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EPA-450/4-90-008b
May 1990

IMPROVE
PROGRESS REPORT
APPENDICES B - H

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Appendix B

Transmissometer Standard Operating Procedures Manual

Optec, Inc.

LPV–2 Transmissometer

Standard Operating Procedures Manual

Prepared for the

National Park Service
Visibility Monitoring and Data Analysis Program
(NPS Contract CX-0001-7-0010)

Prepared by

Air Resource Specialists, Inc.

May 1988

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PREFACE

This document was prepared in partial fulfillment of the National Park Service Visibility Monitoring and Data Analysis Program (Contract CX-0001-7-0010). This manual describes the Optec LPV-2 transmissometer and its standard operating procedures. The LPV-2 transmissometer is a relatively new instrument that is still undergoing field evaluation tests to define measurement and calibration uncertainties. The results of these tests, as well as any procedural changes, will be included in future versions of this document.

1.0 INTRODUCTION

The LPV-2 transmissometer is designed and manufactured by Optec, Inc. of Lowell, Michigan. The instrument has evolved to its present configuration as a result of the visibility monitoring needs defined by the National Park Service (NPS) Visibility Monitoring and Data Analysis Program and the Interagency Monitoring of Protected Visual Environments (IMPROVE) Committee. The transmissometer was designed to meet the following criteria:

- Measure atmospheric extinction at 550 nm;
- Measure extinction both day and night;
- Provide a variety of sampling and averaging options;
- Operate unattended for extended periods;
- Operate at low power to accommodate remote solar applications;
- Operate at ambient temperatures;
- Be capable of self recovery in the event of power interruptions;
- Provide analog voltage outputs and panel digital displays of selected visual air quality measurements;
- Be modular, light weight, and easily transported to accommodate remote installations or field replacement of components; and
- Be easily serviced by trained, non-technical personnel;

The first LPV-2 transmissometer was installed in August 1986. The primary configuration of the system has remained unchanged. However, system improvements have occurred and are expected to continue as additional field experience is gained.

Comparison studies between the LPV-2 transmissometer and other extinction/scattering measurement techniques indicate that extinction derived from the LPV-2 transmission measurements is accurate to better than $\pm$ 10% (Malm et al., 1988). The uncertainties associated with calibration and routine operation are yet to be quantified. The NPS is currently conducting a comprehensive testing program to quantify these uncertainties.

This manual was prepared by Air Resource Specialists, Inc. (ARS) under the NPS Visibility Monitoring and Data Analysis Program (Contract CX-0001-7-0010). The manual overviews the general LPV-2 instrument specifications and standard operating procedures. Additional documents that more fully describe specific instrument and operational details include:

- Optec LPV-2 Instrument Manual (Optec, Inc., 1987) - This manual describes the primary design and electronic principles of the instrument, details the instrument specifications, and presents operations and calibration procedures.

- Transmissometer System Field Operator's Manual (Air Resource Specialists, Inc., 1988) - This manual presents a detailed description of all information necessary for field operators to properly operate and maintain the IMPROVE transmissometer systems based on the LPV-2 instrument.

2.0 INSTRUMENT DESCRIPTION

2.1 Concept

The Optec LPV-2 transmissometer has been designed to measure the ability of the atmosphere to transmit light of a specific wavelength (550 nm, green). It accomplishes this by measuring the loss in light received from a light source of known intensity as the light beam travels a known distant.

The LPV-2 transmissometer has two primary components: a light source (transmitter), and a light detector (receiver) as displayed in Figure 2-1. Depending on the average visual air quality, the components are generally placed from .5 to 10 kilometers apart. The system can take measurements day and night; the light emitted from the transmitter is "chopped" at 78 pulses a second to allow the receiver to differentiate the lamp signal from background, ambient lighting. The receiver-measured transmitter light intensity is compared to the known (calibrated) transmitter light output to calculate the percent transmission of the atmosphere. When the path distance is supplied (user set), the receiver computer can calculate and express visibility measurements in terms of extinction (km^{-1}) or visual range (km).

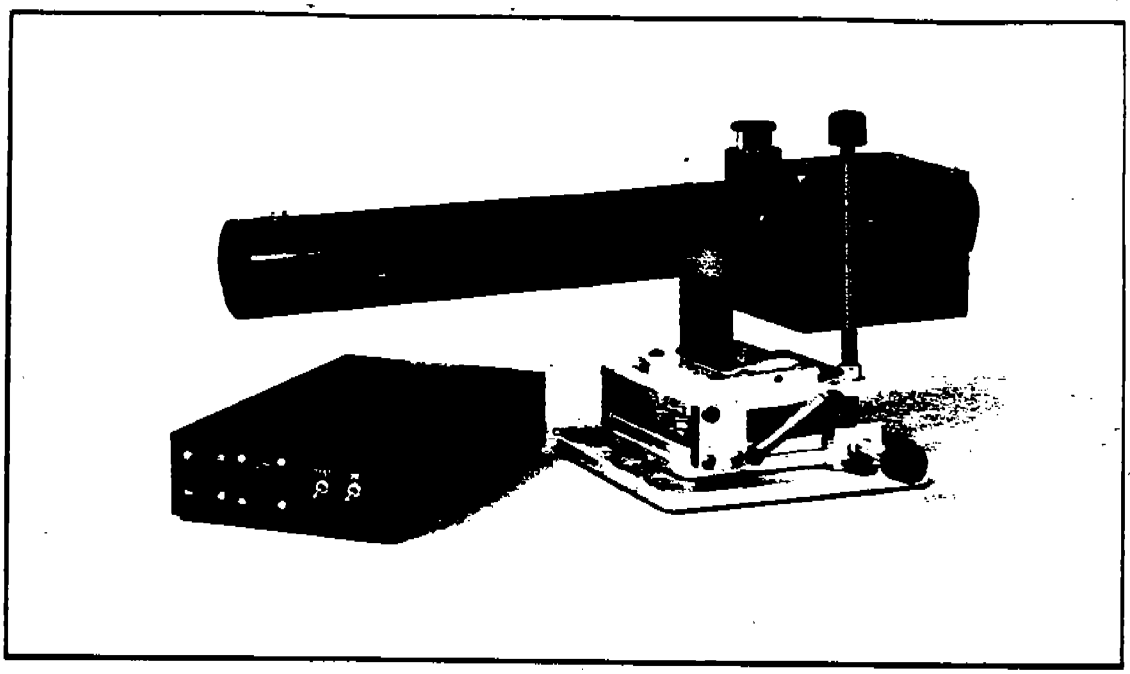
The LPV-2 transmissometer system's low power consumption provides remote operation from a small power supply, such as a solar power system. Both components contain self-resetting and battery backup circuitry for extended periods of unattended operation. Both components require shelter from precipitation and dirt, but can operate at ambient temperatures. Routine operation of the system can be performed by trained, non-technical personnel. Instrument calibration and repair requires trained technical personnel or factory service.

2.2 Transmitter

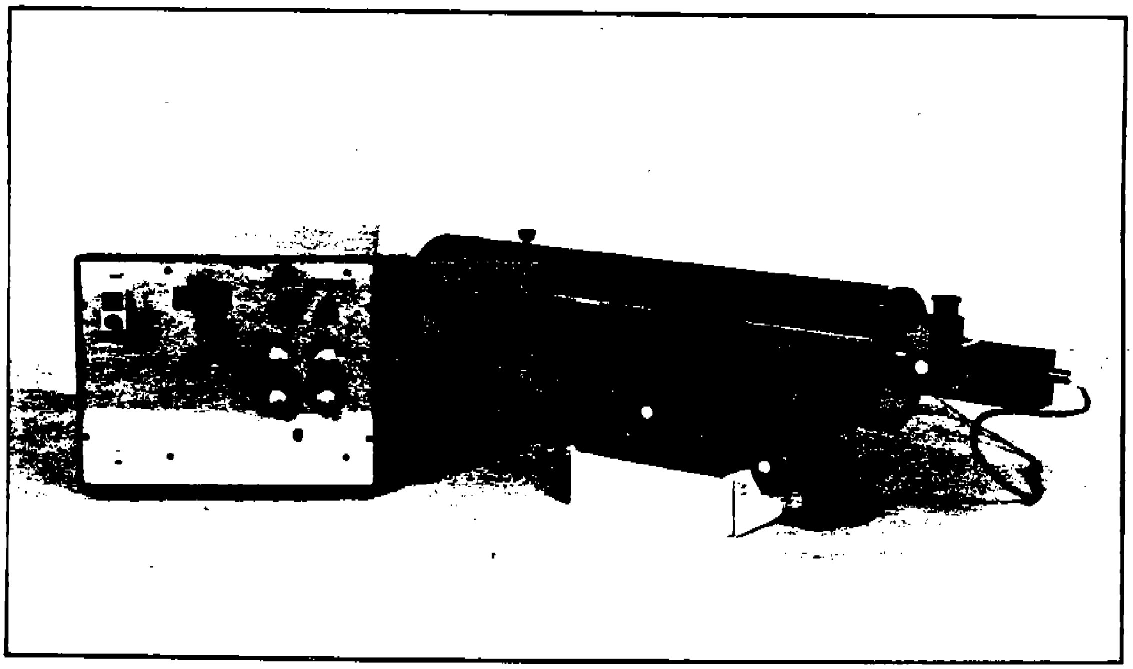
The LPV-2 transmitter emits a uniform, chopped light beam of constant intensity at regular intervals for a programmed duration. The transmitter has two components: an electronic control box, and a light source or transmitter. Transmitter components are shown in Section 7.0, Figure 7-4.

The transmitter optics perform two functions: 1) concentrate light from the 15-watt tungsten filament lamp into a narrow, well-defined uniform cone, magnifying the beam to the equivalent of a bare 1500-watt lamp; and 2) allow the operator to precisely aim the light beam at the receiver.

Although a 1-degree cone of light is emitted from the transmitter, only the center 0.17 degree portion is used for routine monitoring. This portion of the beam, denoted to the operator by a reticule circle, is very uniform in illumination.



Transmitter



Receiver

Figure 2-1. Optec LPV-2 Transmissometer System.

The intensity of the light emitted from the transmitter is precisely controlled by an optical feedback system which continuously samples the center 0.17 degree portion of the outgoing beam and makes fine adjustments to keep the light output constant. Although the lamp light is white, only the green (550 nm) portion of the output is monitored and controlled by the feedback circuitry.

Light emitted from the transmitter is "chopped" at 78 pulses a second by a mechanical spinning disk located in front of the lamp. The light is chopped to allow the receiver computer to differentiate the lamp signal from the background or ambient lighting. By using this technique, the transmissometer can operate day and night.

The transmissometer can be operated in either a "continuous" or "cycled" mode. In the continuous mode, the transmitter projects the chopped signal continuously. To prolong lamp life, reduce power consumption, or to accommodate various sampling strategies, the transmitter can be operated in the cycled mode. In the cycled mode, the transmitter can be set to turn on at precise intervals and to stay on for selected durations as shown below:

Intervals	Durations
20 minute	2 minutes
1 hour	16 minute
2 hour	32 minute
4 hour	64 minute

For example, with an interval setting of 1 hour and a duration setting of 16 minutes, the transmitter would turn on every hour and stay on for 16 minutes. Other combinations, such as a 2-hour interval and a duration of 2 minutes, are possible. A push-button switch in the transmitter control box defines the start time of the intervals. When using the system in a cycled mode, the transmitter and receiver clocks must be synchronized.

The transmitter is not weatherproof and requires a shelter. The instrument can operate at ambient temperatures. Primary specifications for the transmitter are listed in Section 7.0, Figure 7-2.

2.3 Receiver

The function of the LPV-2 receiver is to:

- o Gather light from the transmitter;
- o Convert it to an electrical signal;
- o Isolate and measure the received transmitter light; and
- o Calculate and output visibility results in the desired form.

The receiver has three components: 1) a long focal-length telescope; 2) a photodetector eyepiece assembly; and 3) a low power computer. Receiver components are shown in Section 7.0, Figure 7-8.

The telescope gathers the transmitter light and focuses it on a photodiode that converts it to an electrical signal. The receiver computer "locks-on" to the transmitter light's chopped frequency and separates the transmitter light from ambient lighting. The received signal can be described as an AC waveform (chopped transmitter light) carried on a DC voltage (background lighting). The effect of atmospheric turbulence is minimized by using 62,500 samples of the signal to calculate a one-minute average reading.

The computer compares the measured transmitter light with the known (calibrated) transmitter light to calculate the transmission of the intervening atmosphere.

Like the transmitter, the receiver is equipped with an eyepiece to precisely aim the detector, and an interval timer to control the interval and duration of measurements. The battery-backed interval timer can be user-set to start the readings at precise intervals and define the averaging time as shown:

Intervals	Durations
20 minute	1 minute
1 hour	10 minute
2 hour	30 minute
4 hour	60 minute

For example, with an interval setting of 1 hour and an averaging time of 10 minutes, the computer would provide one 10-minute averaged reading every hour. Other combinations, such as an interval of 4 hours and an averaging time of 60 minutes, are possible. The receiver computer has a momentary switch to define the start time of the intervals and to synchronize the receiver and transmitter timers when the system is used in the cycled mode.

The transmissometer system timing used in the National Park Service monitoring network is as follows:

HR:MI:SEC	Action
09:00:00	Transmitter turns on
09:03:00	Receiver begins 10-minute average reading
09:13:20	Receiver finishes reading, toggle changes
09:16:00	Transmitter turns off
:	
10:00:00	Transmitter turns on
	Sequence repeats hourly

The transmitter duration (lamp on) times are greater than the computer averaging times to allow for timing system clock drift.

The receiver is not weatherproof, and requires a shelter. The instrument can operate at ambient temperature. Primary specifications for the receiver are listed in Section 7.0, Figure 7-3.

2.4 Data Output

The receiver computer outputs visibility measurements to data loggers in the following user-selected formats:

1. Raw receiver reading (counts)
2. Extinction (km^{-1})
3. Visual range (km)

The working path distance must be measured to the nearest 0.01 kilometer. In most cases, a slope-distance measurement with this accuracy can only be made with an electronic distance meter. The working path must be entered on the computer front panel to allow calculation of extinction and visual range.

The receiver computer provides three analog outputs which are available to data loggers. The first two outputs can be user defined with the A1 and A2 switches on the computer front panel. The third analog output is dedicated to a signal called the toggle. A brief description of the analog signals is presented below:

<u>A1 Switch</u>

A1 Switch Position	Units	0-10 Volt Range Represents
C	Raw Reading (counts)	0 - 1000 Counts
B	Extinction (km^{-1})	0.000 - 1.000 km^{-1}
VR	Visual Range (km)	0 - 1000 km

The A1 switch position also determines the value shown on the receiver computer front panel display.

<u>A2 Switch</u>

A2 Switch Position	Units	0-10 Volt Range Represents
SD	Standard Deviation (counts)	0 - 100 Counts
CR	Raw Reading (counts)	0 - 1000 Counts

The A2 value is not available for display on the receiver front panel.

Toggle

The toggle signal indicates that the receiver computer has made a valid reading. Under normal operation, the toggle signal will change state each time a new valid reading is made (i.e., low to high, or high to low).

Toggle Signal	Analog Output
Low	Approx. 2.5 volts
High	Approx. 10 volts

The toggle state is also displayed on the receiver computer front panel with an LED indicator light (light on = high).

The 0-10 volt DC, individually grounded, analog signals may be sampled with any high impedance, single-ended, or differential input data logger. Connector configurations are shown in Section 7.0, Figure 7-13.

When the receiver is used in the cycled mode, the analog signals representing the readings are held constant and available to the data logger until the next reading update.

3.0 SITING CRITERIA

The fundamental requirement for operation of the LPV-2 transmissometer is a clear, unobstructed line-of-sight between the transmitter and receiver. When siting the transmissometer, the objectives of the monitoring program and the requirements and limitations of the instrument should be considered.

3.1 General Siting Criteria

The following general siting criteria should be considered:

- o Local or regional monitoring emphasis;
- o Representativeness of the sight path to the air mass of concern;
- o Isolation from local sources;
- o Proximity to seasonal or special use areas;
- o Proximity to and desired relationship with other air quality monitoring systems; and
- o Local weather conditions.

3.2 Path Length

When choosing a sight path distance, the expected range of visual air quality should be considered. As a general guideline, remote areas in the Western United States will require a separation distance of between 5 and 10 kilometers, while sites in the East will need a sight path of between 0.5 and 4 kilometers. A usable transmissometer sight path for remote locations can be calculated if the mean visual range is known, as follows:

Sight Path = Mean Visual Range X 0.033

The working path should be selected carefully when siting a transmissometer in a location with a wide range of visual air quality.

3.3 Path Height

The basic operating assumption of the LPV-2 transmissometer is that, in the absence of atmospheric extinction, the irradiance from the source decreases inversely as the square of the distance from the transmitter:

$I_r = I_0/r^2$

I_r = irradiance at some distance r with $b_{ext} = o$

I_0 = irradiance of source

This premise will be invalid if the transmitted beam is distorted by refraction due to temperature discontinuities or by surface reflections. To eliminate these effects, the transmitted light should not intercept or pass near any surface visible in the detector field of view. If possible, the sight path should be elevated above the terrain surface and both the receiver and transmitter should be located at the edge of a drop-off.

The LPV-2 transmissometer has the following optical configuration:

Transmitter:	0.17^{o} uniform portion of beam 1.00^{o} total cone of light 2.30^{o} telescope field of view
Receiver:	0.07^{o} detector acceptance cone 1.30^{o} telescope field of view

The field of view of both transmitter and receiver telescopes in relation to the terrain surface should be considered when choosing a sight path. Diagrams of the reticule circles as viewed through the telescope are presented in Section 7.0, Figure 7-12. Figure 3-1 depicts acceptable and unacceptable sight paths:

3-1a - This figure depicts an ideal sight path where both the transmitter light beam and the receiver detector cone of acceptance are well elevated above terrain features.

3-1b - This figure depicts a good sight path. Although the transmitter beam touches the terrain surface, it does so at a point well away from the detector cone. The detector cone is also well elevated above the terrain.

3-1c - In this figure, the transmitter beam passes too close to the terrain surface. Surface heating may distort the beam.

3-1d - This figure depicts a transmitter beam striking the ground within the detector cone. Both refraction and reflection of the beam will occur producing invalid measurements.

Avoid locating the transmissometer sight path over terrain that will produce a high frequency of temperature inversions, such as bodies of water.

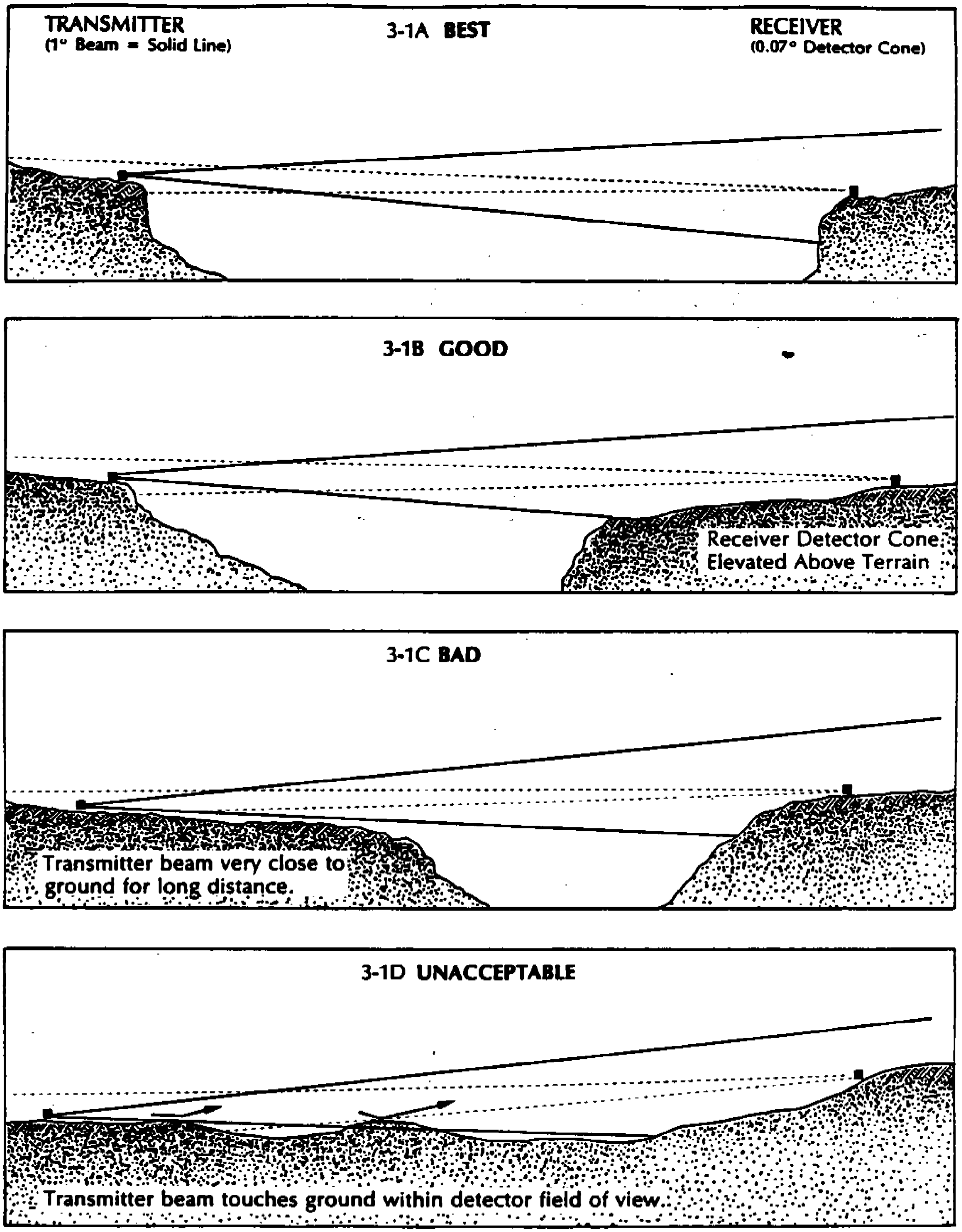


Figure 3-1. Sight Path Examples.

3.4 Other Technical and Logistic Considerations

Additional technical siting considerations include:

- o Power
- o Ground Stability - Mounting piers should be as stable and free of movement as possible.
- o Radio Frequency Interference - The low power CMOS circuitry used in both components is sensitive to strong radio signals. Avoid siting very close to broadcast antennas or repeaters.
- o Data logger requirements

Logistic siting considerations include:

- o Installation access
- o Servicing access
- o Proximity to servicing personnel
- o Vandalism
- o Beam Intrusion

4.0 SYSTEM INSTALLATION

An LPV-2 transmissometer visibility monitoring system configuration for remote, unattended operation will require a stable mounting platform, adequate sheltering, and a reliable power supply. A diagram of a typical installation is presented in Figure 4-1.

4.1 Instrument Mounting

Transmitter and receiver telescope alignment is critical for proper operation of the system. The small angle of the transmitter light used for monitoring (0.17°), and the very small angle of acceptance of the receiver detector (0.07°) require mounting platforms that are not susceptible to movement due to differential thermal expansion, slippage, or vibration. Receiver mounting is more critical than transmitter mounting.

A massive concrete pier, or rock, should be used to support the mounting posts. Soil stability and frost depth should be considered when locating the pier. The mounting pier should have a large thermal mass and be designed to avoid movement created by thermal distortion.

Alti-azimuth bases are available that allow precise positioning of the transmitter and receiver telescopes. They should be designed to minimize movement due to thermal expansion or contraction.

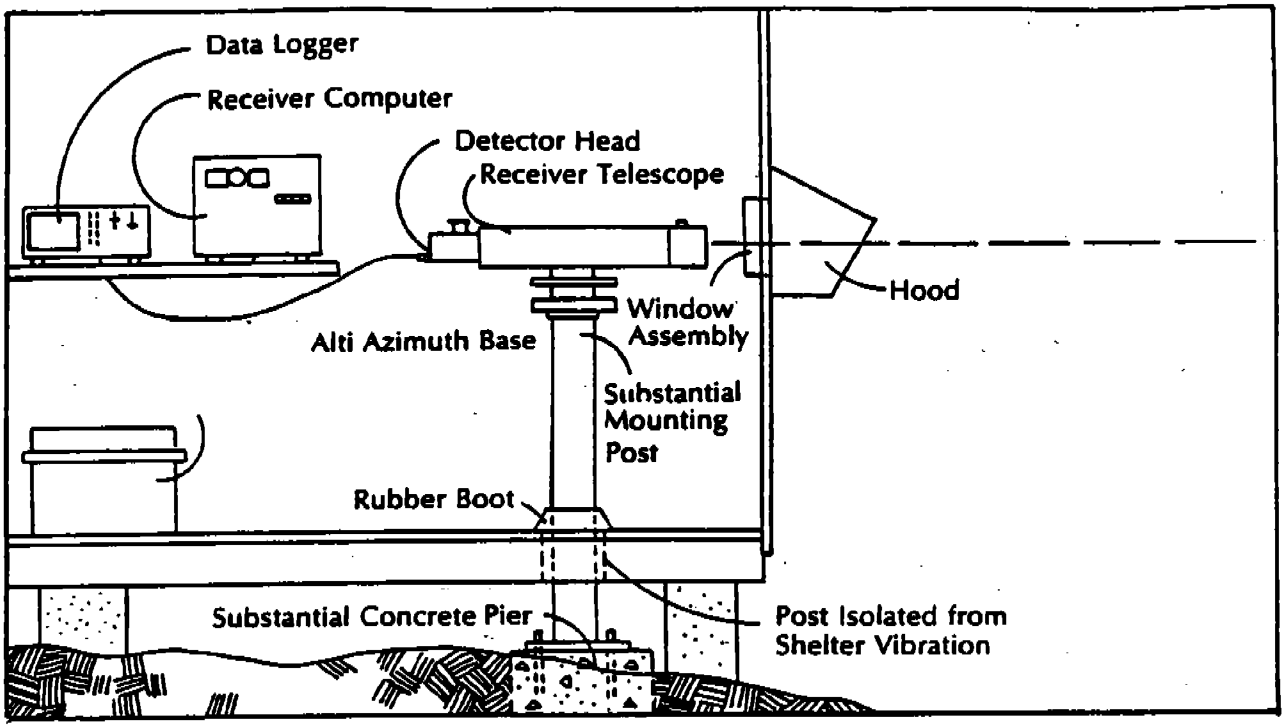
4.2 Sheltering

The LPV-2 transmissometer requires sheltering to protect the optics and electronics, to house support equipment, and to shelter the operator during servicing. Because transmissometer components will operate at ambient temperatures, climate-controlled shelters are not necessary. The type of shelter will depend on the local weather conditions and site logistics. Shelters can range from small environmental enclosures to full-size instrument shelters. Considerations for sheltering system components may include:

- Weather conditions
- Shelters aesthetics
- Sealed well against precipitation and dust
- Vandalism
- Access for installation
- Adequate room for support equipment
- Adequate space for operator movement
- Future additions of instrumentation

Two instrument-related requirements should be accommodated: 1) The mounting post should be isolated from shelter vibrations and movement, and 2) transmittance at 550 nm for all windows must be known to within ± 0.1%.

Receiver Station



Transmitter Station

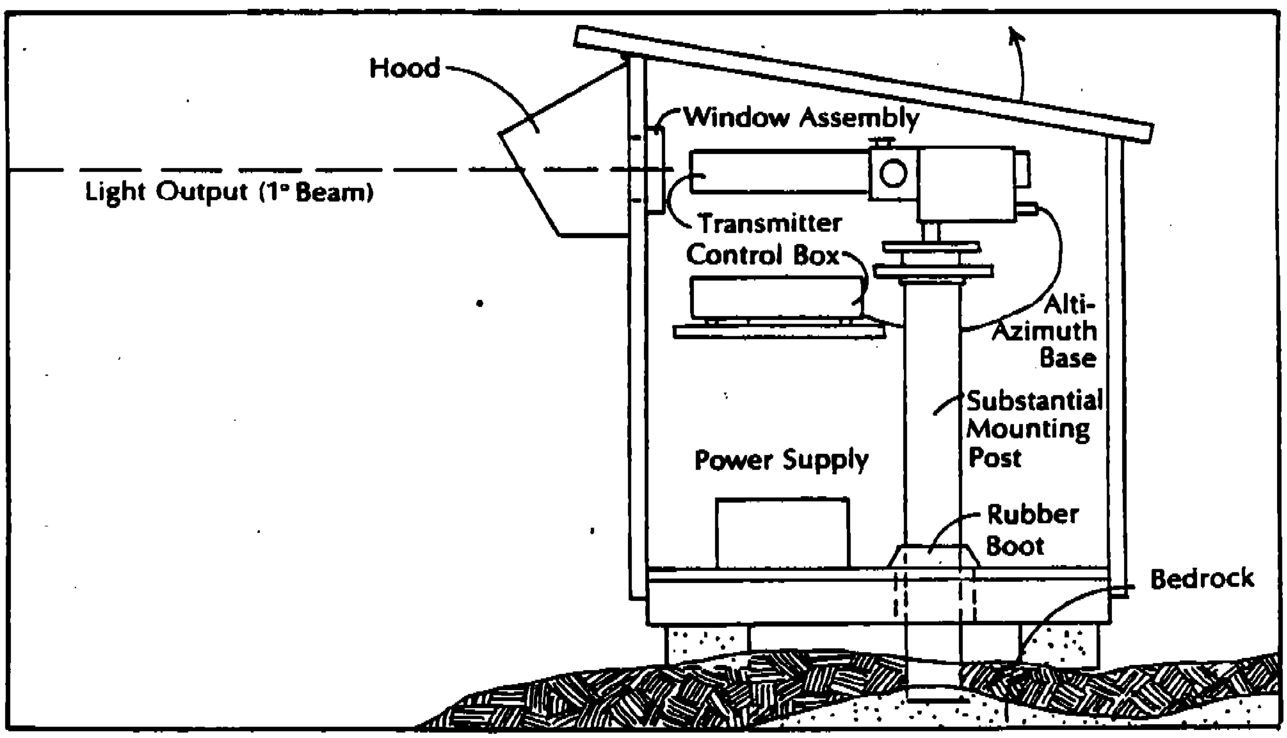


Figure 4-1. Transmissometer Shelter Diagrams.

4.3 Power Requirements

Both the transmitter and receiver operate from 12 volts DC, requiring 34 and 5 watts respectively. Any well-filtered, stable power supply may be used; however, the system lends itself well to battery operation.

When AC line power is available, the transmitter can be powered from a deep-cycle battery that is maintained by a surge-protected automatic charger. The receiver can also operate from the same power supply configuration.

Solar, or alternative power systems, may also be used. Care must be taken to adequately size the power supply to accommodate periods of insufficient sun, and to provide power for selected support equipment.

Both the transmitter and receiver circuitry contain battery-backed timing circuits to maintain correct system timing in the event of a power failure. The transmitter is equipped with a supply voltage sensing circuit which will interrupt operation when the supply voltage is insufficient. This prevents the transmitter from emitting improperly regulated light and also protects the power supply. The receiver computer has a self-starting capability to avoid computer lock-ups during power failures.

5.0 SERVICING REQUIREMENTS

Routine servicing of the Optec LPV-2 transmissometer system can be performed by trained, non-technical personnel. Servicing tasks can be separated into four classifications:

WEEKLY SERVICING
- Transmitter and receiver telescope alignment
- Cleaning of transmitter and receiver optical surfaces

MONTHLY SERVICING
- Transmitter and receiver system timing check and reset (if necessary)
- Transmitter lamp status check

LAMP REPLACEMENT (500-750 hours use)
- Transmitter lamp change at 500 hours for 6-volt lamp supply
- Transmitter lamp change at 750 hours for 5-volt lamp supply
- Pre- and post-calibration of lamps

YEARLY SERVICING
- Field technician site visit and/or factory servicing of system
- Post-calibration of all lamps
- Pre- and post-calibration of lamps

Field operator Log Sheets should document servicing of the Optec LPV-2 transmissometer system, as well as for support equipment such as data loggers. It is advisable to design the Log Sheets in a checklist format in the order servicing tasks will be performed.

6.0 INSTRUMENT CALIBRATION

Calibration determines the light output of the transmitter as measured by its receiver. The LPV-2 transmissometer system must be calibrated as a unit.

- Transmitter
- Transmitter Control Box
- Receiver Telescope
- Receiver Detector Head
- Receiver Computer

In addition, each lamp will have its own calibration number for use in the specific transmissometer system. No component of the system, including lamps, may be interchanged without re-calibration.

Calibration requires moving the transmitter and receiver close enough together to negate the effects of the atmosphere on the light beam. Calibration path distances of between 700 to 1300 feet accomplish this as the table below shows:

Atmospheric Transmittance for Calibration
Paths at Various Extinction Values

	Extinction (km^{-1})						
Path Length	.01	.02	.03	.04	.05	.06	.07
0.2 km (656 ft.)	.998	.996	.994	.992	.990	.998	.980
0.3 km (984 ft.)	.997	.994	.991	.988	.985	.982	.970
0.4 km (1312 ft.)	.996	.992	.988	.984	.980	.976	.961

The LPV-2 optical/electronic systems are very sensitive to allow operation at long paths with very small signals. To avoid detector overload due to light saturation when operating at short distances, precisely machined aperture rings are used to reduce the light gathering ability of the receiver telescope by a known amount. A typical diameter for a calibration aperture would be 11.0 mm.

The calibration number is used by the receiver computer to calculate extinction. Error in the calibration number will, therefore, affect the accuracy of extinction values. Tests are underway to determine the accuracy of the calibration numbers derived under field conditions.

6.1 Calibration Paths

The calibration path should be chosen carefully with the following considerations:

- Calibration path approximately 700 to 1300 feet (0.2 to 0.4 km)
- Beam elevated well above heated surface
- No local pollution sources
- Stable atmosphere of estimable extinction

The calibration path distance must be measured to an accuracy of 0.1% which is usually only possible with an electronic distance measuring device.

6.2 Calibration Instrument Configuration

The receiver and transmitter telescopes can be supported by portable tripods for calibration. A well-charged, deep-cycle battery is required to power the transmitter because it is operated in the continuous "run" mode. The following is a list of some of the more important support equipment needed for calibration:

- Electronic distance meter
- Substantial tripod for receiver telescope
- Regular camera tripod for transmitter
- Two deep-cycle batteries
- Transmissometer lamps
- Calibration Log Sheets
- Communication radios

A precisely machined lamp housing positions the lamp filament in the correct optical position. Because of this, it is possible to pre-calibrate a number of lamps for later use. With a pre-marked calibration path, experienced technicians can calibrate four lamps in approximately three hours, including set-up and take-down.

6.3 Calibration Data Collection and Analysis

Calibration readings should be documented on a LPV Calibration Data Sheet (or equivalent), as shown in Figure 6-1. At least ten one-minute readings should be taken for each lamp. The mean value of the readings should be used in the following equation to calculate the calibration number:

LPV CALIBRATION DATA SHEET

page 1 of 2

Location: ______________________ Date: __________

Instrument ID: ______________ Technician: ______________

Weather/Comments: ______________________________

==

WORKING SETTINGS

Working Path (WP) __________ km Integration Time: 1 10 30 60

Working Gain (WG) __________ Cycle Time: C 20M 1H 2H 4H

Working Aperture (WA) __________ mm A1 Setting: C B VR

A2 Setting: SD CR

Shelter Windows Transmittances (WT)
Receiver . Transmitter _____ . _____ Previous Calib. Number ______

==

CALIBRATION SETTINGS

Calib. Path (CP) __________ km Receiver Through Glass: Y N

Calib. Gain (CG) __________ Transmitter Through Glass: Y N

Calib. Aperture (CA) __________ mm

==

EXTINCTION CONDITION BEFORE AND AFTER CALIBRATION

	TIME	Bext			TIME	Bext	
Before:	_____	_____	M E	After:	_____	_____	M E

(M measured or E estimated)

Atmospheric transmittance at time of calibration (T): __________

(calculate T using $e^{-(Bext \times CP)}$ or use Table 5-1)

Figure 6-1. LPV-2 Calibration Data Sheet, Page 1.

CALIBRATION READINGS

Start time: ________ (spare data area)

	Reading	Toggle	Reading	Toggle
1	______	______	______	______
2	______	______	______	______
3	______	______	______	______
4	______	______	______	______
5	______	______	______	______
6	______	______	______	______
7	______	______	______	______
8	______	______	______	______
9	______	______	______	______
10	______	______	______	______
Total	________		________	

Average (CR) ________

CALIBRATION NUMBER CALCULATION

Calib.# ________ $= (CP/WP)^2 \times (WG/CG) \times (WA/CA)^2 \times WT \times (1/T) \times CR$

Note: modify WT if calibration is done through a shelter window

ADDITIONAL COMMENTS

____

____

Figure 6-1. LPV-2 Calibration Data Sheet, Page 2.

$$\text{Calib. \#} = (CP/WP)^2 \times (WG/CG) \times (WA/CA)^2 \times WT \times (1/T) \times CR$$

where

CP = calibration path length, 0.200 to 0.400 km
WP = working path length, 0.500 to 10.000 km

CG = calibration gain, 100.0 to 999.9 (optimum calibration readings in 800 to 900 range)
WG = working gain, 100.0 to 999.9

CA = calibration aperture, approximately 11.00 mm
WA = working aperture, approximately 110.00 mm

WT = total shelter(s) window transmittance. If windows are used on both ends, multiply their transmittance together. Typical value for two windows is 0.846.

T = estimated or measured atmospheric transmittance for calibration path, 0.950 to 0.996 typical

CR = average of 10 readings at the calibration path

The transmissometer calibration number represents the reading in counts that would be measured if the atmosphere between the transmitter and receiver allowed 100% light transmission. With the calibration number dialed-in on the computer front panel, the percent transmission (%T) is directly calculated by the receiver computer by dividing the measured reading by the calibration number.

Each lamp will have its own calibration number that must be entered on the computer front panel when the lamp is put into service. Once a system is calibrated, no further adjustments to the telescope focus or any other optical changes can be made or the calibration must be repeated.

The uncertainties associated with calibration are yet to be quantified. The NPS is currently conducting a comprehensive testing program to quantify these uncertainties.

7.0 DIAGRAMS AND SCHEMATICS

Diagrams and schematics that may be helpful in understanding the LPV-2 transmissometer are presented in this section. Included are:

EXTINCTION RANGE		.010 TO 1.000 /km
RESOLUTION	Extinction (B) Visual Range (VR)	.001 /km 1 km
ACCURACY	Transmission Extinction	+/-3% +/-0.003 /km for 10 km working path and 0.010 nominal extinction value
MEASURED WAVELENGTH	Filter	550 +/-2 nm, 10 +/-1 nm bandwith at 1/2 power points
OUTPUT, PANEL METER	A1	Extinction (/km) to .001 Visual Range (km) to 1 km Raw instrument values to .010 V
OUTPUT, REAR CONNECTOR	A1 (Extinction)	0 to 10 V, 0.01 V = 0.001/km
	A1 (Visual Range)	0 to 10 V, 0.01 V = 1 km
	A1 (Calibration)	0 to 10 V raw instrument value
	A2 (Chart Rec.)	0 to 10 V raw instrument value
	A2 (Std. Dev.)	Standard deviation (N-1 samples) of the raw 1 minute instrument values
POWER SUPPLY	12 Battery	
AMBIENT OPERATING TEMPERATURE	-20 TO +45 deg. Centigrade	

Figure 7-1. General Operating Specifications (Optec, Inc., 1987).

TELESCOPE	Field of View	2.3 degrees
BEAM	Total Diameter	1 degree, projected cone of light
	Used for Routine Monitoring	0.17 degree center portion of beam denoted by reticule circle
	Feedback Diameter	0.17 degree as referenced to the projected cone and centered within the 1 degree cone
	Uniformity	5% over 1 degree cone 1% over 0.17 deg. center cone
FEEDBACK FILTER	Center Wavelength Bandwidth	550 +/-2 nm 10 +/-1 nm
LAMP	Type	6 volt, 15 watt special prefocused tungsten filament lamp mounted in machined base
	Regulation Life	constant to +/-1.5% 500 hrs. continuous at 6.0 volts
CHOPPER FREQUENCY	78.1250 +/-.0001 Hz	
CLOCK	Cycle times Lamp-on times Freq. Tolerance	20 minutes, 1, 2, and 4 hours 2, 16, 32, 64 minutes and continuous 78.125 ± .0004 Hz (70°F)
POWER SUPPLY	Voltage, input Power (lamp off) Power (lamp on)	10.2 to 15 volts DC 0.12 watt at 12.5 volt input 34 watts at 12.5 volt input
SIZE	Projector Controller	18 x 4 x 6 inches (LxWxH) 9.5 x 5.4 x 1.9 inches
WEIGHT	Projector Controller	4 lb. 2 lb.

Figure 7-2. Transmitter Specifications (Optec, Inc., 1987).

TELESCOPE	Field of View	1.3 degrees
	Detector Acceptance Cone	0.07 degrees
	Clear Aperture	110.00 mm
	Focal Length	629 mm
	Lens Type	coated cemented achromat
PHOTOMETER HEAD	Detector	silicon PIN photodiode
	Detector NEP	8 x 10E-16 W/ Hz
	Active Dia.	0.75 mm
	Filter	550 nm with 10 nm bandwidth
DET/ ELECTROMETER	Type	current-to-voltage
	Gain	4x10E9
	Bandwidth	DC to 500 Hz
	Noise	5 mv p-p DC to 500 Hz
	Gain T-C	0.02%/C°
BANDPASS AMPLIFIER	Center Frequency	78.125 +/-0.100 Hz
	Q	32
A/D INPUT AMP	Gain	30
	Bandwidth	1 to 1000 Hz
	Gain T-C	0.005%/C°
SIGNAL GAIN CONTROL	Turns	10
	Linearity	0.25%
	Accuracy	0.5%
COMPUTER	Processor	NSC800, Z-80 8-bit CMOS
	Memory	32K RAM, 32K ROM all CMOS
	I/O	60 lines total
	Clock Speed	4 Mhz
	Buss Type	NS CIM-BUS, Euro-card connectors
	A/D	12-bit, 50uS conversion all CMOS
	D/A	12-bit, 0 - 10 V output, 2-channel, CMOS
OPERATING SYSTEM AND PROGRAM	Custom version of RTL (relocatable threaded language) a variation of FORTH resident on ROM	
INPUT CHANNELS	POWER	On-off toggle switch
	GAIN	10-turn pot with digital readout
	A1	3-pos. switch (C,B,VR)
	A2	2-pos. switch (SD,CR)
	CYCLE TIME	5-pos. switch (C,20M,1H,2H,4H)
	INTEGRATION TIME	4-pos. switch (1,10,30,60 M)
	PATH LENGTH	4-digit BCD switch
	CALIB. CONSTANT	3-digit BCD switch
DISPLAY	A1	3 1/2 digit panel meter
	OV	A/D over voltage, LED lamp
	OR	D/A over range, LED lamp
	TOG	Changes state after integ., LED lamp
POWER SUPPLY	Input Voltage	9 - 15 V DC, reverse polarity protected
	Input Current	400 ma at 12.5 V DC input voltage
	Output Voltages	+5, +15, -15
SIZE	Telescope	23 x 5.5 inches (L x Dia.)
	Computer	14 x 12 x 9.5 inches (LxWxH)
	Photometer Head	5 x 2.5 x 3.5 inches (LxWxH)
WEIGHT	Telescope	17 lb.
	Computer	7 lb.
	Photometer Head	2 lb.

Figure 7-3. Receiver Specifications (Optec, Inc., 1987).

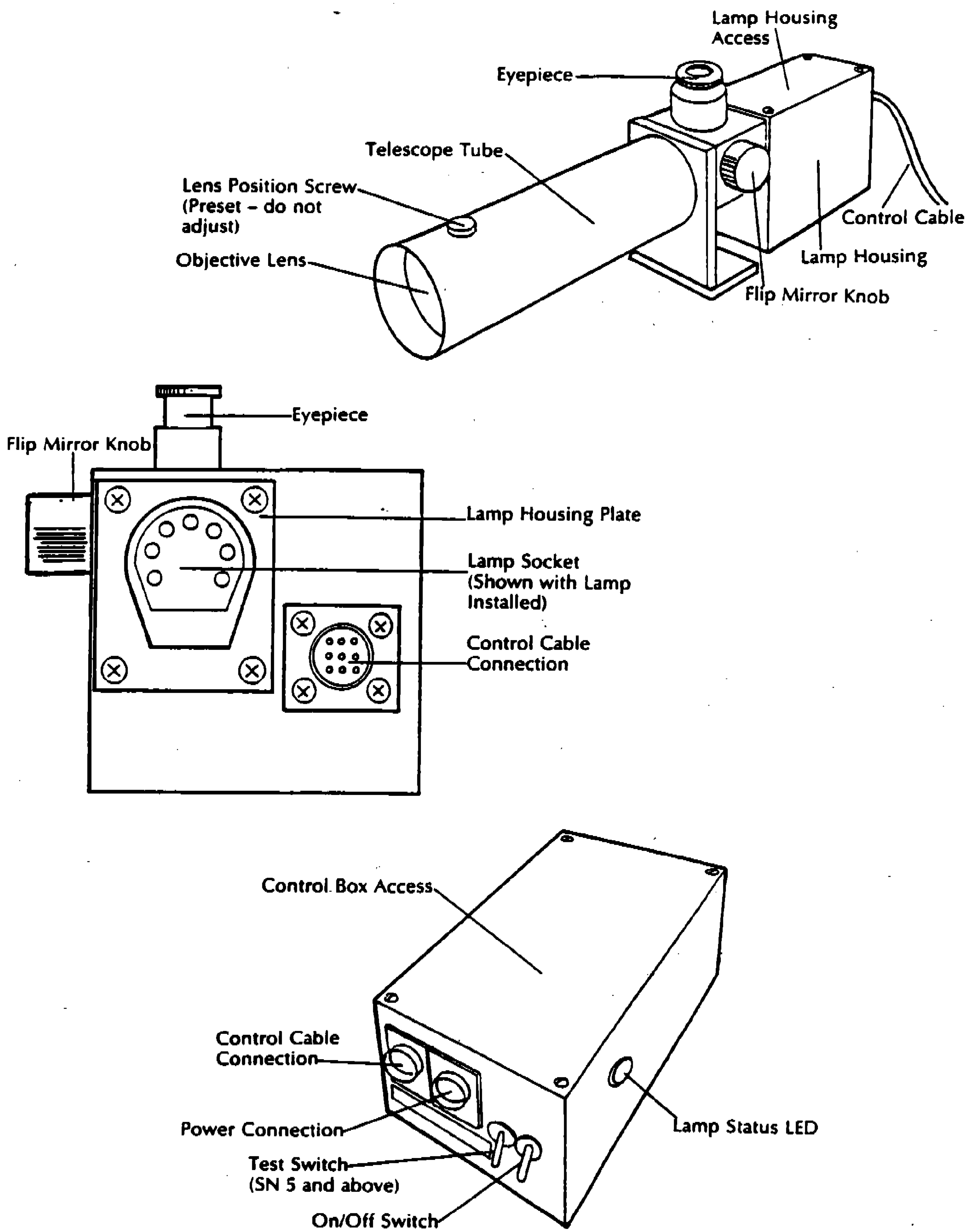
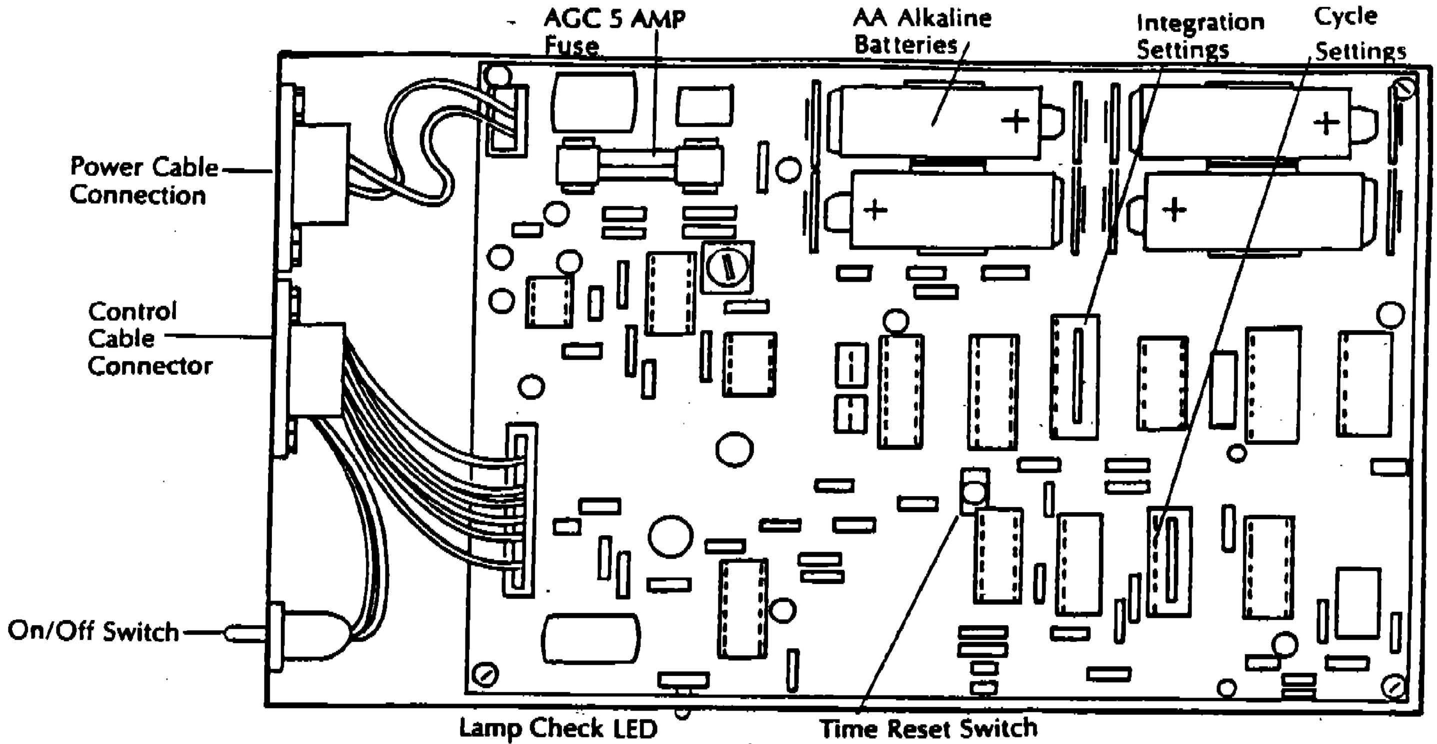
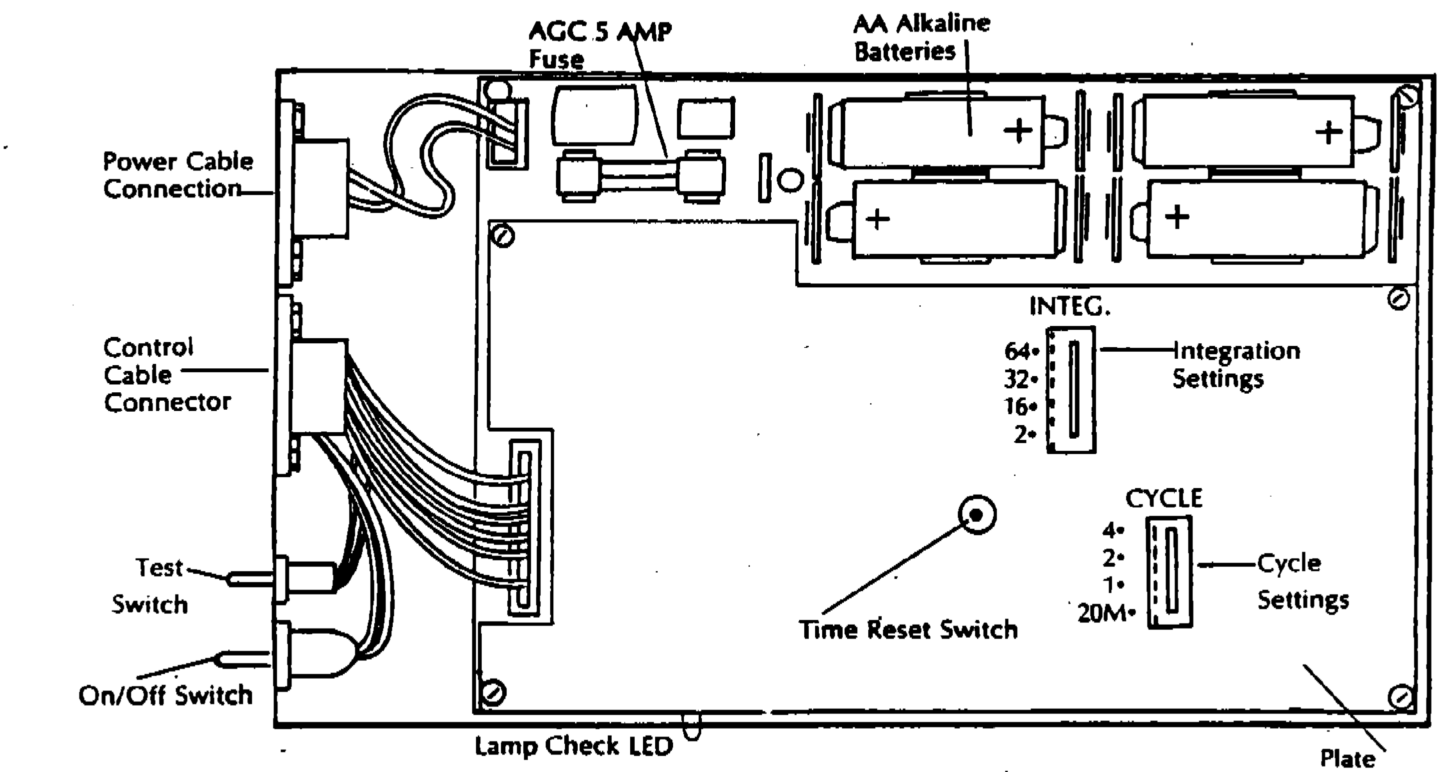


Figure 7-4. Transmitter Components.



Control Box – Serial Nos. 001-004



Control Box – Serial Nos. 005 and higher

Figure 7-5. Transmitter Control Box.

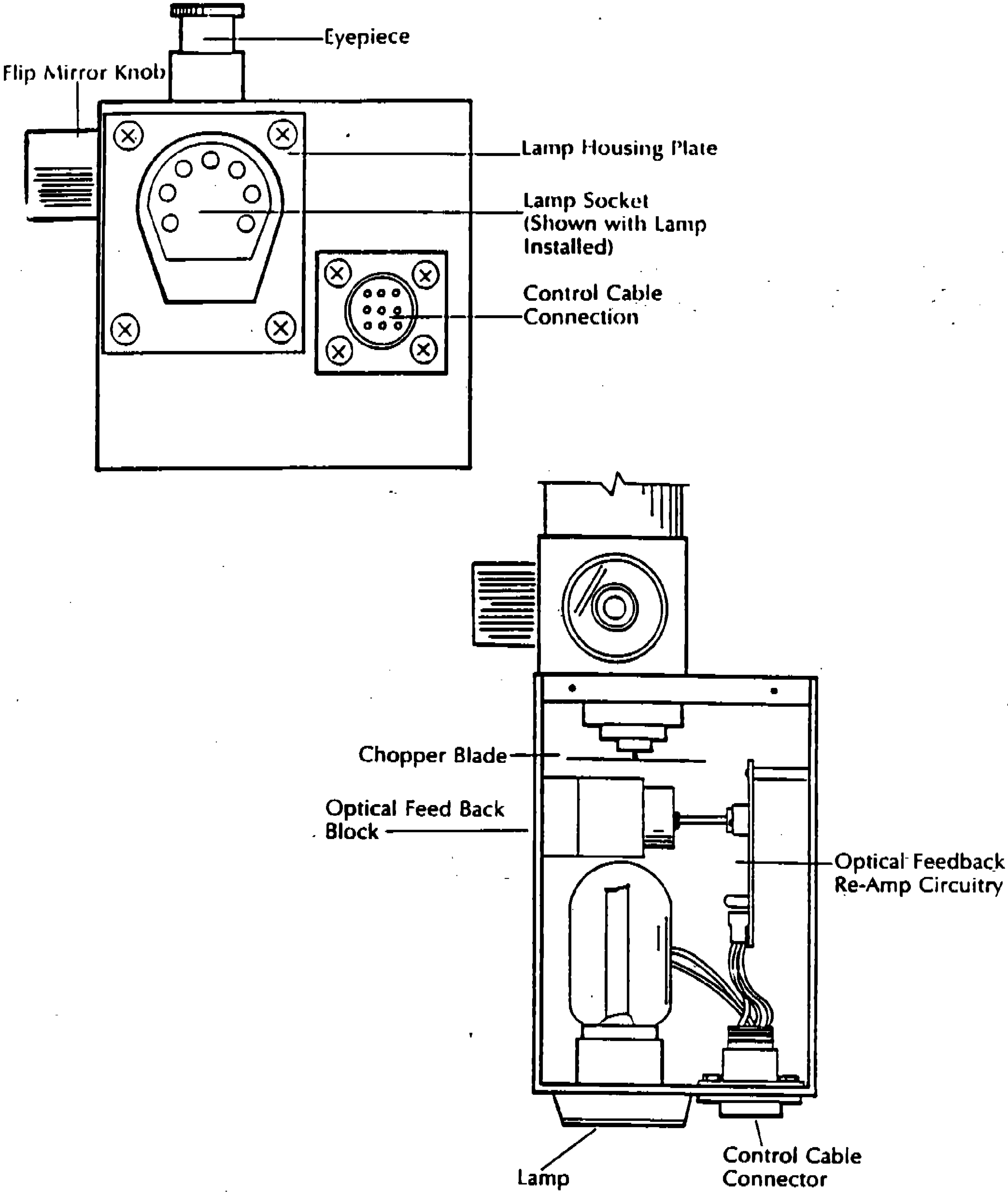


Figure 7-6. Transmitter Lamp Chamber.

