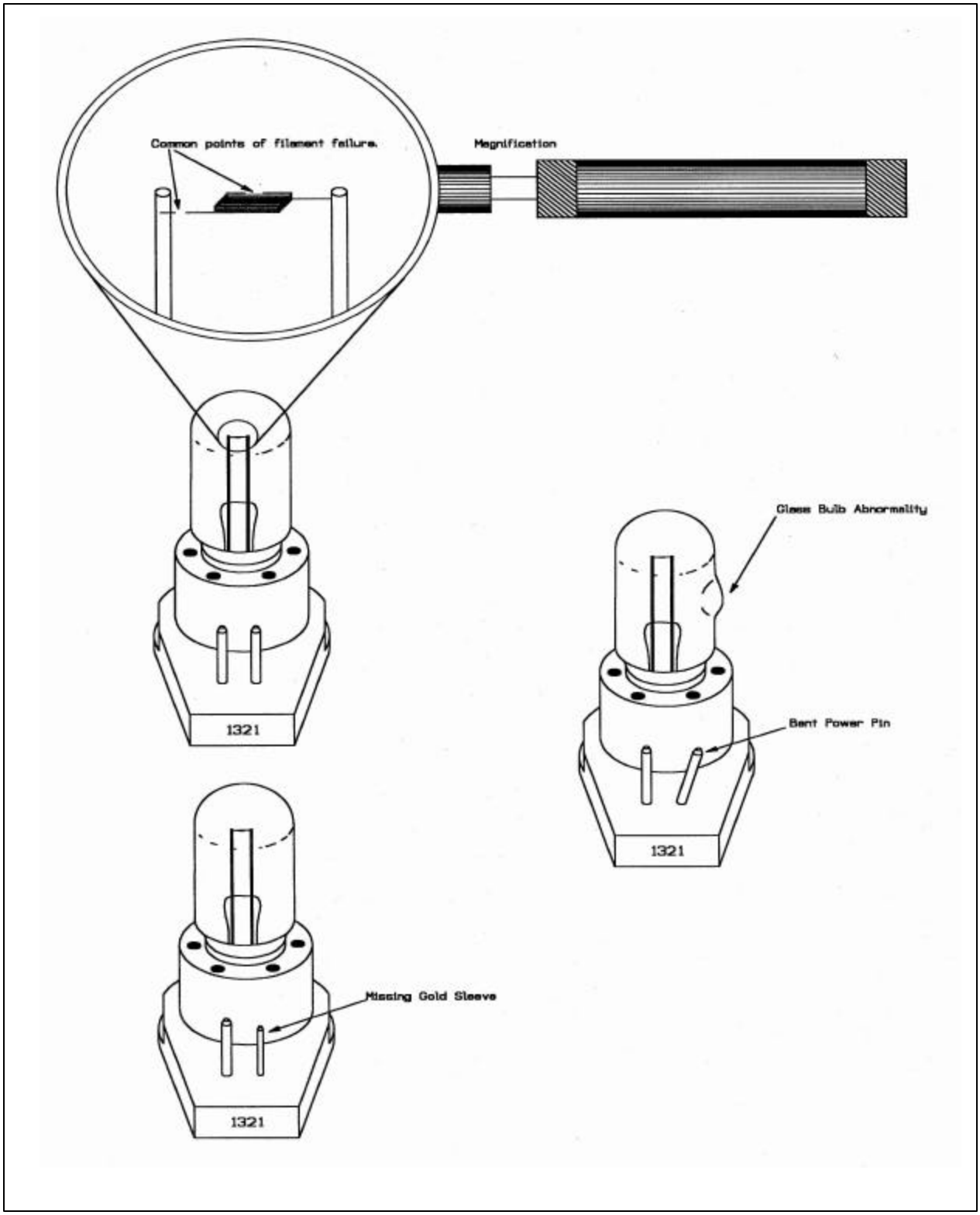

Figure 4-4. Lamp Flaws to Look For During Lamp Inspection.