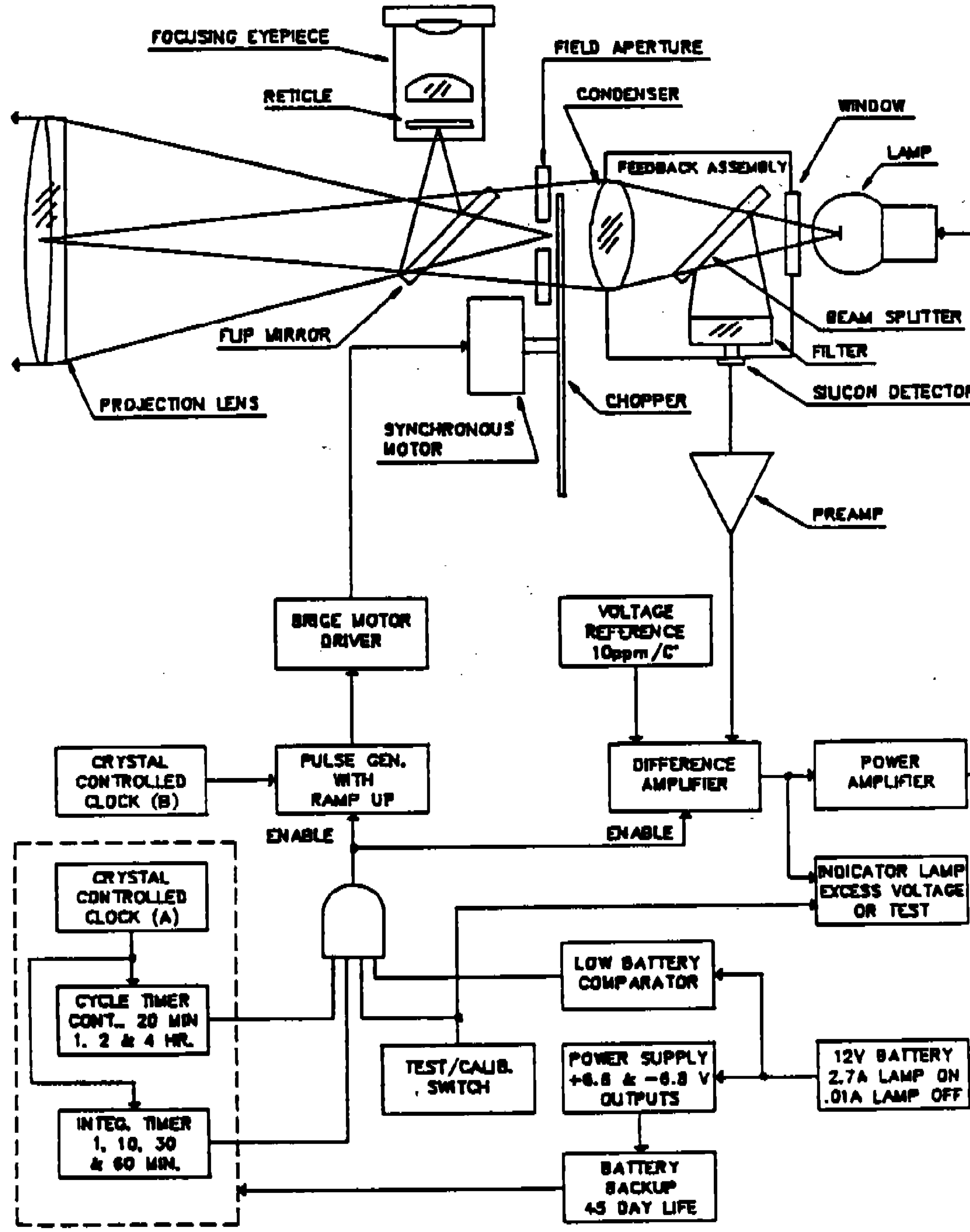


Figure 7-7. Transmitter Functional Diagram (Optec, Inc., 1987).

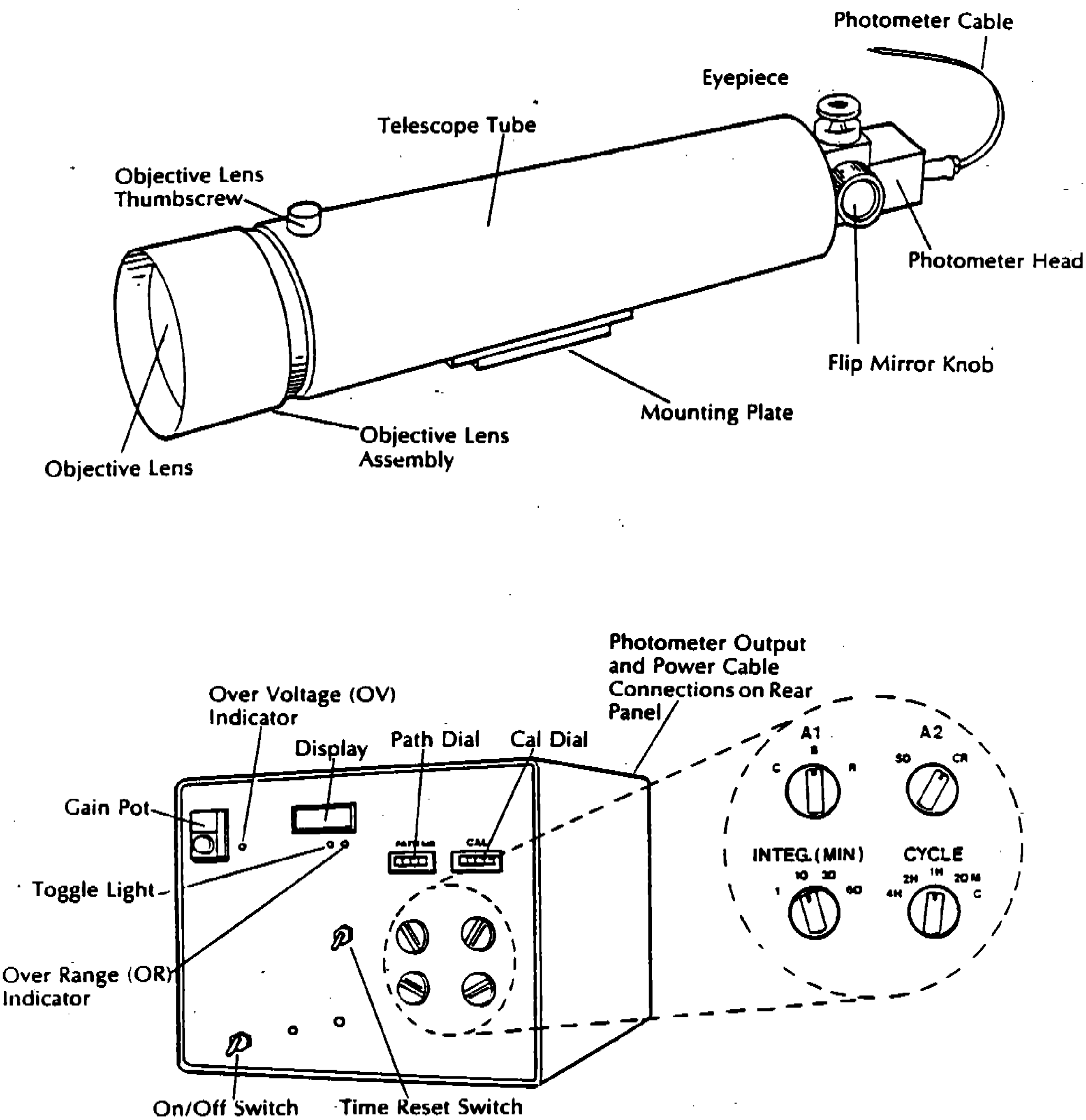


Figure 7-8. Receiver Components.

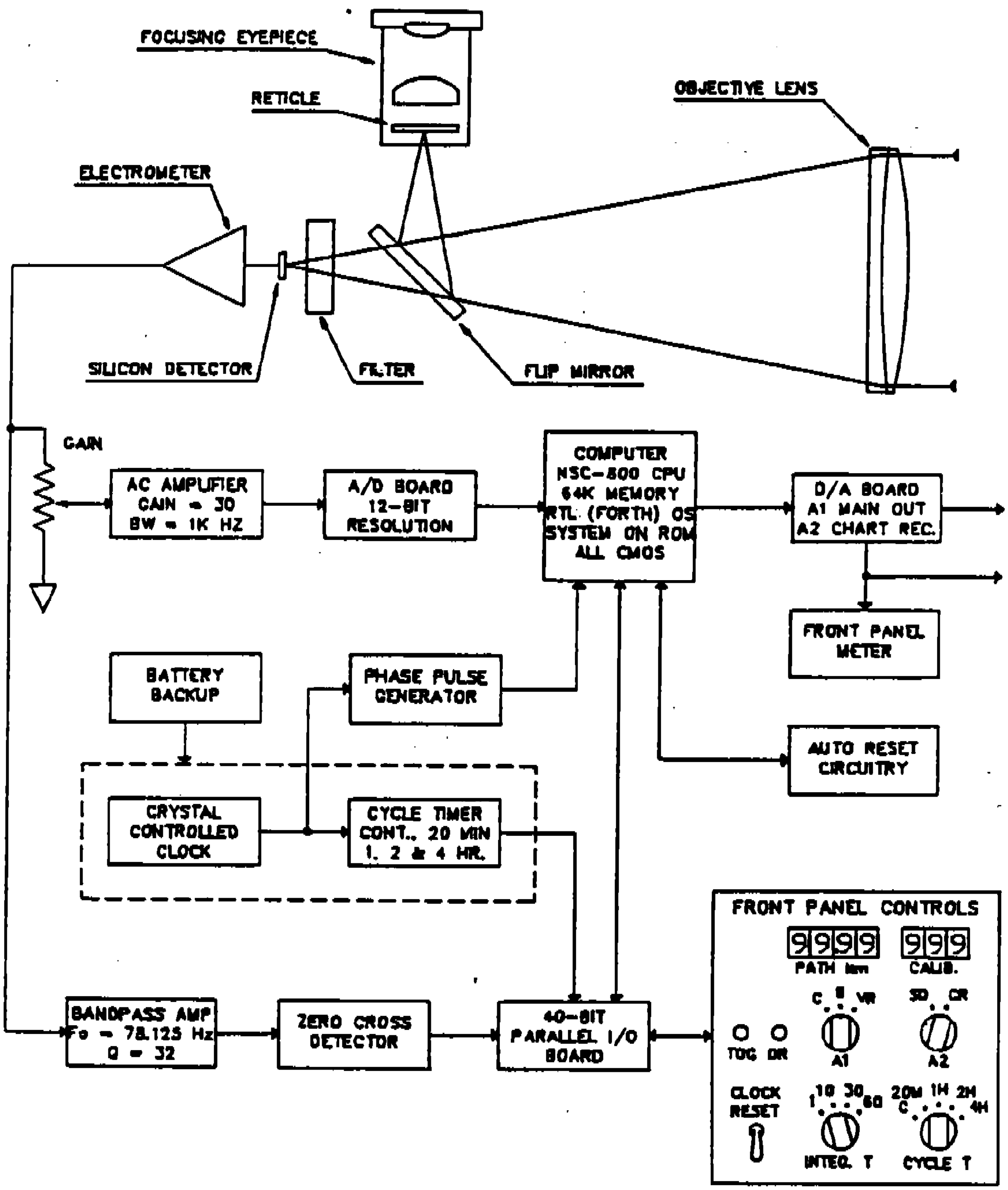


Figure 7-9. Receiver Functional Diagram (Optec, Inc., 1987).

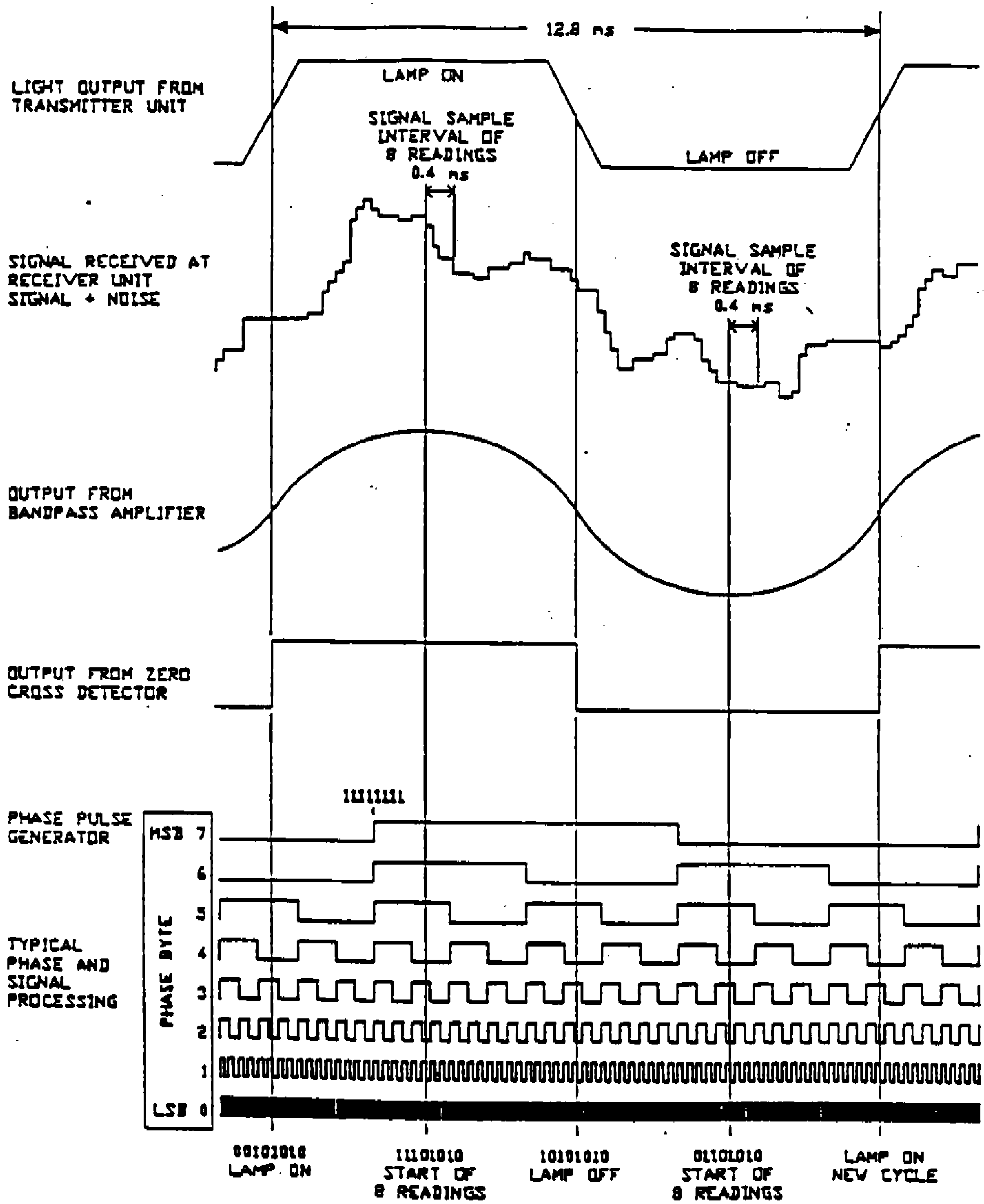


Figure 7-10. Receiver Signal Processing Waveforms (Optec, Inc., 1987).

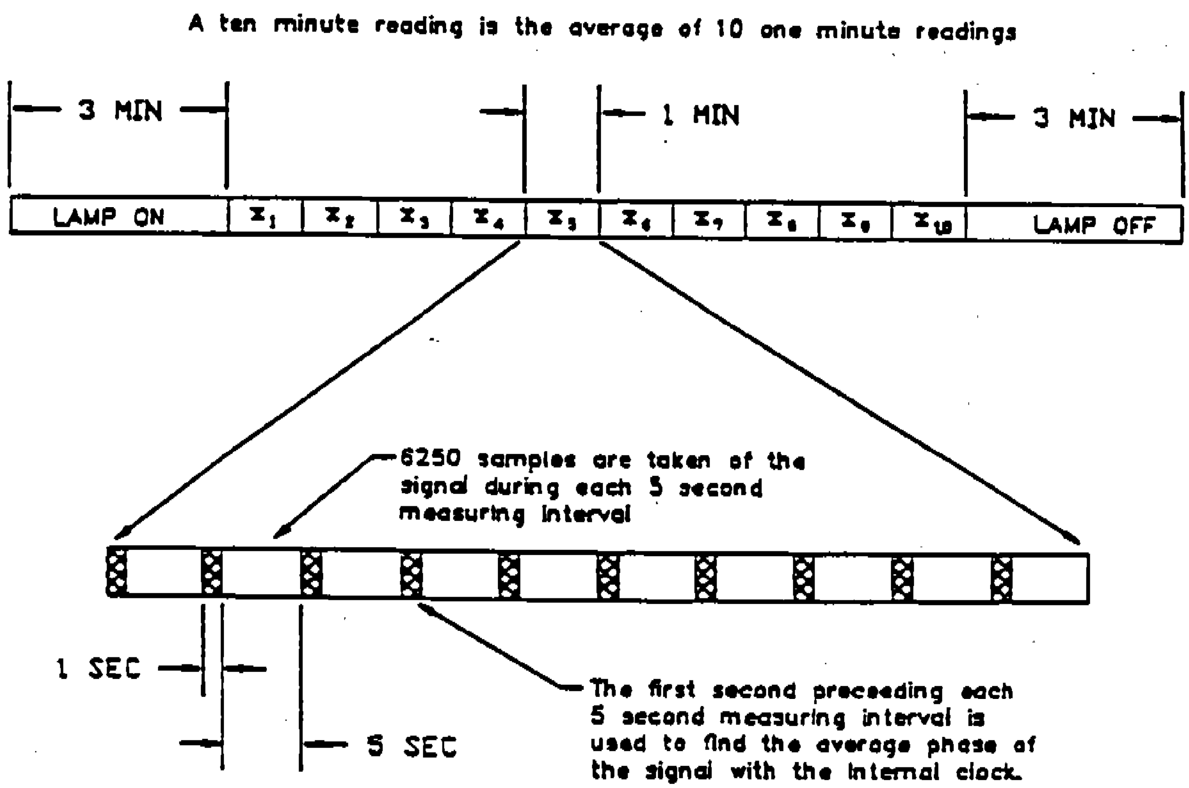
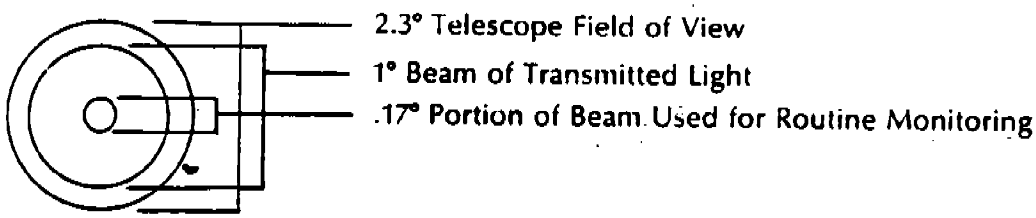


Figure 7-11. Ten-Minute Integration - Sample (Optec, Inc., 1987).

Transmitter

Alignment Reticule

The figure below depicts the reticule as viewed through the transmitter eyepiece:

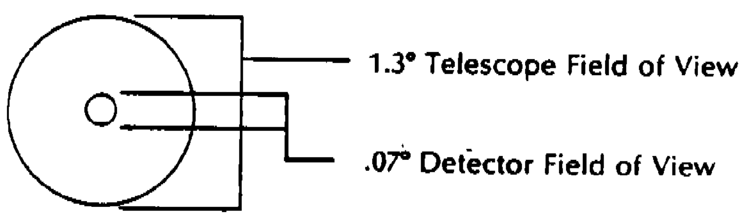


The circle depicted on the Log Sheet represents the small .17° inner reticule circle. It is this circle which should remain aligned on the receiver telescope for correct instrument operation.

Receiver

Alignment Reticule

The figure below depicts the reticule as viewed through the receiver eyepiece.

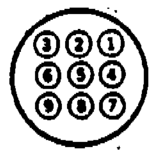


The circle depicted on the Log Sheet represents the small .07° inner reticule circle. It is this circle which should remain aligned on the transmitter for correct instrument operation.

Figure 7-12. Reticule Diagrams.

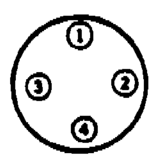
Receiver computer

Output Connector



Pin No.	*Function*	*Wire Color*
1	A1 Switchable to: Raw Reading, B_{EXT} or V_R	Yellow
2	A2 Switchable to: Raw Reading, Std. Deviation	White
3	Toggle Switch	Orange
4	A1 Return	Green
5	A2 Return	Black
6	Toggle Ground	Brown
7	Not Used	
8	Not Used	
9		Bare

Power Connector



Pin No.	*Function*	*Wire Color*
1	Not Used	
2	+ 12 Volt DC	Black (Ribbed)
3	- 12 Volt DC	Black
4	Not Used	

Figure 7-13. Connector Configurations.

8.0 NPS TRANSMISSOMETER OPERATING SPECIFICATIONS

A number of LPV-2 transmissometers are currently operating in the NPS Visibility Monitoring and Data Analysis and IMPROVE programs. These transmissometers operate according to the following specifications:

PATH LENGTH

- Acadia National Park, Maine:	3.67 km
- Badlands National Park, N. Dakota:	4.15 km
- Canyonlands National Park, Utah:	6.43 km
- Glacier National Park, Montana:	5.28 km
- Grand Canyon National Park, Arizona:	5.79 km
- Petrified Forest National Park, Arizona:	5.94 km
- Pinnacles National Monument, California:	4.80 km
- Rocky Mountain National Park, Colorado:	5.27 km
- San Gorgonio Wilderness, California:	4.10 km
- Shenandoah National Park, Virginia:	0.68 km
- Voyageurs National Park, Minnesota:	1.68 km

SYSTEM TIMING

Transmitter
- Cycle mode, 1-hour interval, 16-minute duration

Receiver
- Cycle mode, 1-hour interval, 10-minute duration

HR:MI:SEC	Action
02:00:00	Transmitter lamp turns on
02:03:00	Receiver begins 10-minute average reading
02:13:20	Receiver finishes reading, updates display and changes toggle state
02:16:00	Transmitter lamp turns off
	Sequence repeats hourly

DATA COLLECTION
1. One 10-minute averaged extinction measurement (km^{-1}) per hour. A1 switch setting: B
2. The last raw reading of 10-minute average (counts) each hour. A2 switch setting: CR
3. Hourly air temperature (^{o}F).
4. Hourly relative humidity (0-100%).

TRANSMITTER LAMP CHANGES
1. Lamp change interval: 4 months
2. Four pre-calibrated lamps are supplied each year (3 working lamps, 1 spare)
3. Spent lamps are stored on-site for post-calibration

SERVICING

1. Seven-to-ten day interval - routine servicing of both stations
2. Monthly interval - system timing checks
3. Four-month interval - transmitter lamp changes by field operators
4. Yearly - site visit by field technician. Post-calibration and replacement of system with pre-calibrated unit.

CALIBRATION

1. Calibration path distance: 900 feet
2. Calibration aperture: 11.05 mm
3. Calibration readings: 800 to 900 count range
4. Number of readings: minimum of 10 within ± 2 counts of average

9.0 REFERENCES

Air Resource Specialists, Inc., 1988, Transmissometer System Field Operator's Manual. Prepared in partial fulfillment of National Park Service Contract CX-0001-7-0010.

Optec, Inc., 1988, Long Path Visibility Transmissometer Version 2, Technical Manual for Theory of Operation and Operating Procedures. Optec, Inc., May.

Additional Reading

Malm, W., G. Persha, R. Tree, H. Iyer, E. Law-Evans, 1988, The Relative Accuracy of Transmissometer Derived Extinction Coefficients. Paper to be presented at the 81st Annual Conference of the Air Pollution Control Association (APCA), Dallas, Texas, June.

Appendix C

Visibility Monitoring and Data Analysis Using Automatic Camera Systems - Standard Operating Procedures and Quality Assurance Document

Visibility Monitoring and Data Analysis Using Automatic Camera Systems

Standard Operating Procedures and Quality Assurance Document

Prepared by:

AIR RESOURCE SPECIALISTS, INC.

May 1988

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FORWARD

This report is produced annually or more frequently if required to include revisions and additions to standard operating and quality assurance procedures. The report release date should be considered when using the information provided herein.

1.0 INTRODUCTION

Documenting visibility events and trends is an important aspect of evaluating existing or potential impairment in class I and other visibility sensitive areas. Many of these areas afforded protection by the Clean Air Act (1977) are remote. In many instances, commercial power is not available, manpower is limited, and access is difficult. An automatic camera visibility monitoring station is an effective and economical way to address these specialized monitoring needs.

An automatic camera visibility monitoring station takes 35mm slides of a selected view any selected number of times a day. These photographs provide a permanent visual record of visibility events, and quantitative visibility measurements such as standard visual range can be estimated from the slides.

This document outlines the data collection, analysis, and quality assurance procedures commonly applied in automatic camera visibility monitoring networks. Figure 1-1 is a flow diagram that highlights the major steps in the data collection, handling, and analysis procedures. In-depth discussions of theoretical and practical monitoring and analysis techniques and considerations are also provided.

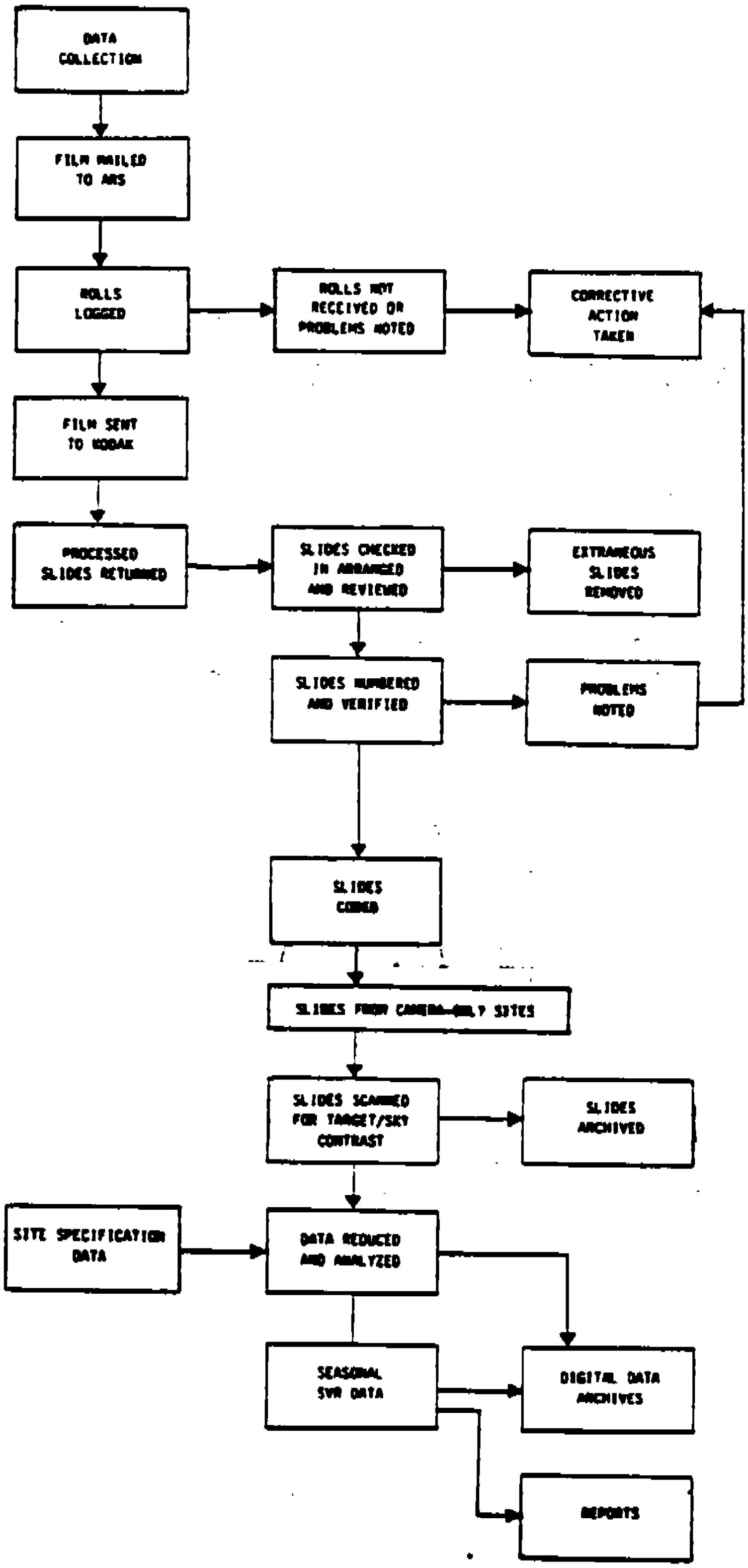


Figure 1-1. Major Steps in the Data Collection, Handling, and Analysis of Photographic Data.

2.0 MEASUREMENT METHODS AND INSTRUMENTATION

Automatic camera systems are an integral part of the visibility monitoring program. The day-to-day variations in visual air quality captured on 35mm color slides can be used to:

- Document how vistas appear under various measured conditions.
- Qualitatively record the frequency that various conditions occur--e.g., incidence of uniform haze, layered haze, or weather events.
- Provide a quality assurance reference for collected measurements.
- Serve as a method to estimate the electro-optical properties of the atmosphere (if appropriate teleradiometric visibility targets are in view).
- Support color and human perception research.
- Provide quality media for visually presenting program goals, objectives, and results to decision makers and the public.

The specifications for a remote, automatic 35mm camera systems are detailed in Table 2-1. Although a variety of configurations currently exist in the field, an example camera system is now available through Air Resource Specialists, Inc., and meets all of the above criteria. The system includes:

- Contax 167MT camera with autowinder and data back
- 135mm lens with UV filter
- Programmable camera timer (Model 103) and cabling
- Environmental enclosure with sunshield and internal locks
- Quick-release camera mount
- Mounting post (single- or double ended)
- Documentation chart
- Instruction manuals and example forms
- Lens cleaning supplies
- Batteries

Table 2-1

Equipment and Siting Protocols for Photographic Visibility Monitoring

Automatic 35mm photographic monitoring equipment will be used to collect optical data for the calculation of standard visual range and the visual characterization of regional haze. Target/sky horizon contrast measured by microdensitometry of 35mm color slides will be the primary electro-optical measurement. To achieve these goals, the following equipment and siting criteria must be met:

Equipment

1. Rugged, reliable 35mm camera body with automatic film winder. The camera's automatic exposure meter must be designed so that it is on only during the actual time of exposure and not continuously operating.

2. 135mm lens with UV filter.

3. Databack that will imprint the day and time the exposure was taken on the film.

4. Battery-powered programmable timer that will trigger the camera at least three times a day.

5. The complete system must be able to operate within the ambient temperature range of -10^{o}F to 130^{o}F.

6. The complete system must be able to be housed in a small stand-alone environmental enclosure.

7. The system must be able to operate unattended for at least 10 days.

Siting Criteria

1. The monitoring location should be reasonably accessible and secure year round.

2. The view must contain at least one horizon visibility target with the following characteristics:

   - Large - Subtend at least 0.1 degrees of solid angle (i.e., approximately 20% of the size of the full moon).
   - Easily identifiable on topographic maps of the area.
   - Dark - Preferably covered with coniferous vegetation.
   - Distance - Preferably in the range of 60% to 90% of the mean visual range for the monitoring site.

Table 2-1 (cont.)

- Elevation Angle - The site and target should be approximately the same elevation. The observer-target elevation angle should be within $+1^{\circ}$.

- The observer-target sight path should not be affected by local sources of visual air pollution.

- The target should be selected to be as free of snow during the winter months as possible.

3. Where possible, the target should be selected within the unit of interest (e.g., within a class I area). If the target is outside of the unit, as large a portion of the observer-target sight path as possible should be within the unit. If views do not contain targets that meet the above requirements, then a view outside of the unit boundary that contains a good visibility target must be chosen.

3.0 FIELD COORDINATION

Field coordination tasks include routine operation and maintenance, standard operating procedures, training and quality assurance. The effective performance of each of these tasks is the key to quality data collection. Each field-related task is discussed in detail in the following subsections.

3.1 Routine Operation

Agency personnel generally serve as the site operators and are responsible for the routine operation of cameras and related data collection equipment at the sites. Effective, two-way communication between Air Resource Specialists (ARS) and the site operators will ensure that routine operations proceed smoothly. Routine operations criteria for camera systems are outlined below.

3.1.1 Camera - Routine Operations

Automatic cameras will take three photographs a day at 0900, 1200, and 1500 local time. Kodachrome ASA 25 color slide film will be used at the site. This film was chosen for its fine grain and excellent color reproduction qualities. For consistency, all film will be developed at the Los Angeles Kodak laboratory. Photographs will be taken using the automatic exposure capabilities of the camera (aperture priority - preferably at a f8.0 setting).

Operators will visit the site a minimum of once every 10 days to change the film and service the camera system. A full explanation of the operator's duties are presented in Section 3.3.1, Quality Assurance. The detailed procedures for handling the film and processed slides are explained in Sections 4.0 and 5.0.

3.2 Training

Training of site operators by ARS staff is encouraged. Trained operators consistently yield higher quality data products. As part of the site installation, ARS's field staff will conduct hands-on training of field operators on all equipment present at the site. Best attempts will be made to train at least two operators at each site, one of whom will be permanent staff. Training will include:

- Monitoring Program Overview and Goals
- Instrument Operations
- Quality Assurance
- Preventive Maintenance
- Trouble Shooting

If additional or refresher operator training is required at a specific site, Air Resource Specialists' staff will work with the agency and the site operator to schedule and provide the appropriate training.

3.3 Quality Assurance

Field quality assurance is necessary for precise, accurate, valid and complete data. Well-designed and regularly-scheduled quality control procedures will be implemented to assess the quality of each step of the operation. Effective quality control locates and corrects problems quickly.

The visibility monitoring field quality assurance program will consist of: operational checks, preventive maintenance, and data control to be carried out by site operators on a routine basis.

Inconsistencies identified by the quality assurance procedures will initiate corrective actions. The following subsections describe the quality assurance procedures and corrective action plans to be applied.

3.3.1 Field Quality Assurance

Site operators will service the camera approximately every 10 days to change film, check the performance of the cameras, clean system components and perform scheduled, preventive maintenance. Site operators will be fully trained and supplied with all necessary materials.

The Automatic 35mm Camera System User's Manual contains standard operating and quality assurance procedures and will be provided to each site (see Appendix A). These written procedures provide step-by-step instructions for regular maintenance, standard settings, camera cleaning and servicing. The detailed procedures described in the manuals will not be repeated in this section; however, the steps are summarized in Table 3-1.

During each routine site visit, the operator will document maintenance performed and note all discrepancies on the "Visibility Status Assessment Sheet." The information on the Status Assessment Sheet for a Contax system is provided as Figure 3-1. The completed sheets will be mailed with each roll of film. If discrepancies or operator comments on the sheets indicate that further action is necessary, immediate corrective action will be taken.

Identification and documentation of the film rolls is essential. The field-related aspects of the film documentation procedures are fully described in Section 4.0 (Data Logging and Editing).

Table 3-1

Automatic Camera System Field Quality Assurance Procedures

Procedure	Frequency
Regular Maintenance	Every 10 Days
o General site/system inspection o Remove camera o Remove film (fill out ID label) o Inspect film compartment o Load new film o Inspect and clean camera lens o Inspect and clean box window o Check batteries o Check databack o Photograph film documentation board o Check camera settings o Replace and align camera o Check timer settings o Complete Visibility Monitoring Status Assessment Sheet o Close and lock camera shelter o Mail film and Status Assessment Sheet to ARS	
Scheduled Maintenance	Scheduled as below or as noted by the site operator.
o Battery changes	
- camera and databack	Once a year
- winder	Every 6 months
- timer	Every 6 months
o Full System	Every 2 years
Unscheduled Maintenance	As required
o If a problem is noted, the operator: - calls ARS - a replacement camera/timer system is express mailed to the site by ARS - the site operator replaces the system and returns the malfunctioning unit to ARS - ARS diagnoses the problem and effects repairs	

Location ____________________

AUTOMATIC CAMERA
VISIBILITY MONITORING STATUS / ASSESSMENT SHEET

Today's Date __________ Time __________ Operator ____________________

Temperature ______ ______ ______ % Cloud Cover ____________________
(°F) Now Max Min

Describe General
Weather Conditions: ____________________

____

YES	NO	
☐	☐	Monitoring target visible
☐	☐	Camera found in proper condition
☐	☐	Timer found in proper condition
☐	☐	Film advanced as expected
☐	☐	Film changed and film canister properly labeled
☐	☐	Lens and window clean
☐	☐	Documentation Photograph Taken
☐	☐	SETTINGS VERIFIED: Circle standard setting or write in setting if not listed.

Switch / Dial	Olympus	Contax
Aperture	8.0	8.0
ASA Dial	25	40
Exposure Compensation Dial	zero	X1
Shutter Control Dial	______	A
Selector Lever	Off (OM2n) Auto (OM2s)	______

☐	☐	Data back display "TIME / DATE" correct
☐	☐	Camera alignment correct

COMMENTS / ACTION TAKEN ____________________

____

____

____

Supplies Needed: ____________________

Enclose the original of this Status / Assessment sheet with the 35 mm film and send to:

Air Resource
Specialists, Inc.
1901 Sharp Point Drive
Suite E
Fort Collins, Colorado 80525
303-484-7941

Figure 3-1. Visibility Status Assessment Sheet for a Contax Automatic Camera System.

Throughout the monitoring effort, close personal communications will be maintained between the contractor and site operators. Operators will be encouraged to call if they have any questions or problems. Many problems can be fully resolved over the phone.

3.3.2 Corrective Action

Two types of corrective action will be considered if monitoring problems are detected or reported:

1. Immediate corrective action to correct or repair non-conforming equipment or procedures; and

2. long-term corrective action taken to eliminate causes of non-conformance.

Immediate Corrective Action

Immediate corrective action will depend upon the specific problem and the type of instrument. Typically, a problem will arise in the field that the field operator cannot solve. The operator will phone ARS and discuss the problem with appropriate staff (e.g., field specialist or photographic data coordinator). An attempt will be made to diagnose the problem and suggest specific corrective action.

If an equipment problem persists, corrective action would depend on the instrument configuration:

- o Camera System - When a camera-related problem is identified, a backup camera/timer system will be shipped to the site as quickly as possible. Site operators will exchange the equipment and will ship the malfunctioning unit to ARS for evaluation and repair.

Long-Term Corrective Action

Long-term corrective action will include detailed evaluation of systematic problems and development of a well planned, thoroughly documented corrective action plan, including procedures which can be used to identify and eliminate problems. Long-term corrective action of operational procedures can usually be handled through a written revision of SOPs and incorporation of the procedural changes in training programs.

4.0 DATA LOGGING AND EDITING

The logging and editing of film includes a series of steps. The contractor will coordinate the logging and editing process from field operator logging procedures to final editing. Effective quality assurance of the data will be of primary importance throughout the logging and editing procedures. These procedures have been developed by ARS and are currently in use.

4.1 Field Documentation

After loading each roll of film, the site operator will fill out a film canister label and attached it to the film canister. Information on the label includes:

- o Site abbreviation
- o Roll number
- o Date and time on
- o Date and time off
- o Film emulsion number

The operator will take a picture of the photo documentation board on the first exposure of each roll. The board contains the following information:

- Monitoring site identification
- Date
- Time
- Film roll number (numbers are consecutive)

Each camera is also equipped with a databack that records the date and time on the lower right corner of each slide.

When the operator returns to remove the film, he will complete the information on the canister label, place the film in a padded envelope, and mail it, along with the Status Assessment Sheet, as soon as possible to ARS via first class mail.

4.2 Internal Documentation

<u>Master Log</u>

Film that arrives from the field will be immediately recorded on a site specific Master Log according to the roll number and the time period that the film documents. An example of a site Master Log is provided in Figure 4-1. The following items will be maintained on each site Master Log:

198_ OPERATIONAL HISTORY

WINTER: ____________
SPRING: ____________
SUMMER: ____________
FALL: ____________

LOCATION ____________

CONTACT PERSON ____________

ROLL #	LG	SENT PROCESS	MAILER	EMULSION NUMBER	BACK PROC	SLIDE #'S	# O	# R	# P	DATE LOGGED	TIME LOGGED	CORRESPONDENCE	PROBLEMS	SPEC. PHOTO	EQUIPMENT CHANGE	SUPPLIES MAILED

NI:2.1 3/80

Figure 4-1. Site Film Master Log.

1. Location Name - Four-character site abbreviation code.

2. Roll Number - The roll number denoted on the film canister label. If a difference exists between the roll number received and the roll number that follows sequentially, reference to the on and off dates of the roll is made. If roll numbering errors occur, the operator will be contacted for correction.

3. Log - The receipt of a Status Assessment Sheet with the film roll is noted.

4. Sent to Process - The date the film is mailed to the LA Kodak processing lab. If film is lost in shipping, this date will help to initiate tracing procedures.

5. Mailer Number - Each Kodak mailer in which an individual roll of film is mailed has a Kodak mailer number. This number is recorded in the event film is lost during processing.

6. Emulsion Number - The Kodak emulsion number denoted on the film canister label is recorded to track the response characteristics of each batch of Kodak film.

7. Back From Process - The date the slides are returned to ARS.

8. Slide Numbers - After editing procedures are completed, the beginning and ending slide numbers of the edited set will be recorded.

9. Number Good (#G) - The number of valid slides (slides that appear usable for quantitative analysis). This number does not include snow-covered targets, weather-obscured targets, or slides that are outside acceptable Rayleigh range.

10. Number Received (#R) - The number of slides taken between the given dates and times for the film roll.

11. Number Possible (#P) - The total possible number of slides that could have been taken between the given dates and times for the film roll.

12. Date and Time Logged - The on/off dates and times entered by the operator on the film canister label will be recorded when the film is first received at ARS. In the event the film is later lost, or no databack information is recorded on the processed slides, this information will be very useful.

13. Correspondence - All written correspondence and telephone conversations will be referenced and dated. Actual letters and telephone documentation notes will accompany the Master Log for complete reference.

14. Problems - Any equipment, operator, or pertinent problems associated with a given roll of film or the time period in which it was taken. Problems that have been addressed are noted on the Master Log and internally documented with a "Site Operation Problem Documentation" (Figure 4-2) for further reference.

15. Special Photos - All supplemental visibility photos will be noted with their corresponding slide numbers. If interesting conditions appear in any group of slides, they will also be noted corresponding with the roll in which they exist.

16. Equipment Change - If a camera, timer, batteries, or any piece of support equipment is changed or altered, it will be noted (with a date), corresponding to the date and roll in which the change occurred.

17. Supplies Mailed - Any time batteries, film, or any other supplies are mailed to a site, a note will be made as to what was sent and the date it was mailed.

Film Processing

After each roll of film received from the field has been identified and recorded on the Master Log, it will be placed in an individual 35mm Kodak film mailer. Each mailer has a specific ID number that will be recorded on the site Master Log. The site abbreviation and film roll number will be placed on the mailer for future identification. These identification measures will track each roll individually, allowing identification even if the field operator forgets to photograph the documentation board. Film mailers will be shipped via UPS to the Kodak Los Angeles processing lab two times a week.

Within 10 to 12 days, the processed film will be returned by UPS to ARS. If film is not returned within fifteen days, the Los Angeles processing lab will be called to verify the arrival and completion of processing. A trace will be made on the film shipment if any discrepancies in shipping/receiving dates are discovered.

Slide Check In, Arrangement, Preliminary Review

The receipt of the developed slides from Kodak will be recorded in the site Master Log.

Air Resource Specialists, Inc.
1901 Sharp Point Drive
Suite E
Fort Collins, Colorado 80525

SITE OPERATION PROBLEM DOCUMENTATION

SITE: ____________

DATE: ____________

CONTACT: ______________________________ PH#: ____________

PROBLEM DETECTION & DESCRIPTION: ______________________________

____

______________________________ INITIALS: ______

POSSIBLE SOLUTIONS: ______________________________

____

____

TELEDOC: BY: ______ TO: ____________ DATE: ______

COMMENTS: ______________________________

____

CORRECTIVE ACTION TAKEN: ______________________________

____

____

EQUIPMENT SHIPPED: ____________ TO ARRIVE: ______

____

PROBLEM SOLVED:

ROLL # ____ CHECKS OUT OK DATE: ______ BY: ______

COMMENTS: ______________________________

____

FOLLOW UP: ______ YES ______ NO DATE: ____________

____

CC:

Figure 4-2. Site Operation Problem Documentation Sheet.

PROBLEM SUMMARY

DATA:

ROLL #S AFFECTED:________ DATES:________

OF INVALID SLIDES:________ SLIDE #S:________

COMMENTS:________

____

____

____

EQUIPMENT:________

RECEIVED:________

TESTED:________

RESULTS:________ REPAIRS:________

REPAIRS MADE:________

COMMENTS:________

____

____

____

PROBLEM ANALYIS:________

____

____

____

FOLLOW-UP ACTION:________

____

____

____

Figure 4-2. Continued

Processed slides will be first checked for extraneous photos:

- Only slides that represent the standard date and time sequence of a given target, or were taken purposely for documentation or as a supplemental visibility documentation will be kept.
- Any blank slides preceding or following the normal date/time sequence will be discarded.

Documentation and target photos will be arranged in polyethylene sheets by date and time. Each protector sheet holds 15 slides (5 rows of 3 slides each). Each row represents the 0900, 1200, and 1500 photos for one day. The documentation board photograph will be placed in the upper left corner of the protector sheet beginning each roll of film.

Slide Numbering, Verification, and Filing

Slides will be initially reviewed to verify that the vista alignment is correct, the databack date and time is recorded on the film, the slides are arranged in proper order, and that no exposure inconsistencies exist. Any discrepancies will be documented by site and roll number on the Master Log and corrective action initiated. Following the initial verification of slide arrangement, each slide will be numbered sequentially and stamped with the four-letter site code. The slide set will be placed in a manila folder labeled with site abbreviation, roll number, and slide numbers.

Each set of slides will be checked one more time by the slide operations supervisor. At this quality control point, all slides will be checked and all log entries verified. If problems are noted, the slide operations supervisor will initiate corrective action procedures that include:

1. Master Log checked to verify that the problem has not already been addressed.
2. Previous slides reviewed to identify symptoms that may pin-point a problem.
3. The photo log or status/assessment sheet reviewed for any appropriate field operator comments.
4. If no previous corrective action has been taken by the field personnel or ARS quality control personnel, the field operator will be called to further identify the malfunction or discrepancy. A telephone document memo or Site Operation Problem Documentation will be written as a permanent record of the conversation.
5. Immediate or long term corrective action will be taken to correct the malfunction and/or discrepancy. A Photographic Monitoring Network Quality Assessment Log (Figure 4-3) will be mailed to the site. All problems and directed actions will be documented. The field operator will document the date of correction and what was done, and return a copy of the log to ARS.

6. All corrective actions will be recorded on the site Master Log and Operation Problem Documentation for future reference. All documentation relating to the corrective action will be placed in the site location file with the Master Log.

7. Photos taken following the date of correction will be checked immediately to verify that proper adjustments were made.

The next step in the film logging and editing process will be the determination of the number of photographs that appear usable for quantitative slide scanning. Photographs will initially be considered valid for quantitative analyses except for:

- Supplemental visibility photos.
- Out-of-alignment photos; e.g., the target is not in the picture.
- Blank photos
- Extremely under or overexposed photos
- Out-of-focus photos; distinct feature cannot be identified.
- Photos taken through a fogged or icy shelter window.

The number of valid slides, that appear usable for quantitative analysis, is recorded in the #G column on the Master Log. The final number of slides usable for quantitative analysis (SVR calculations) is determined after slide coding and scanning are completed.

The actual number of slides taken between the given dates and times for a film roll is recorded in the #R column of the Master Log.

The total number of observations that could have been taken between the given dates and times for a film roll is documented in the #P column of the Master Log.

The number of received slides (R) for each roll recorded on the Master Log will be totaled to determine the number of observations collected for the season. The total possible observations (cases) for a season is determined by considering the number of days in the season and the number of observations a day. A resulting, seasonal percentage of collection efficiency is calculated, for example:

$$\frac{\text{265 slides available for the summer season}}{\text{92 days X 3 photos a day possible}} = 96\%$$

The resulting seasonal percentage will be recorded in the upper left corner of the Master Log.

Film roll folders will be filed by season, and retrieved at the end of a season for coding and quantitative analysis.

PHOTOGRAPHIC MONITORING NETWORK
QUALITY ASSESSMENT LOG

Site: ______________________

Date: ______________________

Operator: ______________________

ACTION ITEM	PROBLEM DESCRIPTION	CORRECTIVE ACTION TAKEN	DATE	INIT
Film				
Film Label				
Assessment Log				
*Photo Log				
Documentation Chart				
Roll #				
Aperture				
ASA Setting				
Exposure Compensation				
Batteries				
Data Back				
Winder(s)				
Camera(s)				
Timer(s)				
Alignment				
All OK				

*Manual Camera Only

Return Yellow Copy To:

Air Resource
Specialists, Inc.
1901 Sharp Point Drive
Suite E
Fort Collins, Colorado 80525
303-484-7941

Figure 4-3. Photographic Monitoring Network Quality Assessment Log.

Slide Coding

Slide coding qualitatively identifies the visibility measurement related condition of the target and sky and other visibility-related conditions within the scene. At the completion of each season, slides from each site will be coded for meteorological and visibility conditions. These codes, summarized in Figure 4-4, are divided into four primary categories:

Target Conditions - in the target detector area;

Sky Conditions - in the sky detector area;

Remainder of Sky - conditions in the remainder of sky visible in the photograph; and

Layered Haze - layered haze conditions that exist, if any.

Each category is represented by a column on the Visibility Network Slide Coding Log presented in Figure 4-5. The Coding Log will be used to record specific coding comments for a given film roll during this phase for processing. Codes are recorded directly on the slides and entered into the digital database during slide scanning.

Each valid slide will be viewed on a light table with the naked eye and an eight-power, hand-held lens. The following criteria will be used to assign a four-digit code for each slide:

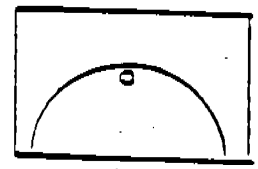
A. Target Conditions - The target condition category describes the visual conditions of the monitoring target in the target detector area only.

0 In shade - no snow
The normal target surface (i.e., trees, rock, grass, soil, etc.) is exposed, but shaded by clouds.

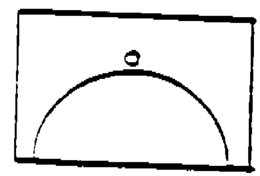
1 Direct sun - no snow
The normal target surface (i.e., trees, rock, grass, soil, etc.) is exposed and in direct sunlight.

2 Snow
The normal target surface is mostly or completely covered by snow.

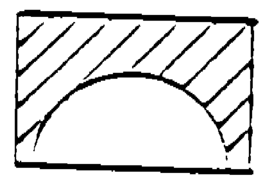
TARGET CONDITIONS (Target Detector Area)		CODE DESCRIPTION
0	In shade, no snow	No snow cover visible in target detector area and area is in shade due to cloud shadow.
1	Direct sun, no snow	No snow cover visible in target detector area and area is generally in sun light.
2	Snow on target	Snow visible in target detector area regardless of lighting.
3	Target not visible due to haze	Target area not detectable by observer due to atmospheric haze (not clouds or precipitation).
5	Weather obstructing target	Target area not visible due to clouds or precipitation.
8	Incorrect exposure or not usable for densitometry	Incorrect exposure, improper metering, lens flare, lens (or window) condensation, or target obstructed by foreign object, causing slide to be unusable for a valid densitometry measurement.
9	No observation	No observation taken.



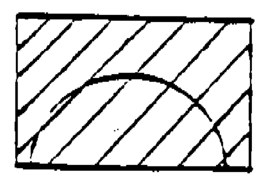
SKY IN DETECTOR AREA		
0	No clouds	No clouds visible in the sky detector area.
1	Clouds	Clouds visible in the sky detector area.
5	Weather obstructing sky detector area	To be used if target code of 5.
9	No observation or cannot be determined	To be used with target code of 9 or if sky value cannot be determined due to reasons other than weather obstruction.



REMAINDER OF SKY		
0	No clouds	No clouds visible anywhere in the sky.
1	Scattered clouds < half of sky	Less than one-half of the sky has clouds present.
2	Overcast > half of sky	Greater than one-half of the sky has clouds present.
5	Weather obstructing scene	To be used with target code of 5.
9	No observation or cannot be determined	To be used with target code of 9 or if sky value cannot be determined due to reasons other than weather obstruction.



LAYERED HAZE		
0	Non-perceptible	No layered haze boundary (intensity of coloration edge) is perceptible.
1	Ground-based layered haze only	Only a single-layered haze boundary is perceptible with the haze layer extending to the surface.
2	Elevated layer only	An elevated layer with two boundaries is present; e.g., horizontal plume.
3	Multiple layers	More than a single ground-based or elevated layer is present. This can be multiple ground-based layers or a combination of both.
5	Weather obstructing scene	Cloud or precipitation are such that determination of the presence of layered hazes is impossible.
9	No observation or cannot be determined	To be used with target code of 9 or if a layered haze value cannot be determined due to reasons other than weather obstruction.



NOTE: It is possible to have a target code of 5 and still see a layered haze in the scene.

Figure 4-4. Visibility Slide Codes Used to Characterize Target, Sky, and Haze Conditions.

Air Resource Specialists, Inc.
1901 Sharp Point Drive
Suite E
Fort Collins, Colorado 80525

VISIBILITY NETWORK SLIDE CODING LOG

SITE: ______________

SEASON: ______________

ROLL # ______________

Slide	Date	Time	T	SD	RS	LH	Comments
		DOC					
		9:00					
		12:00					
		3:00					
		9:00					
		12:00					
		3:00					
		9:00					
		12:00					
		3:00					
		9:00					
		12:00					
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		12:00					
		3:00					
		9:00					
		12:00					
		3:00					

Sky/Target Code

T - Target Conditions SD - Sky in Detector Area RS - Remainder of Sky LH - Layered Haze

2.13 8/17/88

Figure 4-5. Visibility Network Slide Coding Log.

3 Target not visible due to haze
The target is not visible due to factors other than those listed in defined codes.

4 (not currently used)

5 Weather obstructing target detector area
The target is not visible due to obstruction by weather such as clouds, fog, rain, snow, blowing dust, or other readily identifiable wind or moisture-related phenomena.

6 (not currently used)
7 (not currently used)

8 Incorrect exposure or not usable for densitometry
The slide is unusable for a valid densitometry measurement due to incorrect exposure, improper metering, lens flare, lens (or window) condensation, or target obstructed by a foreign object.

9 No observations

B. Sky in Detector Area - This category describes the visual conditions of the sky in the sky detector area only.

0 No clouds
No clouds are visible in the sky detector area.

1 Clouds
A cloud or clouds are in the detector area.

2 (not currently used)
3 (not currently used)
4 (not currently used)

5 Weather obstructing sky detector area
The sky detector area is not visible due to obstruction by weather such as clouds, fog, rain, snow, blowing dust, or other easily identifiable wind or moisture-related phenomena.

6 (not currently used)
7 (not currently used)
8 (not currently used)

9 No observation or cannot be determined
To be used with target code or when a sky value cannot be determined due to reasons other than weather obstruction.

C. Remainder of Sky - this category describes the cloud conditions in the entire portion of the sky visible on the slide. Only distinguishable, opaque cloud types are considered; thin cirrus clouds are not coded.

0 No clouds
The sky is completely free of clouds or the existence of clouds cannot be determined due to obscuring haze.

1 Scattered clouds < half of sky
Less than half of the sky visible is covered with clouds.

2 Overcast > half of sky
More than half of the sky visible is covered with clouds.

3 (not currently used)
4 (not currently used)

5 Weather obstructing scene
None of the sky area is visible due to obstruction by weather such as clouds, fog, rain, snow, blowing dust, or other easily distinguishable wind or moisture related phenomena.

6 (not currently used)
7 (not currently used)
8 (not currently used)

9 To be used with target code of 9 or if a sky value cannot be determined due to reasons other than weather obstruction.

D. Layered Haze - This category describes the type of layered haze visible anywhere on the slide.

0 Non-perceptible
No haze layer with defined boundaries is visible on the slide.

1 Ground-based layer only
Ground-based layered haze is classified as a haze layer having an defined upper boundary, which is visible on the slide. The lower boundary is the ground.

2 Elevated layer only
An elevated, layered haze is classified as a haze having a defined upper and lower boundary, with the lower boundary not being the ground.

3 Multiple layers
More than one ground-based and/or elevated haze is visible in the slide.

4 (not currently used)

5 Weather obstructing scene
No haze layers are detected due to obstruction by weather phenomena such as clouds, fog, rain, snow, blowing dust, or other easily identifiable wind or moisture-related phenomena.

6 (not currently used)
7 (not currently used)
8 (not currently used)

9 To be used with target code of 9 or if a sky value cannot be determined due to reasons other than weather obstruction.

Completed Slide Coding Logs for each film roll will be stored with the slides in the designated film roll file folder. Slide codes will be entered into the slide database during slide scanning.

4.3 Quality Assurance

The quality of photographic material is subject to deviation in various forms. Throughout the purchasing, handling, and processing of film, care must be taken to maintain the highest possible quality standards. Through the observance of certain controls, near maximum quality results may be expected from photographic materials.

4.3.1 Film Purchasing, Handling, and Processing Quality Assurance Procedures

Quality assurance in purchasing, handling, and processing of visibility monitoring film necessitates the procedures outlined below:

I. Film Purchase

A. Buy cases of film directly from Kodak or through a direct Kodak distributor. All film in the cases must be from the same emulsion number.

B. Store all film in a low-humidity freezer.

C. Pull five rolls of film from the batch for permanent storage. This film archive will be used if further analysis of the emulsion characteristics is required.

D. Separate a number of rolls from the batch for quality assurance testing (see Field Procedures and Quality Assurance Tests discussions).

II. Field Procedures

A. Enough film will be shipped to each site to cover two seasons of monitoring.

B. All film will have the same emulsion number.

C. All film will be shipped in a labeled film storage box to allow for convenient separate storage at the site.

D. Film in the film storage box will be sealed in a zip-lock freezer bag with desiccant.

E. Two control rolls of film, pre-exposed with a grey scale and color bar, will be included in each film storage box. These rolls will be clearly labeled so that they can not be inadvertently used. A control roll will be returned to ARS at the end of each season with the last roll of film taken during the season. At ARS, the control roll will again be exposed with a grey scale and color bar. After processing, the two grey scales and color bars will be compared to evaluate the potential effects of film storage and transport (See Quality Assurance Tests discussions).

F. Film instructions will be issued to each site to keep the film frozen or at least refrigerated until use.

G. No film should be stored in the camera shelters.

H. Individual rolls of film will be tracked by emulsion number and roll number as entered by the operator on the film canister label.

I. Each camera box will have a maximum temperature recording thermometer. At each film change, the maximum temperature should be read, written on the Status Assessment Sheet, and the thermometer reset.

J. Field operators should mail exposed film immediately to ARS.

III. Quality Assurance (QA) Tests

A. Environmental Conditions - Field Storage Test

Two control rolls will be sent with each two seasons shipment of film to each site. The control rolls must be stored under conditions identical to the rest of the film for the site. At the end of each season a control roll will be returned to ARS. The following outline details the QA test.

- The beginning of the film will be exposed with a grey scale and color bar at ARS.
- Two rolls of the film will be mailed to each site with each two seasons supply of film.

- The film will be pre-numbered and clearly labeled so that the site operators will not inadvertently use the film.
- The control rolls will be stored under the same conditions as the rest of the film.
- At the end of each season, the operator will mail a control roll to ARS.
- Control rolls received at ARS will be stored in a cool location until all control rolls for a season are received. (This usually occurs over a two-week period.) After all rolls are received, the end of each control roll will be exposed to a grey scale and color bar.
- The end of a control roll that has been kept in the ARS freezer since the film was purchased will also be exposed to a color bar and grey scale to document any variations in grey scale and color bar exposure due to non-field-related circumstances.
- The control film will be sent to the L.A. Kodak processing lab.
- When the film is returned from the lab, the grey scale and color bars will be compared to identify any changes in film characteristics that could be attributed to how the film was shipped to and from the site or stored at the site.

B. Film Processing QA

- All film will be processed at the LA Kodak processing lab.
- Approximately 40 rolls of film from each emulsion will be exposed with a grey scale and color bar.
- A roll of this film will be sent along with each shipment of film that is sent to the LA Kodak lab for processing.
- The grey scale and color bars will be compared from shipment to shipment to identify any differences in film characteristics attributed to the shipment of film to the lab or the variation in processing.

5.0 DATA REDUCTION

A primary goal of visibility monitoring is to quantify how well the image-forming information in a vista is transmitted through the atmosphere to an observer some distance away. Determining how well information is transmitted requires an understanding of atmospheric extinction; the scattering and absorbing properties of the atmosphere that influence the transmission of light.

Until the recent development of this transmissometer, two primary operational measurement techniques were available: integrating nephelometers (Charlson et al., 1967) and teleradiometric techniques using natural targets (Malm and Molenar, 1984 and Johnson et al., 1986).

The approach used to quantify the visual air quality at this site is the measurement of sky/target contrast from 35mm color slides. These measurements emulate teleradiometer measurements.

The details of the data reduction techniques to be applied to the color slides are detailed in the following subsections.

5.1 Theoretical Considerations of Horizon/Sky Contrast Measurements

Color slides taken with cameras can be analyzed to emulate teleradiometer measurements. The following theoretical considerations will be applied in the data reduction process:

Basic Equations

Slide densitometry methods will be used to measure the sky/natural target contrast in the 550nm (green) wavelength 35mm color slides. The 550nm wavelength was chosen since it is the most dominant visible wavelength in the solar spectrum. These measurements will be reduced and reported as standard visual range (SVR) or extinction values. The equations and considerations used to calculate SVR and extinction from the measured sky/target contrast are based on various deviations and approximations in the literature (Middleton, 1958; Malm, 1979; Allard and Tombach, 1981). The basic equation relating sky and target (horizon) radiance (as measured by the teleradiometer) and atmospheric extinction is:

$$C_r = C_o \frac{{}_sN_o}{{}_sN_r} \exp\left(-\overline{b}_{ext} r\right) \qquad (5\text{-}1)$$

where $\overline{b}_{ext}$ is the average extinction coefficient between the observation point and a target located at a distance r; ${}_sN_o$ and ${}_sN_r$ are the sky radiance at the target and observation point respectively; and C_r and C_o are the apparent and inherent target contrasts given by:

$$C_r = \frac{{}_tN_r - {}_sN_r}{{}_sN_r} \tag{5-2}$$

$$C_o = \frac{{}_tN_o - {}_sN_o}{{}_sN_o} \tag{5-3}$$

where ${}_tN_o$ and ${}_tN_r$ are the inherent radiances of the target observed from distance = 0 and the observation point to target distance r.

C_r is a site specific value related to the characteristics of the target and to the target distance. To normalize site specific C_r values, a visual range, V_r, can be calculated from the C_r value by assuming:

1. ${}_sN_o = {}_sN_r$; (the sky radiance at the target and observer are equal);

2. $\bar{b}_{ext}$ is the same over the entire distance equal to the visual range as it is for the sight path r; and

3. C_o is known.

Under these conditions, Equation (5-1) can be solved for $\bar{b}_{ext}$ and related to V_r by:

$$V_r = 3.912/\bar{b}_{ext} \tag{5-4}$$

where:

$$\bar{b}_{ext} = \frac{1}{r} \ln \frac{C_o}{C_r} \tag{5-5}$$

A problem results when visual ranges, derived from sites at different altitudes, are directly compared. Even in a Rayleigh atmosphere, where only air molecules affect visual range, an observer can see farther at higher elevations than at sea level. Thus, a standard visual range (SVR) is calculated to normalize all visual ranges to a Rayleigh scattering coefficient of 0.01 km $^{-1}$ or an altitude of 1.55 km. SVR is calculated using:

$$SVR = 3.912/(\bar{b}_{ext} - b_{ray} + 0.01\ \text{km}^{-1}) \tag{5-6}$$

The Rayleigh scattering coefficient, b_{ray}, for the mean sight path altitude is subtracted from the calculated extinction coefficient, b_{ext}, and the standard Rayleigh scattering coefficient of 0.01 km^{-1} is added back (EPA, 1980).

Standard visual range can be interpreted as the farthest distance that a large, black target can be seen on the horizon. It is a useful visibility index that allows for comparison of data taken at various locations. Note that SVR only describes the conditions in the measured sight path and does not account for layered haze or other visibility-related influences in a vista that do not fall within the measured sight path.

Determining Target Inherent Contrast

Careful approximation of inherent contrast for each target and time of day that contrast measurements are made is essential. Four primary methods have been used to approximate C_0:

1. Direct measurement;
2. Calculation from target contrast measurements obtained on near Rayleigh days;
3. Estimated from SVR cumulative frequency plots; and
4. Extrapolations of C_0 from target contrast measurements of the same target at various distances, or measurement of C_r of a number of identical collinear targets that are located at different distances.

Table 5-1 summarizes the advantages and limitations associated with each technique.

The direct measurement technique requires that radiometric measurements be made within a few meters of the target. At these close distances, the field of view of the standard monitoring instruments severely limits the size of the target from which the measurement is made. Consequently, a successful direct measurement of inherent contrast requires either very uniform targets, spatially average inherent radiance measurements made from the face of the target so that the average inherent radiance is comparable to the teleradiometer's field of view at normal operating distances, or a specific teleradiometer with a significantly larger field of view. In practice, it is almost always difficult to achieve the proximity to actual targets required to make a measurement. Also, the target usually is not entirely uniform, and it is nearly impossible to make an inherent contrast measurement that corresponds to the exact field of view of the teleradiometer at normal operating distances.

The second method of determining C_0 from measurements of C_r on clear days requires an independent measurement to establish that the atmosphere is essentially free of particles so that only Rayleigh scattering takes place. If it is assumed that ${}_sN_0 = {}_sN_r$, and $b_{ext} = b_{ray}$, Equation 5-1 can be solved for C_0 in terms of C_r and b_{ray}. A difficulty associated with this technique is the requirement that a monitoring program must have been operated over an extended time period in order to be certain that a number of measurements are made on particle-free days.

A third method to estimate C_0 uses the cumulative frequency distributions of SVR. The cumulative frequency technique (CFT) is used to

Table 5-1

Summary of Assumptions, Advantages, and Disadvantages of Various Techniques for Determining Inherent Contrast

	Direct measurement of C_0	Calculation from C_r on Rayleigh clear sky days	Estimation from cumulative frequency distribution of SVR	Interpolation from multiple measurements of C_r: Multiple teleradiometer, single target	Interpolation from multiple measurements of C_r: Multiple collinear targets with single teleradiometer
Assumptions	1. Uniform target over large spatial area	1. $\bar{b}_{ray} \gg \bar{b}_{aerosol}$ 2. ${}_sN_0/{}_tN_0$ and $\bar{b}_{ext}$ errors cancel on near Rayleigh days	1. Lognormal distribution of SVR 2. No local sources of air pollution affecting target sight paths	1. ${}_sN_0/{}_sN_r$ and $\bar{b}_{ext}$ cancel under all atmospheric loading conditions 2. Uniform target/targets 3. Uniform sight paths	
Disadvantages	1. Difficult to measure same field of view at various distances 2. Difficult to get close to most real targets	1. Atmosphere never truly free of aerosols 2. Monitoring over extensive time period needed to make a number of measurements on near Rayleigh days	1. Nonuniform sight paths 2. Monitoring over extensive time period needed to make a number of measurements on near Rayleigh days	1. Costly; manpower and time in field 2. Above assumptions rarely if ever met	1. Very few colinear uniform targets having same C_0
Advantages	1. Only technique that is a direct measurement of C_0	1. Simple data processing 2. With large data base technique can be reiterated to improve estimates of C_0	1. Simple data processing 2. When combined with Rayleigh estimates, allows fine tuning of estimates	1. None	1. For a few specific sites may be practical and useful

fine-tune C_o values that have been measured or calculated using methods 1 or 2. The use of CFT is best understood by examining log-normal probability plots of SVR. Figures 5-1a and 5-1b are log-normal cumulative frequency plots of SVR derived from teleradiometer measurements of four different targets at Grand Canyon during fall 1982 (September, October, and November). Figure 5-1a shows the distribution of SVR with proper C_o while Figure 5-1b shows the effect of choosing the wrong C_o for one target. In Figure 5-1a, with the proper choice of C_o values, the distribution of SVR corresponding to each target will be similar and converge at 391 km, the theoretical maximum SVR. Figure 5-1b, on the other hand, shows the effect of choosing a C_o which is too large. In Figure 5-1a, the C_o values for the Red Butte target are -0.87, -0.87, and -0.87 at 9:00, 12:00 noon, and 15:00 respectively, while in Figure 5-1b the C_o values are -0.60, -0.60, and -0.60. Figure 5-1b shows that the SVR calculation with the wrong choice C_o yields a distribution of SVR which is not physically possible; seventy percent of the time SVR was greater than the Rayleigh limit of 391 km. As in method 2, this technique requires monitoring over an extended time period to provide sufficient data.

The fourth method employs either: 1) simultaneous teleradiometer measurements of sky-target contrast of a number of targets located at various distances from the observer, but with the same directional orientation (same observation zenith and azimuth angles), or 2) simultaneous measurements of sky-target contrast of the same target at various distances. The rationale for making a set of measurements of this type for the purpose of calculating C_o lies in rearranging Equation 5-1 so that it fits the form of a straight line:

$$\ln C_r = -\bar{b}_{ext} r + \ln \left(\frac{C_o\,{}_sN_o}{{}_sN_r}\right) \qquad (5\text{-}7)$$

If the natural log of sky-target contrast is plotted as a function of target distance r, the slope of this line is $-b_{ext}$ and the intercept is $\ln (C_o\ {}_sN_o/{}_sN_r)$.

This method has several limitations. First, $\ln (C_r)$ does not vary linearly with r because b_{ext} and ${}_sN_o/{}_sN_r$ are not constant with distance; both are a function of observation angle and distance between the observer and target. Second, targets with nearly the same observation zenith and azimuth angles that are located at different distances are not commonly available. Third, it is inconvenient, and many times physically impossible, to make measurements of the same target at different distances and at the same angles of observation.

All four of these procedures have been applied to contrast data gathered in monitoring networks. In most cases method 2 is used to establish a first approximation for C_o, while method 3 is used to refine the initial C_o estimations. Method 1 and particularly Method 4, although conceptually sound, have proved to be difficult to employ under "real-world" conditions.

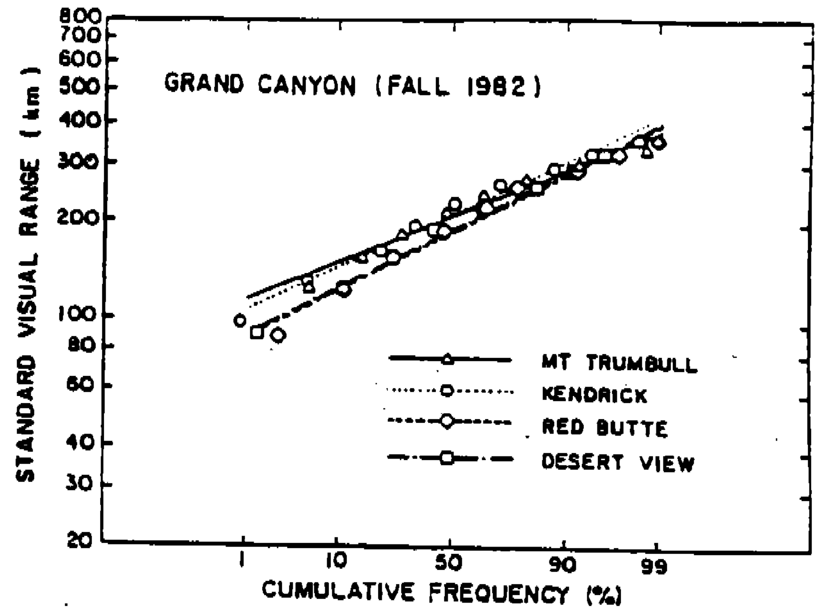


Figure 5-1a.

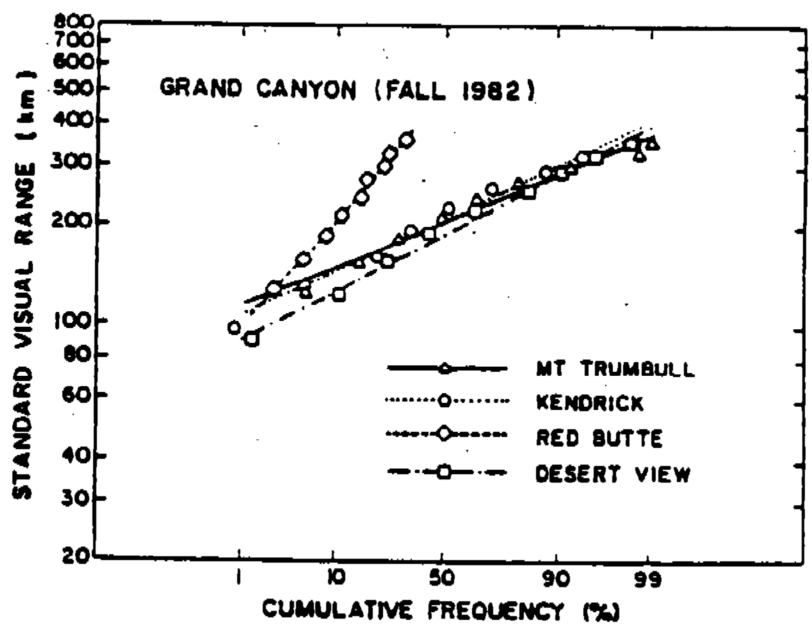


Figure 5-1b.

Figure 5-1. Cumulative Frequency of SVR That Corresponds to Contrast Measurements of Four Different Grand Canyon Teleradiometer Targets. Figure 5-1a Shows the Distribution of SVR With Correct C_0's While Figure 5-1b Shows the Effect of Increasing the Inherent Contrast of the Red Butte Target From -0.87 to -0.60.

At this site, Methods 2 (calculation from near Rayleigh days) and 3 (estimation from cumulative frequency plots), be applied to estimate inherent contrasts. An annual C_o will be estimated for each time and target for each site.

Proper site and target selection also reduces the uncertainty in estimating C_o values. The sensitivity of C_o is reduced for dark targets selected at distances between 60% and 90% of the visual range. By selecting multiple targets at various distances from the observation point, SVR values calculated for each target as a function of the individual target C_os values can be compared to help identify C_o errors.

Consideration of Error

The assumptions required to solve Equation 5-1 for visual range or b_{ext} are rarely met. Specifically, ${}_sN_o/{}_sN_r$ is rarely ever equal to one, and for most natural targets C_o varies with target and sky illumination conditions. Malm and Tomback (1986) investigated the error in calculated extinction associated with the uncertainty in ${}_sN_o/{}_sN_r$ and C_o under idealized clear-sky, uniform illumination conditions. Figure 5-2 presents the results of their investigation for a 50 km target with inherent contrast values on a Rayleigh day of -1.0, -0.80, and -0.60, as a function of aerosol extinction. Figure 5-2a shows the expected error in extinction when back scattering conditions occur (scattering angle 158^o). Figure 5-2b shows the expected error in extinction when forward scattering occurs (scattering angle 27^o). For C_o = -1.0, extinction error is only due to changes in ${}_sN_o/{}_sN_r$ as the aerosol loading changes. Extinction error curves for C_o = -0.80 and -0.60 show the additional error associated with variations in C_o as a function of aerosol loading.

The results of this analysis show that, "as b_{ext} increases, there is an increasing error in C_o and the error in "measured" extinction increases. The error is most pronounced for "back scatter" conditions and for targets with a Rayleigh inherent contrast smaller in magnitude than about -0.80" (Malm and Tombach, 1986).

Malm and Tombach further emphasize that:

- Brightly colored targets should only be used when shaded or when forward scattering conditions exist.
- Imperfect C_o estimates for targets less than 50 km would yield higher error than imperfect C_o estimates for targets greater than 50 km. However, as target distance increases to a point where apparent contrast measurements of -0.05 occur, the error in apparent contrast measurements will begin to dominate.
- To minimize C_o and C_r errors, target distances should be kept between 60% and 90% of the average visual range (U.S. EPA, 1980), and the observation point and target should be at nearly the same elevation.

Figure 5-2a.

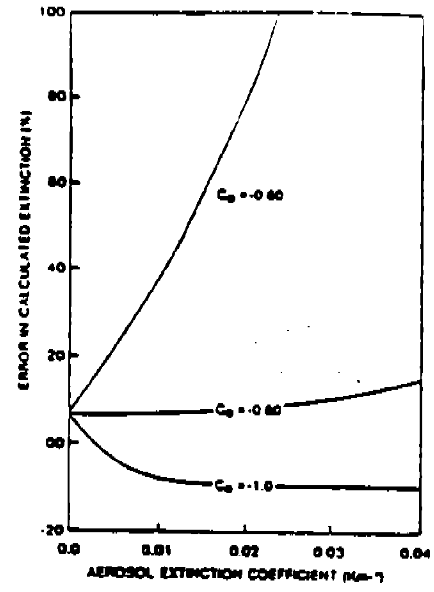


Figure 5-2b.

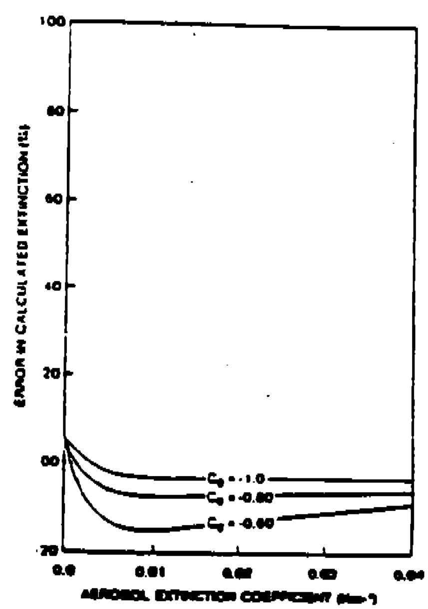


Figure 5-2. Error Associated With Calculating Extinction From a Single Contrast Measurement of a 50 km Target as a Function of Aerosol Extinction and Inherent Contrast Measured on a Rayleigh Day. The Scattering Angle Between Sun and Observer in Figure 5-2a is 158° (backscatter), and in Figure 5-2b it is 27° (forward scattering). From Malm and Tombach (1986).

- For other than cloud-free conditions where illumination is uniform, the non-uniformity in illumination of the target, sky or cloud behind the target, and sight path increases the uncertainty in calculated extinction.

This error analysis by Malm and Tombach emphasizes the need to carefully select visibility monitoring sites and targets, individually evaluate each visibility measurement and carefully estimate C_0 values.

Perfect site and target selection is often difficult. Geography and operational logistics do not always follow the rules required to minimize error. The conditions associated with each visibility measurement must be also be individually considered. The sky and target conditions must be considered in the analysis routines. However, with the measurement techniques applied, it is impossible to accurately account for every variation in target, sky, and sight path illumination. Averaging, estimating and reporting over longer time periods, such as seasons, may help compensate for random measurement error.

The best monitoring, analysis, and quality control techniques available to minimize error will be applied to the collection and processing of visibility data in this proposed effort.

5.2 Slide Densitometry

Theoretical System and Processing Considerations

Air Resource Specialists, the National Park Service, and Optec developed an integrated system to make quantitative measurements of visibility-related parameters directly from photographic slides. The slide scanner is a microcomputer-controlled optical densitometer specifically developed to handle slides. The system is coupled with a larger data-processing computer. System specifications are detailed in Table 5-2. The system can make precise readings of slide transmissions. Most importantly, the scanner can emulate the geometry of the teleradiometer and make sky and target slide transmission readings at the same angular separation as a teleradiometer would directly make readings of the same vista. The measured sky and target slide transmission readings can be used to estimate extinction and SVR. The slide scanning densitometer and specific analysis techniques are fully discussed in a paper by Johnson (et al., 1986), and are briefly described below.

The photographic slide is a transformed representation of a scene's radiance field at the moment of exposure; the transformation function is the light response of the film known as the charachertistic curve. At a later time this transformed radiance field can be regenerated by passing light through the slide, and slide transmission measurements can be made by a densitometer.

The immediate output of the slide scanning densitometer is two slide transmission readings: one of the target and the other of the sky

Table 5-2

Slide Scanning Densitometer
"Slide Scanner" Specifications

Scanning Densitometer	
Aperture diameter (μm)	100
Minimum scan increment (μm)	2.64
Maximum number of increments	8192
Maximum scan length (mm)	21.6
Maximum number of readings	768
Slide density limit	3.61
Narrow band filters (nm)	405,450,500,550,600,630
Cone-response filters	Blue, Green, Red
Teleradiometer Simulator	
Effective detector diameter (μm)	152
Detector angle (degrees)[a]	0.065
Sky-target separation	805.2
Sky-target angle (degrees)[a]	0.342

[a]Assuming a 135mm lens on the field camera.

immediately above the target. These two values are combined to give target/sky slide contrast, where C is the target/sky target contrast, T_t is the target slide transmission, and T_s is the sky slide transmission.

$$C = T_t/T_s - 1 \qquad (5\text{-}8)$$

This quantity does not yet relate directly to actual atmospheric or associated visibility parameters because of the function relating sky and target radiance (expressed as film exposure) to film density. This function is the characteristic curve of the film expressed as density vs. $\log_{10}$ exposure (where exposure = radiance multiplied by time). To calculate actual target/sky contrast, the above slide transmission values first must be converted to corresponding density values by using:

$$D = \log_{10}(1/T) \qquad (5\text{-}9)$$

where T is a target or sky slide transmission and D is the resulting density. Then, by using the characterisitc curve function, the resulting slide densities can be converted to actual target/sky contrast using:

$$C' = 10^{g(D_s)}/10^{g(D_t)} - 1 \qquad (5\text{-}10)$$

where C' is the actual target/sky contrast (the slide contrast C with effects of the film response removed), and g is the film response function that converts absolute slide density to the logarithm of film exposure.

Even though only relative sky and target radiances can be calculated (unless the duration of film exposure is known), an absolute contrast calculation is still possible because of the ratio of radiances in Equation 5-10. This also means that shifts in the film speed (horizontal translations of the characteristic curve) due to variations in emulsion sensitivity or processing do not affect the calculation of target/sky contrast. However, changes in the slope of this function can affect the calculation. Once target/sky contrast is calculated, standard teleradiometric data-processing procedures can convert these values to standard visual range or extinction.

System performance of the slide scanning densitometer relative to simultaneous teleradiometer measurements was evaluated by Johnson. Several statistical analyses on up to 1441 data pairs were performed including correlation, linear regression, average bias and difference calculations, and cumulative frequency distribution comparisons. Absolute densitometer precision was very good. Accuracy and precision in estimating target/sky contrast and standard visual range from photographic slides, when compared to simultaneous teleradiometer measurements, were also high and peaked when middle-range targets, around 50 km, were used. Imperfectly quantified nonlinearities in the film characteristic curve caused a small reduction in accuracy when using near or distant targets. Table 5-3 presents a summary of the analysis results.

Table 5-3

Statistics, Regression Results, and Correlations
Between Teleradiometer and Slide Radiance Ratios

Location	Target distance (km)	Number of data points	Teleradiometer ratio mean	Slide ratio mean	Correlation Coefficient	Regression coeff.	Regression intercept	Variance explained (R^2)	Average absolute difference[a]	Average bias[a]
Shenandoah	14	41	.786	.732	.96	.82	.188	.92	.116	.089
Theodore Roosevelt	27	258	.662	.662	.94	.88	.081	.88	.055	.004
Big Bend	31	193	.682	.671	.88	.90	.075	.78	.074	.015
Joshua Tree	47	174	.757	.748	.97	.97	.031	.95	.035	.012
Grand Canyon	77	232	.818	.799	.89	.85	.136	.80	.040	.024
Grand Canyon	96	259	.859	.816	.92	.80	.205	.85	.044	.041
Bryce Canyon	130	284	.898	.882	.92	.77	.221	.84	.029	.019

[a]Average absolute difference = $(1/N)\Sigma|2(T_i-S_i)/(T_i+S_i)|$, and
Average bias = $(1/N)\Sigma 2(T_i-S_i)/(T_i+S_i)$, where
N=number of data points, T_i and S_i are the teleradiometer and slide radiance ratios,
and the sums are over all data points. Formulas are from reference 13.

Referring to Table 5-3, at all locations the means of the teleradiometer and slide radiance ratios were very close, with Shenandoah having the largest difference. Correlation between the radiance ratios was greater than 0.88 in all cases and reached as high as 0.97 for Joshua Tree. R^2 (variance explained) was very high in all cases, ranging from 0.78 to 0.95; this reflected the high correlation between the independent and dependent variables, good system precision, and the overall adequacy of the statistical model.

In addition, judging from the regression coefficient, intercept and regression plots, system accuracy was also very good, although the slide ratios were slightly lower than simultaneous teleradiometer ratios.

Since Johnson's work was completed, identical tests performed on simultaneous slide and teleradiometer data sets from the Pacific Northwest yielded similar results (Air Resource Specialists, 1985). Overall research indicates that 35mm cameras taking color photographs are an acceptable technique for simulating relative teleradiometer radiance measurements. Slide-derived measurements accurately emulate teleradiometer measurements.

Slide Scanning

At the end of each season, slides will be quantitatively scanned. All scanning will be performed by slide scanning technicians under the direction of the Photographic Data Coordinator. ARS has over four year's experience in the quality assured operation and maintenance of the slide scanner.

Operational slide scanning procedures are listed below:

- Calibration - At four-hour intervals, the scanner is calibrated against a standard step grey scale slide. The density of each step of the gray scale is known, as measured by a standard calibrated densitometer. A direct comparison can be made between the calibrated densitometer and the scanner. A calibration curve derived from the calibration procedure is entered into the scanner and is automatically applied to each measurement. All calibrations are logged in the slide scanning operations log.

- Interactive Scanning - The slide scanning program is completely interactive and efficient. The slide scanning technician first visually reviews the slide, checks the slide sequence, checks the slide codes, and notes any inconsistencies. The technician next aligns and scans the target/sky contrast for each target on each slide. The interactive scanner program prompts the operator for site, date, slide number, time, target, and slide code. The results of the scan are immediately available to the operator for review as slide contrast, scene contrast (characteristic curve corrected), and roughly estimated SVR.

The results of the previous scan are also simultaneously displayed to allow for sequence consistency.

- Data Storage - If the operator chooses to accept the scan, the data are automatically transferred to the site file on the NPS computer. A quality assurance code is also calculated and tagged to the data that includes scan date, time, operator initials, and edit protect codes.

- Quality Assurance - When all scanning for a site is completed, the file is reviewed by the Photographic Data Coordinator. The file must account for each day and time during the season, whether a slide was taken or not. Five percent of the slides for each site for each season will be randomly selected and re-scanned. All scan values must be within ± 0.02 slide contrast or a re-scanning of the site will be ordered. All completed files will be stored as .SLD files. A copy of a portion of a seasonal .SLD file is provided as Figure 5-3.

Processing

Data will be processed seasonally. Each .SLD file will be run through the existing SVR program, a program specifically designed to perform edit checks and yield SVR or extinction results. The edit checks and processing considerations applied by the program include:

- File Integrity Check - Each site file is checked to verify that each date, time, and target is accounted for and that the range in each file field is acceptable. Each file must contain all possible dates and times for a season regardless of whether or not an observation was taken. This approach ensures consistency in all files.

- Site/Target Specifications - The site and target specifications, including inherent contrasts, used by the program are extracted from the master site specifications file.

- Non-Standard Target Illumination - Because estimates of C_o are made with data from cloud-free days, these estimates take into account any direct illumination of the target by the sun. However, it is important to identify when a target is shaded by clouds. If the target is shaded and a C_o is used that will account for the target in the sun, the calculated SVR will be too high. The SVR program will check for visibility slide codes indicating non standard illumination conditions. If a target is identified as shaded, a default target-in-shade C_o of -0.95 will be assigned for calculation of SVR.

```
B:TACB863.SLD
12:11 pm, Friday, January 23, 1987

!---------+---------+---------+---------+---------+---------+---------+

TACB    1086 6 11111207355 4184080 0.894-0.043860820201817DJD768B
TACB    1086 6 11211202620 4094080 0.894-0.043860820201900DJD164D
TACB    1186 6 12111208465 4744080 0.894-0.043860820201937DJD768B
TACB    1186 6 12211205744 4814080 0.894-0.043860820202000DJDD6C0
TACB    1286 6 13101208467 5454080 0.894-0.043860820202035DJDD6C0
TACB    1286 6 13201207056 5374080 0.894-0.043860820202106DJD360F
TACB    1386 6 21110107859 4324080 0.894-0.043860820202147DJD56C9
TACB    1386 6 21210103225 4364080 0.894-0.043860820202213DJD56C9
TACB    1486 6 22111206551 4814080 0.894-0.043860820202303DJDD6C0
TACB    1486 6 22211203729 4784080 0.894-0.043860820202330DJD066C
TACB    1586 6 23101208468 5494080 0.894-0.043860820202406DJDE6A3
TACB    1586 6 23201207360 5694080 0.894-0.043860820202426DJDD6C0
TACB    1686 6 31110015843 3804080 0.894-0.043860820202505DJD46E8
TACB    1686 6 31210011914 3924080 0.894-0.043860820202526DJD262E
TACB    1786 6 32111205341 4504080 0.894-0.043860820202558DJDF682
```

EXPLANATION OF SLIDE FILE (.SLD) CHARACTERS

```
         1         2         3         4         5         6
1234567890123456789012345678901234567890123456789012345678901234

TACB     785122021101054322094092 0.872-0.017860819003116DJDF790
TACB     785122022101035202184092 0.872-0.017860819003142DJD9756
TACB     885122031000070493654092 0.872-0.017860819003217DJD273C
TACB     885122032000057403704092 0.872-0.017860819003242DJD9756
```

COLUMNS	DATA
1-4	SITE CODE
5-9	SLIDE ID NUMBER
10-11	YEAR
12-13	MONTH
14-15	DAY
16	TIME CODE (1=9:00, 2=12:00, 3=15:00 LOCAL TIME)
17	TARGET CODE
18-21	SLIDE METEOROLOGICAL CODE
22-23	SLIDE CONTRAST
24-25	SCENE CONTRAST
26-29	AVERAGE SKY A/D VALUE
30-33	CLEAR VALUE
34-39	CALIBRATION SLOPE
40-45	CALIBRATION INTERCEPT
46-51	DATE SLIDE SCANNED
52-57	TIME SLIDE SCANNED
58-60	OPERATORS INITIALS
61-64	16-BIT ERROR CHECK CODE

Figure 5-3. Portion of a .SLD Seasonal Contrast Slide Scanning Results File.

- o Snow-Covered Targets - If a target is snow-covered, the apparent contrast measurement is not used to calculate an SVR. Because extreme variations in C_o occur for snow covered targets, reasonable estimates of C_o are impossible.

- o Obscured Targets - When the target cannot be seen, a contrast measurement cannot be made, but the reason that the target was obscured is important. If a monitoring target cannot be seen due to weather conditions, such as clouds that hide the target, a SVR is not calculated or estimated. However, if the target is not visible due to haze that exists between the observer and the target, the following SVR considerations are applied:

  - Calculation of a finite SVR for haze-obscured targets is impossible; however, the SVR must be less than or equal to the target distance. To consider haze-obscured observations in the cumulative frequency distribution used to approximate the seasonal median SVR, a finite SVR value must be assigned to the haze-obscured observations. The standard procedure is to assign an SVR equal to the target distance to any target so obscured-by-haze that the observer cannot see the target.

  The occurrence of haze-obscured targets must be included in the SVR cumulative frequency distribution, otherwise severe haze conditions would be ignored and the SVR distribution would be biased toward clean values.

- o All Other Conditions - Measured contrast values taken under all other conditions that pass specified edit checks are considered valid and are used to calculate SVR.

The results of data processing include a SVR data file, a seasonal summary plot file, and a printed report file. Examples of the SVR data file is provided as Figure 5-4; report files are discussed in more detail in Section 6. All results are thoroughly reviewed with project technical administration. Because all files and programs are easily handled and efficiently run, any identified inconsistencies in the results can be readily investigated.

6.0 REPORTING AND ARCHIVING

All data and analytical results will be output as a combination of listings, summaries, discussions, charts and graphs. All results will present information clearly so that it can be interpreted effectively by scientific and non-scientific personnel. Collected data will be presented in quarterly reports. Data presentations vary based on user needs and preference. The typical or standard data presentations included in the seasonal reports are presented in the following subsections.

All presentations listed below assume that data will be primarily summarized as standard visual range.

6.1 Quarterly Data Report Products

The standard seasonal reporting format for collected visibility data will be the Quarterly Data Report. The report will be delivered 90 days after the conclusion of the season to which the data pertains. It is assumed that the visibility monitoring seasons will be defined by the NPS standard:

Winter - December, January, February
Spring - March, April, May
Summer - June, July, August
Fall - September, October, November

The major components of the Quarterly Data Report will be the site specific seasonal summary plots, daily SVR plots by month, cumulative frequency analysis statistical summary, and a qualitative slide code summary. All raw and analyzed data will also be provided on IBM PC-compatible disks or stored in a user-specified database. All original slides will be either archived at ARS of delivered quarterly as specified by the client.

6.1.1 Seasonal Summary Plot

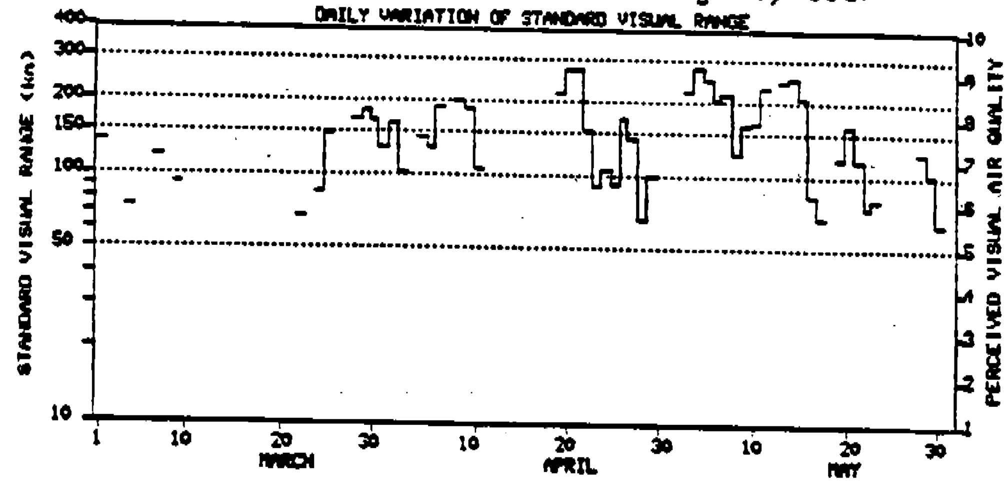
An example Seasonal Summary Plot is provided as Figure 6-1. The plot includes three data summaries entitled:

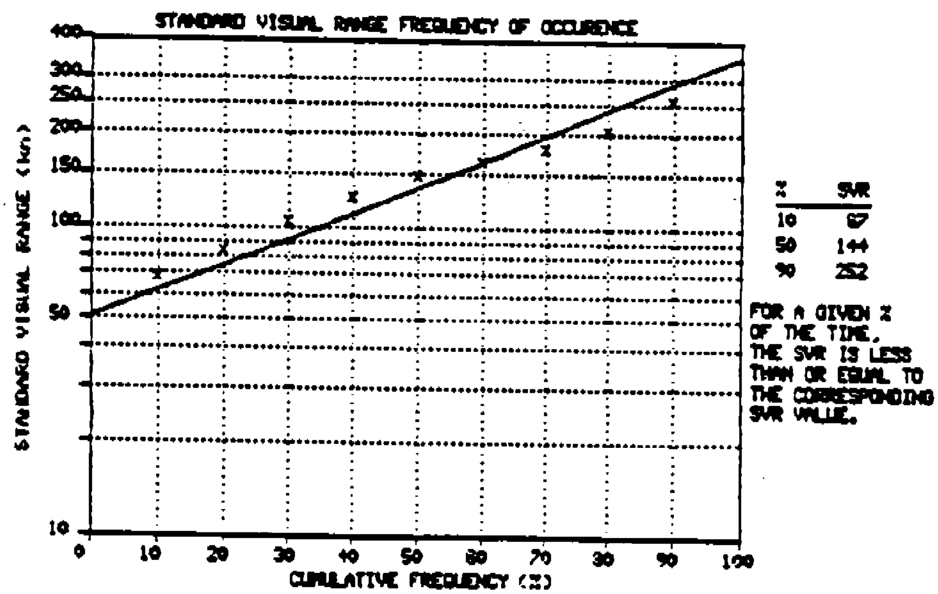
Daily Variation of Standard Visual Range
Standard Visual Range Frequency of Occurrence
Data Recovery Statistics.

Daily Variations of Standard Visual Range

The daily variation of standard visual range plot displays the daily geometric mean SVR values for each day of the reporting season. Each bar represents the daily geometric mean SVR calculated from all observations taken during that day. The plot includes values calculated for all targets and times. Gaps in the plot indicate that data were missing or failed the edit procedures.

IMPROVE Network
Data Analysis Report
Crater Lake National Park, Oregon
Spring Season: March 1 to May 31, 1987





DATA RECOVERY STATISTICS

CATEGORY	NUM	%
TOTAL POSSIBLE OBSERVATIONS IN THE TIME PERIOD	276	100
OBSERVATIONS COLLECTED	180	65
OBSERVATIONS USABLE FOR SVR CALCULATIONS	135	49

Figure 6-1. Seasonal Summary Plot.

Standard Visual Range Frequency of Occurrence

Cumulative frequency distributions are a concise way to represent and analyze seasonal visibility data. A rank-order cumulative frequency method (or count method) has been selected to represent the SVR results. Starting with the Fall 1986 season this method replaces the log-normal cumulative frequency distribution method for reporting seasonal SVR values.

Each valid visibility observation of target/sky contrast is converted to an SVR value. When the target cannot be seen a contrast measurement cannot be made, but the reason that the target was invisible is important. If a monitoring target cannot be seen due to weather conditions, such as clouds that hide the target, a SVR is not calculated or estimated. However, if the target is not visible due to haze that exists between the observer and the target, the following SVR considerations are applied.

- Calculation of a finite SVR is impossible; however, the SVR must be less than or equal to the target distance. Since a cumulative frequency distribution cannot include non-finite SVR values, the standard NPS procedure is to assign an SVR equal to the target distance to any target so obscured-by-haze that the observer cannot see the target.

The occurrences of haze-obscured targets must be included in the SVR cumulative frequency distribution, otherwise, severe haze conditions would be ignored and the SVR distribution would be biased toward clean values.

After each individual observation is considered, the SVR data set is analyzed as a rank-order cumulative frequency distribution. All valid SVR values for a particular site and season are sorted from low to high. The minimum SVR possible is the target distance and the theoretical maximum SVR is 391 km. The 50% value is the median value of the set of valid observations, half of the ordered values are lower than the 50% value and half of the values are higher. The 10% level represents that 10% of the valid observations are lower than or equal to the 10% value. The 90% level represents that 90% of the valid observations are lower than or equal to the 90% value. The actual 10%, 50%, and 90% values are reported. The SVR values corresponding to every tenth percent of the data are then plotted on a rank-order cumulative probability graph. A least squares line is computed to fit this distribution. The slope of the line is an indication of the variability of the SVR values calculated for the time period. A steep slope indicates high variability and a flat slope indicates little variability.

Data Recovery Statistics

The data recovery statistics are presented as numerical and percentage representations of actual to possible observations:

- Total Possible Observations in the Time Period - Refers to the number of observations a day times the number of days in the season. The Total Possible Category is the theoretical maximum number of observations possible during a season.

- Observations Collected - Represents the number of observations actually collected during a season. The percentage collection efficiency represents the number of observations as compared to the total possible observations.
- Observations Usable for SVR Calculations - Is the number of observations remaining after discounting data that failed edit or quality control checks. The percentage of Observations Usable represents the number of usable observations as compared to the total possible observations.

6.1.2 Daily SVR Plots by Month

The daily SVR plots by month include a graphic representation of the daily maximum, minimum, and geometric mean SVR. An example plot is provided as Figure 6-2.

6.1.3 Cumulative Frequency Statistics Table

The Cumulative Frequency Statistics Table summarizes the site specification, target conditions, SVR statistics, and cumulative frequency parameters. An example summary table is presented as Figure 6-3. The slope and intercept data available in the table can be used to determine a cumulative frequency level for any SVR value. An example calculation is provided in Appendix B.

6.1.4 Qualitative Slide Code Summary

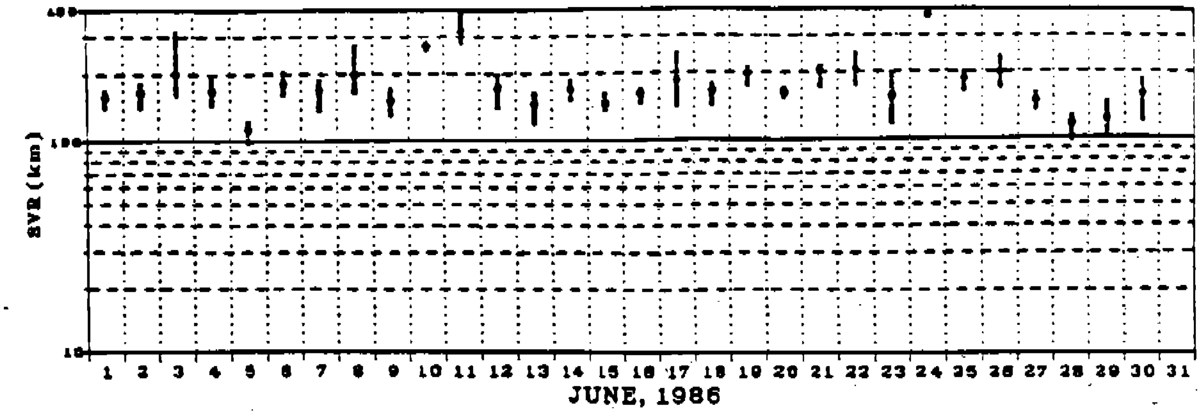
As described in Section 4.2, each slide will be visually scrutinized to identify the types of meteorological and haze conditions that exist in the view. From these codes, a summary of observed haze types will be compiled for each season. An example summary is provided as Figure 6-4. When distinct haze layers are visible, they will be identified as ground-based, elevated or simultaneous ground-based and elevated hazes. All cases where the target is visible and no distinct haze layer occurred will be classified as uniform haze. All cases when haze or weather obscure the target will also be noted.

6.2 Archive

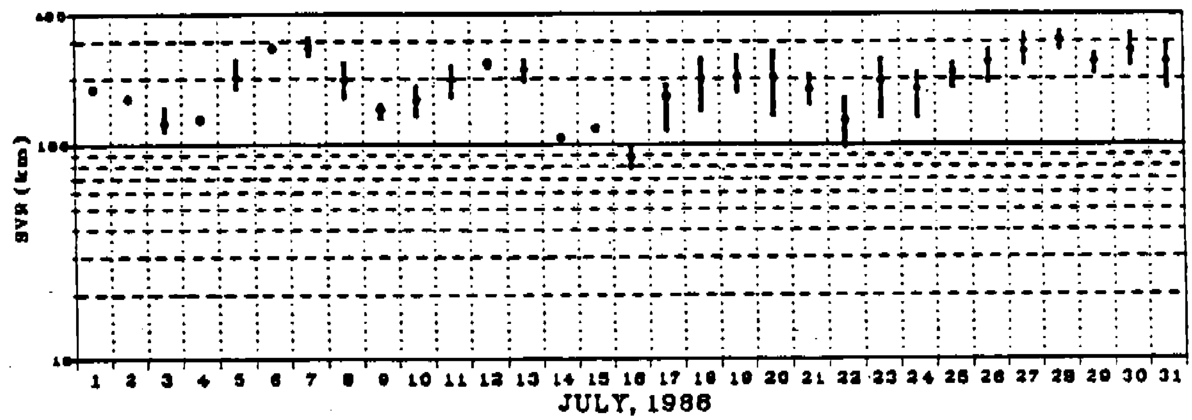
6.2.1 Slide Archive

All slides are stored in non-gassing, polyethylene sheets. All slides from federal land management agency sites are filed by site, season, and date (roll). All files are kept alphabetically in standard file cabinets at ARS. Slides are returned directly to most other clients such as state agencies.

SIERRA ANCHA WILDERNESS, ARIZONA
STANDARD VISUAL RANGE DAILY SUMMARY



SIERRA ANCHA WILDERNESS, ARIZONA
STANDARD VISUAL RANGE DAILY SUMMARY



SIERRA ANCHA WILDERNESS, ARIZONA
STANDARD VISUAL RANGE DAILY SUMMARY

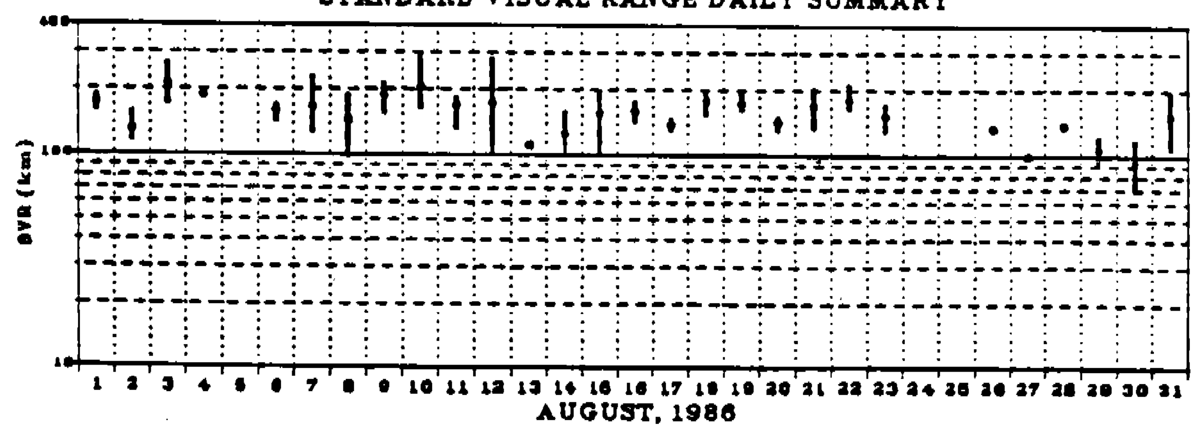


Figure 6-2. Example Monthly Plots of Daily Mean, Maximum, and Minimum SVR Values.

Fall 1987 Elevation: 0.60 km

Target	D	Z	E	A	R	0900	1200	1500
1 TARGET 1	31.5	319	1.950	2.45	1.022	-0.78	-0.72	-0.72
2 TARGET 2	26.7	323	1.660	2.27	1.033	-0.85	-0.74	-0.78

D The straight-line distance in kilometers from the monitoring site to the target.
Z Azimuth in degrees true from the monitoring site to the target.
E Elevation of the target in kilometers.
A Angle of elevation in degrees from the monitoring site to the target.
R Rayleigh coefficient at 550 nanometers for the median site path elevation.

The values following the target geographic statistics are the inherent contrast values determined for the target(s) at the indicated times.

TARGET CONDITION SUMMARY
(Number of occurrences for each condition)

TARGET #	1	2	ALL
Snow covered:	0	0	0
Shaded:	103	99	202
Cloud behind:	108	111	219
Cloud-obscured:	14	9	23
Haze-obscured:	0	0	0
Bad contrast:	0	0	0
Missed readings:	14	14	28
Not usable:	0	0	0
SVR>391:	0	0	0
CR<Rayleigh:	4	4	8
Good SVR's:	248	253	501
Total Observed:	262	262	524

SVR STATISTICS

TARGET #	1	2	ALL
Minimum SVR:	39	38	38
Maximum SVR:	391	391	391
Arithmetic mean:	156.6	146.1	151.3
Arithmetic SD:	64.9	64.6	64.9
Geometric mean:	144.8	134.0	139.2
Geometric SD:	1.49	1.51	1.50

LOG-LINEAR SVR CUMULATIVE FREQUENCY ANALYSIS

TARGET #	1	2	ALL
Points:	248	253	501
Slope:	1.37	1.44	1.41
Intercept:	75.17	67.09	71.01
Correlation:	0.96	0.95	0.95
10% level:	87	79	83
50% level:	142	133	138
90% level:	242	224	233

The "Slope"and "Intercept" values in the statistics summary may be used for calculating the SVR for any given cumulative frequency value. See Appendix B for a discussion and the applicable equations with examples.

Figure 6-3. Example Cumulative Frequency Statistics Table.

Qualitative Slide Analysis
Sierra Ancha, AZ
Summer 1986

Site & Target	Month	Total Observation	Uniform Haze	Ground Based Layered Haze	Elevated Layered Haze	Multiple Layers	Target Obscurred by Haze	Target Obscurred by Weather
SIERRA ANCHA "Mount Turnbull" T1	JUNE	89	54	10	1	0	19	5
	JUL	87	57	8	0	0	7	15
Summer 86	AUG	84	23	1	0	0	41	19
	TOTAL	260 (100%)	134 (52%)	19 (7%)	1 (0%)	0 (0%)	67 (26%)	39 (15%)
SIERRA ANCHA "Apache Ridges" T2	JUN	89	77	10	1	0	0	1
	JUL	87	75	8	0	0	0	4
Summer 86	AUG	84	70	3	0	0	0	11
	TOTAL	260 (100%)	222 (85%)	21 (8%)	1 (0%)	0 (0%)	0 (0%)	16 (6%)

Figure 6-4. Example Qualitative Slide Code Analysis.

6.2.2 Data Archive

An original and duplicate digital copy of all slide contrast and SVR data files are kept at ARS. NPS and IMPROVE files are currently being integrated into a comprehensive visibility database. For other federal agencies and clients, duplicate IBM, PC-compatible floppy disks or 9-track ASCII tapes of all data are sent along with the seasonal report.

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APPENDIX A

Automatic 35mm Camera System User's Manual

Automatic 35 mm Camera System
User's Manual

CONTAX SYSTEM

INTRODUCTION

Photographs are a quality way to monitor visibility. Following the procedures in this manual will ensure high quality, consistent visibility monitoring.