LAMP BURN-IN LOG SHEET

START BURN-IN: DATE: _____ TIME: _____
BURN-IN COMPLETE: DATE: _____ TIME: _____

BURN-IN COMPLETED

SOCKET #	LAMP #	YES	NO	ID LABEL MARKED	COMMENTS
1		☐	☐	☐	
2		☐	☐	☐	
3		☐	☐	☐	
4		☐	☐	☐	
5		☐	☐	☐	
6		☐	☐	☐	
7		☐	☐	☐	
8		☐	☐	☐	
9		☐	☐	☐	
10		☐	☐	☐	
11		☐	☐	☐	
12		☐	☐	☐	

OPERATION VERIFIED

DATE	TIME	TIMER HOURS

FAILED LAMPS

LAMP #	RETURNED TO OPTEC	REPLACEMENT RECEIVED

lampburn.log 8/96

Figure 4-5. Lamp Burn-in Log Sheet.

CONNECT POWER SUPPLY	Connect the 13.8 VDC power supply to the burn-in fixture.
TURN ON	Turn the power supply on and document the burn-in start time on the Lamp Burn-in Log Sheet. Reset the burn-in cycle timer to zero.
DOCUMENT HOURS	Periodically, verify that all lamps in both banks are cycling properly. Use the Lamp Burn-in Log Sheet to document the accumulated hours reading (from the burn-in cycle timer) at the time operation is verified.
TURN POWER OFF	When the burn-in timer indicates 72 accumulated hours of operational time, turn the power supply off and record the burn-in finish time on the Lamp Burn-in Log Sheet.
COOL LAMPS	Let the lamps cool in the burn-in fixture for 20 minutes.
MARK LABELS	Use a black felt tip marker to mark the ID labels with a dot to indicate that the lamp has been burned-in.
INSPECT LAMP	Remove each lamp from the burn-in fixture, and inspect the lamp for: • A cracked or broken filament. • A white film (milky appearance) on the inside surface of the bulb (indicates an air leak in the bulb - see Figure 4-6).
STORE LAMP	Return the lamps to the storage drawer.

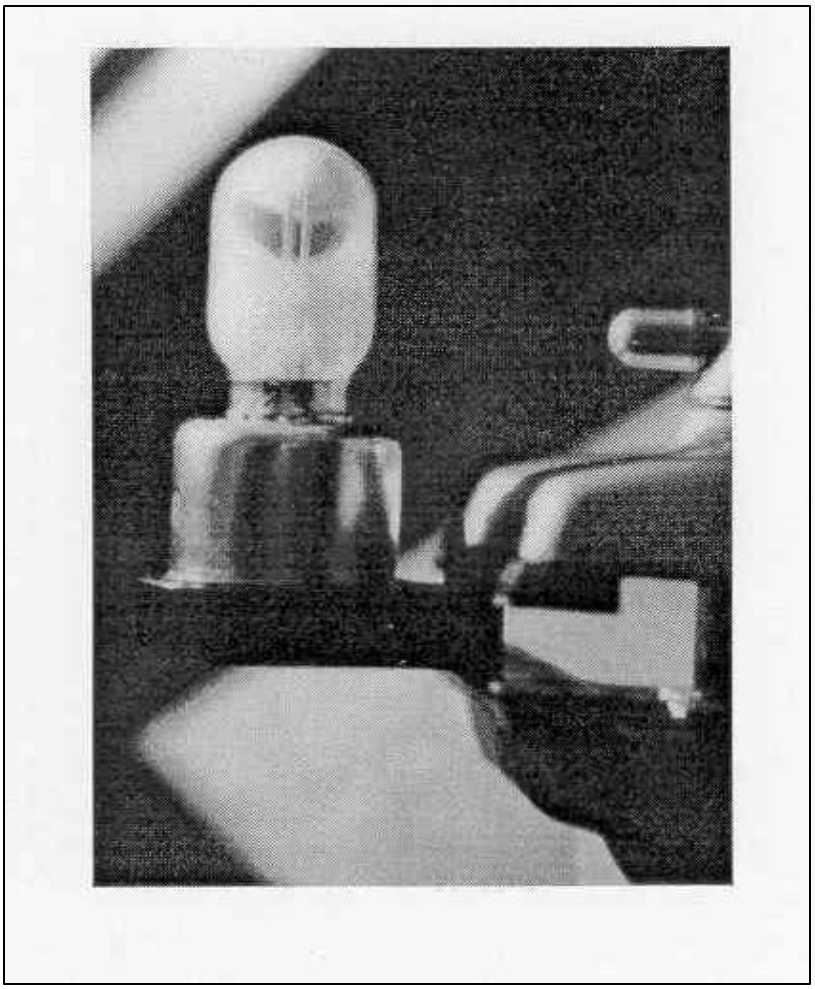

Figure 4-6. Transmissometer Lamp With Air Leak.