This manual supplements, but does not replace the Contax Equipment Instruction Manuals. *Manuals for each camera component should be read and kept with your camera log book for easy reference.*

CAMERA HARDWARE

Camera: Contax 137MA Quartz
Lens: Yashica 135mm, with UV (haze) filter
Film: Kodachrome 25KM 135-36
Databack: Contax Databack Quartz D-5
Timer: 3-Clock Timer

FORMS AND SUPPLIES

The following items are necessary for continued operation of this camera system. They may, or may not, be kept at the camera location:

- Log Notebook
- Visibility Monitoring Status Assessment Sheets
- Spare Batteries:
  1 - 9 V Transistor
  4 - AA
  2 - 1.5 V EPX-76 silver oxide
- Padded Mailing Envelopes
- Film Cannister Labels

FILM STORAGE

To ensure proper film storage, pack the film inside a ziploc bag with dessicant, inside a Film Storage Box. Store the film in this manner until it is used. Place the film storage box in a refrigerator or preferably a freezer. If no cooling unit is available, try to store the film in a cool (less than 70 degrees), dry location.

Keep all film inside the Film Storage Box until it is used. If the film is kept in a freezer, allow the film to thaw at room temperature for 24 hours before loading it in the visibility camera.

REGULAR MAINTENANCE

Use your Visibility Monitoring Status/Assessment Sheet every time you perform regular maintenance on the system. It is an excellent maintenance guide and can help you identify problems.

1. **Inspect** interior and exterior of cabinet for damage or other problems (water leakage, etc.). Inspect outside of camera, lens, and window for dirt.

2. **Remove camera from box.** Disconnect the timer cable from the camera at the midpoint jack. Remove the camera body by pushing the quick release lever on the tripod.

3. **Remove exposed film** from the camera, and place it in the plastic cannister supplied with the new film.
   - Fill out the label provided and attach it to the outside of the plastic cannister. The label should contain the following information:
     - Monitoring site name or abbreviation
     - Roll number
     - Date and time of first shot on roll
     - Date and time of last shot on roll
     - Emulsion number – Expiration date

4. **Inspect film compartment** for fragments of film. Remove these by blowing lightly. DO NOT TOUCH the film guides or the shutter curtain.

5. **Load** new roll of film (see p.28 of Contax Instruction Booklet).
   - Confirm proper film advance by observing rotation of film feed indicator during film advance.

6. **Inspect camera lens** and UV filter for dirt. Clean. if necessary (see *Camera Servicing Section*).

7. **Check Camera Batteries**
   Check the batteries by moving main switch to the battery check position. Note the condition of the green lamp.
   LAMP ON – Battery voltage good
   LAMP OFF – Drained, replace batteries
   Batteries should last about a year, depending on sight conditions. Replace as required.

8. **Check Data Back** day and time.

9. **Photograph Documentation Board**
The FIRST exposure on EVERY roll must be the documentation board on the inside of the camera shelter door. The board must contain:
- Monitoring Site Name or Abbreviation
- Roll Number
- Date
- Time
- Grey Scale
- Color Chart

The board should be photographed in full, uniform lighting – no shadows or reflections.
A. Fill the view finder of the camera with the board, allowing only a slight border between the grey scale and the edge of the frame. You may have to shift your position slightly to find a spot where there are no shadows or glare from the board. The board is mounted with velcro tabs and may be moved if proper lighting conditions are not possible with the board mounted on the box.
B. Bring the documentation board into SHARP focus.
C. Take the exposure.

10. **CHECK camera settings** for automatic operation:

Main Switch	Setting On
Aperture Ring	f8.0
ASA Dial	40*
Exposure Compensation Dial	XI
Shutter Control Dial	A
Exposure Mode Selector	S

* – Film remains Kodachrome 25

11. **Replace and Align Camera**
A. Mount camera and tripod head onto tripod base.
B. Check cable connections. Timer cable to left front side of camera and midpoint cable jack.
C. Look through View Finder and align camera with the vista to be photographed. *It is important that the alignment is constant from one roll of film to the next.* Check:
- Horizon is level
- Vista is framed the same as previous alignment
- Sun shade is not visible in view finder

Firmly tighten all locking levers on the tripod head, and recheck alignment.

12. **Check timer settings.** See *Clock Timer Section* if timer must be reset.

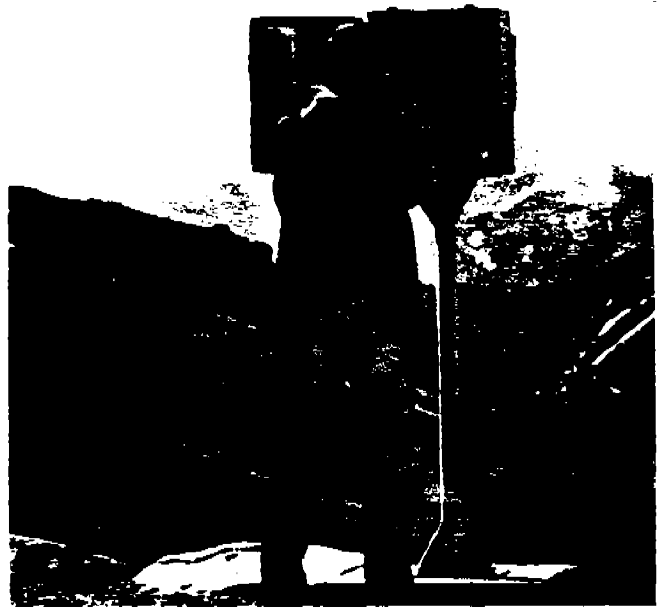
13. Complete all items on **Visibility Monitoring Status/ Assessment Sheet,** insert yellow copy of status sheet in log book.

14. Remember to bring exposed film and original copy of Visibility Monitoring Status Assessment/Sheet back for **mailing.**

15. **Close and lock** camera box.

16. **Mail film** and Visibility Monitoring Status/Assessment Sheet to:

Air Resource Specialists, Inc.
1901 Sharp Point Drive, Suite E
Fort Collins, Colorado 80525
ATTN: Betsy Davis



CAMERA SERVICING

1. **Lens**
A. Periodically check the camera lens and filter for excess dust.
B. Use the supplied lens paper, and cleaning fluid to clean lens.
C. Unscrew the UV filter and clean the lens and inside surface of the UV filter only if necessary.
D. Fold a piece of lens paper into a size that will clean the eye-piece. Do not use sharp objects or Q-tips to clean.
E. Do NOT remove the lens to clean inner surfaces.

2. **Film Compartment**
A. Before loading new roll of film, check the film compartment for fragments of film. Remove these by blowing lightly.
B. Do NOT touch the film guides or the shutter curtain.

3. **Camera Batteries**
A. Check the batteries by moving main switch to the battery check position. Note the condition of the green lamp
LAMP ON – Battery voltage good
LAMP OFF – Drained, replace batteries
B. Batteries should last about a year.
C. The Contax uses four AA (1.5 volt) alkaline batteries. Check Contax Instruction Book (p.12) for installation instructions.

4. **Data Back Batteries** The Data Back D-5 uses two 1.5 volt button (EPX-76) batteries. Check Contax Data Back manual for installation and resetting instructions. Batteries should last about one year.

THREE CLOCK TIMER

The timer provides a contact closure at up to three user-selected times per day. The contact closure trips the Contax camera to take a photograph.

Three individual clocks are incorporated into the timer. Each clock displays the actual time of day, and each clock alarm is set for the desired photograph time. When the alarm time is reached, the clock alarm output trips a contact closure at the terminal strip on the bottom of the timer. In normal operation, the top clock alarm time is set for 9:00 (9:00 a.m.), the middle clock alarm time is set for 12:00 (12 noon), and the bottom clock alarm time is set for 15:00 (3:00 p.m.).

To Set the Time

1. Slide the SET/ALARM switch to SET/T.
2. Press the HOUR set button once to advance one hour. Press and hold to advance the hours quickly. Release at the correct hour.
3. Press the MINUTE set button once to advance the time one minute. Press and hold to advance quickly. Release at the correct minute.
4. Slide the SET/ALARM switch to ALARM/ON.

To Set the Alarm

1. Slide the SET/ALARM switch to SET/A. The time displayed is the time for which the alarm is presently set.
2. Press MINUTE set and/or HOUR set following the steps in "To Set the Time" to set the desired alarm time.
3. Slide the SET/ALARM switch to ALARM/ON to activate the alarm.

Batteries

There are two types of batteries in the timer, one 9 volt transistor and one AA battery.

1. The 9 volt battery controls the contact closure signal to the camera. To change the 9 volt battery, slide the battery compartment on the rear of the timer case open. Replace with a good quality alkaline 9 volt transistor battery. This battery is expected to last six months. When this battery fails, the clocks will still display the time; however, no photographs will be taken.
2. One AA battery powers the three clock display. To change the battery, remove the four phillips-head screws which are accessible from the back of the timer. Remove the back cover and replace the battery, observing the same polarity. The clock display will appear dim or go blank when this battery is exhausted.

WIRING THE CAMERA TO THE TIMER

A two screw terminal strip is mounted on the bottom of the timer . To wire the camera to the timer, connect the lug ends of the camera remote triggering cord provided to the terminal strip.

CAMERA OPERATION – PROBLEMS

It is important to read the Contax Instruction Booklet thoroughly before operating the camera.

Experience has shown that the following camera and operator problems result in most of the bad photographs in the network. Page numbers refer to the pertinent section in the Contax instruction booklet.

Problems with the Camera:	Page
1. Loading Film	28
2. Unloading Film	52
3. Incorrect ASA setting	34
4. F-stop on improper setting	40
5. Weak camera batteries	16
6. Main lamp flashing	64
7. Weak timer batteries	See Three Clock Timer section

CONTACT US
if any questions or problems arise:

PHONE: Kristi Savig
Air Resource Specialists, Inc.
1901 Sharp Point Drive, Suite E
Fort Collins, Colorado 80525
303 / 224-9300

APPENDIX B

Determination of SVR and Cumulative Frequency from the Slope and Intercept Available in a Cumulative Frequency Statistics Table

DETERMINATION OF SVR AND CUMULATIVE FREQUENCY FROM THE SLOPE AND INTERCEPT

(Note: The following discussion is only valid for visibility analysis statistical tables produced by the count method and published after April 1988.)

The slope and intercept data available on the Cumulative Frequency Statistics Table may be used to determine an SVR value from any cumulative frequency level, or to determine a cumulative frequency level from any SVR value. An example table is presented in Figure A-1.

TABLE #	1	ALL
Points	238	238
Slope	2.05	2.05
Intercept	43.93	43.93
Correlation	0.99	0.99
10% Level	52	52
50% Level	121	121
90% Level	275	275

Figure A-1. Cumulative Frequency Statistics Table.

The slope (2.05) and the intercept (43.93) along with the cumulative frequency value may be used to calculate any cumulative frequency level (0 to 100%) or the corresponding SVR value.

To determine the SVR given the slope, intercept, and the cumulative frequency value, use Equation 1,

$$SVR = EXP[(SLOPE \times CUMF) + \ln(INTERCEPT)] \tag{1}$$

where:

- CUMF is the cumulative frequency (in decimal);
- SLOPE is given in the Cumulative Frequency Statistics Table;
- INTERCEPT is given in the Cumulative Frequency Statistics Table; and
- SVR is the standard visual range value.

To determine the cumulative frequency level given the SVR and the slope, intercept and cumulative frequency value, use Equation 2 using the same variable designation as Equation 1.

$$CUMF = \frac{\ln(SVR) - \ln(INTERCEPT)}{SLOPE} \tag{2}$$

Example Calculation 1: using data presented in Figure A-1, apply Equation 1 to find the SVR value for the 25% cumulative frequency value.

$$SVR = EXP(2.05 \times 0.25 + \ln(43.93))$$

$$SVR = EXP(0.51 + 3.78)$$

$$SVR = EXP(4.30)$$

$$SVR = 73 \text{ km}$$

Example Calculation 2: using the data presented in Figure A-1, apply Equation 2 to find the cumulative frequency value for an SVR of 154.

$$CUMF = \frac{\ln(154) - \ln(43.93)}{205}$$

$$CUMF = \frac{5.04 - 3.78}{2.05}$$

$$CUMF = \frac{1.25}{2.05}$$

$$CUMF = .61$$

$$CUMF = 61\%$$

Appendix D

Transmissometer Systems Field Operator's Manual

TRANSMISSOMETER SYSTEM
FIELD OPERATOR'S MANUAL

Prepared for the

NATIONAL PARK SERVICE
Visibility Monitoring & Data Analysis Program
(NPS Contract CX-0001-7-0010)

Prepared by

AIR RESOURCE SPECIALISTS, INC.

August 1988

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PREFACE

This manual was prepared in partial fulfillment of the National Park Service Visibility Monitoring and Data Analysis Program (Contract CX-001-7-0010). The manual presents all information necessary for field operators to properly operate and maintain transmissometer systems based on the Optec, Inc., LPV-2 long-range transmissometer. Transmissometers are a new and evolving technology. As required, this manual will be updated to reflect changes in instrumentation or operational procedures.

1.0 INTRODUCTION

This manual details field operations and maintenance procedures required to operate the Optec LPV-2 transmissometer system. The manual is for use by on-site field operators and contains general and detailed system descriptions and step-by-step servicing and trouble-shooting procedures.

1.1 Background

Visitor enjoyment of national parks and wildernesses is often enhanced by the opportunity to clearly see spectacular vistas. In all areas of the country, clean, clear air is an important aspect of the quality of life. Many parks and wildernesses are located in pristine areas where even small amounts of air pollution cause noticeable reductions in the visual air quality.

Recognizing the importance of visual air quality, Congress highlighted visibility protection in class I areas as a national goal in the 1977 Amendments to the Clean Air Act. The National Park Service (NPS) air quality program responded to this congressional mandate by establishing a Visibility Monitoring and Data Analysis Program in 1978.

The monitoring program has three components. The first, view monitoring, documents the visual impairment of specific, unique vistas under existing air quality conditions. Another monitoring component measures basic electro-optical properties of the atmosphere, independent of specific vista characteristics. The third component measures the atmospheric aerosols responsible for reduced visibility.

The primary view-monitoring technique has been the use of cameras to qualitatively document visibility conditions of unique vistas. The principle electro-optical technique has been teleradiometric measurement of natural targets. The instruments used include several generations of manual and automatic teleradiometers and camera/slide scanning densitometer systems.

Throughout the eight-year history of the Visibility Monitoring and Data Analysis Program, the NPS has cooperated with the Environmental Protection Agency (EPA), other federal land management agencies, states, and private industry to perform monitoring and research aimed at enhancing their ability to meet national visibility goals. Through these cooperative efforts, the program has evolved to incorporate improved monitoring and analysis techniques.

As a result of recent analyses and research, certain deficiencies in the applied electro-optical measurement technologies have been identified. Specifically, electro-optical techniques applied in the past do not measure atmospheric extinction with sufficient accuracy to satisfactorily make the link between particulates and visibility reduction.

The goal to directly and accurately measure atmospheric extinction led to the development of a long-range transmissometer system. To operationally apply this system in the pursuit of national visibility goals, the NPS, the EPA, and other federal land management agencies enhanced their long-standing cooperative relationships to establish the Interagency Monitoring of Protected Visibility Environments (IMPROVE) program.

The IMPROVE program and NPS obtained transmissometers (Model LPV-2) from Optec, Inc., for implementation in selected class I areas. The LPV-2 system directly monitors the light transmission properties of the atmosphere. The data can be reduced to yield atmospheric extinction or standard visual range measurements. Field installation of transmissometer systems is being performed by Air Resource Specialists, Inc. LPV-2 systems have been successfully operated in class I areas and in other urban and rural areas.

1.2 Report Format

This manual contains the following sections:

2.0 GENERAL INSTRUMENT AND SYSTEM DESCRIPTION
3.0 SERVICING SCHEDULE AND SUMMARY REQUIREMENTS
4.0 ROUTINE SERVICING
5.0 INTERMITTENT SERVICING AND MAINTENANCE
6.0 TROUBLE-SHOOTING
7.0 REPLACING AND SHIPPING INSTRUMENTS
8.0 MONITORING SYSTEM DIAGRAMS AND COMPONENT DESCRIPTIONS

Any questions on instruments and operational procedures should be directed to:

Roger Tree or
Ivar Rennat
Air Resource Specialists, Inc.
1901 Sharp Point Drive, Suite E
Fort Collins, Colorado 80525

303/484-7941

2.0 INSTRUMENT AND SYSTEM DESCRIPTIONS

This section introduces and describes the operation of instruments and support equipment used in the transmissometer visibility monitoring system. Instrument and support equipment discussed in this section are:

2.1 Monitoring System Overview
2.2 Optec LPV-2 Transmissometer
2.3 Handar 540A Data Collection Platform
2.4 Primeline 6723 Strip Chart Recorder
2.5 Handar 435A Temperature/Humidity Sensor

2.1 Monitoring System Overview

The transmissometer monitoring system collects visibility and related meteorological data. A long-path transmissometer makes the visibility measurements and data are collected by a satellite telemetered data collection platform (DCP). The DCP transmits the data through a geostationary satellite to a collection facility where it is available for access. A strip chart recorder provides data collection backup as well as an on-site visual record of instrument performance for the field operator.

Each component of the transmissometer monitoring system is a separate functioning unit; however, to obtain high quality data, all components must work together. Figure 2-1 presents the monitoring system overview. Figure 2-2 displays instrument and equipment placements within the transmitter and receiver shelters.

It is important to understand how the transmissometer functions and what the collected data represent. With a working knowledge of the system, field operators are better prepared to maintain the instrument, recognize problems, and reduce down-time. Major components of the monitoring system are described in the following sections.

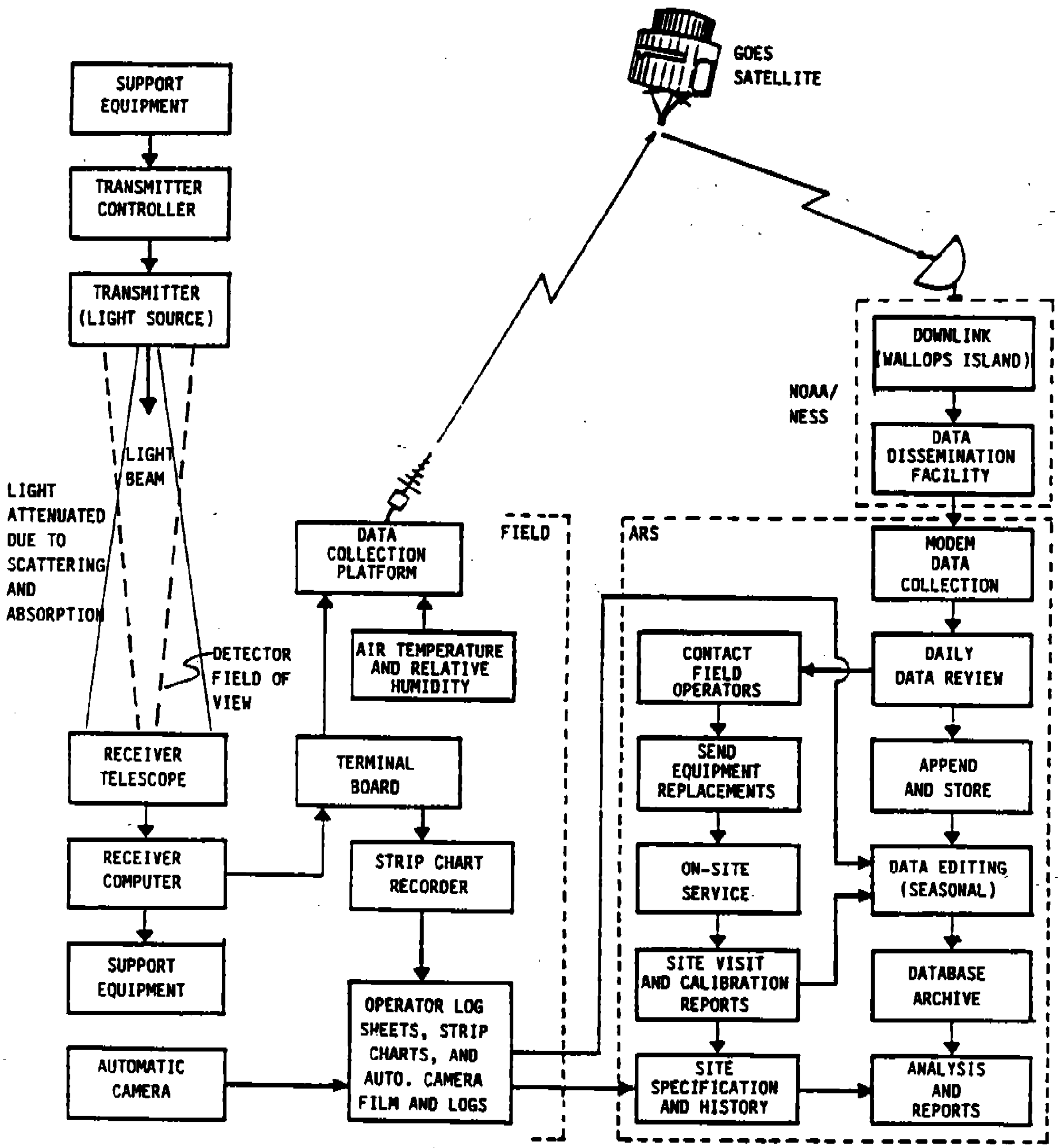
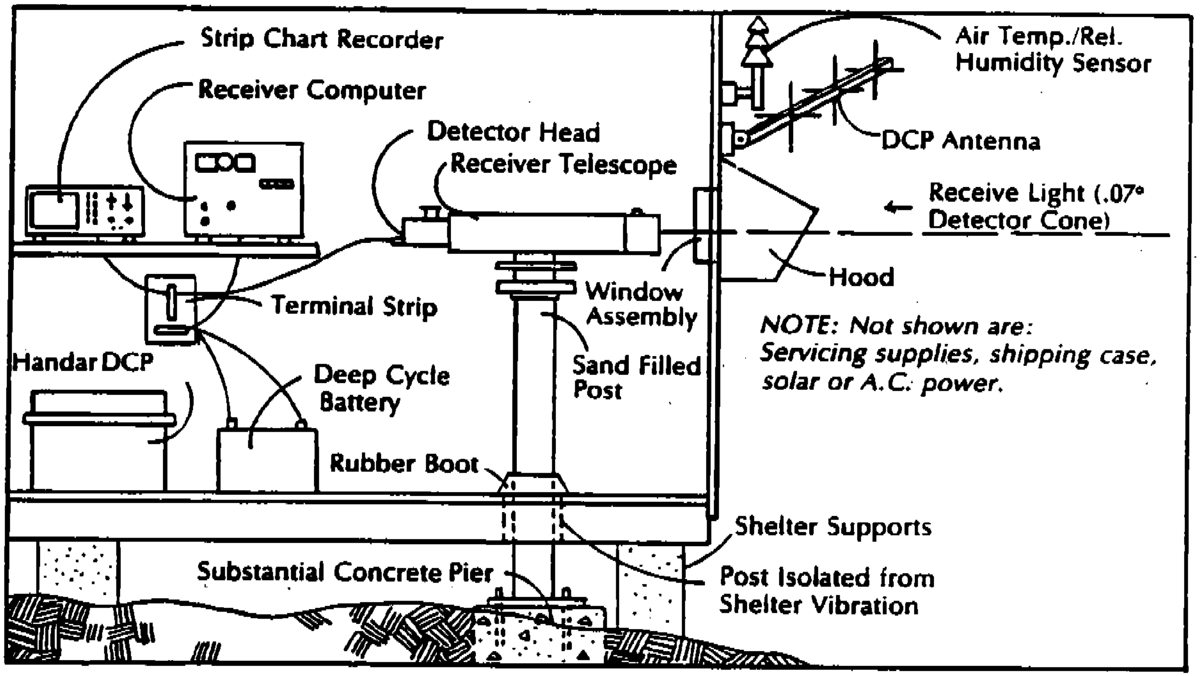


Figure 2-1. Monitoring System Overview

Receiver Station
(6'x 6'x 8')



Transmitter Station
(3'x3'x4'6")

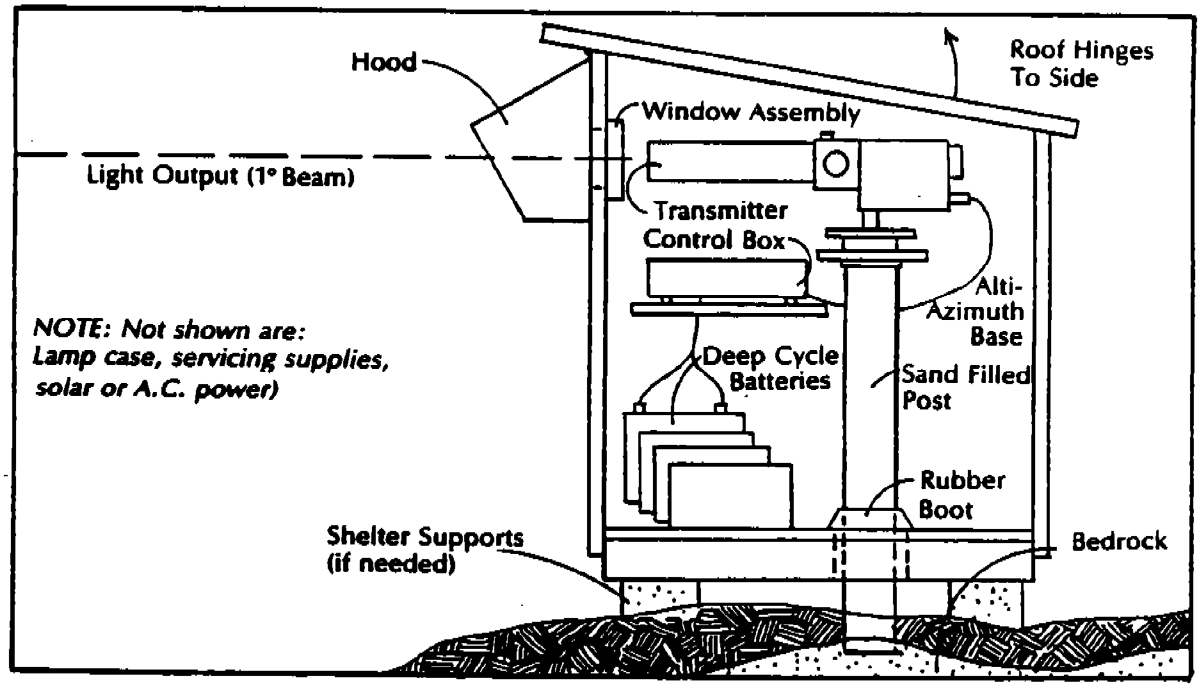


Figure 2-2. Monitoring Component Placement.

2.2 Optec LPV-2 Transmissometer

2.2.1 Transmissometer Overview

A transmissometer is designed to measure the light transmission properties of the atmosphere at a specific wavelength (color). It accomplishes this by measuring the loss in light received from a light source of known intensity, as the light beam travels a known distance.

An Optec, Inc., LPV-2 transmissometer has two primary components: a light source (transmitter) and a light detector (receiver). The individually-housed components are normally separated by a line-of-sight distance of between 0.5 and 10.0 kilometers. The distance between the transmitter and receiver is dependent on the expected visual air quality, instrument performance factors, and physical constraints such as power and servicing access.

Extinction, or the attenuation of light as it passes through the atmosphere, is a combination of light loss due to both scattering and absorption. Transmissometers are the only instruments capable of directly measuring extinction. The Optec LPV-2 transmissometer measures extinction at a wavelength of 550 nm (green)--an area of the spectrum where the human eye is most sensitive.

Transmission measurements can be expressed as extinction or visual range. A discussion of these terms and visibility theory as it relates to the transmissometer is presented in Appendix A. Sample data, and a list of related reading material are included in Appendix B and C respectively. Additional technical information on the transmissometer can be found in the Optec LPV-2 Instrument Manual (Optec, Inc., 1987).

2.2.2 Transmissometer Transmitter

The LPV-2 Transmitter emits a uniform, chopped light beam of constant intensity at regular intervals for a programmed duration.

The transmitter has two components: an electronic control box and a light source or transmitter. The control box houses most of the instrument electronics, such as the lamp power supply and controller, the chopper frequency control, and the internal auto-timer. The transmitter assembly houses the lamp, chopper, optical feedback detector, and the magnification and alignment optics. A diagram of the transmitter and description of its components can be found in Section 8.0 (Figure 8-1).

The transmitter optics perform two functions: 1) they concentrate light from the 15-watt tungsten filament lamp into a narrow, well-defined uniform cone, magnifying the beam to the equivalent of a bare 1500-watt lamp, and 2) the optics also allow the operator to precisely aim the light beam at the receiver.

The intensity of the light emitted from the transmitter is precisely controlled by an optical feedback system within the lamp chamber. This system continuously samples a small portion of the outgoing beam and makes fine adjustments to keep the light output constant. Although the lamp light is white, only the green (550 nm) portion of the output is monitored and controlled by the feedback circuitry.

Light emitted from the transmitter is "chopped" into approximately 78 pulses a second by a mechanical spinning disk located in front of the lamp. The light is chopped to allow the receiver computer to differentiate the lamp signal from the background or ambient lighting. By using this technique, the transmissometer can operate continuously, both day and night.

The timing circuit within the control box is programmed to turn the transmitter on at regular intervals for a specified duration. The transmitter is "cycled" to extend lamp life and to reduce power consumption. In a typical monitoring configuration, the transmitter turns on at the top of each hour and stays on for 16 minutes. The cycle repeats hourly.

2.2.3 Transmissometer Receiver

The Optec LPV-2 receiver gathers light from the transmitter, converts it to an electrical signal, calculates results in the desired form, and outputs the results to both a display and to data loggers.

The receiver is comprised of three components: 1) a long focal-length telescope, 2) a photodetector/eyepiece assembly, and 3) a low power computer. A diagram of the receiver and a description of its components can be found in Section 8.0 (Figure 8-2).

The telescope gathers light from the transmitter and focuses it on a photodiode housed in the detector head. The photodiode converts the light energy to an analog electrical signal which is sent to the receiver computer. The signal can be described as an AC waveform (chopped transmitter light) carried on a DC voltage (background lighting).

The computer separates the chopped transmitter light from the ambient background light and "locks-on" to the transmitter frequency. Once "locked-on" to the frequency, it determines when the light was on and when it was off (chopped). The receiver circuitry then converts the analog signal into a digital form.

The computer compares the lamp-on signal with the lamp-off signal approximately 4000 times (waveforms) a minute. By determining the amount of transmitter light that reaches the receiver, based on an average of many measurements (waveforms), the effects of turbulence on the light beam are minimized. The computer then compares the measured transmitter light with the known (calibrated) transmitter light to calculate the transmittance of the atmosphere.

When the path distance is supplied (user set), the computer calculates and expresses visibility measurements in terms of:

1. Raw receiver reading (counts)
2. Extinction (km^{-1})
3. Visual range (km)

In addition, the receiver outputs a "toggle" signal that changes state (high to low, or low to high) when a new reading is calculated and output. A change in the toggle state indicates that a new reading has been made.

Like the transmitter, the receiver is equipped with an eyepiece for precisely aiming the detector and an internal timer to control the start and duration of measurements. In a typical monitoring configuration, the receiver will make a 10-minute averaged reading between 3 and 13 minutes after the hour (centered within the transmitter "lamp-on" interval).

2.3 Handar 540A Data Collection Platform

The Handar 540A data collection platform (DCP) is a low-power, microprocessor-based data logger. The DCP samples sensor inputs, such as the transmissometer extinction signal, at precise intervals as defined by an internal computer program. Every three hours at a specified time and radio frequency, the DCP transmits the data it has collected to a geostationary satellite. The satellite relays the data to a downlink facility where it is stored and is available for dissemination.

The DCP-transmitted data are collected daily at ARS where the transmissometer, air temperature, and relative humidity measurements are checked to verify the instruments are functioning properly.

In addition, ARS monitors DCP operating parameters such as transmission time, battery voltage, signal strength, and deviation of the transmissions from the assigned frequency. By closely monitoring instrument and DCP performance, it is often possible to identify and resolve problems, reducing down-time.

If the DCP fails and efforts to trouble-shoot the system are not productive, the strip chart recorder will collect data until a replacement DCP is installed.

A diagram of the DCP and a description of its features are located in Section 8.0 (Figure 8-5). Additional technical information can be found in the Handar 540A Operation and Servicing Manual (Handar, Inc., 1982). Further information on the satellite data collection system is presented in Appendix D.

2.4 Primeline 6723 Strip Chart Recorder

The Primeline 6723 strip chart recorder serves two functions: 1) it acts as a backup data logger in the event of a DCP failure, and 2) it provides the field operator with a visual record of transmissometer performance.

The strip chart logger is a recording voltmeter that documents transmissometer extinction measurements and the toggle signal. Notes written on the strip chart also provide a useful record of field operator site visits.

Strip chart paper and pens must to be changed at two-month intervals. Completed and labeled strip charts are normally sent in with exposed film from automatic camera systems. A diagram of the strip chart and a description of its components is located in Section 8.0 (Figure 8-4), and a sample section of chart paper is shown in Appendix B. Additional technical and servicing information can be found in the Primeline 6723 Instruction Manual (Soltec, Inc.).

2.5 Handar 435A Temperature/Humidity Sensor.

A Handar 435A sensor measures air temperature and relative humidity. The sensor is housed in a white, parallel-plate radiation shield mounted on the outside of the receiver shelter. The sensor is controlled by, and directly connected to, the DCP. No on-site record of these measurements is made.

The air temperature and relative humidity measurements are monitored daily as the DCP-transmitted data are collected.

3.0 SERVICING SCHEDULE AND SUMMARY OF REQUIREMENTS

This section outlines the field operator servicing schedule and lists servicing tasks required at both the transmitter and receiver stations.

The objective of field servicing is to assure the collection of high quality data with minimal loss. This requires the following information from the field operator Log Sheets:

1. Was the instrument capable of producing high quality data in the interval between operator servicing visits?
2. Have servicing tasks been performed so that the instrument will produce high quality data until the next site visit?
3. Have preventative maintenance tasks been performed to minimize the possibility of downtime?

Prior to servicing, transmissometer alignment and optics must be checked and the "as found" conditions documented. Log Sheets must be completed correctly as verification of servicing.

3.1 Servicing Schedules

The transmissometer servicing schedule is presented in Figure 3-1. The following figures present the suggested order of completing servicing tasks for both the transmitter station (Figure 3-2) and the receiver transmitter station (Figure 3-3).

3.0 SERVICING SCHEDULE AND SUMMARY OF REQUIREMENTS

TRANSMISSOMETER SERVICING SCHEDULE

7 to 10 Day Interval

- o Complete the servicing tasks listed.on the Site Assessment Log Sheets.
- o Both the receiver and transmitter shelters must be visited at 7 to 10 day intervals.

Monthly Interval

- o At least once a month both the transmitter and receiver system timing should be checked and reset if necessary.
- o The transmitter lamp status LED must be checked at least once a month.
- o Inspect solar panels, batteries, and DCP antenna.

Bi-Monthly Interval

- o Strip chart paper and pens should be changed on the first site visit of every-other month. The chart paper magazine should also be cleaned at this time.

Four-Month Interval

- o Transmitter lamps should be changed every four months. ARS will notify sites when a lamp change is needed.

Yearly

- o ARS field technicians will make site visits once a year to exchange the existing transmissometer system for a serviced system.
- o Training of field operators in the servicing and maintenance of the monitoring system components will take place during yearly ARS technician visits.

Figure 3-1. Transmissometer Servicing Schedule.

TRANSMISSOMETER TRANSMITTER STATION
SUMMARY OF SERVICING TASKS

Tasks are listed in the suggested order of completion. For more detailed instructions, see the following section.

Before Leaving the Office:

1. At least once a month, schedule your servicing trip to be at the transmitter station while the transmitter is in the "run" mode to check the lamp status LED and the system timing.

2. If checking the system timing, set your digital watch to the correct time prior to leaving the office by calling the Bureau of Standards recording 303/499-7111 (Boulder, CO).

At the Transmitter Station:

1. Complete the general information section and reset the thermometer.
2. Document the initial alignment conditions and/or comment.
3. Make sure the flip mirror is in the correct position.
4. Inspect and document the window cleanliness.
5. Clean the window or comment as necessary.
6. Dust the transmitter lens with canned air.
7. Clean the solar panels, inspect them for damage.
8. Observe and record the transmitter on time.
9. Observe and record the LED status light while transmitter is on.
10. Observe and record the transmitter turn off time.
11. Check supply inventory. Request needed supplies on the Log Sheet.
12. Record any comments on the Log Sheet.
13. Leave a copy of the Log Sheet in the shelter; take the original back to the office and send to ARS.
14. Double-check the alignment and the flip mirror position before leaving the shelter.

Back at the Office:

1. Send original Log Sheets from both the receiver and transmitter to ARS along with film from the auto camera.

2. Call ARS field technicians promptly if a problem or need arises.

Figure 3-2. Transmitter Station Servicing Tasks.

TRANSMISSOMETER RECEIVER STATION
SUMMARY OF SERVICING TASKS

Tasks are listed in the suggested order of completion. For more detailed instructions, see the following section.

Before Leaving the Office:

1. At least once a month, schedule your servicing trip to be at the receiver station as the computer reading updates (13 minutes past the hour) to check the system timing. The transmitter off time (16 min. past the hour) can also be observed and documented from the receiver station.

2. If checking the system timing, set your digital watch to the correct time prior to leaving the office by calling the Bureau of Standards recording 303/499-7111 (Boulder, CO).

At the Receiver Station:

1. Complete Log Sheet general info section; reset the thermometer.
2. Record the time and receiver computer reading and toggle state.
3. Record the receiver computer settings.
4. Document the initial alignment conditions and/or comment.
5. Inspect and document the window cleanliness.
6. Clean the window or comment as necessary.
7. Dust the telescope objective lens with canned air.
8. Document the site visit on the strip chart.
9. Change chart paper and pens if necessary and re-document visit.
10. Clean solar panels and inspect for damage.
11. Inspect the antenna for damage or loose mounts.
12. Observe and record the transmitter turn-off time.
13. Observe receiver reading up-date (toggle light change) and record time.
14. Make final alignment check after reading updates and while transmitter is still on.
15. Observe transmitter turn-off and record time.
16. Verify the flip mirror is in "run" position.
17. Record the new reading on the Log Sheet.
18. Check supply inventory. Request needed supplies on the Log Sheet.
19. Record any comments on the Log Sheet.
20. Leave a copy of the Log Sheet in the shelter. Take the original back to the office and send to ARS.
21. Double-check the alignment and the flip mirror position before leaving shelter.

Back at the Office:

1. Send original Log Sheets from both the receiver and transmitter shelters to ARS along with film from the auto camera.

2. Call ARS field technicians promptly if a problem or need arises.

Figure 3-3. Receiver Station Servicing Tasks.

4.0 ROUTINE SERVICING

This section describes transmissometer monitoring system routine servicing tasks and Log Sheet entries. Task descriptions are listed in the order in which they appear on the Operator Log Sheets. Information or procedures to be followed are described with the appropriate Log Sheet entry.

Log Sheet entries and general task descriptions common to servicing of both the transmitter and receiver stations are presented in the following section. Servicing tasks and Log Sheet entries relating to only the transmitter or receiver stations follow in separate sections. Blank operator Log Sheets are shown in Figures 4-1 and 4-2. Examples of completed Log Sheets are included in the Appendix (E and F).

HAND-HELD RADIO PRECAUTION	The transmitter circuitry, especially the internal auto-timer, can be adversely affected by strong radio signals. Do not transmit on a hand-held radio within 10 feet of the transmitter. Avoid aiming the antenna at, or over, the circuitry. Strong radio signals may reset the internal auto-timer, resulting in incorrect system timing.

4.1 Receiver and Transmitter - Common Routine Servicing Tasks

The following general information appears on the top of both the transmitter and receiver Log Sheets.

LOCATION	Either the full location name or the four-letter abbreviation can be used.
DATE	Use the standard calendar date, not a Julian date.
TIME	Current local time in 12-hour format should be used. Use Daylight Savings Time when applicable.
OPERATOR(S)	Use your full name or first initial and last name.
SHELTER TEMPERATURE	All shelters are equipped with a Brannan max/min thermometer. Temperature readings are used to monitor the instruments and support equipment.
MAXIMUM TEMPERATURE	The maximum temperature since the last site visit is noted by the bottom of the marker column on the right side of the thermometer.

Air Resource Specialists, Inc.

Location ____________________

TRANSMISSOMETER OPERATOR LOG SHEET
TRANSMITTER STATION

Date ____________ Time ____________ Operator(s) ____________________

Shelter Temp. (°F) Max ____________ Min ____________ Current ____________

Describe Weather & Haze Conditons: ____________________

ALIGNMENT Mark initial location of light source with a "+". Align and/or comment as needed.

Initial — Comments

○

ROUTINE PROCEDURES

YES	NO	
☐	☐	Alignment corrected
☐	☐	Window clean upon arriving
☐	☐	Window cleaned (if no, comment)
☐	☐	Solar panels cleaned
☐	☐	Lamp LED "on"; if yes, call ARS (This check is only valid during lamp "on" time.)
☐	☐	Lamp changed (To be done only on specified dates or upon direction from ARS.) New lamp # ____
☐	☐	Time reset (upon direction of ARS only)

SPECIAL PROCEDURES

Lamp No. In Use: ________ Comments: ____________________

Timing Check: Transmitter ON/OFF at (HR:MIN:SEC): ____________________

COMMENTS/SUPPLIES NEEDED ____________________

Enclose the original of this Log Sheet and send to:

Air Resource Specialists, Inc., 1901 Sharp Point Dr., Suite E, Fort Collins, CO 80525, 303/484-7941

03/88

Figure 4-1. Transmitter Station Log Sheet.

Air Resource
Specialists, Inc.

Location ____________________

TRANSMISSOMETER OPERATOR LOG SHEET
RECEIVER STATION

Date __________ Time __________ Operator(s) ____________________

Shelter Temp. (°F) Max __________ Min __________ Current __________

Describe Weather & Haze Conditons: ____________________

READINGS

Before Align.: Time __________ Reading __________ Toggle ON/OFF __________

After Align.: Time __________ Reading __________ Toggle ON/OFF __________

Time Check: Transmitter Light ON/OFF __________ Time (HR:MIN:SEC) __________

Receiver Toggle Chg. ON/OFF __________ Time (HR:MIN:SEC) __________

COMPUTER SETTINGS GAIN __________ CAL __________ DIST __________

A1 – C, B, VR A2 – SD, CR INT – 1, 10, 30, 60 Cycle – 4H, 2H, 1H, 20M, 6

ALIGNMENT Mark initial location of light source with a "+". Align and/or comment as needed.

Initial Comments

○

ROUTINE PROCEDURES

YES	NO		YES	NO	
☐	☐	Alignment corrected	☐	☐	OV light "on" (If yes, call ARS)
☐	☐	Window clean upon arriving	☐	☐	Strip chart marked
☐	☐	Window cleaned (if no, comment)	☐	☐	Chart paper O.K.
☐	☐	Solar panels cleaned	☐	☐	Chart pens O.K.

SPECIAL PROCEDURES (Use only after receiving instructions from ARS)

☐ ☐ Computer reset

☐ ☐ Time reset

COMMENTS/SUPPLIES NEEDED ____________________

Enclose the original of this Log Sheet and send to:

Air Resource Specialists, Inc., 1901 Sharp Point Dr., Suite E, Fort Collins, CO 80525, 303/484-7941

03/88

Figure 4-2. Receiver Station Log Sheet.

MINIMUM TEMPERATURE — The minimum temperature since the last site visit is noted by the bottom of the marker column on the left side of the thermometer. Note that the temperature scale increases towards the bottom.

CURRENT TEMPERATURE — The current temperature can be found on either scale although the maximum, or right scale, is easiest to read.

Resetting the Thermometer

Reset the thermometer after each set of readings by pushing in the red bar in the middle. Hold the bar in until the marker columns have come to rest on the mercury columns.

WEATHER AND HAZE CONDITIONS — Comments regarding the weather and haze conditions may deal with present conditions, such as "extremely clean" or "control burn in area." They may also describe more broad conditions, such as "storm front passing through" or "scattered rain showers all week." Describe any weather or haze occurrence that you think may be of value in interpreting data.

4.2 Transmitter Station - Routine Servicing

The following information describes Log Sheet entries and servicing tasks required at the transmitter station.

DOCUMENTING INITIAL ALIGNMENT — To check the alignment, turn the flip mirror knob fully clockwise against the stop to the "view" position. Document the position of the receiver window with respect to the circle on the data sheet with a "+." The receiver would be at the intersection of the "+."

Alignment Viewing Times

Do not make alignment checks or adjustments while the transmitter is on. If the flip mirror knob is moved from the "run" position to the "view" position while the transmitter is on, the extinction reading for that hour will not be valid. If a reading has been affected by an alignment check, note this on the Log Sheet comment section.

Bad Viewing Conditions

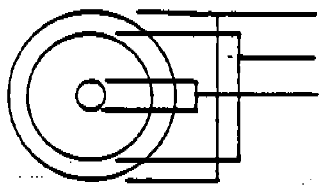
If an initial alignment check is impossible due to haze, turbulence, or lighting conditions, return the flip mirror to the "run" position--Do not attempt to align. Record pertinent comments regarding alignment problems to the right of the circle on the Log Sheet.

CORRECTING ALIGNMENT

If the alignment has drifted so that the receiver is not in the center of the reticule circle, adjust the alti-azimuth base controls to center the receiver. Make sure the flip mirror knob is fully against the stop while aligning. Do this only after the initial alignment has been documented.

Alignment Reticule

The figure below depicts the reticule as viewed through The transmitter eyepiece:



The circle depicted on the Log Sheet represents the small .17^{0} inner reticule circle. It is this circle which must remain aligned on the receiver telescope for correct instrument operation.

Alignment Hints

One of your eyes will be dominant; if you are having difficulty viewing the scene, try it with your other eye. Some people find it easier to view the scene from behind the telescope while others prefer to view from the side. Schedule site visits for times of the day with the best viewing conditions. All shelters are equipped with signal mirrors and flashlights for occasions when alignment checks are made with operators at both stations. Finally, keep the eyepiece clean for better viewing.

ALIGNMENT CORRECTED

This entry is included to verify whether the alignment was corrected. If the alignment was not corrected, comments describing conditions should be written next to the alignment circle.

WINDOWS CLEAN UPON ARRIVAL

Remove the window pane from its frame and visually inspect the shelter window for water drop deposits, film, unusually heavy dust, and insects or pests that may reduce the transmission of light through the glass. Make comments when applicable. It is important to inspect the portion of the glass pane which is directly in front of the transmitter lens.

Cleaning Optical Surfaces

The objective in cleaning glass is to remove highly abrasive dust particles and film without damaging the surface. Always remove the large particles with canned air first and progress towards the removal of films. Use a light touch, plenty of cleaning fluid, and frequent changes of cleaning paper. Clean with a circular, rubbing motion. Always use compressed air in an upright position. If the can is tilted, the propellant may be expelled onto the glass surface. The propellant is greasy and difficult to remove.

WINDOW CLEANED

Shelter windows should be cleaned during every servicing visit. If for some reason, windows are not cleaned, document conditions in the comments section.

Window Cleaning Instructions

1. Remove the window pane from the frame.
2. Use canned air to dislodge particles from both sides of the glass.
3. Use the compressed air to clean the window slot in the frame, particularly at the bottom.
4. Inspect the hood and frame for spider webs.
5. Use only Kimwipes and alcohol to clean both sides of the glass. Use plenty of cleaning fluid, change Kimwipes often, and use a light hand.
6. Use compressed air on both sides to remove any cleaning paper lint.
7. Reinstall window pane.

Transmitter Optics Cleaning

Use the compressed air to remove dust from the body of the transmitter. Carefully, keeping the air can in the upright position, remove dust particles from the transmitter objective (front) lens. Clean the eyepiece with alcohol and Kimwipes, but use only canned air to clean the objective lens.

SOLAR PANELS CLEANED

Use glass cleaner and paper towels to clean dust and dirt from the solar panels. In the winter, sweep accumulated snow off the panels, but avoid scraping ice as damage to the panels could occur.

LAMP LED "ON"

If the lamp voltage LED is lit while the transmitter light is on, the lamp needs replacing. This check is only valid when the instrument is in its "auto on" mode; if the instrument is turned on with the test switch, the LED will always go on. Leave the checklist square blank if this check was not completed. The lamp LED check should be made at least once a month.

The status of the LED is difficult to determine while in direct sunlight. Shade the LED with your hand before checking.

LAMP CHANGED	Procedures for changing lamps are described in Section 5.2. If a lamp change is made, document it on the Log Sheet. The lamp number is written on a sticker affixed to the back of the lamp.
TIME RESET	Procedures for checking and resetting the transmitter internal auto-timer are described in Section 5.1. Document the results of a timing check before resetting the time. If the time is reset, document this on the Log Sheet. Timing checks should be made monthly. <u>Transmitter Timing</u> The transmitter should turn on under automatic control at the top of every hour and turn off at 16 minutes past the hour. Refer to Section 5.1 for additional information.
LAMP NUMBER IN USE	Document the lamp number in use. Use the comments section to document lamp changes.
TIMING CHECKS	Document the results of timing checks here. Procedures for checking the system timing are discussed in Section 5.1.
COMMENTS SUPPLIES NEEDED	Space for comments is provided at the bottom of the Log Sheet. This space should also be used to request additional servicing supplies.

4.3 Receiver Station - Routine Servicing

The following information describes Log Sheet entries and servicing tasks required at the receiver station.

READINGS BEFORE ALIGNMENT	Record the reading shown on the receiver computer display upon entering the shelter. Also record the time and toggle state.
READINGS AFTER ALIGNMENT	If you are still in the shelter when the receiver computer updates to a new reading, record the new information.
TIME CHECK	Record the exact time the transmitter light turns on or off and the receiver toggle light changes state in the appropriate space. Procedures for making system timing checks are given in Section 5.1. Circle "on" or "off" and write the time in the blank space. <u>System Timing</u> The transmissometer system operates according to the timed sequence described below. It is possible to check the system timing of both the receiver and the transmitter from the receiver station.

HR:MI:SEC	Action
09:00:00	Transmitter turns on
09:03:00	Receiver begins 10-min. average reading (cannot be observed)
09:13:20	Receiver finishes reading, toggle changes
09:16:00	Transmitter turns off
:	
10:00:00	Transmitter turns on
	Sequence repeats hourly

The system clocks will drift over time. For correct operation, it is critical that the receiver take its reading well-centered within the lamp-on interval.

Receiver Computer Sticker

Correct switch and dial settings are documented on a sticker affixed to the front panel of the computer. An example of the sticker is included in Section 8.0 (Figure 8-7).

GAIN

Record the value on the gain pot next to the indicator bar. The value is always set to a whole number, such as 250 or 319.

CAL

Record the CAL (calibration) number dialed in with the thumb switches.

DIST

Record the DIST (distance) dialed in on the thumbwheel switches.

A1

Record the A1 switch setting by circling the position indicated on the Log Sheet.

A2

Record the A2 switch setting by circling the position indicated on the Log Sheet.

INT

Document the INT (integration) setting by circling the position indicated on the Log Sheet.

CYCLE

Document the cycle setting by circling the position indicated on the Log Sheet.

Switch Setting Precaution

Do not change the INT and CYCLE switch positions; if the settings are changed, a time reset may be required.

DOCUMENTING INITIAL ALIGNMENT

To check the alignment, turn the flip mirror knob fully clockwise against the stop to the "view" position. Document the position of the transmitter with respect to the circle on the data sheet with a "+." The light source would be at the intersection of the "+."

Alignment Viewing Times

If the transmitter shelter is easily visible, do not interrupt a reading to make an alignment check. When viewing conditions are marginal, use the transmitter light source as an aid in alignment. The receiver can be placed in the "view mode" for a short time immediately after the transmitter turns on, or following a toggle and reading update, without affecting a measurement. Document any interruption of a reading on the Log Sheet.

Bad Viewing Conditions

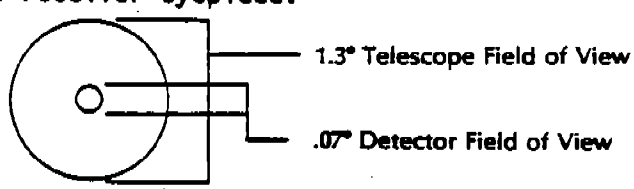
If an initial alignment check is impossible due to haze turbulence, or lighting conditions, return the flip mirror to the "run" position--Do not attempt to align. Record pertinent comments regarding alignment problems to the right of the circle on the Log Sheet.

CORRECTING ALIGNMENT

If the alignment has drifted so that the transmitter is not in the center of the reticule circle, adjust the alti-azimuth base controls to center the transmitter. Make sure the flip mirror knob is fully against the stop while aligning. Do this only after the initial alignment has been documented.

Alignment Reticule

The figure below depicts the reticule as viewed through The receiver eyepiece:



The circle depicted on the Log Sheet represents the small .07° inner reticule circle. It is this circle which should remain aligned on the transmitter for correct instrument operation.

ALIGNMENT CORRECTED

This entry verifies whether the alignment was corrected. If the alignment was not centered, document its location using the circle on the data sheet.

WINDOWS CLEAN UPON ARRIVAL

Visually inspect the shelter window for water-drop deposits, film, unusually heavy dust, and insects or pests that may reduce the transmission of light through the glass. Make comments when applicable. It is important to inspect the glass directly in front of the receiver lens.

WINDOW CLEANED Shelter windows should be cleaned during every site visit. If, for some reason, windows are not cleaned, document conditions in the comments section.

Window Cleaning Instructions

1. Remove the window pane from the frame.
2. Use canned air to dislodge particles from both sides of the glass.
3. Use the compressed air to clean the window slot in the frame, particularly at the bottom.
4. Inspect the hood and frame for spider webs.
5. Use only Kimwipes and alcohol to clean both sides of the glass. Use plenty of cleaning fluid, change Kimwipes often, and use a light hand.
6. Use compressed air on both sides to remove any cleaning paper lint. Make sure the compressed air can is always held in the upright position.
7. Re-install window pane.

Cleaning Optical Surfaces

The objective in cleaning glass is to remove the highly abrasive dust particles and film without damaging the glass surface. Always remove the large particles with canned air first and progress towards the removal of films. Use a light touch, plenty of cleaning fluid, and frequent changes of cleaning paper. Clean with a circular, rubbing motion. Always use compressed air in an upright position. If the can is tilted, the propellant may be expelled onto the glass surface. The propellant is greasy and difficult to remove.

Receiver Optics Cleaning

Use the compressed air to remove dust from the body of the receiver telescope. Carefully, keeping the air can in the upright position, remove dust particles from the telescope objective lens. Clean the eyepiece with alcohol and Kimwipes. Use only canned air to clean the objective lens.

4b. **SOLAR PANELS CLEANED** Use glass cleaner and paper towels to clean dust and dirt from the solar panels. In the winter, sweep accumulated snow off the panels, but avoid scraping ice as damage to the panels could occur.

OV LIGHT ON If the over-voltage light is on, reset the computer by turning the "on/off" switch off for a few seconds, and then back "on." The light should not come back on. Document this action in the Log Sheet comment section. Refer to Section 8.3 for a discussion of this indicator light.

STRIP CHART MARKED

The following information must be recorded on the chart at each site visit:

1. Event markers or "ticks"
2. Date and time
3. Location
4. Operator name
5. Receiver computer display value
6. Other information, such as:
   A. Pens zeroed
   B. New pens/paper
   C. Computer reset
   D. Alignment off/corrected
   E. System timing off/corrected

Documenting Start and End of Chart Paper

When installing new chart paper, record the location, date and time started on the outside of the chart. The same information should be written and the end of the roll upon chart removal. The procedure for changing chart paper is described in the manufacturer's Instruction Manual.

CHART PAPER

Check the amount of chart paper remaining. A red line will appear on the right side of the chart paper when there is less than two days remaining on the chart.

CHART PENS

Make sure the pens are leaving a bold trace and track freely across the chart. Pen replacement is described in the manufacturer's Instruction Manual.

COMPUTER RESET

Document whether or not a computer reset was done during this site visit.

Resetting the Computer

The computer is reset by turning the power switch "off" for at least one second and returning it to the "on" position (see Section 5.1). This does not require resetting the time.

TIME RESET

Document whether or not a time reset was done during this site visit.

COMMENTS AND SUPPLIES

Space for additional comments is provided at the bottom of the Log Sheet. This space should also be used to request servicing supplies.

5.0 INTERMITTENT SERVICING AND MAINTENANCE

This section details procedures for providing special system servicing or maintenance tasks. The frequency of these tasks is outlined in Section 4.0, Figure 4-1. The following topics are discussed:

1. System Timing Checks and Resets
2. Transmitter Lamp Changes
3. Strip Chart Servicing
4. Solar Power System Checks
5. AC Line Power System Checks
6. DCP System Checks

5.1 Checking and Resetting System Timing

When resetting the timing at both stations, reset the transmitter timing first.

TRANSMITTER TIMING CHECK

1. Set your digital watch by calling the National Bureau of Standards in Boulder, Colorado (303/499-7111).

2. The transmitter beam can be observed at the receiver station with the un-aided eye or through the telescope. At the transmitter, light can be seen at the back of the instrument through the lamp housing. Do not look into the transmitter.

3. Observe the time the transmitter light turns either "on" or "off." Document this on the appropriate Log Sheet.

RECEIVER TIMING CHECK

Observe the receiver computer toggle light and record the time it changes state (i.e., on to off, or off to on).

TIMING SEQUENCE

The transmissometer system should follow the following timing sequence:

HR:MI:SEC	Action
02:00:00	Transmitter lamp turns "on"
02:03:00	Receiver begins 10-min. average reading
02:13:20	Receiver finishes reading, updates display and changes toggle state
02:16:00	Transmitter lamp turns "off"
03:00:00	Sequence repeats.

TIMING TOLERANCE

IMPORTANT--When there is less than 45 seconds, or more than 5 minutes, between the toggle update and the lamp turnoff, the timing system needs resetting.

TRANSMITTER TIME RESET

1. Set your digital watch before going to the station.

2. Arrive at the transmitter station at least five minutes before the hour.

3. Leave the on/off switch in the "on" position (up), and the test switch in the "off" position (down). Test switches are on units with serial number 004 or higher.

4. Remove the control box cover (4 screws).

5. Precisely at the top of the hour (any hour), push the time reset button all the way down, hold for 1/2 second, and release (see Figure 5-1).

6. Upon release of the time reset switch, the transmitter will turn "on."

7. Replace the control box cover.

8. Verify the transmitter turns "off" at 16 minutes past the hour.

9. Document the time reset on the transmitter Log Sheet.

RECEIVER TIME RESET

1. Set your digital watch before going to the station.

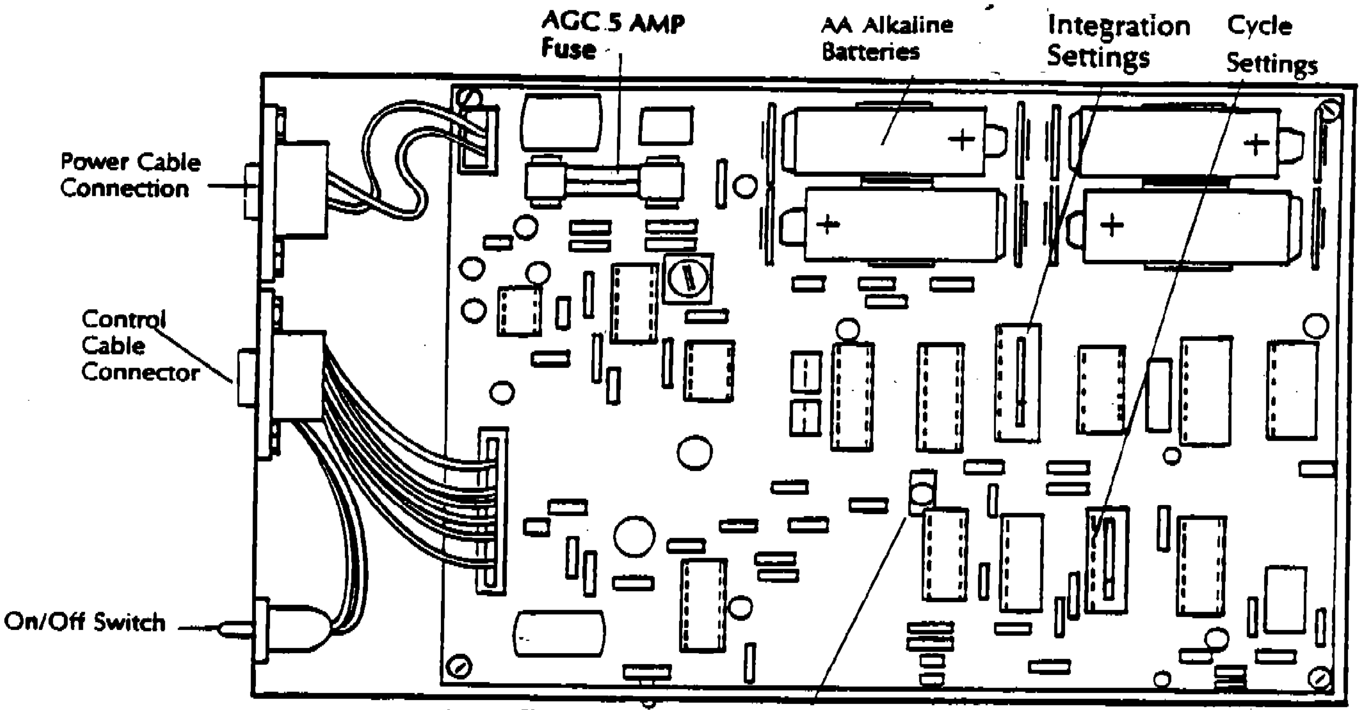
2. Arrive at the receiver station at least five minutes before the hour.

3. At two minutes and 30 seconds after the hour, turn the computer power switch "off," leave the switch in the "off" position for at least one second, and turn back "on." For switch locations, see Section 8.0 (Figure 8-2).

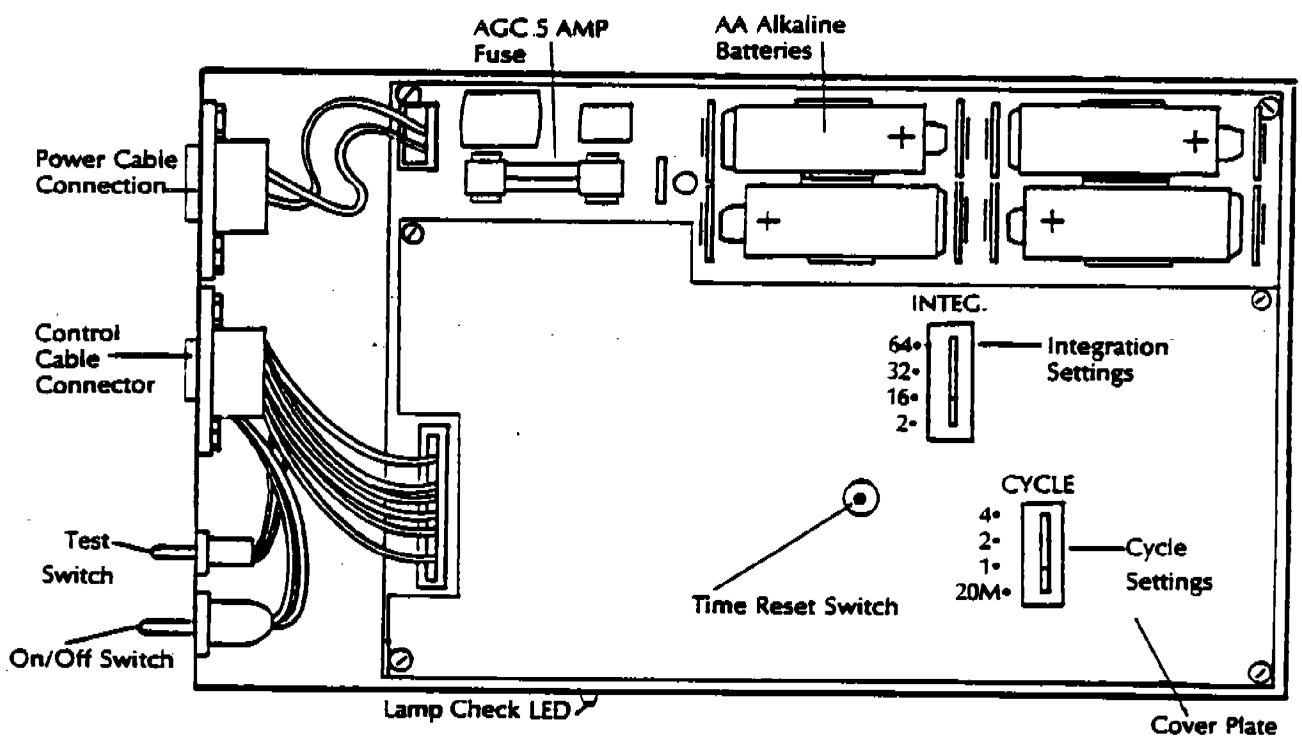
4. At precisely 3 minutes after the hour, hold the time reset switch in the "up" position for 1/2 second. Let it return to its down or "run" position.

5. Verify that the reading updates and the toggle light changes state at approximately 13 minutes and 20 seconds after the hour.

6. Document the time reset on the receiver Log Sheet.



Control Box – Serial Nos. 001-004



Control Box – Serial Nos. 005 and higher

Figure 5-1. Transmitter Control Box.

5.2 Transmitter Lamp Changes

IMPORTANT: Lamps are removed by pulling them out; do not loosen the screws on the lamp housing plate.

LAMP REMOVAL PROCEDURE

1. Refer to Figures 5-2 and 5-3 for the location of the items described.

2. If the transmitter is in the "run" mode and a reading is being taken, do not disrupt the reading--wait until the transmitter has turned "off."

3. Do not attempt to change lamps if there is less than 5 minutes before the start of the hour.

4. Before removing the replacement lamp from the lamp case, write today's date in the space labeled "lamp on" on the lamp sticker.

5. Take the new lamp out of the lamp case, handling it by the holder only. Do not touch the glass with your fingers.

6. Clean the lamp with alcohol and Kimwipes and remove lint from the lamp by blowing with canned air. Be sure to hold the can in the "upright" position. Carefully set the lamp aside in a safe place.

7. Turn the transmitter power "off" at the control box.

8. Remove three of the four screws that hold the lamp chamber cover in place. Loosen the front right screw slightly--this screw will hold the cover in place. The cover can pivot on the screw, exposing the lamp chamber.

9. Remove the old lamp by pulling out on the lamp holder. Some lamps may have to be removed with the aid of a flat-blade screwdriver. Do not push on the lamp from inside the lamp chamber.

10. Place the old lamp in the lamp case. Mark the date the lamp was removed on the "date off" space on the lamp sticker.

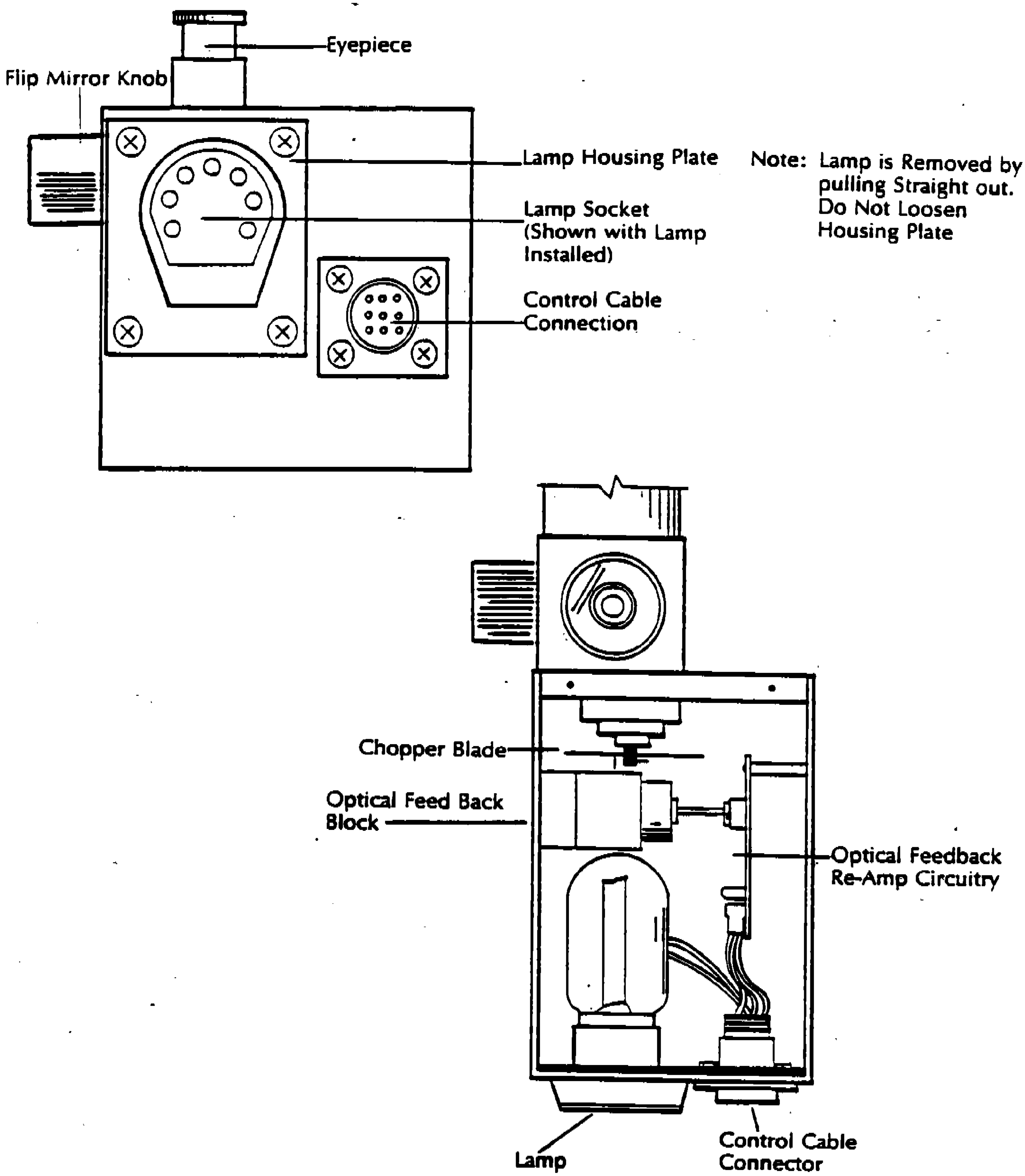
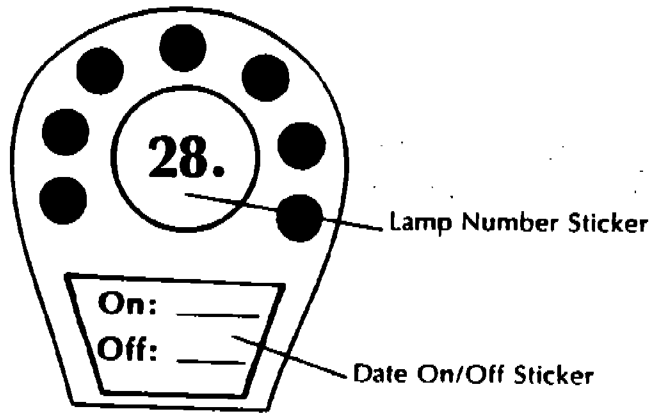


Figure 5-2. Transmitter Lamp Chamber.



Lamp Calibration Number Settings

1. Lamp #__________ requires a cal # of __________ .
2. Lamp #__________ requires a cal # of __________ .
3. Lamp #__________ requires a cal # of __________ .
4. Lamp #__________ requires a cal # of __________ .

1. When replacing spent lamps, always use lamp of next highest number.
2. Change Cal Number when replacement lamp is put into use.
3. Document lamp changes on Lamp Stickers and Operator Log Sheets.
4. Store spent lamps in lamp case.

This sticker is located in the lamp case.

Figure 5-3. Lamp Use and Calibration Stickers.

LAMP INSERTION PROCEDURE

1. Insert the cleaned and labeled replacement lamp into the lamp socket.

2. Be very careful to align the lamp contact pins with the holder sockets before pushing the lamp in.

3. Observe the contact sockets inside the lamp chamber as you are inserting the lamp. If the contact pins were not aligned correctly with the sockets, the sockets may be pushed out while inserting the new lamp. If the socket is pushed into the lamp chamber, remove the lamp, push the socket back in and try again.

IMPORTANT--the lamp will not turn on unless proper contact is made.

6. Push the lamp fully into the socket.

7. Replace the lamp chamber cover.

8. Turn the power switch to the "on" (up) position.

9. If your transmitter control box is equipped with a test switch, move the switch to the "test" (up) position. Verify that the new lamp works and return the test switch to the "off" (down) position.

10. If your transmitter control box does not have a test switch, verify that the lamp comes "on" under auto-control.

11. Document the lamp change on the operator Log Sheet.

CALIBRATION SETTING

Each lamp outputs a slightly different amount of light, requiring a new calibration setting on the receiver computer with each lamp replacement. Calibration numbers associated with each lamp are documented on a sheet (Figure 5-3) located in the lamp case. If a sheet is not supplied, or is lost, the correct calibration number can be obtained by calling ARS.

POST CALIBRATIONS (used lamps)

Lamps removed from service will be post-calibrated by ARS technicians after yearly site visits. Care should be taken in handling and transporting these lamps because the filaments become very brittle and fragile with use.

SPARE LAMPS

One spare, calibrated lamp has been left at each site. If a replacement lamp has been damaged, use the lamp with the next higher number. Document this on the Log Sheet under comments.

5.3 Strip Chart Servicing

CHART PAPER REPLACEMENT	Instructions for installation of chart paper can be found in the manufacturer's Operators' Manual on pages 2-8 through 2-10. Advance the paper by hand for a few sheets before loading the magazine to make sure the paper is feeding correctly.
CHART MAGAZINE CLEANING	At each paper change, the chart paper roller should be cleaned with alcohol and Kimwipes. This will remove any paper dust and chart pen ink that may have accumulated. Use canned air, with can in upright position, to remove paper dust from the drive gear assembly.
RECORDER CLEANING	Use canned air to remove dust from the control panel and the top of the recorder.
PEN REPLACEMENT	Instructions for changing pens can be found on page 2-10 of the manufacturer's Operators' Manual.

5.4 Solar Power System Servicing

SOLAR PANELS AND WIRING

1. Clean solar panels with the supplied glass cleaner and paper towels.

2. Inspect the glass for cracks and scratches.

3. Check mounting nuts and bolts for tightness.

4. Visually inspect wiring for signs of damage due to rodents or chaffing.

5. If the panels are on a free-standing mount, check that the alignment perpendicular to true south has not been altered.

6. Document results of these checks on the operator Log Sheets. Contact ARS if signs of damage are observed.

BATTERIES — See Section 5-6.

5.5 AC Power System Servicing

SURGE PROTECTORS — Visually check the status of the surge protector indicator lights. For proper operation, the light should be green. Refer to Section 8.10 for a description of the surge protector. If the surge protector green indicator light is not lit while the power is on, call ARS and a replacement unit will be sent.

BATTERY CHARGER	Periodically check the indicator dial on the face of the battery charger. The charger at the receiver station should always be very close to zero. The charger at the transmitter station will rise to approximately 3 amps while the light is "on" and will drop to zero as the battery charges. Meter readings greater than this may indicate a problem with the battery.
WIRING AND CONNECTORS	Periodically check wiring for damage and connectors for tightness. Inspect battery connections for corrosion and deposits.
BATTERIES	See Section 5.6.

5.6 Storage Battery Servicing

BATTERY FLUID LEVEL

Battery fluid level should be checked monthly. The fluid level is visible through the plastic case of the battery and should be between the two indicator marks on the battery case. Batteries in the small version transmitter shelters may be difficult to check. In that case, a check of one battery would suffice.

If the battery fluid level is low, use only distilled water to bring the level up. Low battery fluid levels indicate a possible problem with the solar panel regulators. ARS technicians should be informed of this situation; more frequent inspections must be made.

Under normal operating conditions, battery fluid should only need to be added during yearly ARS technician site visits.

BATTERY CONTACTS

Visually inspect battery contacts for signs of excess corrosion or deposits. Wire brushes have been supplied to remove the deposits if needed. Under most conditions, terminals will only need cleaning once a year by ARS field technicians. If terminals need cleaning, follow the directions listed below:

CLEANING BATTERY CONTACTS

1. Notify ARS of the need to clean the terminals. Do not attempt this if you are unsure.

2. Turn off power to the following instruments (do not disrupt a transmissometer reading):

Receiver Station	1. Receiver computer 2. Strip chart recorder 3. Unplug AC battery charger

Transmitter	1.	Transmitter
Station	2.	Unplug AC battery charger

3. Make sure the wiring is labeled and is easily identifiable as to positive (+) and negative (-) leads.

4. Draw a diagram depicting power lead attachments.

5. Remove and clean one contact surface at a time starting with all negative leads (-).

CAUTION--sparks will occur if battery leads touch metal objects or each other.

6. Clean contacts with the supplied wire brush.

7. Check the battery system wiring with your diagram after you have finished and the wires are re-connected.

8. Turn all instrumentation back "on" and verify correct operation of each component.

9. Document this servicing on the operator Log Sheets.

10. Call ARS and advise them that the servicing has been completed.

DEEP CYCLE BATTERIES

Due to the heavy power consumption of the transmitter while the light is "on" (2.7 amps), deep cycle batteries are used at the transmitter station. With their increased plate thickness, they are able to withstand the constant "deep cycle" of heavy usage and charging. Automobile batteries would not last long in this application.

Deep cycle batteries are also used at the receiver station. Due to the constant load of the instruments, an automobile battery would suffice for this application. Deep cycle batteries are used throughout to keep the batteries standard.

BATTERY REPLACEMENT

Batteries will be replaced every two years by ARS field technicians. If an emergency replacement is needed, dry batteries will be sent by freight. Battery acid will need to be purchased and used on-site as acid cannot be mailed. An alternate plan would be for ARS to send the necessary funds for local purchase of replacement batteries.

5.7 Data Collection Platform (DCP) Antenna Servicing

DCP SERVICING	On outward appearances alone, it is not possible to tell if the DCP is working correctly. Therefore, aside from physical inspection of the antenna, cable connectors, and trickle charger, no servicing of the DCP is required.
ANTENNA INSPECTION	The DCP antenna should be visually inspected periodically. First, check that the mounting base is securely affixed to the shelter. Secondly, the driver, reflector, and directional elements should be securely attached and in position. Lastly and most important, the antenna alignment should be correct. See Section 8.7 for a description of antenna components.
CABLE AND CONNECTOR INSPECTION	Inspect the antenna cable for rodent damage or chaffing. The cable connector at the base of the antenna should be checked for tightness periodically.

6.0 TROUBLE-SHOOTING

Many times operators can diagnose and solve instrument problems in the field, reducing costly site visits or loss of data. Two good practices to follow in trouble-shooting are: 1) start with the simple checks and progress towards the more complicated; and 2) break a system down into individually testable sub-systems.

Many transmissometer system problems can be solved by checking items in the following categories:

1. The "Obvious"
   - A. Power unplugged or not turned "on."
   - B. Flip mirror(s) not in correct "on" position.
   - C. Misalignment at one, or both, ends.
   - D. System timing out of synchronization.
   - E. Incorrect instrument settings used.

2. Power Supply
   - A. Battery voltage not high enough to run system.
   - B. Fuse Blown.
   - C. Incorrect polarity on power leads.
   - D. Power connectors not making good contact (pins).

3. Connectors
   - A. Connector not plugged in, or in wrong input position.
   - B. Connector not making good contact.
   - C. Connector pins or sockets damaged.
   - D. Damage to cable/connector, resulting in broken wire or short.

6.1 Before Calling for Assistance

Before reporting problems or requesting assistance in diagnosing an instrument problem, please do the following:

1. Check problem areas listed in Section 6.0 (obvious sources, power supply, connectors, etc.).

2. Follow procedures for trouble-shooting the component in question.

3. Have documentation of your tests available.

4. Have a field Operators' Manual available.

Please call promptly with suspected or observed instrument problems. If the person you need to speak with is not in, ask to be directed to another or leave a message, including your name, location, and a brief description of the problem(s) or need(s).

6.2 Transmitter Trouble-Shooting

INOPERABLE TRANSMITTER — If the transmitter will not operate, check the following:

1. On/off switch in "on" position.

2. Power cable contacts at battery not loose, corroded, or covered with excessive deposits.

3. Connectors firmly tightened at control box and transmitter.

4. Battery voltage adequate (above 11 VDC).

5. Fuse inside control box intact.

CHOPPER ON/ NO LIGHT — If the light chopper activates and stays "on," but the lamp does not turn on, check the following:

1. Lamp filament broken. The lamp check LED will light when the unit is "on" under auto-control.

2. Lamp pin/socket contact not made.

TRANSMITTER NOT "ON" FOR FULL 16 MINUTES — If the transmitter turns "on" at the correct time, but does not stay "on" for the full 16 minutes, check the battery voltage while the transmitter is "on." It should remain above 10.5 volts.

6.3 Receiver Trouble-Shooting

POWERING UP — When the receiver computer power is turned "on," the computer will perform a series of internal checks and then set the display to "001" (Serial #1-4) or "000" (Serial #5 and up). The toggle, OV, and OR lights should be "off." If the display does not go to "000" or "001" upon powering-up, this indicates a system or component failure. Call ARS for further directions.

TOGGLE LIGHT FLASHING — If during internal checks, the computer finds a problem on the memory card, the toggle light will flash at approximately one-second intervals upon powering up. If this occurs, call ARS for further directions.

OVER-VOLTAGE LIGHT "ON"	Refer to Section 8.3 for a description of the function of the over-voltage light. To clear (turn-off) the over-voltage light, the computer must be reset. Resets are accomplished simply by turning the computer power "off" for one second and turning the power back "on."
TOGGLE DOES NOT UPDATE	If the toggle light does not change state at the correct time: 1. Check the system timing--refer to Section 5.1 to reset. 2. The computer may be locked up. When this happens, both the toggle and the reading will stay the same until it is reset. Reset by turning power "off" for 1 second. 3. The chopper may not be working--see chopper failure description. 4. The computer may be malfunctioning--call ARS for further direction.
CHOPPER FAILURE	If the transmissometer is not taking readings when checks on all components of the system show that it should be capable of taking readings, check the following: 1. Remove the transmitter lamp chamber cover. 2. Verify that the light chopper blade (slotted disk) is still mounted to the motor shaft. 3. If the chopper blade has detached, turn power to the system "off." Remove the transmitter only and take it back to the office--telephone ARS for further instructions. Note: It is not possible to determine whether or not the chopper blade is attached by observing the transmitter through the telescope. Due to the speed at which the chopper rotates, both conditions will look the same.

6.4 Strip Chart Trouble-Shooting

The following is a list of the most common strip chart operational problems, resulting in lost data:

1. Zero/record button left in "zero" position.
2. Chart speed button left in "CM/Min" position.
3. Chart start/stop switch left in "stop" position.
4. Pen lifters left in "up" position.
5. Paper loaded incorrectly, resulting in jam.

If problems with the strip chart occur, take a minute to verify that the control switch or button settings match those listed on the strip chart sticker.

FUSES:
AC OPERATION

If the strip chart does not function, the fuse may have blown. If the unit operates from AC line power, proceed with the following:

1. Check that the power indicator switch on the back panel (Figure 8-4) is on the "AC line" position.

2. Check the surge protector for correct operating status (see Section 8.10).

3. Check the fuse located in a black holder on the back panel.

4. Check the circuit breaker if the fuse is intact.

5. If the fuse has blown, locate a replacement fuse. Verify that the replacement fuse is the same as the blown fuse by reading the specifications stamped on the end of the fuse.

6. Before inserting the replacement fuse, turn recorder power "off"--also turn off the chart drive. Disconnect the Channel A and B "-" lines on the back panel (2 jacks).

7. Insert the replacement fuse and turn the recorder "on." If the power on indicator does not light, turn the unit off and recheck the fuse. If the fuse has blown, call ARS.

8. If the power indicator light remains "on," connect the signal input "-" lines one at a time while observing the power indicator light.

9. If the fuse blows while connecting either input line, disconnect the input "-" lines and turn the recorder power switch "off."

10. If the problem cannot be corrected, call ARS for further directions. If a replacement unit is sent, be sure to read Section 7.7 on installing a new strip chart recorder.

FUSES:
DC OPERATION

If the strip chart does not function, an internal fuse may have blown. Fuses protecting recorders that operate from DC power will "blow" if the power leads are connected improperly (reverse polarity), if signal grounds are attached incorrectly, or if recorder components have failed.

The fuses are located inside the recorder. To check the recorder operation:

1. Check that the power indicator switch on the back panel (see Figure 8-4) is in the "12V" position.

2. Check the power leads on the terminal strip and the battery for excessive corrosion or a bad connection.

3. Check the voltage reaching the recorder at the power input banana jacks on the back panel. The voltage should be above 10 VDC.

4. Before checking the fuse, turn the power switch "off" and disconnect the Channel A and B "-" leads.

5. Take off the recorder cover by removing the six Phillips head screws. Two screws are located on the top of the cover, the other four are located on the sides (two to a side near the bottom).

6. Carefully remove the cover by first sliding it towards the back slightly before pulling up.

7. Inspect the two fuses located on a small circuit board on the left side of the recorder.

8. Replace the bad fuse with the supplied replacement. Verify that the replacement fuse is correct by comparing specifications stamped on the fuse.

9. With the cover still off, turn the power switch back "on" and observe the power indicator light. If the fuse blows, turn the power switch "off," reinstall the cover, leave the signal "-" leads disconnected, and call ARS for further directions.

10. If the power indicator light remains "on," connect the Channel A and B "-" lines one at a time while observing the power indicator light and the fuses. If a fuse blows, disconnect the signal "-" input lines, turn the power switch "off," reinstall the cover, and call ARS for further directions.

11. If the problem cannot be corrected, call ARS for further directions. If a replacement is needed, be sure to read Section 7.8 on installing a new strip chart recorder.

6.5 DCP Trouble-Shooting

The operation of the DCP, as well as the monitoring of parameters important to the correct operation of the DCP, is tracked daily at ARS. Should a potential problem arise, a technician will call to have you check the following:

1. Antenna alignment
2. Antenna elements
3. Cables
4. Connectors

Refer to Section 5.8 for descriptions of checks that can be made of DCP components and Section 8.6 which describes DCP features (Figure 8-5). If a data collection platform is transmitting at an errant frequency or time, ARS technicians may ask that you disable the DCP. Refer to Section 7.2 for instructions.

6.6 Solar Power System Trouble-Shooting

If a problem with the solar panel power system is suspected, first check the servicing and maintenance items described in Sections 5.4 and 5.6, then call ARS for directions before proceeding with further tests.

PANELS — Solar panel systems are wired in parallel, so that an individual, bad panel may not be easily identified aside from physical damage; however, there is not much that can go wrong with a solar panel. The most likely problem would be with the regulators or with the storage batteries.

REGULATORS — A bad regulator may inhibit panels from charging the batteries. To check the voltage output of the panels, proceed with the following:

1. Check the storage battery voltage when the panels have been exposed to full sun for several hours. The batteries should be "floating" at approximately 13 volts.

Note: Check the batteries at the transmitter station at 45 minutes past the hour after they have had a chance to recharge from powering the lamp.

2. If the batteries do not read approximately 13 volts, check the state of the charge of each battery cell with a hydrometer. If any cell is bad or if all cells are low, call ARS for instructions.

3. If the battery voltages are acceptable, turn off all the instruments, disconnect the solar panel "-" cable from the regulator or battery and measure the output. The panels should produce 18 to 22 volts under full sun.

4. Call ARS with the results of your tests.

6.7 AC Power System Trouble-Shooting

BLOWN BREAKERS-RECEIVER

If a breaker has tripped, follow the procedure listed below:

1. Unplug the surge protector. Do not plug the battery charger back in.

2. Unplug the DCP trickle charger (3"x3"x4" metal box).

3. Reset the breaker. If the breaker trips, consult an electrician.

4. If the breaker does not trip, try to isolate the faulty component by the following tests:

   A. Plug the DCP trickle charger in--note breaker condition.

   B. Plug the surge protector in after first disconnecting the battery charger--note breaker condition.

   C. Plug the battery charger in--note breaker condition. If the breaker blows, disconnect the charger from the battery and try again.

8. Phone ARS with the results of the test.

9. If either the DCP trickle charger or the battery charger are malfunctioning, leave the units unplugged. The system will operate for a few days on battery power alone. ARS will send replacement components.

7.0 REPLACING AND SHIPPING INSTRUMENTS

Follow the procedures described in this section for disabling, shipping, and installing instruments. Damage to instruments can occur not only during installation, but also while disconnecting. When removing or replacing instruments, keep the following considerations in mind:

1. Always leave the on/off switch in the "off" position when removing or installing instruments.
2. Avoid touching connector pins or circuit boards as static electricity could damage sensitive components.
3. Double-check connectors, power polarity, and instrument settings before applying power.
4. Follow procedures in the order they are given.
5. Call ARS technicians before proceeding if you have questions.

7.1 Removing the Transmissometer System

Take the appropriate shipping cases to the site with you when removing the transmissometer system so that the instrument will be protected during transit. See Section 7.10 for packing and shipping instructions.

TRANSMITTER REMOVAL

1. Take the gray, suitcase-style transmitter shipping case with you to the site.

2. Turn the control box power switch "off."

3. Disconnect the power cable from the control box only. Coil the cable and set next to the battery or, if fixed, leave in position.

4. Disconnect the control cable from both the control box and the transmitter. Coil and band the cable and place in the shipping case.

5. Place the control box in the shipping case after first enclosing in a plastic bag.

6. Remove the lamp from the transmitter. Label the lamp sticker with the "off date" and store the lamp in the lamp case.

TRANSMITTER REMOVAL-Cont.

7. Cover the telescope and lamp chamber ends of the transmitter with plastic bags. Secure the bags in place with rubber bands. Place the transmitter in the shipping case.

8. Document removal of the instrument on the operator Log Sheet.

RECEIVER REMOVAL

1. Have both wooden shipping cases and the gray, suitcase-style case on-site as you prepare to remove the receiver.

2. Turn "off" power to the receiver computer.

3. Disconnect the receiver power, output, and photometer head cables from the computer and place them aside. Coil and band the photometer head cable.

4. Place the receiver computer in its shipping case.

5. Remove the detector head from the telescope with an Allen wrench which has been included in the tool kit. Wrap the detector head in a plastic bag and place it in the gray, suitcase-style shipping case.

6. Cover both ends of the telescope with plastic bags and place in the shipping case.

7. Document removal of the instrument on the operator Log Sheet.

7.2 Removing the DCP

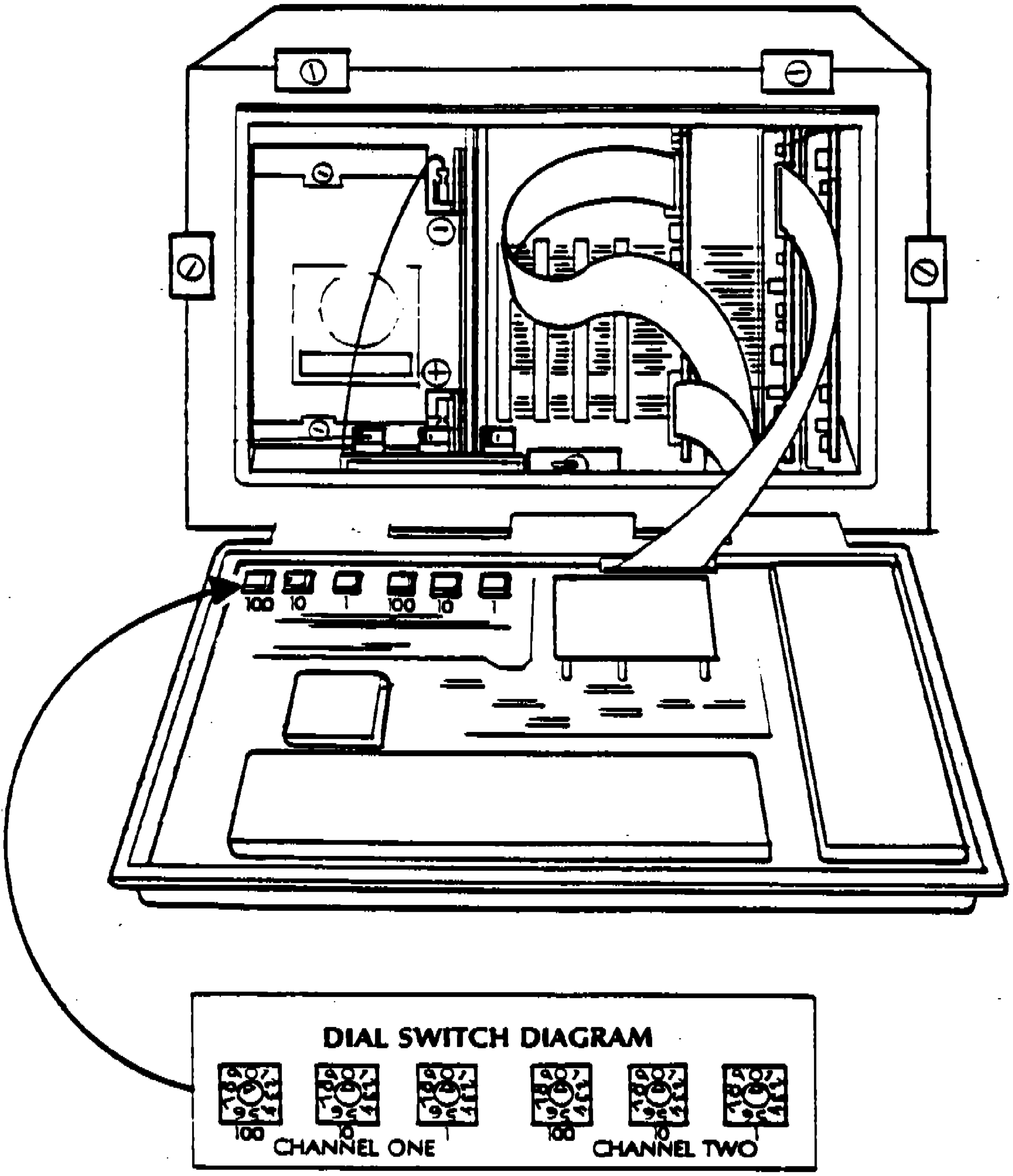
Refer to Figure 8-5 for the location of the switches and connectors discussed. Figure 7.1 depicts the switches in detail.

DCP REMOVAL

IMPORTANT--Before disconnecting the DCP antenna cable, some internal switch settings must be changed to inhibit transmissions. Failure to do so may result in damage to the DCP.

1. Open the hinged door of the DCP. Locate the six, square red dial switches located on the circuit board on the inside of the door.

2. Using a small flat-blade screwdriver, reset the switches under "CHAN 1" to 9, 0, 0. The switch immediately below the "100" on the circuit board should be set to 9.



CH1 Setting of 900 Inhibits Transmission

CH2 Not Used; Leave on 000

Figure 7-1. DCP Transmission Channel Switches.

DCP REMOVAL Cont.

3. Close the DCP door and tighten the clasps.

4. Before disconnecting the connectors on the side of the DCP, note their locations and mark, if necessary. Draw a wiring diagram if you think it will be helpful.

5. Disconnect all cables from the DCP input panel and remove the DCP. Pack the unit for shipping in the supplied box.

6. Document the removal of the DCP on the operator Log Sheet.

7.3 Removing the Strip Chart Recorder

The strip chart recorder should be removed carefully, as both signal wires from the receiver computer and power from the battery (DC operation) are "live." Follow the procedures given below:

STRIP CHART RECORDER REMOVAL

1. Turn off the receiver computer power.

2. Turn off the strip chart recorder power and unplug at the surge protector if the unit is AC powered.

3. Disconnect the "+" lead of the power supply and completely cover the metal portion of the banana jack with electrical tape.

IMPORTANT--do not let this connector touch metal as a large, potentially damaging spark will occur.

4. Remove the "-" lead of the power supply and tape the end.

5. Remove the "+" leads of CHA and CHB inputs and tape each one as it is taken off.

6. Remove the "-" leads of CHA and CHB inputs and tape each one as it is taken off.

7. Place pen lifters for both channels in the "up" position.

8. Remove and discard the chart recorder pens.

9. Remove any chart paper containing data after documenting removal date, time, and comments. Mail the used portion of the strip chart to ARS.

STRIP CHART RECORDER REMOVAL Cont.

10. Enclose the recorder in a plastic bag before placing it in the shipping case. Also coil the AC line-powered cord (if supplied) and place it in the shipping box.

11. Record the following information regarding chart removal and place inside the shipping box.

1. Location name
2. Date/Time
3. Operator name
4. Brief description of chart recorder problems, if known.

12. Document removal of the strip chart on the Operator Log Sheet.

7.4 Removing Air Temperature/Relative Humidity Sensors

1. Disconnect the air temperature/relative humidity cable at the sensor.
2. Tape the end of the cable connector with electrician's tape. Allow the connector to hang down to avoid moisture entering the connector.
3. Loosen the two clamps that hold the sensor in place and slide the sensor out.
4. Pack the sensor in a cardboard box for shipping. No shipping case has been supplied for this.
5. Document the removal of this sensor on the Operator Log Sheet.

7.5 Transmitter Installation

Transmissometers sent from ARS or Optec, Inc. will have receiver and transmitter timers pre-set; however, to verify system timing is correct, follow the procedure described in Section 5.1.

1. Inspect shipping case(s) for signs of damage upon receiving the instrumentation. Remove the transmitter from the shipping case and remove the plastic bags from the instrument.
2. Mount the transmitter on the alti-azimuth base and tighten the lock-bolt. **IMPORTANT**--do not re-focus the transmitter.
3. Install the lamp with the lowest number after first cleaning and labeling.

4. Dust the objective lens with canned air. Be careful to hold the can in the "upright" position.

5. Install the control box. Make sure the on/off and test switches are in the "off" (down) position.

6. Connect the control cable to the instrument and the control box making sure to seat the connectors properly. A small "detent" can be felt when the connectors are fully seated.

7. Connect the control box power cable. Check that the power cable is securely connected to the battery.

8. Turn "on" the control box on/off switch. If the time is between the top of the hour and 16 minutes past, the transmitter will turn "on" automatically. If the unit is operating, wait until 16 minutes past the hour to verify the lamp turns "off" at this time.

9. If the time is not right for the transmitter to turn "on" under auto-control, use the test switch (if equipped) to verify lamp operation.

10. Verify that the system timer is set correctly. If the timer is not set correctly, refer to Section 5.1 for instructions on how to reset the timer.

11. Upon successful installation of the transmitter, complete the tasks listed on the Transmitter Station Log Sheet. Document the installation of the system and the lamp number placed into service.

7.6 Receiver Installation

1. Remove the receiver telescope from the wooden shipping case. Remove the plastic bags from the instrument.

2. Mount the telescope on the alti-azimuth base and tighten the lock-bolt.

3. Dust off the objective lens with canned air. Be sure to keep the can in the "upright" position.

4. Mount the detector to the telescope by tightening the two retaining Allen screws after fully seating the assembly. The sides of the eyepiece/detector assembly should be perpendicular to the ground.

5. Remove the receiver computer from the wooden shipping case and place it in its correct position. Make sure the power switch is in the "off" (down) position. Remove the four screws and take off the top cover of the receiver computer.

6. Touch the receiver computer case and any large, metal object (such as the unpainted portion of post) to rid yourself of static electricity.

7. Carefully, push down on the computer cards to make sure they are fully seated.

8. Push down on the ribbon connector and the small two-conductor connector located on the top cards.

9. Replace the computer cover and tighten the four screws. Connect the output cable from the terminal strip board, and power cable from the battery to the back panel of the receiver computer.

9. Plug the cable from the detector into the photometer input on the back panel of the receiver computer.

10. Turn the computer "on"--the display should go to "000" or "001" and the toggle, OR, and OV lights should be "off." If this is not the case, re-check board and connector seating.

11. Align the telescope, leave the flip mirror in the "on" position, and await a reading and toggle update at 13 minutes past the hour.

12. Upon successful installation of the system, complete the tasks listed on the Receiver Station Log Sheet. Document the installation of the system on the Log Sheet.

13. Store the shipping cases in the receiver station.

14. Call ARS and notify field technicians after the transmissometer has been installed.

7.7 DCP Installation

Any replacement data collection platform (DCP) sent from ARS will be pre-programmed and in its "run" mode. It will start collecting data as soon as the sensor input cables are attached. Data will be transmitted after the antenna cable is attached and internal channel selection switches are set to the proper position. Follow the steps listed below to install the DCP. Refer to Figure 7.1 for the location of described parts.

1. Notify ARS technicians before going into the field to install the DCP. The channel must be "activated" with the satellite service center prior to transmitting.

2. Locate the new DCP in the correct position within the shelter.

3. Connect the trickle charger or solar panel power cable to the correct position on the DCP panel. If a solar panel is used, it should be connected directly to the connector labeled either "15 to 30 volt input" or "solar panel/batt charger." If AC power is used, the trickle charger should also be plugged into the same connector.

4. Connect the antenna to the gold coaxial connector located on the upper right of the input panel.

5. Connect the sensor input cable from the terminal strip board to the connector labeled either "transmissometer" or "tele #1."

6. Connect the air temperature/relative humidity sensor cable to the position labeled "air temp/rel humidity."

7. Open the DCP door after loosening the clamps with a large, flat-blade screwdriver

8. Change the setting of transmission Channel 1 from (3 switches) 900 to the channel noted on the DCP sticker (see Figure 8-7). Channels used will be 009 for Eastern sites, and either 014 or 038 for Western sites.

9. Close the DCP door and re-tighten clasps.

10. Check the antenna alignment, elements, and cable, as described in Section 8.7.

11. Store the DCP shipping box, unless it is needed to return a malfunctioning DCP.

12. Document the DCP installation on the receiver station Operator Log Sheet.

13. Notify ARS technicians when the installation is complete.

7.8 Strip Chart Recorder Installation

Care must be taken when connecting DC power to the strip chart because the +12VDC wire comes directly from the battery. To avoid damage to the recorder or the receiver computer, follow the procedures listed below:

IMPORTANT--<u>do not</u> allow the "+" lead of the DC power cord to touch metal or the "-" lead as a potentially-damaging spark will occur.

1. Place the strip chart in its normal position within the shelter.

2. Make sure the strip chart settings match those listed on the strip chart sticker. See Section 8.5 for a description of the controls.

3. Set the power source switch, located on the back panel, to the correct position:

   "AC line" - if AC line power is used
   "12V" - if battery power is used

4. Leave the strip chart power switch in the "off" position.

5. Turn the receiver computer power "off."

6. Connect the green (-) and yellow (+) labeled sensor input banana jacks to the back of the strip chart recorder. The (-) leads attach to the black connectors, and the (+) leads attach to the red connectors under the appropriate channels.

7. If battery power is used, connect the red "+" lead of the power supply to "Ext Battery +" before connecting the black "-" lead.

8. If AC line power is used, plug the power cord into the chart recorder and then into the surge protector.

9. Before turning on the power, double-check the wiring.

10. Turn the power "on"--the power on indicator should light. If it does not, check the settings and wiring.

11. Service the strip chart as described in Section 5.3.

12. Document the installation of the strip chart on the Receiver Station Log Sheet.

13. Call ARS to advise technicians of the installation.

7.9 Air Temperature/Relative Humidity Sensor Installation

1. Slip the sensor into the mounting clamps. Do not tighten yet.

2. Attach the sensor input cable after inspecting for dust and debris within the connector. Use canned air to clean the connector if needed. Wipe a rag around the thread inside the connector if excess dust has collected there.

3. Tighten the sensor mounting clamps.

4. Document the installation of the sensor on the Receiver Station Operating Log Sheet.

5. Call ARS to advise technicians of the installation.

7.10 Packing and Shipping

SHIPPING CASES Shipping cases have been provided for the transmissometer computer, telescope, and transmitter. The original manufacturer's box for the strip chart recorder has also been left on-site. Some sites have DCP shipping boxes; these can be sent from ARS if needed. Shipping containers for other equipment or instruments must be found locally.

SHIPPING COSTS Shipping costs should be charged to the air quality project's account. Other arrangements can be made if:

1. UPS shipment is required and cannot be charged to the air quality account, or

2. There are problems meeting insurance requirements (government use of U.S. mail), or

3. An air quality account does not exist.

Call ARS to discuss alternate plans for covering shipping costs.

INSURANCE Items shipped to ARS should be insured for the following amounts:

1.	Receiver computer	$ 6,000
2.	Receiver telescope	4,000
3.	Transmitter	6,000
4.	Data collection platform	6,000
5.	Air temp/rel humidity sensor	1,000
6.	DCP antenna	300

Most other items do not need to be insured. If you have questions regarding insurance, call ARS technicians.

SHIPPING MISCELLANEOUS Use packing tape in addition to a nut and bolt to seal the shipping cases. When shipping items in a cardboard box, use nylon filament packing tape to help strengthen the box. If government mailing franks are used, write your location above the "return address." If the shipped items are not expected at ARS, or if an explanation on the return of the items would be valuable, enclose it in an envelope within the shipping case or box.

SHIPPING ADDRESS

Mail all items, including correspondence and instruments, to:

Air Resource Specialists, Inc.
1901 Sharp Point Drive, Suite E
Fort Collins, Colorado 80525

(303) 484-7941

Notify ARS when and with which shipper monitoring components were sent so that an expected date of delivery is known.

8.0 MONITORING SYSTEM DIAGRAMS AND COMPONENT DESCRIPTIONS

This section presents transmissometer system component diagrams and detailed descriptions of system components, including:

- Transmissometer transmitter
- Transmissometer receiver
- Terminal strip connector board
- Strip chart recorder
- Data collection platform
- Air temperature/relative humidity sensor
- Solar power system
- AC line power system
- Support equipment

8.1 Monitoring System Diagrams

Diagrams of the transmissometer system monitoring components presented in this section support the discussions and operating procedures presented throughout this manual. The following diagrams are presented:

Figure Number	Title
8-1	Transmitter Component Diagram
8-2	Receiver Component Diagram
8-3	Terminal Strip Wiring Diagram
8-4	Strip Chart Component Diagram
8-5	DCP Logger Component Diagram
8-6	DCP Antenna Component Diagram
8-7	DCP, Receiver, and Strip Chart Stickers

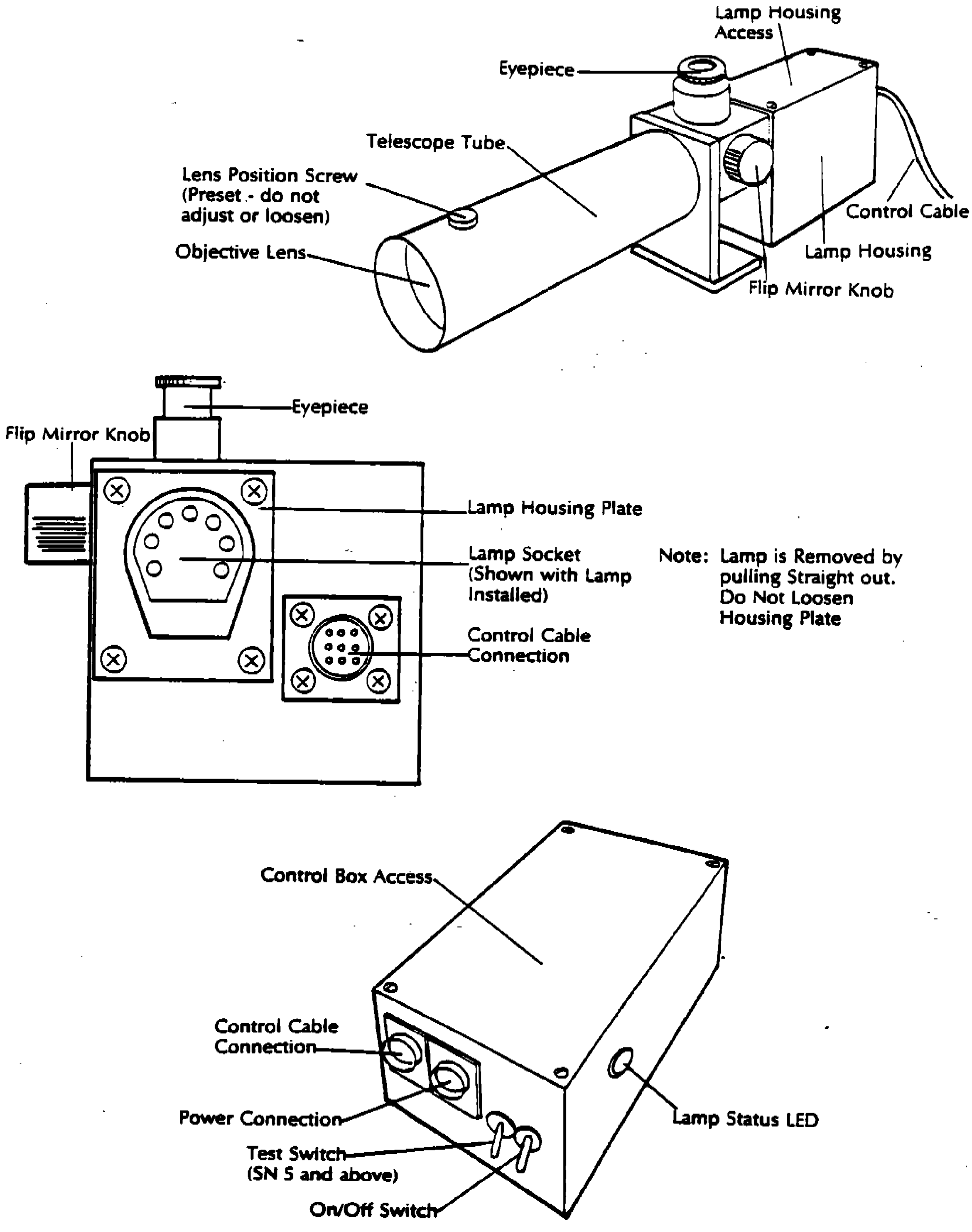
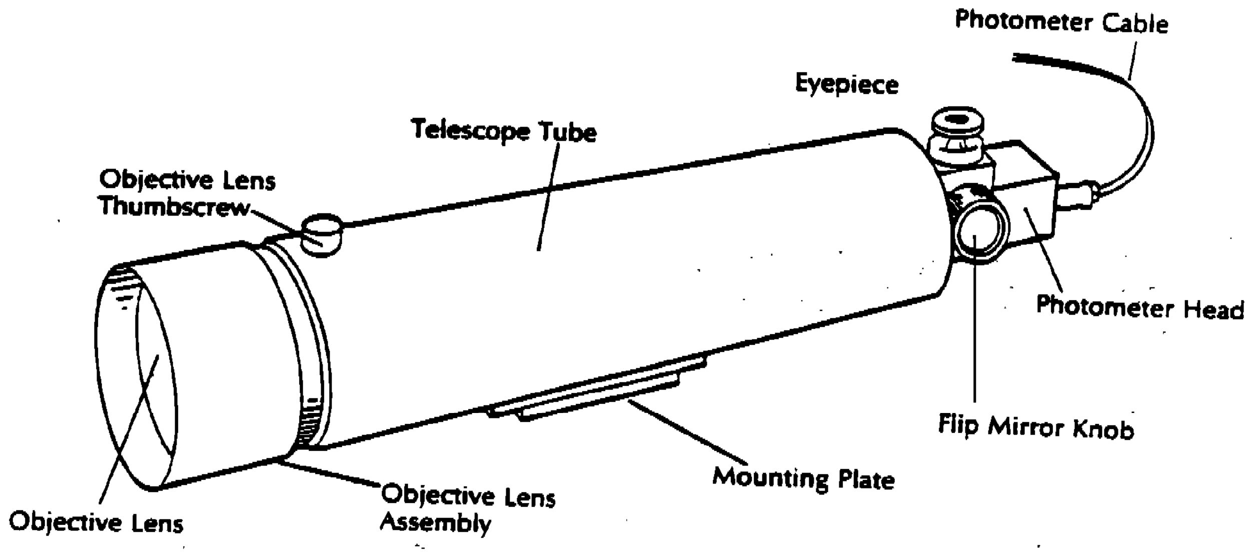


Figure 8-1. Transmitter Component Diagram.



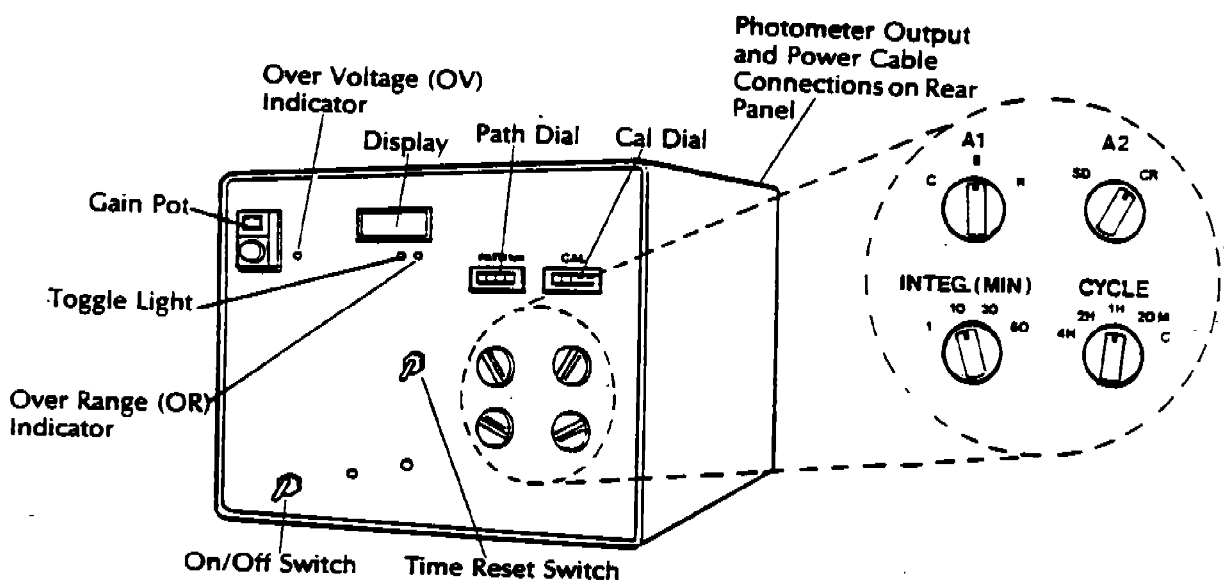


Figure 8-2. Receiver Component Diagram.

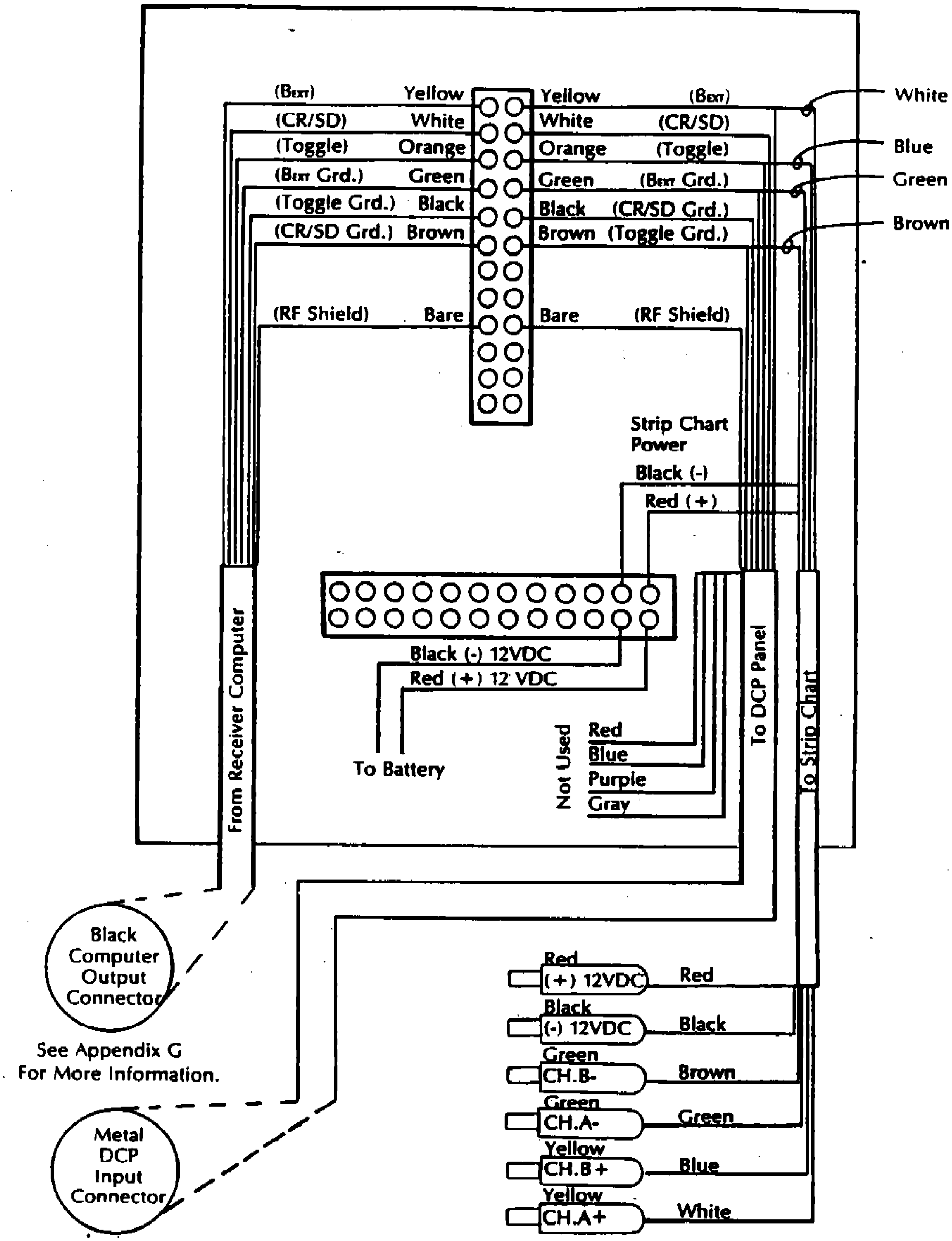
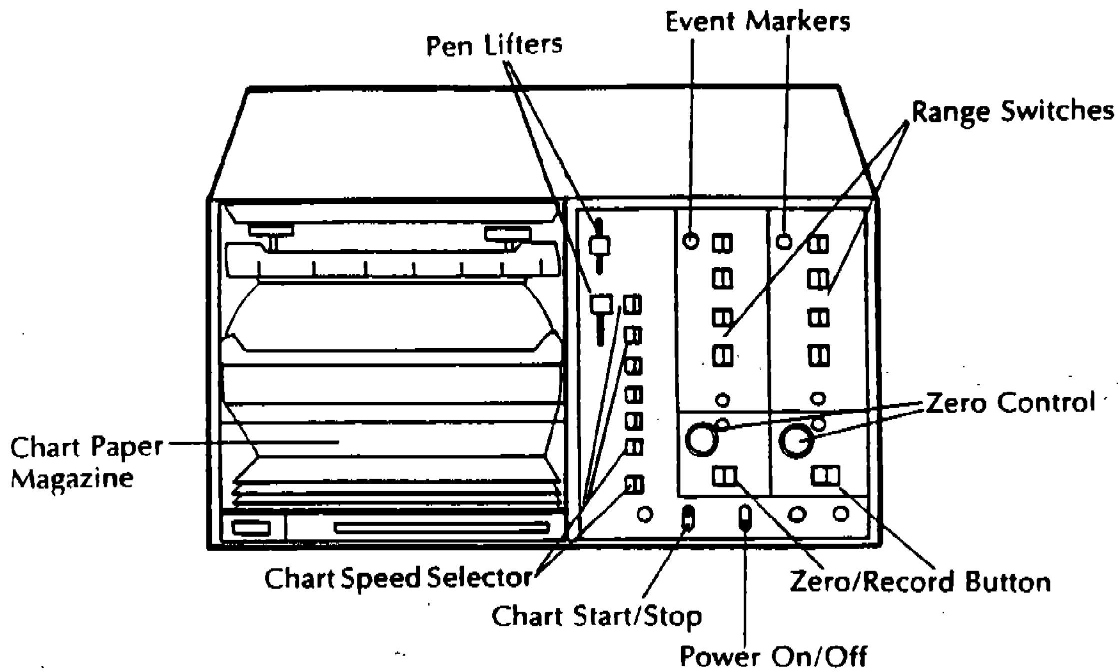


Figure 8-3. Terminal Strip Wiring Diagram.



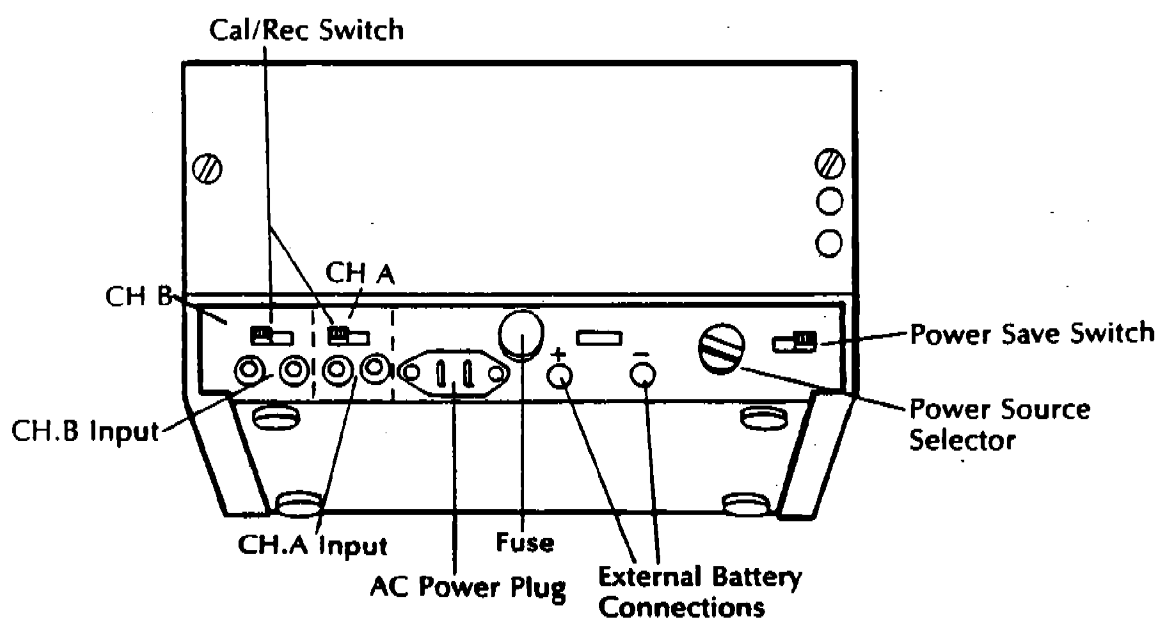
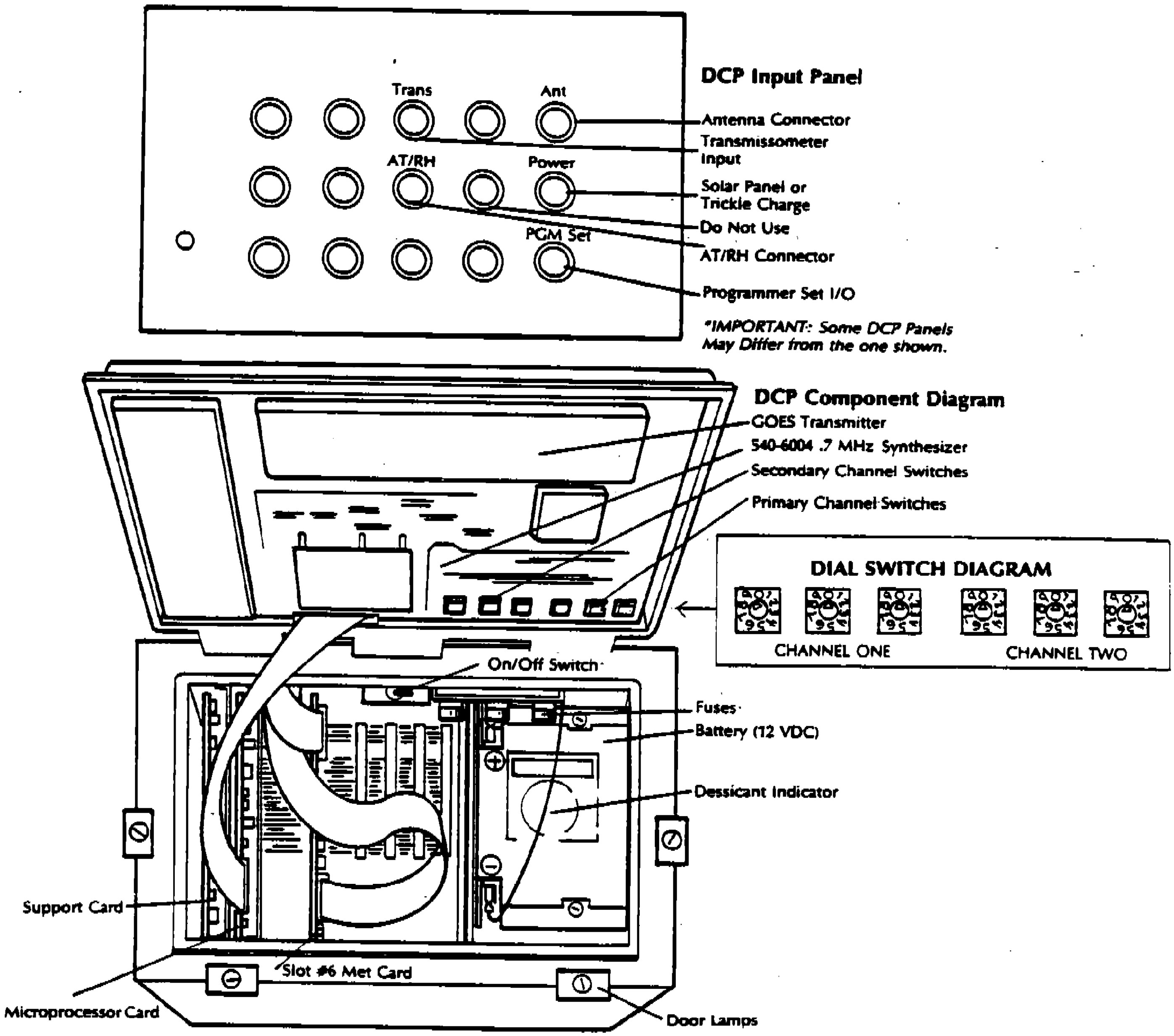


Figure 8-4. Strip Chart Component Diagram.



Side view DCP input panel
IMPORTANT--DCP panels may differ from the above unit.

Figure 8-5. DCP Logger Component Diagram.

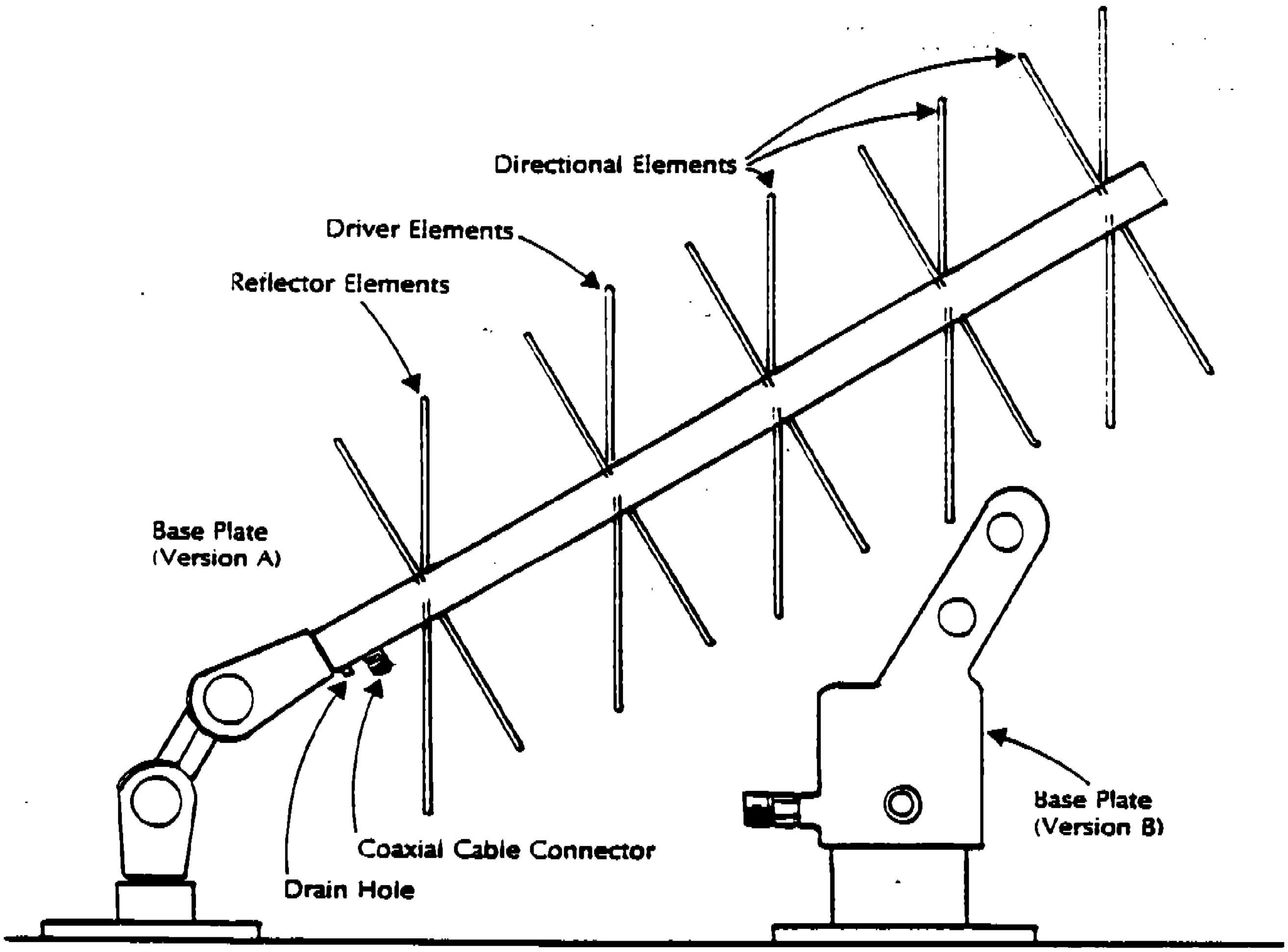


Figure 8-6. DCP Antenna Component Diagram.

Strip Chart Settings

1. Chart speed - ________ CM/HR
2. CHA range - ____________
3. CHB range - ____________
4. Both zero buttons - record position.
5. CHB zero knob pulled out (x5 position).
6. CHA zero on chart paper at 0.0.
7. CHB zero on chart paper at 8.8.
8. Both pens in down position.
9. Chart and power switches "On".

This sticker should be affixed to the top right corner of the strip chart recorder.

Strip Chart Documentation

1. "Hack" marks on chart paper (orange buttons).
2. Location, date and local time.
3. Operator name.
4. Receiver panel reading.
5. Receiver alignment comments.
6. Stirp chart servicing comments.
7. Any additional monitoring comments.

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This sticker should be affixed to the top left surface of the strip chart recorder.

DCP Operating Parameters

Serial #: ____________________

ID: ____________________

Channel: ____________________

Transmit Times: ____________________

Antenna Azimuth (°T): ____________

Antenna Inclination: ____________

Comments: ____________________

____

____

This sticker should be affixed to the top left corner of the DCP door.

Panel Setting

A1: C B VR

A2: SD CR

Integ. Time: 1 10 30 60

Cycle Time: C 20M 1H 2H 4H

Path: ____________ (km) Gain: ________

Calib: ____________________

This sticker should be affixed to the receiver computer front panel.

Figure 8-7. DCP, Receiver, and Strip Chart Stickers.

8.2 Transmitter Component Descriptions

Refer to Figure 8-1 for the location of the following components:

8.2.1 Transmitter Telescope

FLIP MIRROR KNOB	The flip mirror knob changes the position of an internal mirror. When the knob is in its fully-clockwise or "view" position, the image is directed to the eyepiece. When the knob is in its fully counter-clockwise or "run" position, the image is directed to the photodetector for measurement.
EYEPIECE	The eyepiece is used to check and re-position transmitter alignment. An image of the scene with the view transposed left to right will be visible when the flip mirror knob is rotated fully clockwise. The reticule markings are super-imposed over the scene as an aid to alignment. The transmitter must be aligned so that the receiver is always within the center circle. **IMPORTANT**--no readings are taken with the flip mirror in the "view" position.
LENS POSITION LOCKING SCREW	The lens adjustment screw holds the objective lens in position. **IMPORTANT**--do not attempt to focus the transmitter. Re-positioning the objective lens will change the transmitter light output, requiring a re-calibration.
TELESCOPE TUBE	The telescope tube holds the objective lens at a constant distance (focus) from the lamp filament. The objective lens is used both to focus the image for alignment and to concentrate the outgoing light beam. The tube should always be mounted securely to the flip mirror assembly with the two Allen screws machined into the flip mirror block.
LAMP CHAMBER	The lamp chamber contains the lamp, chopper system, and the optical feedback block. To avoid the possibility of contaminating the optical surfaces with dust, the chamber should only be opened if servicing is required.
LAMP SOCKET	The type of optical system used in the transmitter to concentrate the light beam requires accurate positioning of the lamp filament. The machined lamp socket assures that each lamp is mounted in the same position.

LAMP SOCKET PLATE — The lamp housing plate accurately positions the lamp socket which, in turn, accurately positions the lamp and its filament.

IMPORTANT--the plate should never be loosened; movement of the lamp housing plate will require factory servicing of the instrument. Access to the lamp chamber is from the top.

8.2.2 Transmitter Control Box

ON/OFF SWITCH — This switch controls power to the control box (on = up). The transmitter time-keeping circuitry runs from an internal battery and is not affected by the position of this switch. If power is applied to the transmitter when the auto timer circuit is in the "operate" mode, the lamp and chopper will come "on." If the auto timer is in the "wait" mode, the light will not come "on."

TEST SWITCH — The test switch, present on units with serial numbers greater than four, is used to manually turn the transmitter "on" without affecting the internal time-keeping circuitry. The lamp status LED will light when the test switch is in the "up" or "test" position. Keep in mind the transmitter will not turn "off" when the test switch is moved to the "off" position (if the internal auto-timer is in the "operate" mode).

LAMP STATUS LED — The lamp status light indicates whether or not the lamp has aged or been damaged to the point where the optical feedback controller cannot keep the light output constant. The LED must be observed while the transmitter is "on" under automatic control. If the LED is "on," the lamp needs to be replaced. Remember, the LED will always light when the test switch is used.

HAND-HELD RADIO PRECAUTION — The transmitter circuitry, especially the internal auto-timer, can be adversely affected by strong radio signals. Do not transmit on a hand-held radio within 10 feet of the transmitter. Avoid aiming the antenna at, or over, the circuitry. Strong radio signals may reset the internal auto-timer, resulting in incorrect system timing.

8.2.3 Transmitter Cables and Connections

POWER CABLE CONNECTION — A two-conductor power cable from a power supply or battery connects to this input plug. Pin 2 of the plug is for +12VDC, Pin 3 is for power return (-). Reversing polarity or connecting a supply greater than 17VDC will cause the fuse inside the controller box to blow.

CONTROL CABLE CONNECTION — The cable that carries power and signals from the control box to the transmitter connects to these input plugs. Both ends of the cable are identical and are interchangeable. A small indentation can be felt when tightening this type of connector, indicating the fully-secured position.

8.3 Receiver Component Descriptions

Refer to Figure 8-2 for the location of the following components:

8.3.1 Receiver Computer

ON/OFF SWITCH — The On/Off switch serves two purposes: it controls power to the computer, and acts as a computer reset. Upon powering up, the LCD display should, after a short period, display 000 or 001. If the computer should lock up, the on/off switch can be used to reset the system. Resetting is accomplished by holding the switch in the "off" position for at least one second before turning "on." Like the transmitter, the receiver's auto-timer circuitry is powered by internal batteries and is not affected by the on/off switch.

TIME RESET — The time reset switch, when activated, resets the internal timer and defines the start times for the integration and cycle intervals. If settings on either the INTEG or CYCLE switches are changed, the internal timer must be reset. The timer reset switch has no effect when the computer is set to the "continuous" mode (INTEG = 1, CYCLE = C).

DISPLAY — The small LCD display, on the receiver computer front panel, displays readings as selected by switch A1. The range of the display for the various readings is:

C Raw Instrument Readings. The range is from 000, indicating no light is visible to 999 counts. Raw readings should always be less than the calibration number. The higher the raw reading, the cleaner the air.

B Extinction Values (in km^{-1}). The range is from .000 (000 displayed), indicating impossibly clean air to an extinction of .999 (999 displayed), which corresponds to a visual range of 3.92 km. For visual ranges less than 3.92 km, .999 will continue to be displayed. Extinction values should not go below 0.007, which is the calculated theoretical minimum of .009 minus instrument and rounding error of .002. The lower the extinction value, the cleaner the air.

VR Visual Range (km). The range for this setting is from 000 km, indicating no transmitter light was visible, to 999 km--an impossibly high value. The maximum possible visual range is 391 km. The higher the visual range, the cleaner the air.

A1 SWITCH

The A1 switch selects the computer output to both the front panel display and to analog line #1 used by the data loggers.

C Raw instrument readings in counts
B Extinction values in units of $/km^{-1}$
VR Visual range in units of km

The switch must remain on the setting shown on the receiver settings sticker.

A2 SWITCH

The A2 switch selects the computer output to analog line #2 used by the data loggers.

SD Standard deviation of the raw instrument readings
CR Chart recorder output of raw readings

This switch must remain on the setting shown on the receiver settings sticker.

INTEG (MIN)

The INTEG switch selects the integration or averaging time period in minutes. The shortest possible time interval for a reading is one minute. A ten-minute averaged reading is, therefore, based upon 10 one-minute readings. A change in switch position requires that a time reset be made.

CYCLE

The CYCLE switch selects the time interval between the start of each reading. A setting of C, for continuous, indicates there is no time delay or interval between readings. Other settings dictate time intervals of between 20 minutes and 4 hours. For example, a cycle time of 1 hour (1H) with an integration time of 10 minutes (10M), would provide a 10-minute average every hour. For routine operation, this switch must remain on the setting shown on the receiver computer settings sticker. A change in switch position requires that a time reset be made.

GAIN POT

The gain pot determines the amount of amplification the raw signal receives before being digitized by the analog to digital (A/D) converter for use in the computer. The gain should only be changed by trained service technicians.

OVER-RANGE (OR) INDICATOR

When the over-range light is "on," it indicates that the value sent from the computer to the display is too great for the display to handle. This may occur, for example, when a storm obscures the transmitter light. The receiver computer will then calculate an infinitely high extinction and output a very high (over-range) value to the display. This condition is indicated by the over-range (OR) light. The display will show 1000, its maximum value. The OR light will extinguish on its own after a within-range reading has been taken.

OVER-VOLTAGE (OV) INDICATOR

The over-voltage light indicates that either the gain boosted raw reading is too great to be accepted by the analog to digital converter, or that the background lighting is bright enough to saturate the detector. The first condition is unlikely as the proper gain setting is determined when calculating the calibration factor. A saturated detector can occur if the sun rises or sets near, or within, the field of view of the receiver telescope. It can also occur if extremely bright clouds or snow cover are within the field of view. Once the OV light goes "on," it will stay "on" as an indication to the operator that an OV condition has occurred. Resetting the computer, by turning the power switch "off" for one second, will clear the indicator light. If this action is taken, it should be noted on the Receiver Station Log Sheet.

TOGGLE LIGHT

The toggle light indicates a reading update. At the end of an integration period, the toggle light will change state from "on," to "off" or vice-versa. The toggle status is also output to the data loggers. The toggle light has three important functions:

1. It indicates a computer lock-up or failure.
2. It can be used to differentiate a computer lock-up from consecutive, identical readings.
3. It provides the only visual indicator to reliably check the receiver auto-timer system.

PATH DIAL

The path dial is used to input the line-of-sight distance between the transmitter and the receiver into the computer. The distance is measured during installation with a laser range finder and is expressed in kilometers. The path distance dial should always be set to the distance marked on the receiver computer settings sticker. An incorrect distance setting will not affect the raw readings, but will result in the calculation of erroneous extinction values.

CAL	A calibration number is calculated for each lamp. Since all lamps are slightly different, a new calibration number must be dialed in for each replacement lamp. The CAL number represents the raw reading which would be obtained if the atmosphere had a theoretical 100% transmission. The CAL number should not be changed, unless directed by field service technicians.
HAND-HELD RADIOS PRECAUTION	The receiver computer circuitry, especially the internal auto timer, can be adversely affected by strong radio signals. Do not transmit on a hand-held radio within 10 feet of the computer. Avoid aiming the antenna at, or over, the computer. Strong radio signals may reset the timer circuit, resulting in an incorrect, out-of-synch system timing.

8.3.2 Receiver Telescope

FLIP MIRROR KNOB	The flip mirror knob is used to change the position of an internal mirror. When the knob is in the fully "clockwise" or "view" position, the image is directed to the eyepiece. When the knob is in the fully "counter-clockwise" or "run" position, the image is directed towards the photo-detector. **IMPORTANT**--during alignment, the knob must be turned fully "clockwise" against the stop to the "view" position. If the knob is not positioned fully against the stop, incorrect alignment could occur. Once alignment is completed, the knob must be turned fully "counter-clockwise" to the "run" position. No readings will be taken if the flip mirror is left in the "view" position.
EYEPIECE	The eyepiece is used to check and re-position instrument alignment. As with the transmitter, an image of the scene with the view transposed left to right will be visible when the flip mirror knob is rotated fully clockwise. Reticule markings are super-imposed on the scene for use in alignment. The transmitter light should be within the small inner circle.
OBJECTIVE LENS THUMBSCREW	The objective lens thumbscrew holds the objective lens assembly in place. The focus is set correctly during installation. Sometimes image degradation due to turbulence is mistaken as incorrect focus. Do not adjust the focus.

OBJECTIVE LENS ASSEMBLY	The objective lens assembly on instruments with serial numbers 001-004 have aperture rings glued or taped in place over the end to allow a known amount of light collection by the telescope. These rings should always be firmly fixed in place. Later units have aperture rings built into the lens assembly.
OBJECTIVE LENS	The receiver telescope is equipped with an expensive objective lens. The delicate, coated surface of this lens can be easily damaged or marked by incorrect cleaning. Field operators should avoid physically touching the lens; periodic cleaning of the surface with photo-quality canned air is sufficient under normal circumstances.
TELESCOPE TUBE	The objective lens is held in place and the detector is shielded from stray light by a thick-walled telescope tube. A light-trapping baffle, mounted inside the tube, further protects the detector from stray light.
PHOTOMETER HEAD	The photometer head contains the photodiode detector, detector signal pre-amplification circuitry, filter, and the flip mirror. The photometer head must be securely attached to the telescope with the two Allen screws provided for this purpose.

8.4 Terminal Strip and Wiring Descriptions

A terminal strip is used as an interface between the transmissometer and the data loggers. It provides an excellent place to trouble-shoot the system. A wiring diagram of the terminal strip board is shown in Figure 8-3.

TERMINAL STRIPS	Two terminal strips are mounted on the board. The vertical strip connects the transmissometer to the data loggers. The horizontal strip is used to provide 12VDC power to the strip chart (when needed) or to other equipment.
TRANSMISSOMETER SIGNALS	Transmissometer signals exit the receiver computer at the port marked "output" and enter the left side of the vertically-mounted terminal strip. The signals are differential--each signal has its own ground.
DCP INPUT SIGNALS	The signal cable to the DCP exits the right side of the vertical terminal strip and enters the Handar 540A DCP at the port marked either "TRANS INPUT," or "TELE #1."

STRIP CHART INPUT SIGNALS The signal cable to the strip chart exits the right side of the vertical terminal strip where it shares terminal positions with the DCP wiring. The signals enter the back of the strip chart with labeled banana jacks. The 12VDC power supply to the strip chart shares this cable and also enters the strip chart with labeled banana jacks.

CONNECTOR PIN-OUTS A description of the signal cabling and connectors can be found in Appendix G.

RECONNECTING WIRES Cables are fixed to the terminal strip board with strain reliefs so it is unlikely that a signal wire will come loose from the terminal strip. If a wire does detach, strip the wire's jacket back 3/8 inch, double the wire back on itself, insert into the screw hole, and tighten to clamp down on the wire. Do not overtighten as the wire strands will break. Refer to the wiring diagram to verify correct wire placement, and document this repair on the Log Sheet.

8.5 Strip Chart Component Descriptions

Refer to Figure 8-4 for the location of the strip chart controls and connections described below:

CHART PAPER MAGAZINE The entire chart paper magazine removes for easy paper installation, as described on pages 2-8 through 2-10 of the manufacturer's instrument manual. Blank paper is stored at the back of the magazine, while paper with recorded data folds into a storage area at the front.

CHART PENS Chart recorder pens slip into holders, as described on pages 2-10 of the manufacturer's manual. It is important that the pens be pushed all the way into the mounts. Note that the pen positions, as they mark on the chart paper, are offset slightly. This is important to keep in mind when looking at the strip chart data.

PEN LIFTERS Pen lifters lift the pens off the chart paper to prohibit recording or to make installation of new pens easier.

IMPORTANT--pen lifters should be in the fully "down" position for routine operation.

EVENT MARKERS — Event markers are momentary-on push buttons that, when depressed, make a "tick" mark on the strip chart trace. These tick marks are used to accurately record events such as field operator servicing visits. Tick marks on the trace should always have a time and date written next to them. When making tick marks, depress the event markers 4 or 5 times rapidly to make a good positive mark.

RANGE SWITCHES — Range switches should be set to the values listed on the strip chart settings sticker. For most locations, CHA should be set to the 1-volt position and CH-B to the 50-volt position. The 50-volt setting is a combination of the 10-volt push-button and the zero control knob pulled out to the X5 position.

ZERO CONTROL KNOB — The zero control knob serves two functions: 1) it positions the pens to the correct zero position on the chart paper (The zero position can only be adjusted when the zero/record button is in the zero position.), and 2) it expands the range settings by a factor of five; for example, a range switch setting of 10 becomes 50 volts full scale when the zero control knob is pulled out.

ZERO RECORD BUTTON — The zero/record button adjusts the pens to their correct zero position when used in conjunction with the zero control knob.

IMPORTANT--the button must be in its record position for routine operation.

POWER ON/OFF SWITCH — The power on/off switch controls the supply of power to the recorder regardless of the power supply used.

CHART START/STOP SWITCH — This switch stops movement of the chart paper. It does not inhibit the pens from changing position as input voltages change. With the slow chart speed used in the transmissometer monitoring system, it is possible to write strip chart documentation on the "moving" chart paper. This switch should never need to be used.

IMPORTANT--no data will be recorded when the switch is in the "stop" position.

CHART SPEED SELECTOR — The speed at which the chart paper passes the recording pens is selected by these switches. The speed is determined by a combination of the setting chosen from the upper six switches, and the setting of the lower switch. These switches should remain in the positions listed on the strip chart settings sticker. For routine monitoring, the button marked "1" should be depressed and the bottom button should be in the "up" or "cm/hr" position.

CH-A INPUT	The analog voltage representing the transmissometer extinction signal inputs the strip chart recorder at CH-A on the back panel. The banana jacks on the strip chart cable are labeled: the CH-A positive lead connects to the plug marked "+," and the negative lead connects to "-."
CH-B INPUT	The analog voltage, representing toggle state (on or off), inputs the strip chart recorder at CH-B on the back panel.
CAL/REC SWITCH	The CAL/REC (calibrate/record) switch puts the recorder in either the "test" or "operate" mode. If the switch is placed in the "CAL" position, an internally-generated 50-millivolt voltage is sent to the channel. This known reference voltage is used to check or verify correct recorder operation. For routine monitoring, the switch should remain in the "record" position. **IMPORTANT**--no data is recorded when the switch is in the "CAL" position.
FUSE	The fuse contained within the fuse holder is used only when the recorder is operated from AC power. Spare fuses are supplied with the servicing equipment.
EXTERNAL BATTERY CONNECTOR	If DC battery power is used to operate the strip chart recorder, the power jacks connect at the position labeled "EXT battery" on the back panel. Care must be taken to observe correct polarity.
POWER SOURCE SELECTOR	The power source switch selector position must match the type of power supplied. When battery power is used, the switch must be set to 12V, <u>not</u> 24V. When the AC power is used, the switch must be set to "AC line."
POWER SAVE SWITCH	The power save switch reduces power consumption when only one channel of data (CHA) is to be collected. If the pen on Channel B fails to respond to signals or changes in control switch settings, check the position of the switch. This switch must remain in the "off" position.

8.6. DCP Component Descriptions

Refer to Figure 8-5 for the location of the components listed below:

ON/OFF SWITCH	The main system on/off power switch is located next to the fuse holder near the hinge. <u>Do not</u> turn this switch "off" unless directed by ARS. **IMPORTANT**--if power is turned "off," the internal program will be destroyed and the unit will require re-programming.

FUSES	Three fuses mounted in holders next to the on/off switch protect the internal battery, an external battery (if used), and the program set power-output circuitry. **IMPORTANT**--removal of internal battery fuse will wipe out the program and will require a site visit or replacement DCP.
BATTERY	The orange, 12VDC, 20-amp-hour gel-cell battery secured in place at the end of the box powers the DCP. Do not attempt to measure the battery voltage unless instructed by ARS. Shorting the positive battery terminal to the holder with the test lead could cause damage to the circuitry or wipe out the program.
DESICCANT INDICATOR	The desiccant indicator affixed to the battery holder monitors the effectiveness of the desiccant. When the desiccant is in good shape or "active," the color of the circle matches that of the rectangle--both should be blue. When the desiccant is spent, the circle color will be pink. It is best to check the indicator immediately upon opening the DCP door as the color will change in approximately two minutes.
BOX CLOSURES	All box closure clamps must be tightened to assure a good fit. Do not overtighten the clamps.
SUPPORT CARD	The support card contains the battery charging circuitry, system power supply, timer, and analog-to-digital converter. This card is always located in card slot number 9. Card slot number 1 is located closest to the battery.
CPU CARD	The CPU card contains the microprocessor, memory, and system firmware (operating system). This card is always placed in slot number 8 between the aluminum plates which act to shield it from interference.
MET CARD	The meteorological sensor card provides signal conditioning for sensor inputs. It is here the transmissometer extinction analog signal is converted to a format that is usable by the computer. For use in our system, this card is always placed in slot #6. Two multi-color ribbon connectors bring sensor signals from the input panel to the met cards. Most DCPs have two pairs of ribbon cables--some may have three pairs. The pair marked "telephotometer #1" or "transmissometer," should be used with the shorter of the two cables connected to the left met card cable input (battery at top). The black conductor is on the left on both cables.

GOES TRANSMITTER The GOES transmitter circuit board located on the inside of the door enables the DCP to transmit data at precise user-selected frequencies to the satellite. The transmitter has the ability to broadcast at 265 frequencies between 401.701 and 402.0985 MHZ in 1.5 KHZ steps. The 10-watt transmitter power output is +40 dBm.

PRIMARY CHANNEL SWITCHES There are six, square, red dial switches located in the upper right corner (battery at top) of the GOES radio transmitter circuit board. The top three switches, labeled "CHAN 1", are used to set the primary radio frequency at which the DCP will transmit. These switches should always be set to the channel noted on the DCP sticker. When the primary channel switches are set to 900, transmissions from the DCP are hardware inhibited. This function is used to field disable a DCP for shipping, or to ship a new DCP from ARS to the field (described in detail in Section 7.2).

SECONDARY CHANNEL SWITCHES The secondary broadcast channel (CHAN 2) is not used in the transmissometer monitoring network. These switches should remain set to "000." The secondary channel is used in some monitoring networks to broadcast random transmissions when an emergency, such as a flood, occurs.

GRAY RIBBON CONNECTOR The gray ribbon cable connecting the GOES radio to the CPU card should never be unplugged. The computer relies on clock signals generated by an oscillator on the GOES radio board for its operation.

IMPORTANT--disconnecting the gray ribbon cable will destroy the internal program requiring a site visit by ARS technicians or a replacement DCP.

8.7 DCP Antenna Component Descriptions

The antenna used with the Handar 540A DCP is a Cross-Yagi type with a gain of 10dB. The antenna has a half-power beam width of 47°, which means that critical alignment is not necessary. Refer to Figure 8-6 for location of the components discussed.

ANTENNA ALIGNMENT The correct antenna alignment is documented on a DCP sticker (Figure 8-7) located on the door of the DCP enclosure. Antenna azimuth is expressed in degrees true; elevation angle is given in degrees from horizontal.

ALIGNMENT CHECKS Antenna alignment, as well as physical checks of the antenna, cable, and connectors, should be made periodically using procedures described in Section 7.6.

BASE PLATE VERSION #1	The base plate used in many installations is chrome plated and adjustable in both the horizontal and vertical directions. The plate is usually mounted to the shelter with lag bolts or wood screws. The antenna bar screws to this base.
BASE PLATE VERSION #2	Another type of base plate in use is designed for post mounting. With this type of mount, antenna alignment is a combination of the vertical component, adjusted with two bolts at the base of the antenna rod, and the rotational component adjusted with the two large Allen screws which clamp to the post.
DRAIN HOLES	At the base of the antenna bar, on all but the oldest units, are two holes which allow water that enters the bar to drain. These holes should remain uncovered and should be positioned towards the ground.
COAXIAL CABLE CONNECTOR	The coax cable from the DCP enters the antenna at this connector. The connector should be oriented towards the bottom of the bar if possible and should be screwed in tightly to avoid moisture penetrating the seal and degrading the signal.
DRIVER ELEMENTS	The driver elements, located in the second position from the bottom on both antenna models, are the elements that do all the work. For the transmissions to be strong enough to reach the satellite reliably, all four elements must be in good shape, and securely fastened in their holders.
REFLECTOR ELEMENTS	These antenna elements function almost like a mirror behind a light bulb, increasing the signal strength.
DIRECTIONAL ELEMENTS	These antenna elements further increase the output power, as well as make the signal more directional.

8.8 Air Temperature/Relative Humidity Sensor Description

Ambient air temperature and relative humidity are monitored with a Handar Model 435A sensor. This sensor combines both measurements within one unit and is controlled by, and directly connected to, the DCP. The temperature sensor measures temperature with a thermistor, an electronic component whose resistance changes proportionally with temperature change. The relative humidity sensor measures humidity with a humicap, a device whose capacitance changes as its surface absorbs moisture.

SENSOR HOLDER	The sensor is mounted in a white, parallel plate shield that acts to dissipate heat and to protect the sensor. The design assures that heat from the shield is not conducted to the sensor causing errant, high readings.
SAMPLING FREQUENCY	Air temperature (°F) and relative humidity (0-100%) measurements are taken once per hour at the same time other measurements are made. Under routine monitoring procedures, all sensors are scanned at 30 minutes past each hour.

8.9 Solar Power System Component Descriptions

At some locations the receiver, transmitter, or both stations are powered from a solar system with the following components: solar panels, regulators, storage batteries, and interconnection cabling. The number of solar panels is based on the estimated hours of sunlight available. Transmitter stations will require at least two panels approximately 1.5'x 3' in size. Most receiver stations can operate from one such panel.

SOLAR PANELS	Solar panels produce electric current when illuminated with sunlight. Panels should be oriented towards true south, and are inclined to angles that are most efficient for winter operation (latitude plus 15 degrees). A coating of dust or dirt on the glass surface will reduce collecting efficiency; procedures to clean the panels are described in Section 7.4.
SOLAR PANEL OUTPUT	The solar panels used in the transmissometer systems produce approximately 18 volts when fully illuminated. With the panel/regulator system connected to a battery, it may be difficult to measure panel voltage output directly. Procedures to trouble-shoot solar panel power systems are described in Section 8.6.
REGULATORS	Electrical current produced by the solar panels is used to charge the storage batteries. A regulator prevents over-charging of the batteries during extended periods of sunny weather. Older systems have separate regulators housed in small, metal enclosures within the shelter. Newer systems have regulators mounted in the junction boxes on the back of the panels.

8.10 AC Line Power System Component Descriptions

At some locations the receiver, transmitter, or both stations operate from an AC line power. As all instrumentation and data collection equipment have the capability of operating from DC power, AC power is used to charge batteries from which the instruments operate. An AC power system is comprised of the following components: a surge protector, automatic battery charger, and a deep-cycle storage battery. Because the AC charging system can charge the battery, unlike a solar system affected by weather, only one storage battery is required at each station.

RECEIVER SHELTERS	Receiver shelters configured for AC power distribution have at least two separate lines--each protected by its own breaker; most shelters have three breakers. The extra capacity was added during shelter construction so that the shelter could accommodate additional equipment, if needed, at a later date.
TRANSMITTER SHELTERS	Transmitter shelters which are AC powered usually do not have more than two breakers as the shelter's small size prohibits the addition of more instrumentation.
POWER USAGE	The transmitter alone requires 2.7 amps at 12.6 volts DC while in the "on" or "transmit" mode and 10 MA in the "wait" mode (9.6 watts/hour). The receiver, DCP, and strip chart recorder combined consume approximately 1.7 amps at 12.6 volts (21.4 watts/hour).
SURGE PROTECTORS	Two versions of Northern Technologies' surge protectors protect instruments from potentially-damaging power surges. One model has two system warning lights, the other has three lights. The lights indicate the surge operating condition of the protector, as described below:

Green Light	The surge protector is in good operating condition.
Yellow Light	The surge protector has sustained partial damage as the result of a power surge, but is still capable of providing protection.
Red Light	The surge protector has sustained a massive power surge and is no longer capable of providing protection.

If the red light on either model surge protector is lit, call ARS for a replacement unit.

BATTERY CHARGERS Standard automobile-type, automatic trickle-chargers charge batteries in both the transmitter and the receiver shelters. Automatic chargers monitor the battery voltage and discontinue charging when a fully-charged state is reached to prevent damage from over charging. Replace these units with chargers that are automatic only.

CHARGER NOISE Battery chargers at the receiver stations have an easy life so their meter needles will almost always be at zero due to the low power requirements of the instrumentation. On the other hand, chargers used at the transmitter will have to output at least 2.5 amps while the transmitter is running; this may cause the chargers to buzz. When a battery is fully charged, the charger can be heard to turn on and off approximately every two seconds--this is normal.

SURGES Most surges of a magnitude large enough to damage instrumentation come from lightning striking near or on power lines. Fluctuations in frequency or noise on the line due to nearby machinery have no effect on the system as the battery acts to minimize or negate these problems.

8.11 Storage Batteries System Description

Deep-cycle storage batteries at most locations power equipment at both receiver and transmitter stations with both solar or AC line power supplies. Deep-cycle batteries with their larger plate mass are needed at the transmitter station. The equipment used at the receiver station does not have the large cyclic power requirements of the receiver; therefore, traditional lead-acid batteries are sufficient. Maintenance-free batteries are not used because of the difficulty in assessing their state of charge. This means that distilled water will need to be added to the batteries periodically, usually only during ARS field technician site visits.

BATTERY NOISE During periods of full sunlight, batteries may produce bubbling sounds. This is normal, and does not indicate the regulator is malfunctioning. Newer solar panel regulators charge the battery very slightly even when the batteries are fully charged, as this has been found to circulate electrolyte within the cells and avoid stratification of the acid electrolyte. Charging of the batteries can be heard most easily for a period after the transmitter turns off.

EXPLOSIVE GASES	The bubbling heard when traditional lead-acid batteries are charging is the production of hydrogen gas. If the batteries are charged in a confined space, hydrogen and oxygen gas may accumulate in proportions that may be explosive. Transmissometer shelters should "breathe" enough to avoid the accumulation of gasses during the fall, winter, and spring. Vents are provided in each shelter for removal during the summer as a precaution, as well as to vent hot air. In any case, it is wise to avoid smoking around lead-acid batteries, and to be aware of the dangers associated with them.
LOW BATTERY FLUID LEVEL	A sudden drop in the level of battery fluid indicates a possible problem with the battery or regulator. In most cases, batteries should go for a full year without adding fluid. Batteries in areas of high temperature and low humidity may need filling at a slightly more frequent interval. Only distilled water should be added to the battery. This has been supplied to only a few locations where freezing of the water is not a problem.
BATTERY CHECKS	A hydrometer has been supplied to all locations to check the charge of storage batteries. This need only be done under the direction of ARS technicians.
INTERCONNECT WIRING	All power wiring used to interconnect solar panels, batteries, and terminal strips should be labeled at the connectors. As a general rule with black and white conductors, the black will be positive. With red and black conductors, the red will be positive. On lamp cord, the marked wire (usually by grooves) will be positive. As with all electrical or electronic conductors, it is important to verify correct polarity before connecting to power; if unsure, call ARS for direction.

8.12 Support Equipment Descriptions

This section describes some of the equipment used in support of the transmissometer monitoring system.

WINDOW GLASS	The glass panes used in transmissometer shelters are special high-quality, polished, flat stock with accurately known, light transmittance properties. The transmittance at 550 nm (green) is etched on a corner of the glass. **IMPORTANT**--do not replace the supplied panes with glass of a lesser quality--instrument readings will be affected.
SPARE GLASS	At least one pane of spare glass should be stored in each shelter. Notify ARS if spare glass is not supplied.

WINDOW FRAMES	All but the earliest shelters are outfitted with standard window frames: 6"x 6" glass (before framing) is used in transmitter shelters, and 12"x 12" glass (before framing) is used in receiver shelters. The window frame permits the removal of glass pane from inside the shelter both for operator convenience and more thorough cleanings. A wooden strip and locking screw retains the pane in place. The frame is also equipped with a second slot that allows for the addition of an aluminum vandal plate.
MOUNTING POSTS	Mounting posts used for both the transmitter and receiver telescopes are made of large diameter steel pipes. To further increase the mass, the post is filled with fine sand. The extra mass makes the post less likely to move the telescope as the post is heated and cooled. The posts enter the shelter without touching the floor to further isolate the instrument from movement due to shelter vibration.
RECEIVER ADJUSTMENT BASE	The alti-azimuth base used with the more alignment-sensitive receiver telescope is supplied by Optec, Inc., the transmissometer manufacturer. It allows for easy, fine adjustment while minimizing mis-alignment problems due to base thermal expansion and contraction.
TRANSMITTER ADJUSTMENT BASE	The alti-azimuth base used with the transmitter was supplied by ARS. This low-cost base provides adequate adjustment capabilities.
SERVICING SUPPLIES	A list of the servicing supplies that should be stocked in each shelter is included in Appendix I. Notify ARS when supplies run low.
RECEIVER STATION TOOL KIT	Tools needed to service instruments and equipment have been provided. They should remain in the receiver shelter.
SPARE SHELTER KEYS	Spare shelter keys are kept at ARS for each location. A key has been hidden close to shelters in most locations. Call ARS for information regarding spare keys.
RECEIVER SHIPPING CASE	Cases for shipping transmissometer components have been supplied to all monitoring locations. The wooden receiver computer case has dimensions of 15"x 21"x 18". The wooden receiver telescope case has dimensions of 12"x 28"x 12" (detector head must be removed for shipping). The transmitter, control box and cable, and receiver detector head are shipped in a gray, suitcase-style case. The original strip chart box has been left at each site for shipping.

LAMP CASES	A small 9"x 12"x 5" black case has been supplied to hold replacement transmitter lamps, as well as spent lamps awaiting post-calibration. Cleaning supplies for the lamps are also included in the case.
CALIBRATION TRIPODS	Tripods for use in instrument calibration have been stored at some monitoring locations. The tripods used with the receiver telescope are large, Celestron (mfg.) astronomy telescopes. Small Bogen tripods are used with the transmitter and may also be stored at some locations.

APPENDICES

APPENDIX A	Transmissometer Measurements
APPENDIX B	Transmissometer Data Examples
APPENDIX C	List of Related Reading Material
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APPENDIX G	Transmissometer System Cable and Connector Description
APPENDIX H	Servicing Supply List

APPENDIX A

Transmissometer Measurements

The Optec, Inc., LPV-2 transmissometer measures the ability of the atmosphere to transmit light. Light from the transmitter is collected, measured, and compared to a pre-determined, user-entered calibration number to determine the transmission coefficient. The calibration number represents the reading in counts which would be measured if the atmosphere between the transmitter and receiver allowed 100% light transmission. With the calibration number dialed-in on the computer front panel, the percent transmission (T(%)) is calculated by the receiver computer as follows:

$$T(\%) = \frac{\text{Transmitter Measurement (Counts)}}{\text{Calibration Number (Counts)}}$$

Transmission measurements are site specific because the measurement is a function of the distance between the transmissometer transmitter and receiver. Two related values--extinction coefficient and visual range--are distance-independent and can also be calculated and output by the computer when the distance between the transmitter and receiver is user-entered on the front panel. These two terms allow intercomparison of visual air quality measurements from site-to-site.

The extinction coefficient, a measure of light loss per unit distance, is expressed in units of inverse kilometers (km^{-1}). The receiver computer calculated the extinction (b_{ext}) as follows:

$$B_{ext}\ (km^{-1}) = \frac{-LN\ T(\%)\ /\ 100)}{\text{Distance (km)}}$$

As the air gets dirtier, the transmission of light through the atmosphere decreases and the extinction increases. The ability of the transmissometer to measure high extinction (low light transmittance), is limited by the instrument's ability to lock-on to the transmitter's chopped light signal. Depending on the path distance and the transmitter light output, the transmissometer can measure down to a 4% transmission level. On the other end of the scale (clean air--low extinction), the lowest measurable extinction is limited by the atmosphere rather than by the instrument. The lowest extinction measurements occur under Rayleigh atmospheric conditions (the theoretically clearest, possible atmosphere). In a Rayleigh atmosphere, extinction measurements should not go below 0.010 km^{-1}.

The extinction coefficient is a useful term, but one that may be difficult to relate to our common experience. Extinction can, however be easily converted to visual range. Visual range can be defined as the distance at which a large, black object on the horizon just disappears from view. If a contrast difference of 2% between the object and its background is used to define "just disappears from view," the visual range (V_r) can be calculated as follows:

$$V_r(\text{km}) = \frac{3.912}{b_{ext}\ (\text{km}^{-1})}$$

The relationship between extinction and visual range is illustrated in Figure A-1.

Visual range should be thought of more as a measure of atmospheric clarity than as an absolute distance. Keep in mind that the calculated visual range is based on a transmission measurement of the air between the receiver and transmitter.

The value shown on the receiver computer display (A1 switch on position B) is the extinction coefficient in units of inverse kilometers. The receiver computer A1 switch can be moved to the C position to display the raw reading in counts, or to the V_r position to display the visual range in kilometers. After viewing the display, the A1 switch should always be returned to the B position.

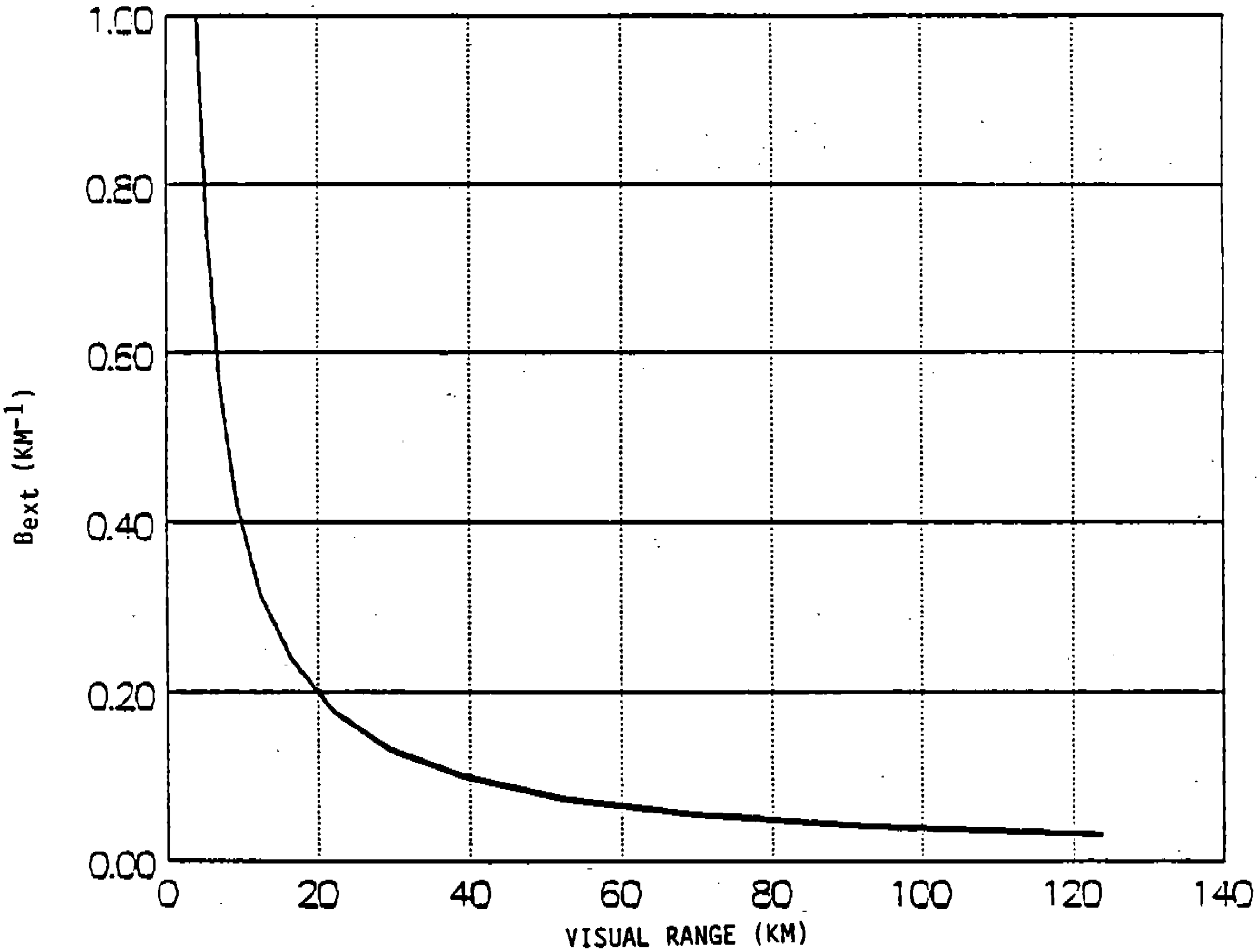


Figure A-1. B_{ext} vs. Visual Range.

APPENDIX B

Transmissometer Data Examples

The transmissometer receiver computer outputs readings to both the strip chart recorder and the telemetered data collection platform (DCP). Figure B-1 below identifies information recorded on a strip chart. Figure B-2 displays an example of plots made weekly at ARS to track the operation of the transmissometer system.

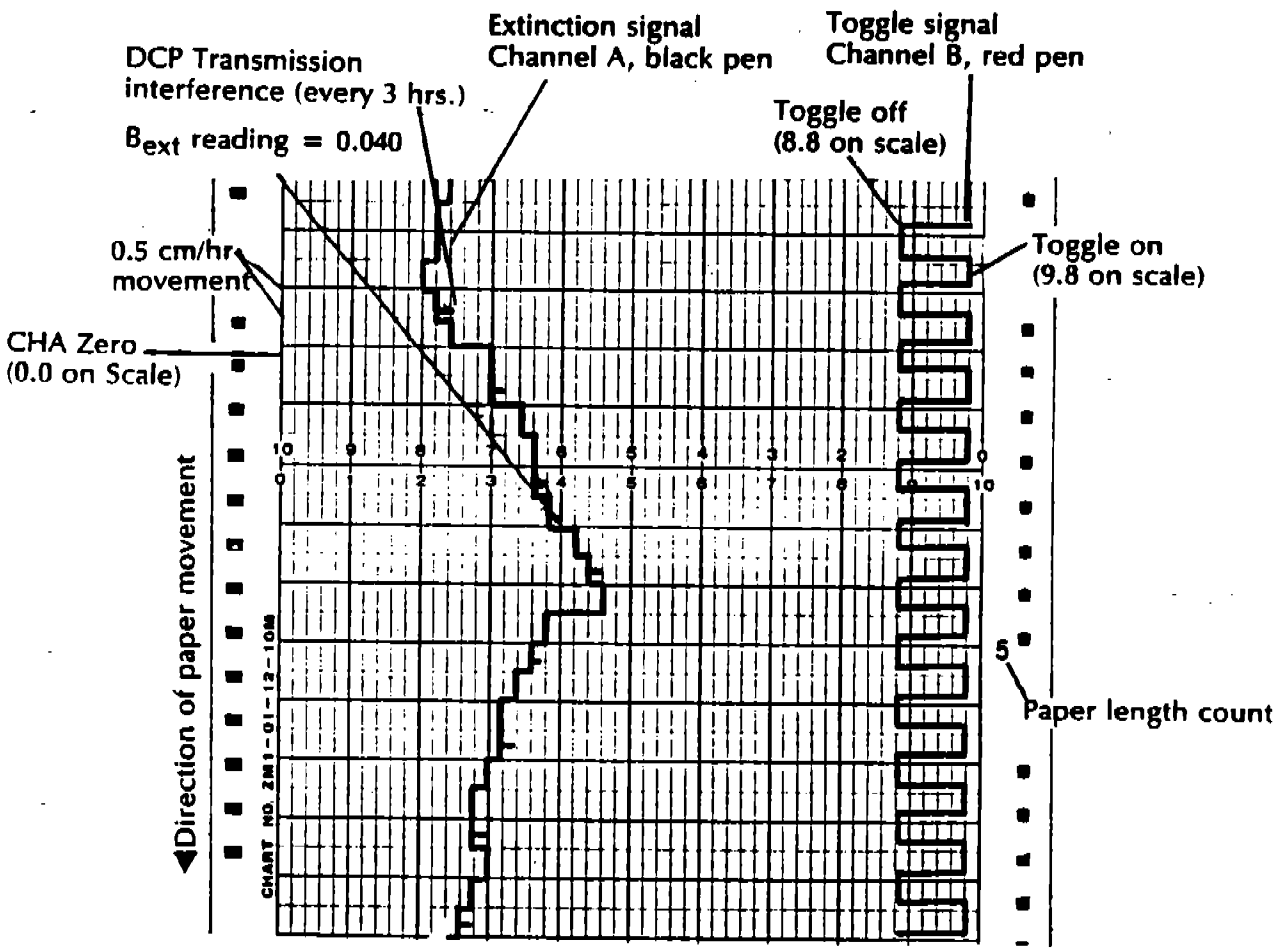


Figure B-1. Example of Strip Chart Data.

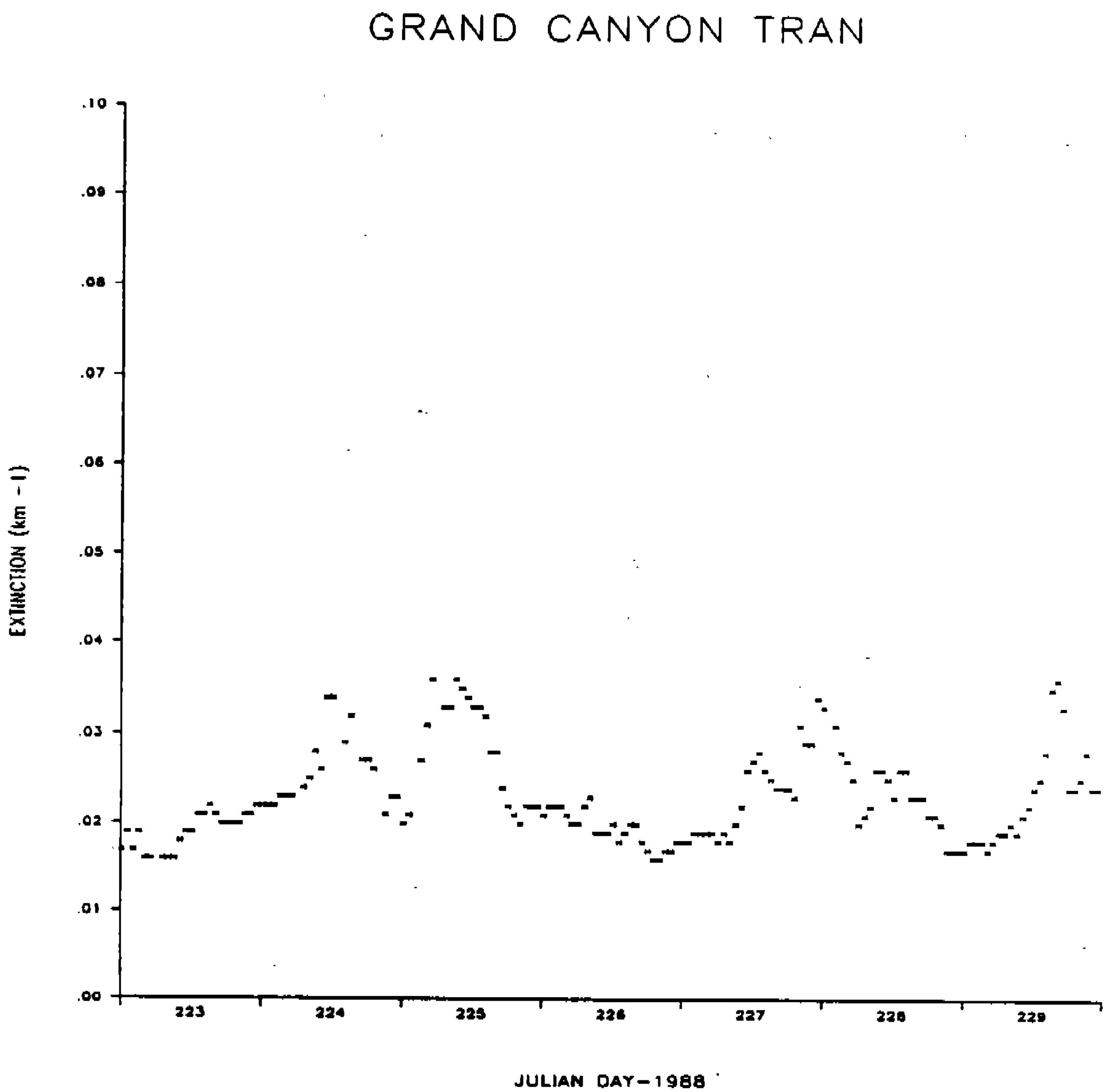


Figure B-2. Example of Transmissometer Tracking Plot.

APPENDIX C

List of Related Reading Material

Malm, W.C., 1983, Introduction to Visibility, National Park Service, Air and Water Quality Division, Air Research Branch, June.

Malm, W.C., 1986, Comparison of Atmospheric Extinction Measurements Made by a Transmissometer, Integrating Nephelometer, and Teleradiometer, with Natural and Artificial Black Targets, APCA International Speciality Conference Proceedings (pgs. 763-782), Grand Teton National Park, WY.

National Environmental Satellite, Data, and Information Service National Oceanic and Atmospheric Administration, 1983, The Geostationary Operational Environmental Satellite Data Collection System, Publication NOAA--S/T 83/98

APPENDIX D

Satellite System Information

USE OF THE SATELLITE	Use of the geostationary orbiting earth satellite (GOES) is free to government agencies. The operation of the satellite system and the authorization to use the system is directed by the National Environmental Satellite, Data, and Information Service (NESDIS) which is a branch of the National Oceanic and Atmospheric Administration (NOAA).
BROADCAST TIME AND FREQUENCY	Each DCP is assigned (by NESDIS) a one-minute time slot every three hours at a specified time to broadcast its data. In addition, the broadcast must be made at a defined frequency. Every DCP is also identified with a unique platform "address," an 8-position, alpha-numeric code.
AMAZING DISTANCES	The data collected in the field must travel quite a distance before it arrives in Fort Collins, Colorado. Data is transmitted approximately 23,500 miles up to the satellite, 23,500 miles down to Wallops Island, 140 miles to Camp Springs, Maryland, and 1,500 miles to Fort Collins, Colorado, for a total of approximately 48,640 miles per data transmission.
SATELLITE LOCATION	The GOES west satellite, used by locations west of the Mississippi, is located at a longitude of 135^0 west, directly over the equator. The GOES east satellite, used by Eastern locations, is located at a latitude of 75^0 west, almost directly above Ecuador.
SATELLITE SYSTEM CAPACITY	The relay of data from DCPs to the downlink facility is a minor portion of the satellite's job. The primary function is to provide weather-related data and images to aid in forecasting. Each satellite is capable of utilizing 233 frequencies for a total capacity of over 12,000 DCPs per hour. Data transmission rate is 100 baud (bits per second). The majority of the DCPs in use throughout the United States help support early warning flood monitoring systems.

APPENDIX E

Example of a Completed Transmitter Station Log Sheet

Air Resource Specialists, Inc.

Location: FORT COLLINS, COLORADO

TRANSMISSOMETER OPERATOR LOG SHEET
TRANSMITTER STATION

Date 4/20/88 Time 9:45 AM Operator(s) JOHN SMITH

Shelter Temp. (°F) Max 83 Min 41 Current 70

Describe Weather & Haze Conditons: ~25% OVERCAST, SLIGHT BREEZE FROM SOUTH, MODERATE HAZE (PROBABLY DUE TO CONTROLLED BURN APPROX. 8 MILES TO EAST)

ALIGNMENT Mark initial location of light source with a "+". Align and/or comment as needed.

Initial: (+)

Comments: ALIGNMENT CHECKED AFTER BULB CHANGE

ROUTINE PROCEDURES

YES	NO	
☐	☑	Alignment corrected
☐	☑	Window clean upon arriving
☑	☐	Window cleaned (if no, comment)
☑	☐	Solar panels cleaned
☐	☑	Lamp LED "on": If yes, call ARS (This check is only valid during lamp "on" time.)
☑	☐	Lamp changed (To be done only on specified dates or upon direction from ARS.) New lamp # 24
☐	☑	Time reset (upon direction of ARS only)

SPECIAL PROCEDURES

Lamp No. In Use: 24 Comments: LAMP #23 REMOVED, LAMP #24 INSTALLED

Timing Check: Transmitter ON/(OFF) at (HR:MIN:SEC): 10:16:19

COMMENTS/SUPPLIES NEEDED NEED ADDITIONAL ISOPROPYL ALCOHOL

Enclose the original of this Log Sheet and send to:

Air Resource Specialists, Inc., 1901 Sharp Point Dr., Suite E, Fort Collins, CO 80525, 303/484-7941

03/88

APPENDIX F

Example of a Completed Receiver Station Log Sheet

Air Resource Specialists, Inc.

Location: FORT COLLINS COLORADO

TRANSMISSOMETER OPERATOR LOG SHEET
RECEIVER STATION

Date 4/20/88 Time 10:55 AM Operator(s) JOHN SMITH

Shelter Temp. (°F) Max 85 Min 42 Current 73

Describe Weather & Haze Conditons: ~30% OVERCAST, SLIGHT BREEZE FROM SOUTH, MODERATE HAZE (PROBABLY DUE TO CONTROLLED BURN APPROX. 10 MILES TO EAST.)

READINGS

Before Align.: Time 10:55 AM Reading 0.040 Toggle ON/OFF ON

After Align.: Time 11:15 AM Reading 0.046 Toggle ON/OFF OFF

Time Check: Transmitter Light ON/OFF ON Time (HR:MIN:SEC) 11:00:18

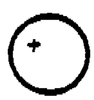
Receiver Toggle Chg. ON/OFF OFF Time (HR:MIN:SEC) 11:13:46

COMPUTER SETTINGS GAIN 350 CAL 424 DIST 4.2 km

A1 – C, (B) VR   A2 – SD, (CR)   INT – 1, (10) 30, 60   Cycle – 4H, 2H, (1H) 20M, 6

ALIGNMENT Mark initial location of light source with a "+". Align and/or comment as needed.

Initial



Comments

ROUTINE PROCEDURES

YES	NO		YES	NO	
☑	☐	Alignment corrected	☐	☑	OV light "on" (If yes, call ARS)
☐	☑	Window clean upon arriving	☑	☐	Strip chart marked
☑	☐	Window cleaned (if no, comment)	☑	☐	Chart paper O.K.
☑	☐	Solar panels cleaned	☐	☑	Chart pens O.K.

SPECIAL PROCEDURES (Use only after receiving instructions from ARS)

☐ ☐ Computer reset

☐ ☐ Time reset

COMMENTS/SUPPLIES NEEDED RED PEN HAD RUN OUT - REPLACED BOTH PENS. NUMEROUS CONTROLLED BURNS IN AREA DURING PAST WEEK.

Enclose the original of this Log Sheet and send to:

Air Resource Specialists, Inc., 1901 Sharp Point Dr., Suite E, Fort Collins, CO 80525, 303/484-7941

03/88

APPENDIX G

Transmissometer System
Cable and Connector Description

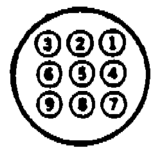
	Function	Wire Color		Wire Color	DCP Input Pin #	Met Card Pin #	Input Addrs	Pwr Addrs	Full Scale	DCP CH #
1	B_{EXT} Signal	Yellow		Yellow	G	J2-8	6	8	1000	1
2	Raw Reading/ Stdev. Signal	White		White	B	J2-14	8	8	500	3
3	Toggle Signal	Orange		Orange	C	J1-12	9	8	001	2
4	B_{EXT} Ground	Green		Green	J	J1-8				
5	Raw Reading/ Std. Ground	Black		Black	K	J2-10				
6	Toggle Ground	Brown		Brown	K	J2-10				
7	Not Used	-----		-----	-----	-----				
8	Not Used	-----		-----	-----	-----				
9	Shield	Bare		Bare	M	DCP Chassis/ Grd.				

Comments:
1. Rec Output Cable - 6 ft. DCP Input Cable - 8 ft.; A1 determines Pin 1 output; A2 determines Pin 2 output.
2. Receiver outputs double ended; Handar DCP has common ground.
3. DCP input pins not listed above
   Wire Color - Wires Not Used
   A - Blue, J1-19, (5,B)
   D - Grey, J1-6, (D,B)
   E - Red, J1-15, (A,B)
   F - Purples, J2-9, (F,B)
   H - Not used

Leave extra wire at terminal strip end - do not trim.

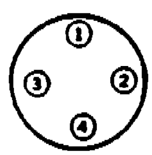
Receiver computer

Output Connector



Pin No.	*Function*	*Wire Color*
1	A1 Switchable to: Raw Reading, B_{EXT} or V_R	Yellow
2	A2 Switchable to: Raw Reading, Std. Deviation	White
3	Toggle Switch	Orange
4	A1 Ground	Green
5	A1 Ground	Black
6	Toggle Ground	Brown
7	Not Used	
8	Not Used	
9		Bare

Power Connector



Pin No.	*Function*	*Wire Color*
1	Not Used	
2	+ 12 Volt DC	Black (Ribbed)
3	- 12 Volt DC	Black
4	Not Used	

APPENDIX H

Transmissometer Servicing Supply List
Transmitter and Receiver Stations

<u>Receiver Station</u>

1. 3-ring binder
2. Log Sheets
3. ARS mailing labels
4. Pens
5. Kimwipes
6. Isopropyl alcohol
7. Compressed air
8. Window cleaner
9. Paper towels
10. Broom
11. Dust pan
12. Signal mirror
13. Flashlight
14. Max/min thermometer
15. Digital clock
16. Strip chart pens--black
17. Strip chart pens--red
18. Strip chart paper
19. Spare fuses--5 amp
20. Spare fuses--1 amp
21. Spare fuses--0.5 amp
22. Receiver station tool kit

<u>Transmitter Station</u>

1. 3-ring binder
2. Log Sheets
3. Pens
4. Signal mirror
5. Flashlight
6. Max/min thermometer
7. Kimwipes
8. Isopropyl alcohol
9. Canned air
10. Window cleaner
11. Paper towels
12. Wisk broom

MONITORING FOR REASONABLY ATTRIBUTABLE IMPACT OF LOCAL SOURCES AT

VOYAGEURS NATIONAL PARK
PETRIFIED FOREST NATIONAL PARK AND
MOOSEHORN WILDERNESS

Submitted to

Marc Pitchford
U.S. EPA
Environmental Monitoring Systems Lab
P.O. Box 15017
944 East Harmon
Las Vegas, Nevada 89114

Prepared by

AIR RESOURCE SPECIALISTS, INC.

May 5, 1988

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LIST OF FIGURES

1.0 INTRODUCTION

The IMPROVE Committee directed Air Resource Specialists, Inc. (ARS) to install 8mm time-lapse and 35mm color-slide camera systems at Voyageurs and Petrified Forest National Parks to access the possible visual air quality impact in class I areas by plumes from local sources. ARS personnel traveled to Petrified Forest National Park with W. Malm, of the National Park Service, to select and install the monitoring systems. W. Malm traveled to Voyageurs to select the monitoring site; the equipment was supplied and shipped by ARS. National Park Service personnel installed the camera systems after phone conversations with ARS staff.

The IMPROVE Committee also directed ARS to provide an 8mm time-lapse system for installation at Moosehorn National Wilderness. Bud Rolofson, of the Fish and Wildlife Service, traveled to Moosehorn Wilderness to site the 8mm time-lapse system. The system was shipped to Moosehorn and installed by Fish and Wildlife personnel. No systematic, 35mm color-slide photography was initiated at the Moosehorn site.

The following sections describe the collected data from each site.

2.0 PETRIFIED FOREST NATIONAL PARK

The combined 8mm time-lapse and 35mm color-slide system began operation on March 13, 1987. The system was installed with the 8mm and 35mm cameras viewing the same sight path. The view was southeast overlooking the length of the Park toward Blue Mesa. The system operated at this location until July 31, 1987. Figure 2-1 is a photograph of the monitoring view.

During this time period, no visible plumes were recorded by either the 8mm time-lapse or 35mm slide systems. The IMPROVE Committee directed ARS to move the monitoring systems to another location in the Park looking southwest outside of the Park boundaries toward the Cholla Generating Station (a coal-fired power plant located approximately 40 km from the Park boundaries). The power plant is to the right of the center-of-view, located just over the horizon and not directly visible in the photographic record. Figure 2-2 is a photograph of the new monitoring vista.

The system operated until March 1, 1988. During this monitoring period, no visible plumes were recorded entering National Park areas. Occasional discoloration on the horizon was visible, but not readily identifiable or traceable to any specific source. Figure 2-3 is an example of this distant, elevated layer of haze. Thus, the IMPROVE Committee decided to discontinue any further special photographic monitoring at Petrified Forest and directed ARS to remove the equipment which was accomplished in early April 1988.

Figure 2-1. Petrified Forest National Park - Initial Monitoring View Southeast Toward Blue Mesa.

Figure 2-2. Petrified Forest National Park - Second Monitoring View Southwest Toward Cholla Power Plant.

Figure 2-3. Petrified Forest National Park - View of Layered Haze on the Distant Horizon.

3.0 VOYAGEURS NATIONAL PARK

The 8mm time-lapse system began operation on October 24, 1986, viewing north across Kabetogama Lake. The nearest sources were approximately 30 km west-northwest of the vista. The 35mm camera was sited by Park personnel to view east through the Park to a more distant horizon feature. The new vista has a more appropriate target for microdensitometry visual air quality analysis. Figure 3-1 is a photograph of this monitoring view.

The systems were in operation until April 1988. During this period, no distinct, easily-identifiable plumes were visible in either the 8mm time-lapse or 35mm slide data. The IMPROVE Committee directed ARS to have Park personnel discontinue operation of the camera systems as of April 20, 1988.

Figure 3-1. Voyageurs National Park - 35mm Camera View.

4.0 MOOSEHORN NATIONAL WILDERNESS

An 8mm time-lapse camera system has been in operation at Moosehorn Wilderness. Due to difficult winter access, the camera was relocated. The two locations are detailed below:

Location 1

October 5, 1987 -	November 15, 1987
Camera Location	Magurrewock Mountain
Vista Photographed	Woodland Georgia Pacific Mill Azimuth 264 degrees

Location 2

November 16, 1987 -	February 14, 1988
Camera Location	Clearcut End of McConvet Road
Vista Photographed	Woodland Georgia Pacific Mill Azimuth 292 degrees

The 8mm time-lapse has shown a visible plume being emitted from the pulp mill nearly every day. The majority of the time, the plume appears to cross over the Wilderness boundary. Since no 35mm photography is available, the time-lapse film has been transferred to video tape which accompanies this report. The camera continues in operation and film is being processed and archived by ARS.

5.0 CONCLUSIONS

Photographic monitoring at Petrified Forest and Voyageurs National Parks for a period of one year has not been able to discern any identifiable plumes entering class I areas. The photographic record has been archived and the special monitoring discontinued as of April 1988 at both Parks.

Time-lapse monitoring of emissions from a pulp mill located near Moosehorn Wilderness has identified many cases of visible plumes entering the class I area. The 8mm time-lapse from October 5, 1987, to February 14, 1988, has been transferred to video tape for distribution with this report. Photographic monitoring with the 8mm time-lapse camera continues.

Appendix E

Transmissometer Data Collection and Processing

TRANSMISSOMETER DATA COLLECTION AND PROCESSING

DAILY PROCEDURES

1. Every day the ground station at Wallops Island, Virginia, is interrogated via modem for the data transmitted by the Data Collection Platforms (DCPs). The communications package used is CROSSTALK. A program called WALLOPS.EXE (or WALLOPS2.EXE) configures CROSSTALK and initiates the call. The user is prompted for the name of a local file in which to store the pulled data, and for the start date and time of the data desired. The data pulled from the ground station are tagged with the date and time received from the DCPs in GMT (Greenwich Mean Time). These date and time tags are translated to standard local date and time on a site-by-site basis when the data are appended to the raw file. The output of step 1 is the **Wallops data file.**

2. The Wallops data file may contain information not pertaining to the data desired. This information may concern solar eclipses, expected DCP messages not received, DCP transmitting at wrong time, as well as non-ASCII characters. The operator examines the Wallops data file for errors, making corrections as necessary. The file is then stripped of its header and message information, with the output going to the stripped Wallops data file; the program STRIP.EXE does this. The program saves the header and message information in a message file for printing and archiving. The operator keeps a written record of the performance of each site, noting bad readings, weather incidents, and operator problems.

3. The data in the stripped Wallops data file are now to be appended to the raw transmissometer files using the program APPEND_T.EXE. There is a raw transmissometer file for each site and each is named as the 4-character site code followed by _T. For example, the Grand Canyon file is called GRCA_T. The APPEND_T.EXE program reads the stripped Wallops data file, translates the GMT date and time to the standard date and time local to the site being processed, and adds the data to (or overwrites the data in) the raw transmissometer file for the site being processed. The program keeps strict track of where it is adding or changing data. The program will not allow data to be changed at the wrong record. The program will add missing (coded 8) hourly records as necessary when adding data past the end of the file. The program will code all data that are added to, or changed in the file as 0. The raw transmissometer file must always start on a seasonal boundary. The raw data are plotted bi-weekly and posted for review by field personnel.

SEASONAL PROCEDURES

1. At the end of a season all written documentation is analyzed to determine dates and times when the instrument was down or when the data were bad due to operator error. This information is included in a special code file for each site. For example, the code file for Grand Canyon is GRCA_C. The documentation is also examined for details concerning lamp changes and periods when the lamp was off. This information is included in a special lamp file for each site. For example, the lamp file for Grand Canyon is GRCA_L. The valid codes in the code file are as follows:

0	Good data (default)
1	Operator error: Flip Mirror Alignment etc.
2	Instrument down
8	Data acquisition error Did not get data from Wallops Island

   When the code file has been updated, the program ACODE_T.EXE is used to update the codes in the raw transmissometer file according to those listed in the code file. ACODE_T.EXE must be run for each site. The raw transmissometer files are now the coded transmissometer files.

2. The coded transmissometer files may contain one-hour duration spikes of bad data caused by the sun or other factors. This is not to be confused with a weather episode which would normally last more than one hour. If their amplitude is at least 15 times that of their neighbors, these spikes will be coded bad data (code 2) when the program SINGLE_T.EXE is run. SINGLE_T must be run for each site. The coded transmissometer files are now the filtered transmissometer files.

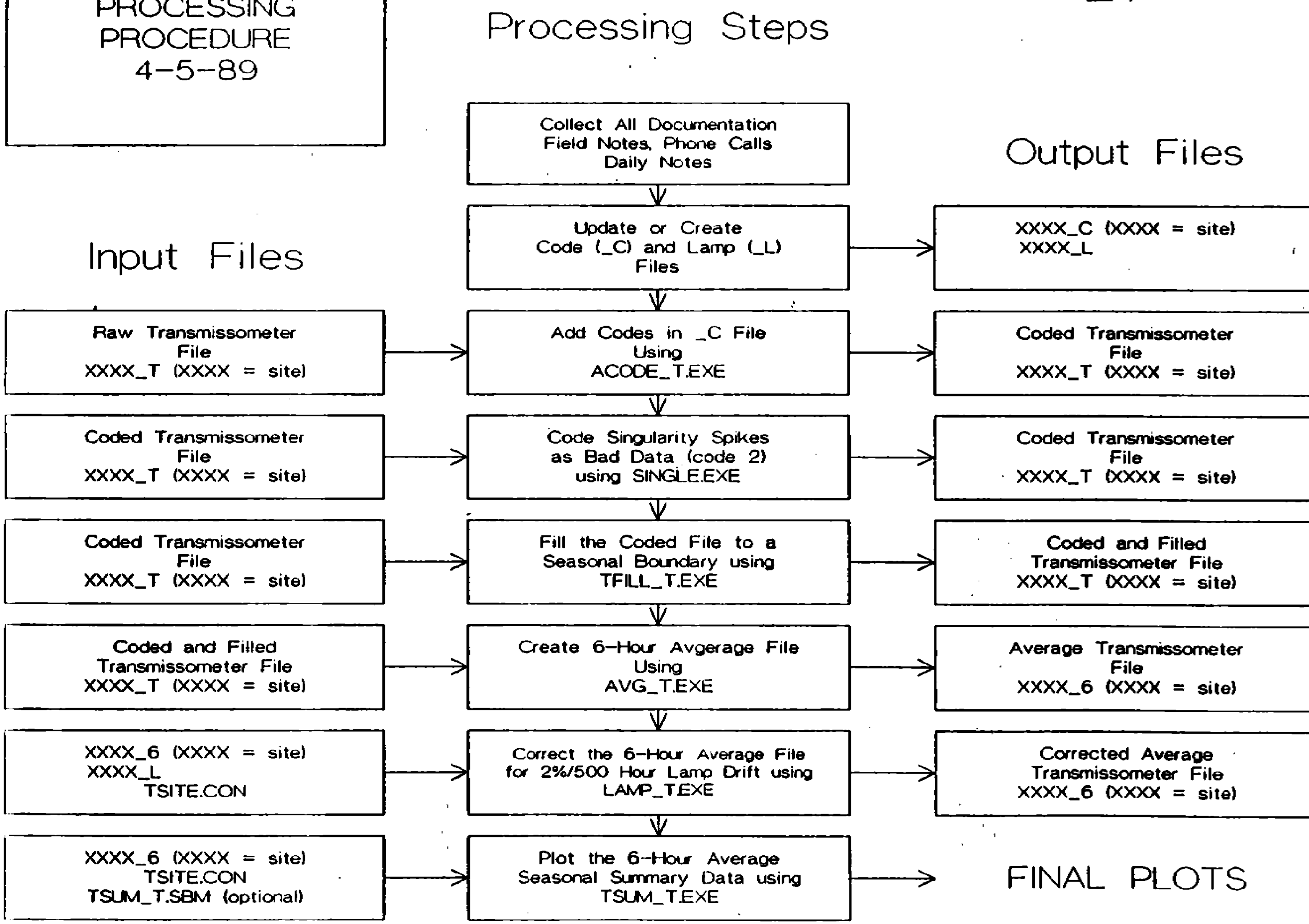
3. The filtered transmissometer files must start on a seasonal boundary for the averaging and seasonal plotting programs to operate correctly. The program TFILL_T.EXE must be run for each site. TFILL_T.EXE fills the filtered transmissometer files to the nearest seasonal boundary specified by the operator with missing data.

4. The data in each filtered transmissometer file are next averaged to create a new file called the average transmissometer file using the program AVG_T.EXE. The average transmissometer file for Grand Canyon is GRCA_6. AVG_T.EXE must be run for each site. AVG_T.EXE calculates 6-hour averages as follows:

   times 1-5
   6-11
   12-17
   18-23

Air Resource Specialists, Inc.

SEASONAL TRANSMISSOMETER PROCESSING PROCEDURE 4-5-89



The program keeps track of the number of hourly readings that was used to calculate each average. This number may be used later as a validity code for the averaging process.

The average B_{ext}, average relative humidity, average temperature, average SVR, and the number of points used in the average are written to the average transmissometer file at times 5, 11, 17 and 23.

5. The average transmissometer file now undergoes the lamp drift correction process. The B_{ext} values are corrected for a lamp drift of 2% per 500 hours of lamp-on time. The dates and times and status of the lamp (ON or OFF) must have been listed in the lamp file for each site. The lamp file for Grand Canyon is GRCA_L. The program LAMP_T.EXE uses this lamp file to apply the correction to the B_{ext} values in the average transmissometer file. The result is the corrected average transmissometer file. This file also contains the lamp numbers that were included in the lamp file. The algorithm used to make the lamp correction is as follows:

Let x1 = 16 number of minutes per hour the lamp is on.
Let x2 = 60 number of minutes in an hour.
Let x3 = 500 number of lamp-on hours for a 2% drift.

Then,

$$y1 = \frac{x3}{\frac{x1}{x2}} = 1875$$ number of actual hours for a 2% drift.

$$y2 = \frac{y1}{6} = 312.5$$ number of 6-hour averages for a 2% drift.

Let N be the number of 6-hour averages since the last lamp change.

Then,

$$y3 = 1 + 0.02\left(\frac{N}{y2}\right)$$

$$y4 = -\left(\frac{1}{\text{path distance}}\right)\ln\left(\frac{1}{y3}\right)$$ the factor to be added to the Nth 6-hour average B_{ext}.

6. The data in the corrected average transmissometer file may now be plotted on a seasonal basis using TSUM_T.EXE, the transmissometer seasonal summary program. This program uses information stored in a special site data file TSITE.CON to determine if the site is an Eastern or Western site. Eastern and Western sites are plotted on different scales. The program allows linear or logarithmic scales on the y-axes, while a linear scale is used on the x-axes. The cumulative frequency calculations use the count method, ignoring data that falls below the threshold for a particular site. This threshold is specified in TSITE.CON for each site. The threshold for Western sites is typically SVR = 13 km, while for Eastern sites it is SVR = 2 km. The program allows the operator to choose the minimum number of points used in the averaging process as a cutoff level. The default is 3. That is, any average whose value was calculated using fewer than 3 points will be ignored in the cumulative frequency and data recovery calculations.

Transmissometer Installation Dates

SITE	DATE
GRCA	12-18-86
CANY	12-19-86
PEFO	04-17-87
ACAD	11-12-87
ROMO	12-01-87
BADL	01-14-88
SHEN	03-09-88
PINN	03-23-88
SAGO	NOT APPLICABLE
VOYA	06-18-88
BRID	07-19-88
YOSE	09-01-88
CRLA	09-01-88
MEVE	09-14-88
BAND	10-05-88
GUMO	12-01-88
BIBE	12-01-88
GLAC	01-20-89
CHIR	02-17-89
TONT	04-19-89

(TranData.Col)

TRANSMISSOMETER QUALITY ASSURANCE NOTES

A transmissometer quality assurance (QA) program is currently under development. The purpose of the QA program is to assure that all transmissometer data are of known and sufficient quality to meet the monitoring objectives of the IMPROVE program. Transmissometer data quality--its accuracy, precision, completeness, representativeness and comparability--will be assured by implementing a system of principles, practices, methods, guidelines, and procedures that are applicable to the monitoring program and its individual components.

Development of the overall QA program is underway. Standard operating procedures and field operator manuals have been developed, published, and distributed to each of the sites, the IMPROVE Committee and other visibility scientists. These documents contain information on:

- o System design;
- o Installation considerations;
- o Operational characteristics;
- o Field operator procedures; and
- o Calibration of the transmissometer systems.

Current work is focusing on formalizing the procedures developed during the past eighteen months to handle routine and emergency maintenance of the transmissometers and related system components in a swift, cost-effective manner. A draft maintenance procedures manual is in preparation. These procedures will then be implemented and tested in the routine operation of the transmissometer network started in March 1989.

Procedures to verify the precision and accuracy of the transmissometer and transmissometer data collection systems will be formulated through a comprehensive instrument and systems testing experiment currently underway at the test site in Fort Collins, Colorado. The major areas to be thoroughly investigated include:

1. Calibration Procedures

   - Determination of optimum calibration path distance
   - Evaluation of electronic receiver sensitivity
   - Evaluation of calibration aperture size
   - Beam intensity reduction with neutral density filters
   - Consistency of lamp calibration between changes

2. Instrument Performance Tests

   - Transmitter beam - uniformity of illumination
   - Transmitter beam - stability of intensity
   - Transmitter - effects of temperature on operation
   - Receiver detector - uniformity of response
   - Receiver - effects of temperature on operation

3. System Performance Tests

   - Window cleanliness and aging
   - Telescope alignment
   - Data retrieval
   - Distance measurements
   - Gain adjustments

4. Operational Improvement Tests

   - Effect of heated windows
   - Effect of distorted windows
   - Evaluation of flip mirror position indicator
   - Evaluation of standard deviation measurements
   - Evaluation of window cleaning techniques
   - Evaluation of various window/hood designs.

5. Data Analysis and Reporting Procedures Tests

These tests will provide the remaining information necessary to complete the QA program documents. A completed, verified, and operational QA program will be in place by December 1989.

(TransQA.Not)

Appendix F

Status of IMPROVE and National Park Service IMPROVE Protocol Optical Monitoring Networks

STATUS OF IMPROVE AND NATIONAL PARK SERVICE IMPROVE PROTOCOL OPTICAL MONITORING NETWORKS

Prepared for the
IMPROVE STEERING COMMITTEE

Prepared by
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1901 Sharp Point Drive, Suite E
Fort Collins, Colorado 80525

November 30, 1988

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1.0 INTRODUCTION

The **IMPROVE** and **National Park Service (NPS) IMPROVE PROTOCOL** visibility monitoring networks consist of a combined 37 sites. Table 1-1 lists these sites by network. Monthly Progress Reports have been issued since March 1987 discussing detailed design, installation, development, and operation of these networks. The following sections present summaries of the current and projected status of the optical monitoring program. The major emphasis will be placed on the transmissometer systems. Monthly Progress Reports contain up-to-date information on the history of the installation, testing, development and operation of all the optical monitoring equipment at each site; they should be referred to for specific questions pertaining to any particular monitoring location.

TABLE 1-1

NATIONAL VISIBILITY MONITORING NETWORKS

IMPROVE

1. ACADIA NATIONAL PARK
2. BIG BEND NATIONAL PARK
3. BRYCE CANYON NATIONAL PARK
4. BRIDGER WILDERNESS
5. CANYONLANDS NATIONAL PARK
6. CHIRICAHUA NATIONAL MONUMENT
7. CRATER LAKE NATIONAL PARK
8. DENALI NATIONAL PARK
9. GLACIER NATIONAL PARK
10. GRAND CANYON NATIONAL PARK
11. GREAT SMOKY MOUNTAINS NATIONAL PARK
12. JARBIDGE WILDERNESS
13. MESA VERDE NATIONAL PARK
14. MOUNT RAINIER NATIONAL PARK
15. ROCKY MOUNTAIN NATIONAL PARK
16. SAN GORGONIO WILDERNESS
17. SHENANDOAH NATIONAL PARK
18. TONTO NATIONAL MONUMENT
19. WEMINUCHE WILDERNESS
20. YOSEMITE NATIONAL PARK

NPS IMPROVE PROTOCOL

21. ARCHES NATIONAL PARK
22. BADLANDS NATIONAL PARK
23. BANDELIER NATIONAL MONUMENT
24. GREAT SAND DUNES NATIONAL MONUMENT
25. GUADALUPE MOUNTAINS NATIONAL PARK
26. HALEAKALA NATIONAL PARK
27. HAWAII VOLCANOES NATIONAL PARK
28. ISLE ROYAL NATIONAL PARK
29. LASSEN VOLCANIC NATIONAL PARK
30. NATIONAL CAPITAL REGION-CENTRAL
31. PETRIFIED FOREST NATIONAL PARK
32. PINNACLES NATIONAL MONUMENT
33. POINT REYES NATIONAL SEASHORE
34. REDWOOD NATIONAL PARK
35. VIRGIN ISLANDS NATIONAL PARK
36. VOYAGEURS NATIONAL PARK
37. YELLOWSTONE NATIONAL PARK

2.0 PHOTOGRAPHIC SYSTEMS

Eventually all 37 sites will have automatic 35mm camera systems. Photographs are taken three times daily at 0900, 1200, and 1500 hours. At monitoring locations where transmissometers are not installed and appropriate horizon target features exist, Kodachrome 25 slides are scanned with a micro-densitometer to estimate Standard Visual Range (SVR). At sites with transmissometers, the photographic monitoring is designed to document the effect of changing visual air quality on a specific scenic vista within the class I area.

Photographic Monitoring has not yet begun at three locations:

Denali National Park (DENA)
National Capital Region-Central (NACC)
Virgin Islands National Park (VIIS)

DENA has had a camera at the Park for the past two years, but has operated the system unsuccessfully. The NACC camera will be installed during the second week of December 1988. Installation of the VIIS system is on indefinite hold as directed by the National Park Service.

Photographic data from the networks have been collected and analyzed on a regular basis from the beginning of the project. Some locations conduct monitoring only during the summer and fall seasons due to severe winter weather.

Standard operational, quality assurance, and data processing procedures have been in effect for the entire project period. Photographic-derived SVR data are released through the National Park Service as Seasonal Summary Reports. The data are archived in the National Park Service optical monitoring database. Detailed site discussions of the photographic monitoring program are available in the *Monthly Progress Reports*, quarterly *Seasonal Summary Reports*, and the *Photographic Systems Standard Operating Procedures Manual*.

3.0 NEPHELOMETER SYSTEMS

Two locations--Great Smoky Mountains and Mount Rainier National Parks--will use nephelometers to monitor atmospheric scattering. Measurements from the EPA Eastern Fine Particle Network nephelometer located at Look Rock, Great Smoky Mountains, will be collected for inclusion into the optical monitoring database. A nephelometer will be installed at Mount Rainier in late 1989. This nephelometer is currently being used in a special study, and will not be available for installation until then.

4.0 TRANSMISSOMETER SYSTEMS

Table 4-1 lists the twenty-two locations that have been chosen to receive transmissometers (14 IMPROVE and 8 NPS IMPROVE Protocol). The distribution of the transmissometer systems within the networks was designed to achieve geographic, meteorological, and visual air quality diversity. The first two years of this program have been devoted to:

- o Deploying the transmissometers;
- o Testing the operation of the systems under widely varying real-world conditions;
- o Developing and implementing standard operating procedures; and
- o Designing standard data editing and reporting protocols.

The goal is to have an operational network of transmissometers by March 1, 1989. The network would then collect high quality atmospheric extinction data for the final year of the contract.

4.1 Deployment

The primary effort has been to deploy the transmissometer systems as quickly as possible during the first two years of the program. To accomplish this, installation of the systems was given the highest priority at the expense of allowing equipment to fail and not be immediately repaired. This resulted in occasional inoperative systems for extended periods of time.

Table 4-1 lists the deployment dates of the eighteen units installed as of December 1, 1988. Two more systems will be installed by February 1989. Due to major fires this year in Yellowstone National Park, the instrument will not be installed until Summer 1989. The Hawaii transmissometer will not be installed until further review of the ability of the transmissometer to operate over the 35 km path length available at this location.

4.2 Operational Status

Table 4-1 lists the projected dates for routine operation of each transmissometer. These dates are considered to be the time of final system configuration for regular data collection. Many of the instruments have been installed in harsh and quite unique environments resulting in major advances in our understanding of the operational characteristics of the transmissometer systems. Return trips to these sites for re-configuration, re-calibration, re-furbishing, and operator re-training are in progress. Ten sites will be considered fully operational as of December 1, 1988. Eight sites will be visited between December 1, 1988, and March 1, 1989, to bring them to fully operational status. Two transmissometers will be installed during February 1989. This will result in a network of twenty operational transmissometers starting March 1, 1989.

TABLE 4-1

TRANSMISSOMETER NETWORK DESCRIPTION

	LOCATION	NETWORK	INSTALLATION DATE	OPERATIONAL DATE
1.	Acadia	IMPROVE	11/14/87	03/01/89
2.	Badlands	PROTOCOL	01/15/88	12/01/88
3.	Bandelier	PROTOCOL	10/07/88	12/01/88
4.	Big Bend	IMPROVE	12/01/88	12/01/88
5.	Bridger	IMPROVE	07/22/88	12/01/88
6.	Canyonlands	IMPROVE	12/20/86	01/01/87
7.	Chiricahua	IMPROVE	Feb-89	03/01/89
8.	Crater Lake	IMPROVE	09/02/88	03/01/89
9.	Glacier	IMPROVE	02/05/88	03/01/89
10.	Grand Canyon	IMPROVE	12/20/86	09/01/87
11.	Guadalupe	PROTOCOL	11/18/88	12/01/88
12.	Hawaii Volcanoes	PROTOCOL	1989	1989
13.	Mesa Verde	IMPROVE	09/16/88	12/01/88
14.	Petrified Forest	PROTOCOL	04/18/87	09/01/87
15.	Pinnacles	PROTOCOL	03/25/88	12/01/88
16.	Rocky Mountain	IMPROVE	12/02/87	03/01/89
17.	San Gorgonio	IMPROVE	04/29/87	03/01/89
18.	Shenandoah	IMPROVE	03/04/88	03/01/89
19.	Tonto	IMPROVE	Feb-89	03/01/89
20.	Voyageurs	PROTOCOL	06/17/88	03/01/89
21.	Yellowstone	PROTOCOL	1989	1989
22.	Yosemite	IMPROVE	08/19/88	12/01/88

As documented in the Monthly Progress Reports, much has been learned about the failure modes and operational characteristics of the transmissometers. Procedures are being developed to quickly handle instrument malfunctions in the operational network. Data collected from the date of installation to the assigned operational date will be processed and included in the optical monitoring database. These data will be flagged as collected during the testing period of the instrumentation. The data collection efficiency during these interim periods will be lower than after the systems reach operational status.

In general, systems installed in the Southwest have been and are expected to continue operating with a higher data collection efficiency than in the North and East.

4.3 Standard Operating Procedures

Standard operating procedures and field operator manuals have been developed, published, and distributed to each of the sites, the IMPROVE Committee and other visibility scientists. These documents contain information on:

- System design;
- Installation considerations;
- Operational characteristics;
- Field operator procedures; and
- Calibration of the transmissometer systems.

Current work is focusing on formalizing the procedures developed during the past eighteen months to handle routine and emergency maintenance of the transmissometers and related system components in a swift, cost-effective manner. A draft maintenance procedures manual is in preparation and expected to be distributed to the IMPROVE Committee by January 15, 1989, for review. These procedures will then be implemented in the routine operation of the transmissometer network by March 1989.

4.4 Data Reporting

The transmissometer calculates and reports average atmospheric extinction over the path length of the instrument. The data are recovered daily from satellite data collection platforms. Along with extinction, ambient temperature and relative humidity are also monitored. The data represent one ten-minute average value for each hour. The measurement interval begins three minutes after the hour. After collection and editing (only removing times when the monitoring equipment was malfunctioning), the data are reduced to six-hour average values. The time periods of the four daily six-hour average values are:

1 - 0000 to 0500 hours
2 - 0600 to 1100 hours
3 - 1200 to 1700 hours
4 - 1800 to 2300 hours

The number of valid ten-minute averages in each six-hour average is recorded and kept in a database.

Data editing consists of removing measurements when the system was known to be inoperative or delivering questionable data due to non-standard operational parameters noted by on-site operators on the Log Sheets. These conditions include optical misalignment, unknown window transmission due to exceptionally dirty, broken, or missing window glass, or questionable data logging and transmission.

The data will be released in quarterly Seasonal Summary Reports. Figure 4-1 is an example of the Fall 1988 seasonal summary for Grand Canyon National Park. The report contains data collected from September 1, 1988, through November 22, 1988. The final version of this report will contain data for the entire season. The Appendix A contains draft Seasonal Summary Reports for all transmissometer data collected at the Grand Canyon from December 1986 to November 1988.

The top graph is a time line of all the collected six-hour average values. The dashed line at an SVR of 13 km (b_{ext}=0.3 km^{-1}) represents an optical depth of the transmissometer sight path of approximately 2. When the optical depth reaches this value, the error in measured extinction becomes relatively large. When b_{ext} is greater than 0.3 km^{-1}, the time line becomes dashed indicating an increased uncertainty in the measurement.

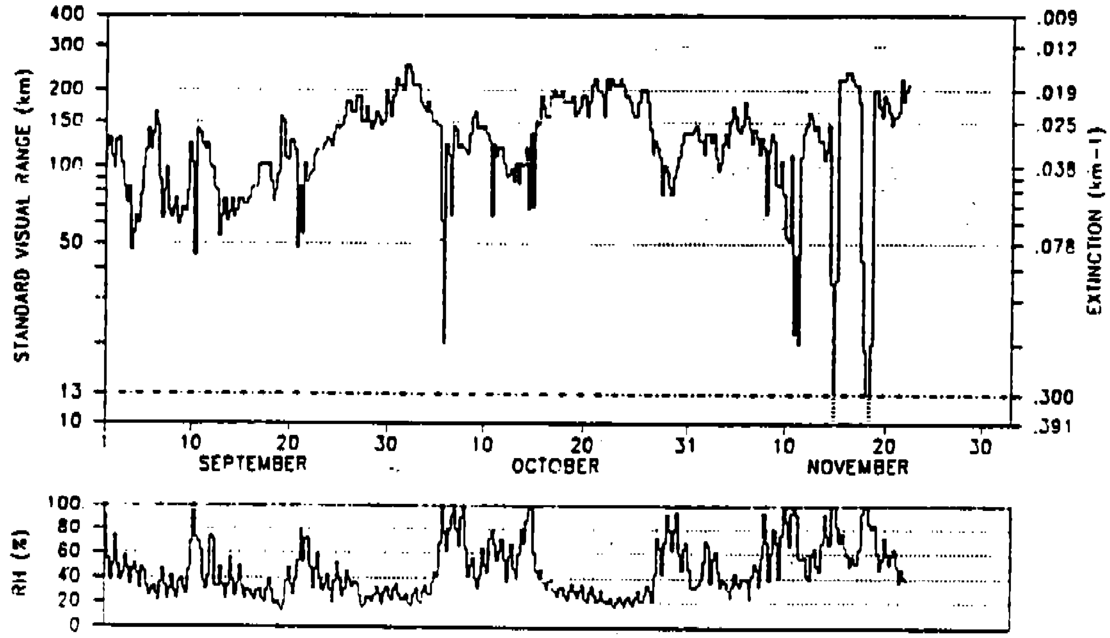
The next graph presents a time line of six-hour average relative humidity measurements. This allows rapid determination of the effect of increasing relative humidity on measured b_{ext}. Long periods of relative humidity near 100% can be seen in the reports in the Appendix A. This usually results in corresponding periods of high b_{ext}. This probably is associated with precipitation events. This assumption can only be verified by reviewing simultaneous photographic data.

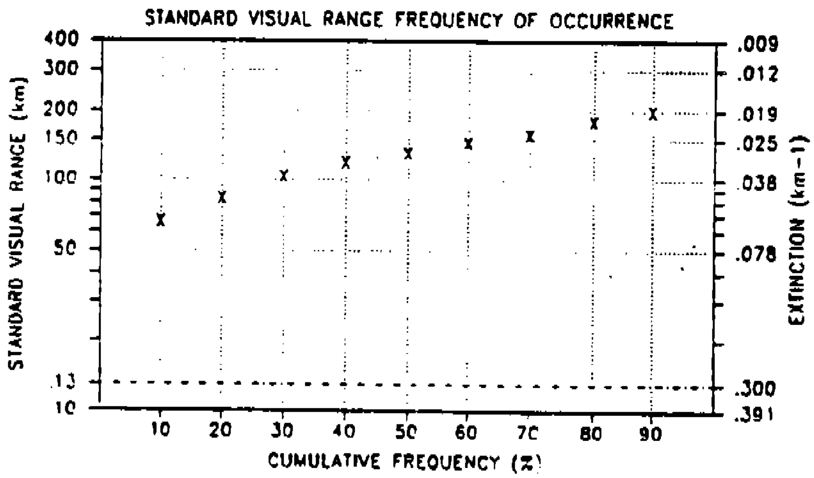
The bottom plot is a rank-ordered cumulative frequency plot of six-hour average extinction values. The 10% to 90% values are plotted in 10% increments. All extinction values greater than 0.3 km^{-1} are placed into one bin at this level. The 10%, 50%, and 90% values are listed to the right of the plot.

The listing at the bottom contains data recovery statistics for the season.

A database will be developed to contain all b_{ext}, ambient temperature, and relative humidity six-hour average values. The number of 10-minute values in each six-hour average will be listed. All raw data will be kept in ASCII files by site.

GRAND CANYON NATIONAL PARK
Transmissometer Data Summary -- 6 Hour Averages
September 1, 1988 - November 30, 1988





%	b_{ext}	SVR
10	.059	66
50	.029	131
90	.019	199

FOR A GIVEN % OF THE TIME, THE SVR IS LESS THAN OR EQUAL TO THE CORRESPONDING SVR VALUE.

TRANSMISSOMETER DATA RECOVERY STATISTICS

CATEGORY	NUM	%
TOTAL POSSIBLE 6-HOUR AVERAGES IN THE TIME PERIOD	364	100
USABLE 6-HOUR AVERAGES IN THE TIME PERIOD	328	90

Figure 4-1. Grand Canyon National Park Transmissometer Data Summary.

4.5 TRANSMISSOMETER TESTING

A comprehensive examination and testing program for the transmissometer system is planned to begin in January 1989. The tests will take place at Ft. Collins, Colorado. Four major areas will be investigated:

1. Calibration Procedures
   - Determination of optimum calibration path distance
   - Evaluation of electronic receiver sensitivity
   - Evaluation of calibration aperture size
   - Beam intensity reduction with neutral density filters
   - Consistency of lamp calibration between changes

2. Instrument Performance Tests
   - Transmitter beam - uniformity of illumination
   - Transmitter beam - stability of intensity
   - Transmitter - effects of temperature on operation
   - Receiver detector - uniformity of response
   - Receiver - effects of temperature on operation

3. System Performance Tests
   - Window cleanliness and aging
   - Telescope alignment
   - Data retrieval
   - Distance measurements
   - Gain adjustments

4. Operational Improvement Tests
   - Effect of heated windows
   - Effect of distorted windows
   - Evaluation of flip mirror position indicator
   - Evaluation of standard deviation measurements
   - Evaluation of window cleaning techniques
   - Evaluation of various window/hood designs.

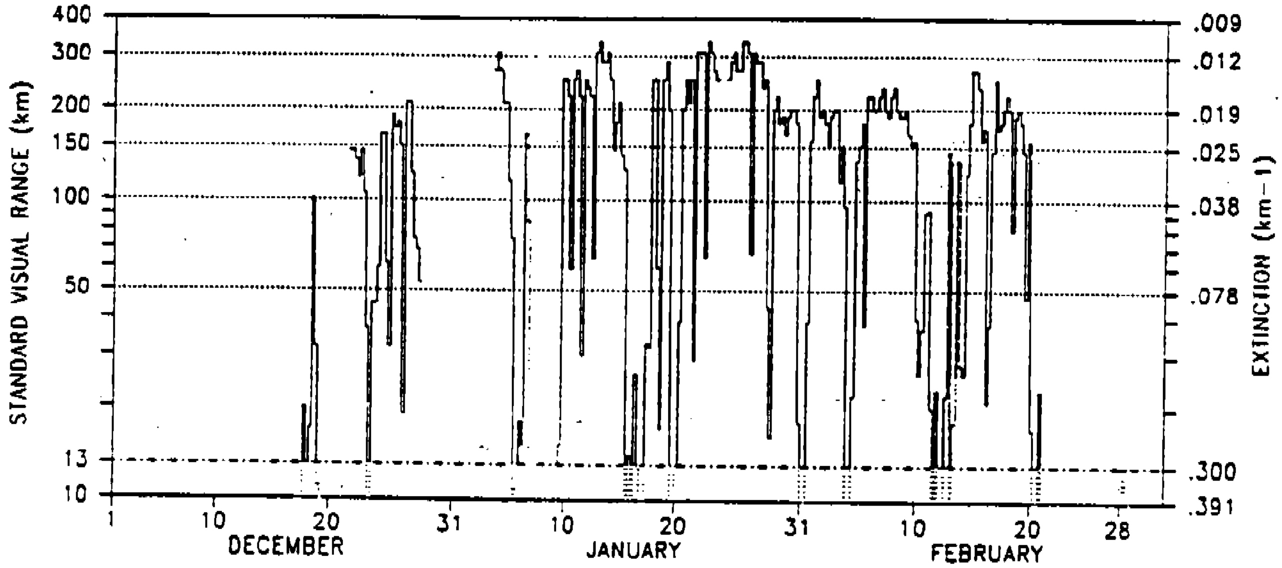
The above is only a brief outline of this intensive test program. A detailed test plan is in preparation and will be distributed in early January 1989. The goal of the test program is to create a quality assurance and performance standards document for the transmissometer system.

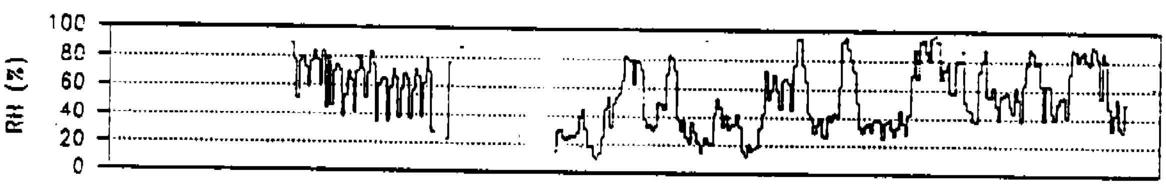
APPENDIX A

DRAFT SEASONAL SUMMARY REPORTS FOR
GRAND CANYON NATIONAL PARK
DECEMBER 1986 THROUGH NOVEMBER 1988

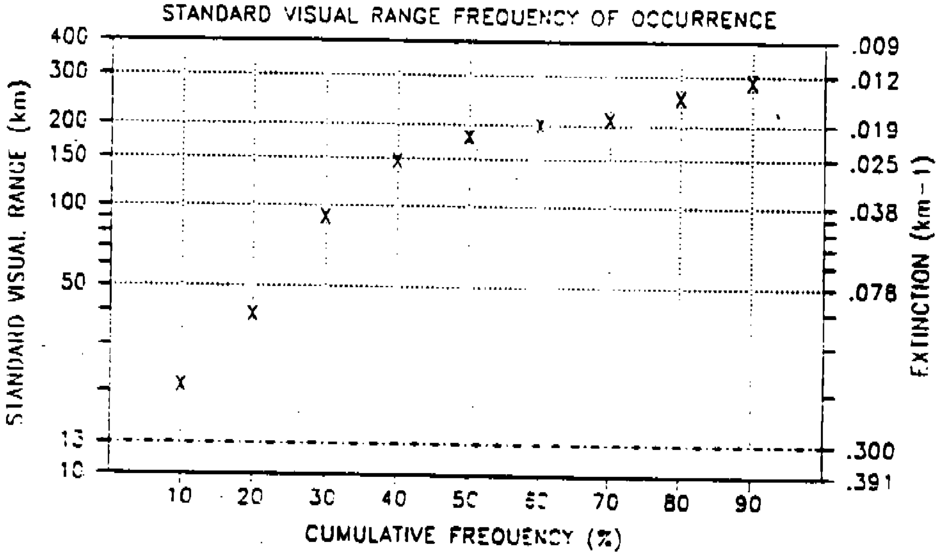
GRAND CANYON NATIONAL PARK

Transmissometer Data Summary -- 6 Hour Averages
December 1, 1986 - February 28, 1987





STANDARD VISUAL RANGE FREQUENCY OF OCCURRENCE



%	b_{ext}	SVR
10	.186	21
50	.021	180
90	.013	286

FOR A GIVEN % OF THE TIME, THE SVR IS LESS THAN OR EQUAL TO THE CORRESPONDING SVR VALUE.

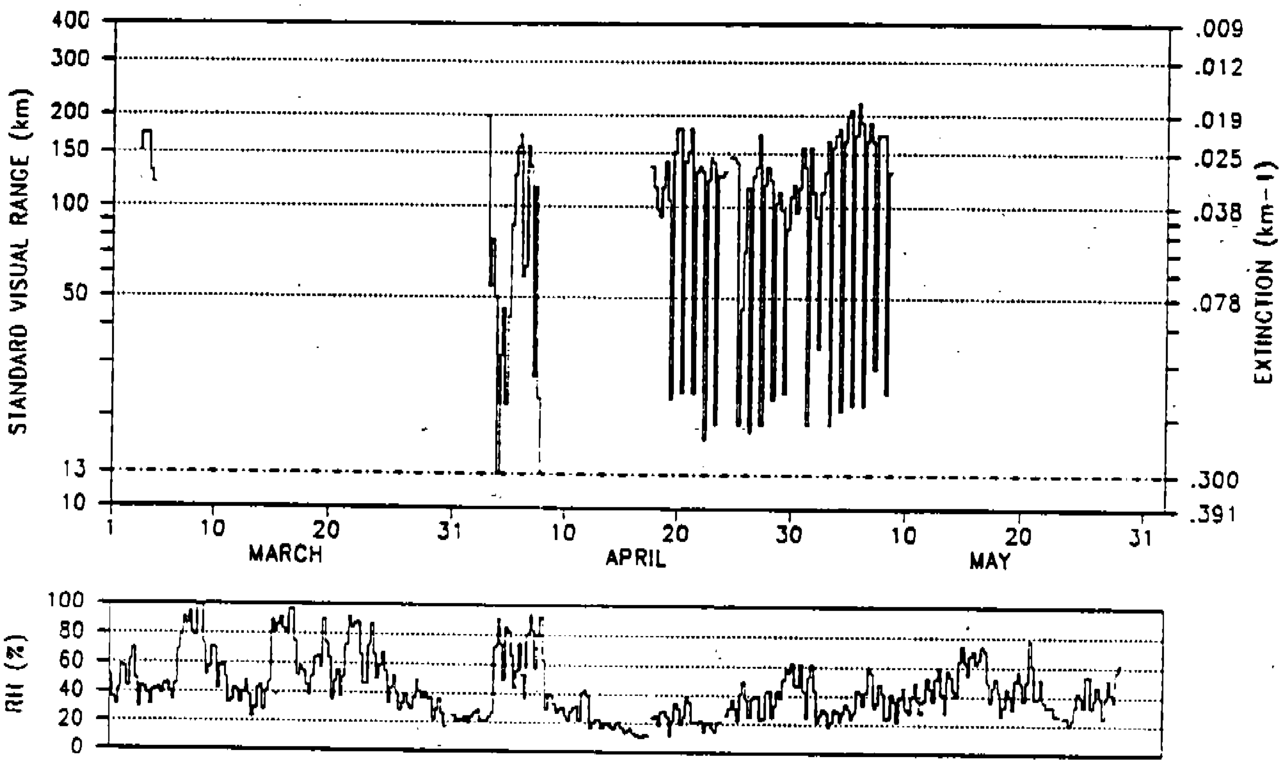
TRANSMISSOMETER DATA RECOVERY STATISTICS

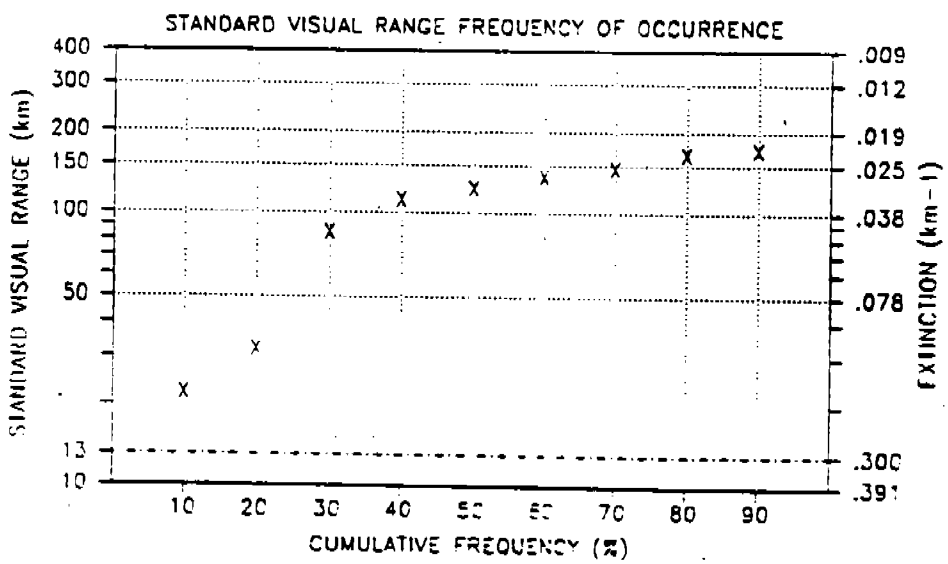
CATEGORY	NUM	%
TOTAL POSSIBLE 6-HOUR AVERAGES IN THE TIME PERIOD	360	100
USABLE 6-HOUR AVERAGES IN THE TIME PERIOD	194	53

GRAND CANYON NATIONAL PARK

Transmissometer Data Summary -- 6 Hour Averages

March 1, 1987 - May 31, 1987





%	b_{ext}	SVR
10	.177	22
50	.031	123
90	.022	172

FOR A GIVEN % OF THE TIME, THE SVR IS LESS THAN OR EQUAL TO THE CORRESPONDING SVR VALUE.

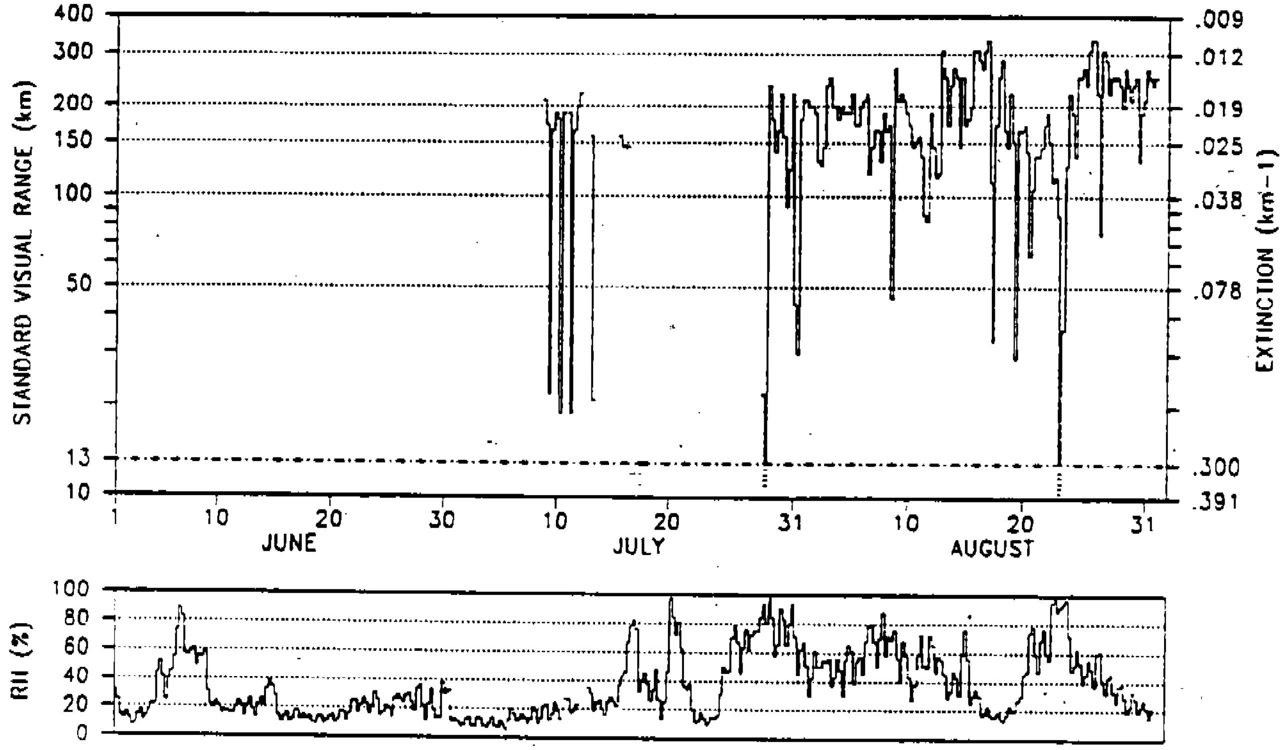
TRANSMISSOMETER DATA RECOVERY STATISTICS

CATEGORY	NUM	%
TOTAL POSSIBLE 6-HOUR AVERAGES IN THE TIME PERIOD	368	100
USABLE 6-HOUR AVERAGES IN THE TIME PERIOD	110	29

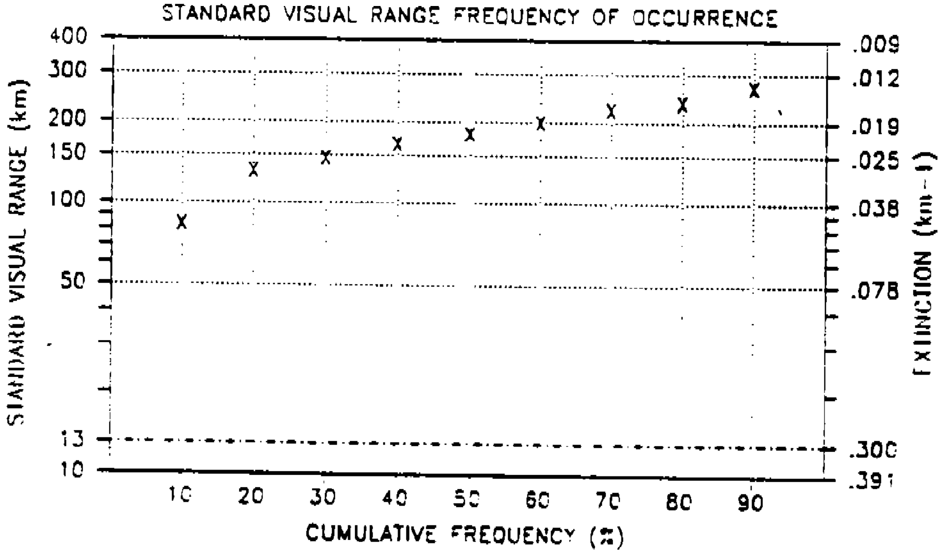
GRAND CANYON NATIONAL PARK

Transmissometer Data Summary -- 6 Hour Averages

June 1, 1987 - August 31, 1987



STANDARD VISUAL RANGE FREQUENCY OF OCCURRENCE



%	b_{ext}	SVR
10	.046	83
50	.021	180
90	.014	267

FOR A GIVEN % OF THE TIME, THE SVR IS LESS THAN OR EQUAL TO THE CORRESPONDING SVR VALUE.

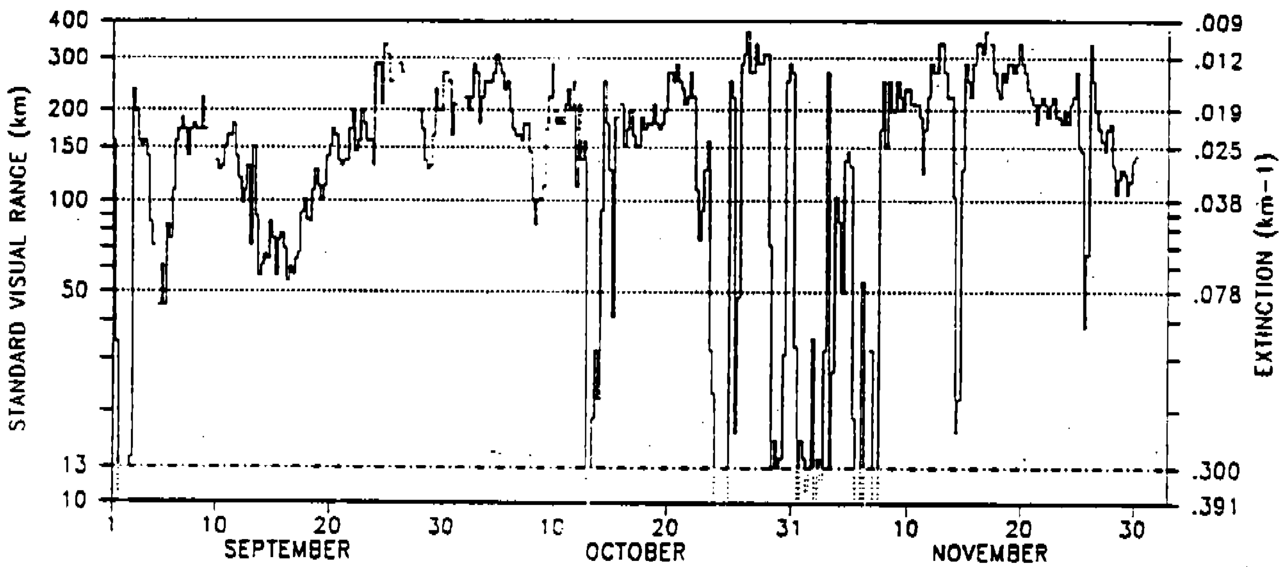
TRANSMISSOMETER DATA RECOVERY STATISTICS

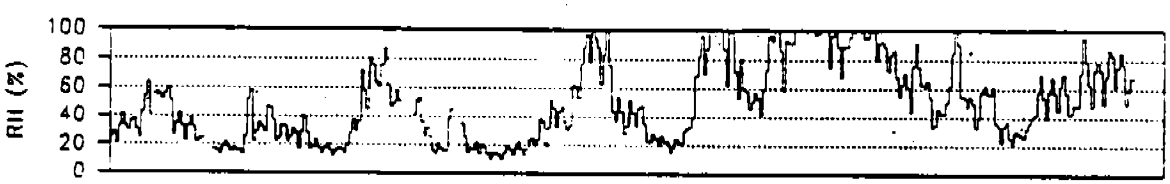
CATEGORY	NUM	%
TOTAL POSSIBLE 6-HOUR AVERAGES IN THE TIME PERIOD	366	100
USABLE 6-HOUR AVERAGES IN THE TIME PERIOD	156	42

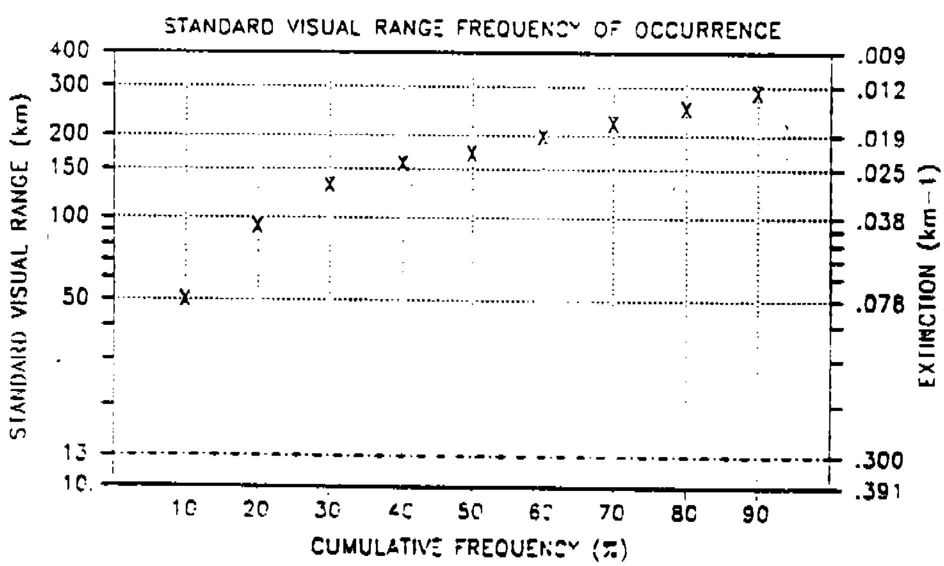
GRAND CANYON NATIONAL PARK

Transmissometer Data Summary -- 6 Hour Averages

September 1, 1987 - November 30, 1987







%	b_{ext}	SVR
10	.078	50
50	.022	172
90	.013	286

FOR A GIVEN % OF THE TIME, THE SVR IS LESS THAN OR EQUAL TO THE CORRESPONDING SVR VALUE.

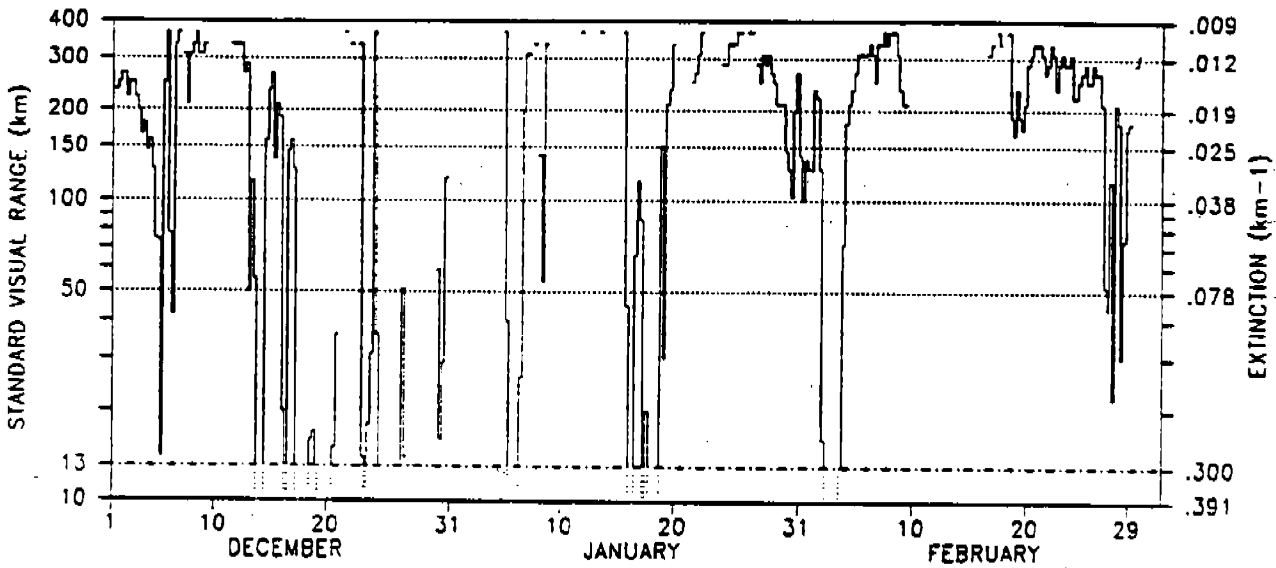
TRANSMISSOMETER DATA RECOVERY STATISTICS

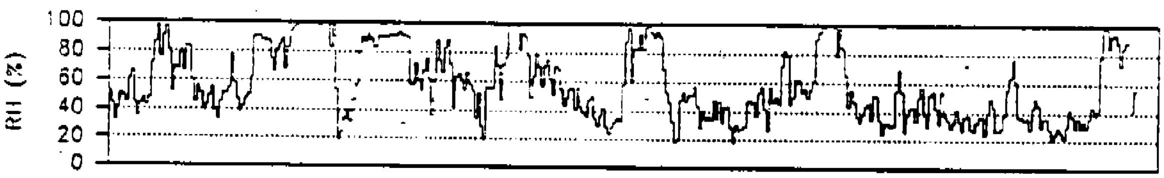
CATEGORY	NUM	%
TOTAL POSSIBLE 6-HOUR AVERAGES IN THE TIME PERIOD	364	100
USABLE 6-HOUR AVERAGES IN THE TIME PERIOD	324	89

GRAND CANYON NATIONAL PARK

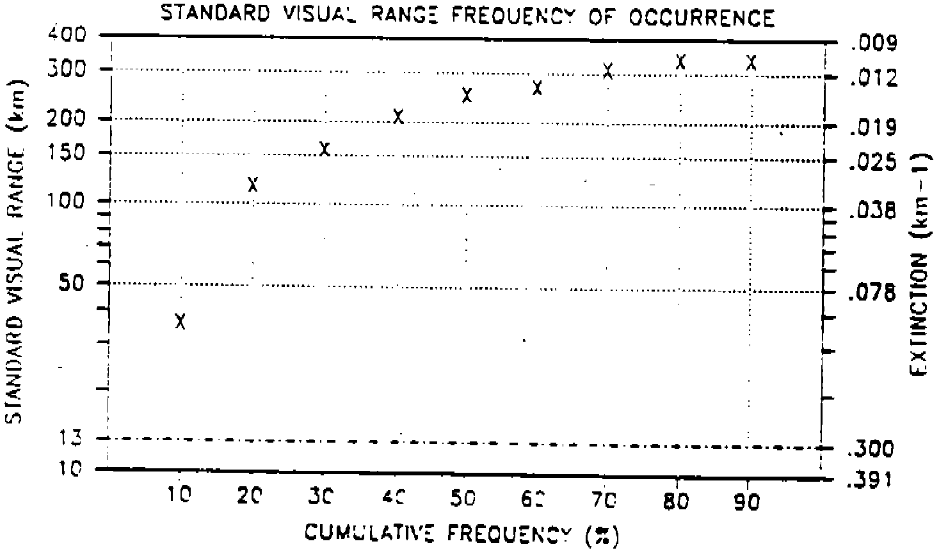
Transmissometer Data Summary -- 6 Hour Averages

December 1, 1987 - February 29, 1988





STANDARD VISUAL RANGE FREQUENCY OF OCCURRENCE



%	b_{ext}	SVR
10	.108	36
50	.015	250
90	.011	335

FOR A GIVEN % OF THE TIME, THE SVR IS LESS THAN OR EQUAL TO THE CORRESPONDING SVR VALUE.

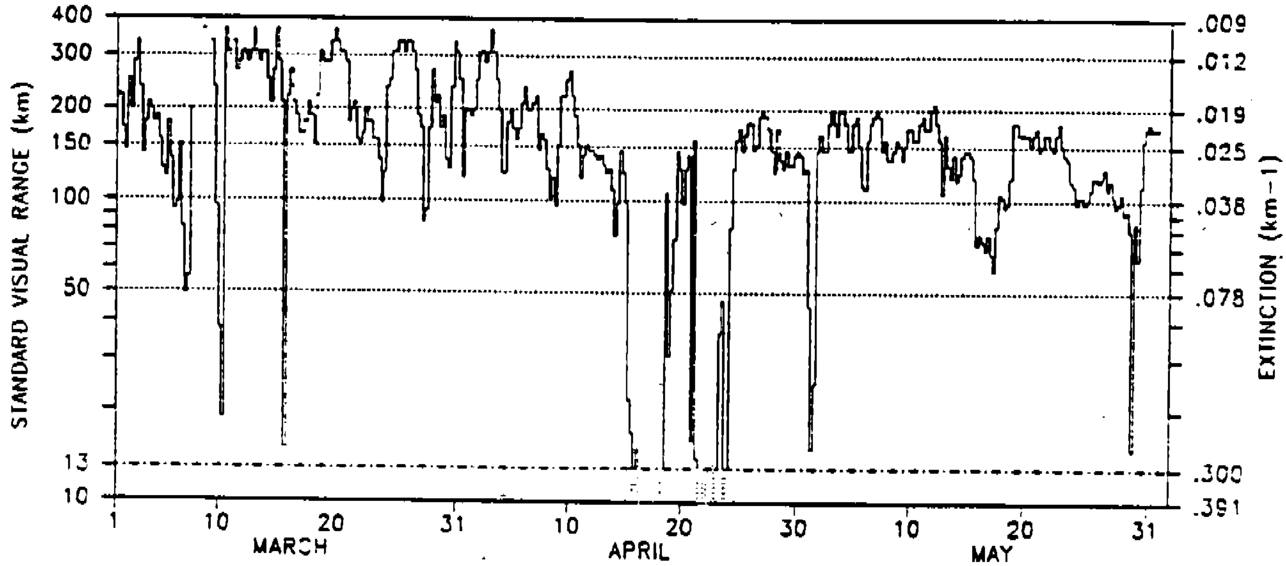
TRANSMISSOMETER DATA RECOVERY STATISTICS

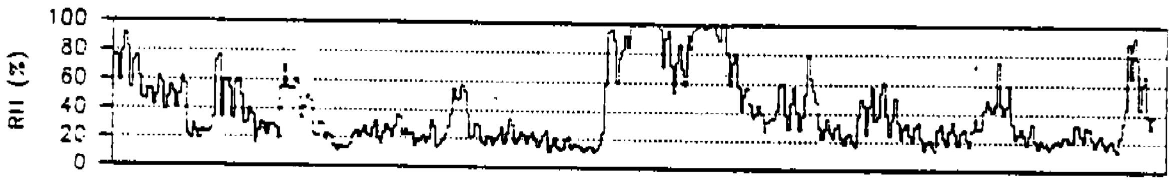
CATEGORY	NUM	%
TOTAL POSSIBLE 6-HOUR AVERAGES IN THE TIME PERIOD	364	100
USABLE 6-HOUR AVERAGES IN THE TIME PERIOD	204	56

GRAND CANYON NATIONAL PARK

Transmissometer Data Summary -- 6 Hour Averages

March 1, 1988 - May 31, 1988





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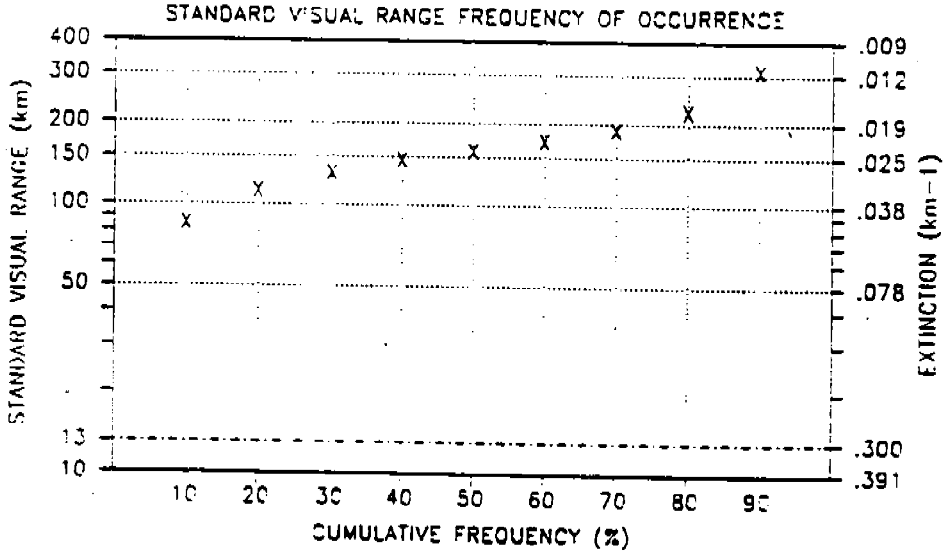


%	b_{ext}	SVR
10	.045	85
50	.024	158
90	.012	309

FOR A GIVEN % OF THE TIME, THE SVR IS LESS THAN OR EQUAL TO THE CORRESPONDING SVR VALUE.

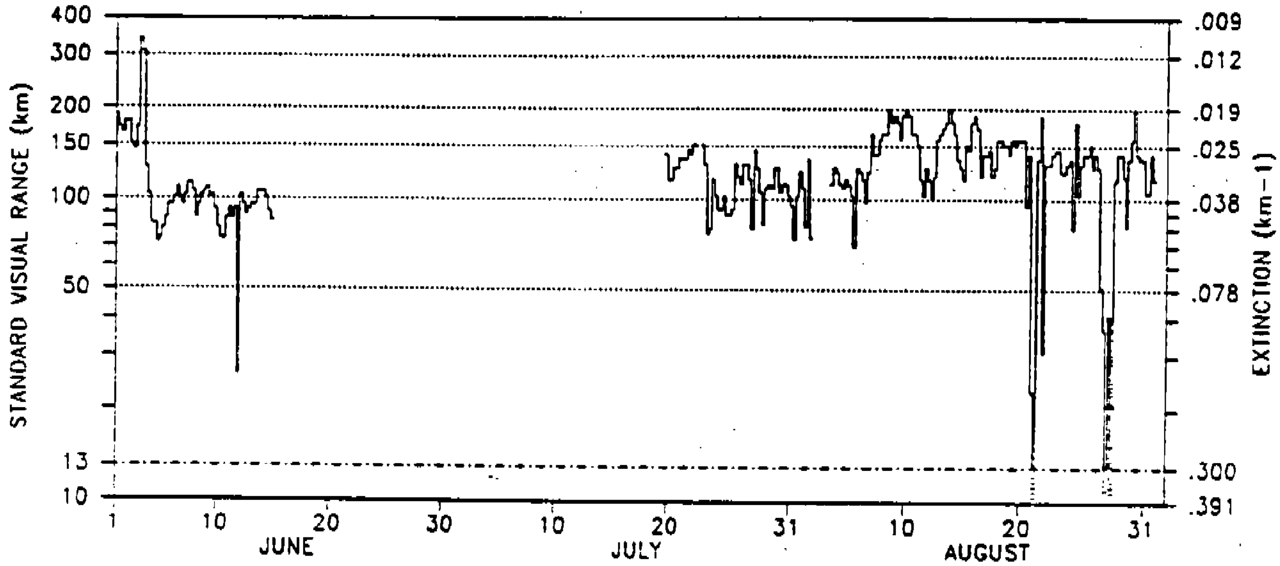
TRANSMISSOMETER DATA RECOVERY STATISTICS

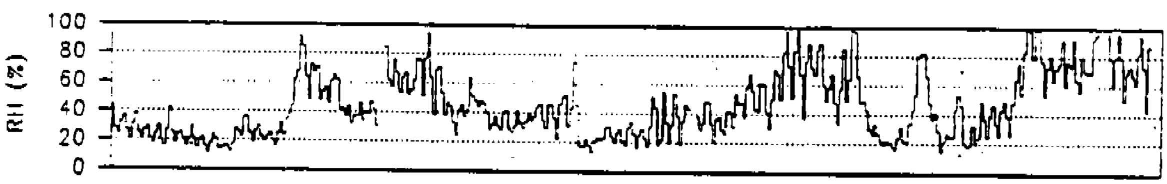
CATEGORY	NUM	%
TOTAL POSSIBLE 6-HOUR AVERAGES IN THE TIME PERIOD	368	100
USABLE 6-HOUR AVERAGES IN THE TIME PERIOD	345	93

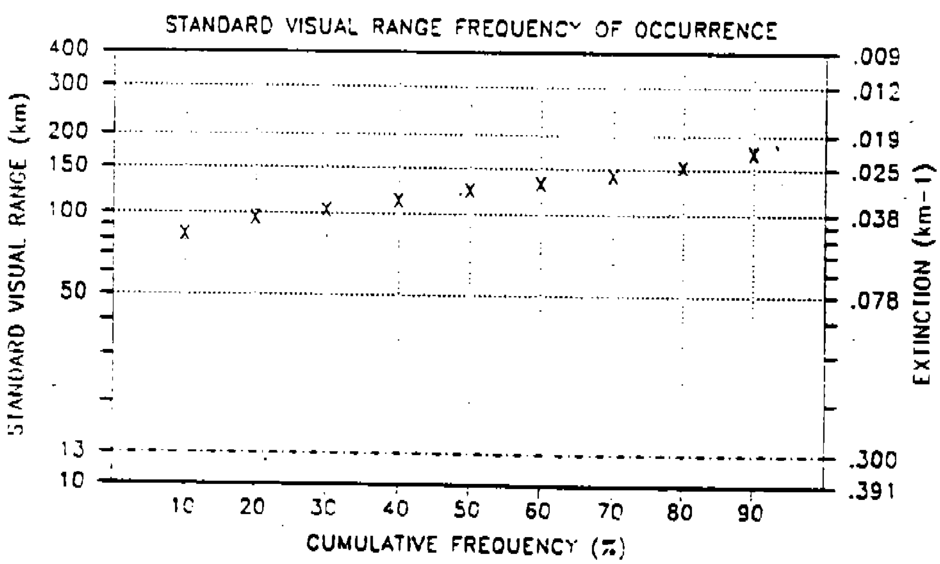
GRAND CANYON NATIONAL PARK

Transmissometer Data Summary -- 6 Hour Averages

June 1, 1988 - August 31, 1988







%	b_{ext}	SVR
10	.046	83
50	.031	123
90	.022	172

FOR A GIVEN % OF THE TIME, THE SVR IS LESS THAN OR EQUAL TO THE CORRESPONDING SVR VALUE.

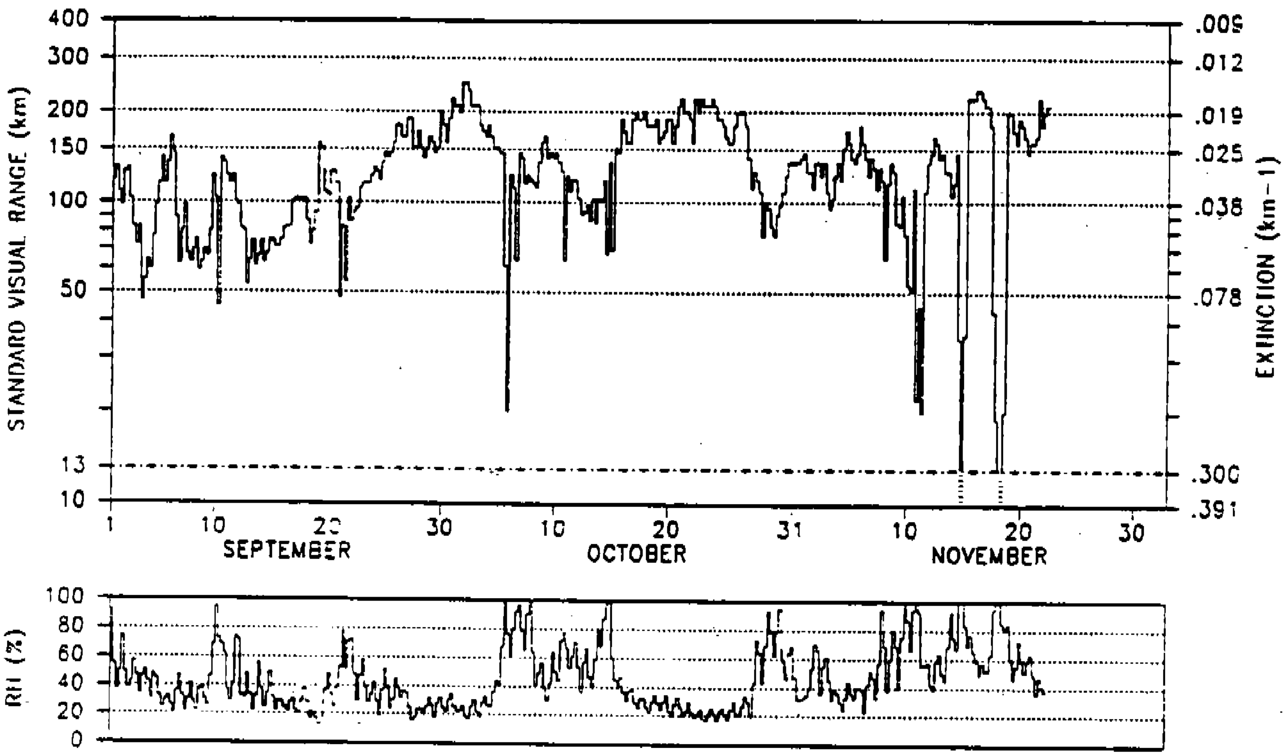
TRANSMISSOMETER DATA RECOVERY STATISTICS

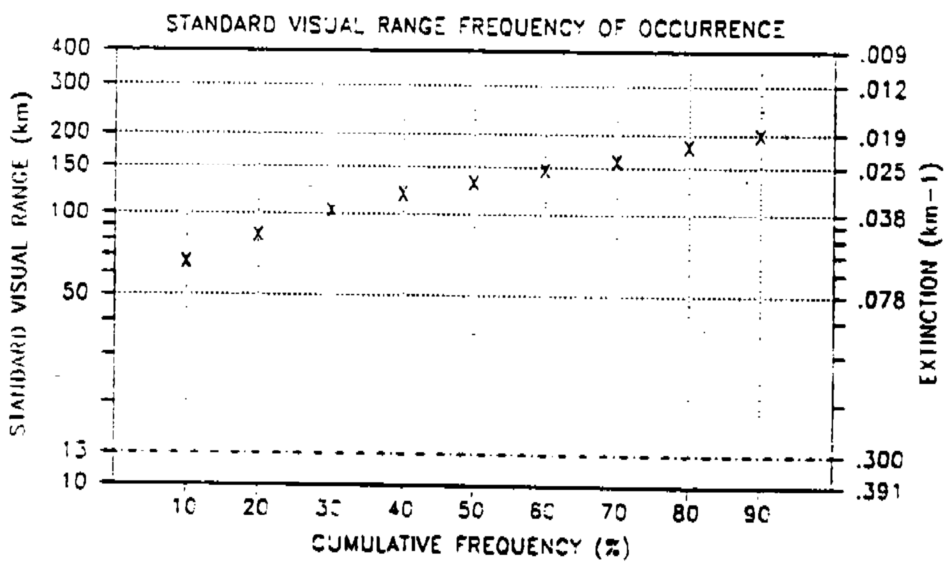
CATEGORY	NUM	%
TOTAL POSSIBLE 6-HOUR AVERAGES IN THE TIME PERIOD	368	100
USABLE 6-HOUR AVERAGES IN THE TIME PERIOD	218	59

GRAND CANYON NATIONAL PARK

Transmissometer Data Summary -- 6 Hour Averages

September 1, 1988 - November 30, 1988





%	b_{ext}	SVR
10	.059	66
50	.029	131
90	.019	199

FOR A GIVEN % OF THE TIME, THE SVR IS LESS THAN OR EQUAL TO THE CORRESPONDING SVR VALUE.

TRANSMISSOMETER DATA RECOVERY STATISTICS

CATEGORY	NUM	%
TOTAL POSSIBLE 6-HOUR AVERAGES IN THE TIME PERIOD	364	100
USABLE 6-HOUR AVERAGES IN THE TIME PERIOD	328	90

Appendix G

Monthly Technical Progress Report
Visibility Monitoring and Data Analysis Program

MONTHLY TECHNICAL PROGRESS REPORT
VISIBILITY MONITORING AND DATA ANALYSIS PROGRAM
(NPS Contract CX-0001-7-0010)

For the Month of
February 1989

Prepared for the

NATIONAL PARK SERVICE
CIRA - Colorado State University
Foothills Campus West
Fort Collins, Colorado 80523

Prepared by

AIR RESOURCE SPECIALISTS, INC.
1901 Sharp Point Drive, Suite E
Fort Collins, Colorado 80525

March 9, 1989

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1.0 INTRODUCTION

This *Monthly Technical Progress Report* summarizes the technical aspects of the Visibility Monitoring and Data Analysis Program (NPS Contract CX-0001-7-0010) performed during February 1989, and outlines project-related major milestones and schedules for March and April 1989.

This contract was awarded to Air Resource Specialists, Inc. (ARS) in March 1987, and work on the contract effectively began on April 1, 1987. This is the twenty-second in a series of Monthly Technical Progress Reports. Separate monthly financial reports are submitted directly to the Contracting Officer and his representatives.

The Visibility Monitoring and Data Analysis Program supports the National Park Service (NPS) and other cooperating agencies in: deploying, operating, and maintaining four visibility monitoring networks; reducing, analyzing, and reporting the results of collected view and electro-optical monitoring data; and supporting the capabilities of the entire program through enhancing instrumentation, monitoring, and analysis techniques. The four monitoring networks are:

- IMPROVE Network (Interagency Monitoring of Protected Visual Environments). The IMPROVE program is sponsored by the National Park Service, Forest Service, Fish and Wildlife Service, Bureau of Land Management, and Environmental Protection Agency. Each agency participates on the IMPROVE technical steering committee which has the overall responsibility for the program. At the direction of the committee, the NPS administers the operational monitoring aspects of the program. The IMPROVE monitoring network will consist of 20 monitoring sites. Each site will ultimately be configured to monitor the optical properties and aerosol constituents of the atmosphere through the use of cameras, transmissometers, and fine particulate monitors.

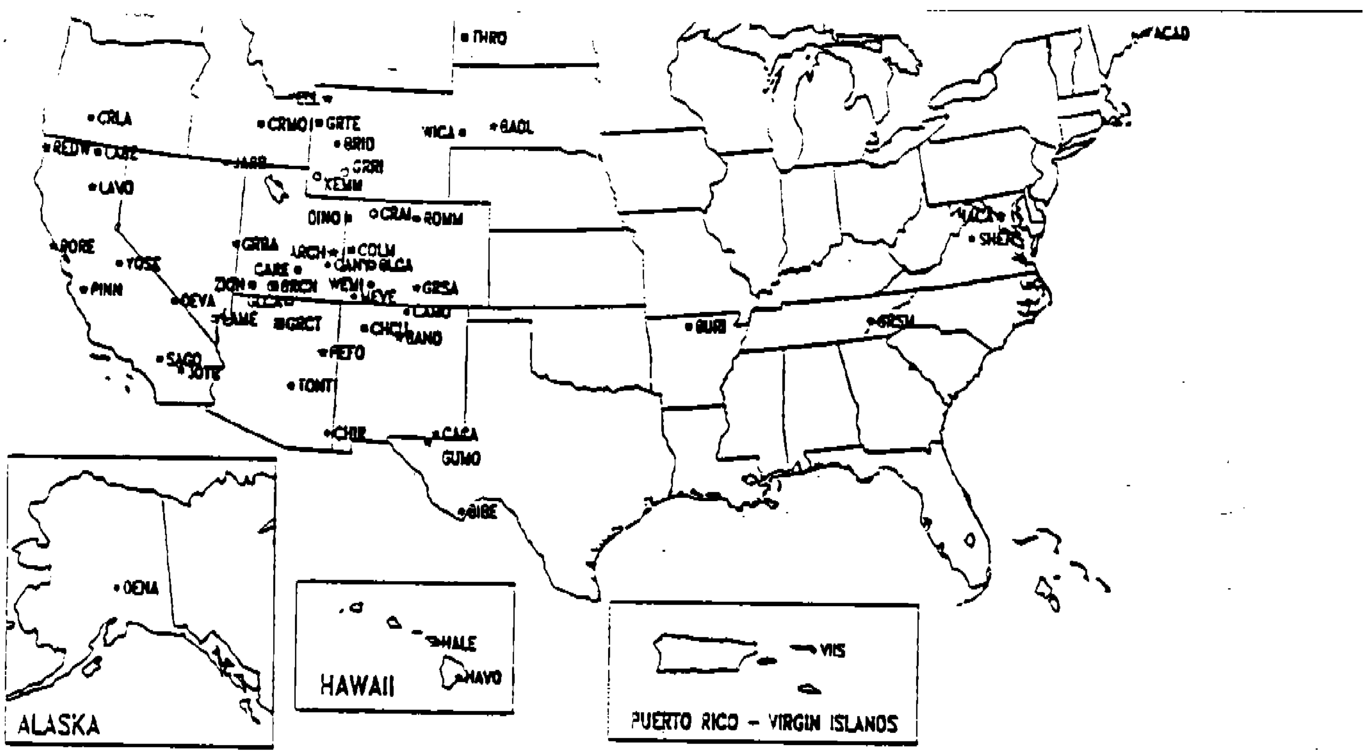
- Non-IMPROVE to be Operated According to IMPROVE Protocol Sites. In May 1985, the Subcommittee on National Parks and Recreation conducted oversight hearings on air pollution effects on units of the National Park System. As a result of the hearings, Congress appropriated additional funds to conduct air quality monitoring in 17 areas where no monitoring was being conducted. Monitoring will consist of a full complement of visibility, ambient gasses, particulate and meteorological instruments. Visibility-related monitoring at each site will ultimately include measurements of the optical properties and aerosol constituents of the atmosphere through the use of cameras, transmissometers and fine particulate monitors.

- SCENES Network (Subregional Cooperative Electric Utility Industry, National Park Service, Department of Defense, and Environmental Protection Agency Visibility Study). The objective of SCENES is to gather data that will provide a better understanding of air pollution source-receptor and cause-effect relationships. The network has been designed to establish the relative contributions that specific local sources have on air quality and visibility degradation in the lower Colorado River Basin. Four NPS units are included in the SCENES network. Two of these sites, Bryce Canyon and Grand Canyon, are also IMPROVE sites. The NPS is responsible for optical visibility monitoring at all SCENES' sites. Monitoring could include cameras, teleradiometers, transmissometers, particulate monitors and other experimental instrumentation, depending on the objectives and design of SCENES intensive monitoring experiments.

- Auxiliary Monitoring Network. Visibility monitoring will be performed throughout the 48 NPS class I areas and sites selected by cooperating agencies to further identify visibility conditions in regions of special interest, in areas where data are sparse, or in areas with existing long-term records. Optical monitoring will be performed with automatic cameras.

Figure 1-1 is a map of all current visibility monitoring sites supported by this contract effort.

This Progress Report details the work performed during the past month, and presents schedules and milestones for the next two months. General operational procedures and protocols common to the networks are discussed in Section 2.0. Network specific details are presented in Sections 3.0 through 6.0. Other contract support tasks are summarized in Section 7.0, and contract administration details are presented in Section 8.0.



SITE NAMES AND FOUR LETTER SITE ABBREVIATIONS BY NETWORK

IMPROVE SITES (●)

SITE ABRV.		SITE NAME
1.	ACAC	ACADIA NP
2.	BIBE	BIG BEND NP
3.	BRCN	BRYCE CANYON NP *
4.	BRID	BRIDGER W
5.	CANY	CANYONLANDS NP
6.	CHIR	CHIRICAHUA NM
7.	CRLA	CRATER LAKE NP
8.	DENA	DENALI NP
9.	GLAT	GLACIER NP
10.	GRCT	GRAND CANYON NP *
11.	GRSM	GREAT SMOKY MOUNTAINS NP
12.	JARB	JARBIDGE W
13.	MEVE	MESA VERDE NP
14.	MORA	MOUNT RAINIER NP
15.	ROMM	ROCKY MOUNTAIN NP
16.	SAGO	SAN GORGONIO W
17.	SHEN	SHENANDOAH NP
18.	TONT	TONTO NM
19.	WEMI	WEMINUCHE W
20.	YOSW	YOSEMITE NP

SCENES SITES (□)

SITE ABRV.		SITE NAME
1.	BRCN	BRYCE CANYON NP **
2.	GLCA	GLEN CANYON NRA
3.	GRCT	GRAND CANYON NP **
4.	LAME	LAKE MEAD NRA

NON-IMPROVE SITES TO BE OPERATED ACCORDING TO IMPROVE PROTOCOL (★)

SITE ABRV.		SITE NAME
1.	ARCH	ARCHES NP
2.	BADL	BADLANDS NP
3.	BAND	BANDELIER NM
4.	GRSA	GREAT SAND DUNES NM
5.	GUMO	GUADALUPE MOUNTAINS NP
6.	HALE	HALEAKALA NP
7.	HAVO	HAWAII VOLCANOES NP
8.	ISRO	ISLE ROYALE NP
9.	LAVO	LASSEN VOLCANIC NP
10.	NACA	NATIONAL CAPITAL REGION
11.	PEFO	PETRIFIED FOREST NP
12.	PINN	PINNACLES NM
13.	PORE	POINT REYES NS
14.	REDW	REDWOOD NP
15.	VIIS	VIRGIN ISLANDS NP
16.	VOYA	VOYAGEURS NP
17.	YELL	YELLOWSTONE NP

NETWORK KEY

- NP - National Park
- NM - National Monument
- NR - National River
- NRA - National Recreation Area
- NHP - National Historic Park
- NWR - National Wildlife Refuge
- RA - Resource Area
- W - Wilderness

AUXILIARY NPS SITES (■)

SITE ABRV.		SITE NAME
1.	BURI	BUFFALO NR
2.	CACA	CARLSBAD CAVERNS NP
3.	CARE	CAPITOL REEF NP
4.	CAMO	CAPULIN VOCANO NM
5.	CHCU	CHACO CULTURE NHP
6.	COLM	COLORADO NM
7.	CRMO	CRATERS OF THE MOON NM
8.	DEVA	DEATH VALLEY NM
9.	DINO	DINOSAUR NM
10.	GRTE	GRAND TETONS NP
11.	GRBA	GREAT BASIN NP
12.	JOTR	JOSHUA TREE NM
13.	LABE	LAVA BEDS NM
14.	MOOS	MOOSEHORN NWR
15.	NOCA	NORTH CASCADES NP
16.	OLYA	OLYMPIC NP
17.	SAGU	SAGUARO NM
18.	THRO	THEODORE ROOSEVELT NP
19.	WICA	WIND CAVE NP
21.	ZION	ZION NP

AUXILIARY BLM SITES (○)

SITE ABRV.		SITE NAME
1.	CRAI	CRAIG
2.	GRRI	GREEN RIVER RA
3.	BLCA	BLACK CANYON NM
4.	KEMM	KEMMERER

* Also a SCENES site
** Also an IMPROVE site

Figure 1-1. IMPROVE, IMPROVE Protocol, SCENES, NPS Auxiliary, and BLM Auxiliary Monitoring Sites Supported through the Visibility Monitoring and Data Analysis Program.

2.0 OPTICAL MONITORING NETWORKS: PROCEDURES AND PROTOCOLS

This section summarizes important actions related to general operational procedures and protocols common to all networks; it emphasizes instrumentation, operations, quality assurance, and reporting. Site-by-site discussions are presented in sections devoted to the individual monitoring networks.

2.1 Photographic Monitoring

2.1.1 Network Operations

The photographic network operated normally during the past month.

2.1.2 Monitoring Equipment and Procedures

The availability of simple, rugged, reliable camera systems is decreasing. To satisfy the "high-tech" consumer market, camera manufacturers are producing fully-automatic, electronic, auto-focus, auto-everything systems. Though these systems are great for the average photographer, they are not well-suited to the remote monitoring demands of the visibility network. At present, only two currently available camera systems have been identified that are suited to these remote monitoring demands--the Contax 167 and Cannon EOS. The Contax is a tried and proven system. The Cannon, operated in a manual mode with a modified lens, meets specifications, but has not been field tested. ARS and its suppliers are constantly monitoring the available equipment; and we are monitoring advances in technology such as video or CCD imaging systems.

The data backs on both the Contax and Cannon are unable to place a clearly visible date and time on Kodachrome 25. These data backs are designed to work with film speeds faster than Kodachrome 25. In discussions with the COTR, ARS has suggested that the move be made to Kodachrome 64 film so that replacement cameras with new data backs can be effectively used. In making this decision, a variety of films were considered and Kodachrome 64 is judged to be an excellent, fine-grain product by all professional evaluations. In addition, by staying with a Kodachrome film, purchasing and quality-assured processing procedures remain unchanged. Quantitative analysis of the film with the slide scanner will require a change in the exposure curve in the system software.

ARS is currently conducting a side-by-side comparison of Kodachrome 25 and 64. These photographs will be scanned to verify the comparability of quantitative results. If all tests are successful, a final recommendation will be made to change the network to Kodachrome 64 beginning with the Summer 1989 season.

2.1.3 Data Analysis and Reporting

The Fall 1988 Seasonal Report was delivered to the COTR on February 16.

As directed, only slides from IMPROVE and IMPROVE Protocol sites without transmissometers have been qualitatively coded for visual air quality characteristics and quantitatively analyzed for standard visual range (SVR). All other slides from the photographic network are only reviewed, numbered, and archived. Data collection statistics are recorded for all photographic monitoring locations.

2.2 Transmissometer Monitoring

2.2.1 Network Operations

In total, 22 transmissometer locations are planned. Sixteen transmissometer systems were operational as of February 28, 1989. These sites are listed in Table 2-1. The six remaining transmissometer monitoring stations were not operational due to reasons beyond our control. An update on each of these sites is provided below:

SAN GORGONIO - This system was fully installed and capable of operating on 4/27/88. Due to Forest Service operator assignment problems, there has been virtually no data from this system. In early February, ARS requested that site personnel return the transmissometer system until the Forest Service decides if and how it will service the site. The Forest Service is expected to make its site servicing decisions in March.

TONTO - ARS selected a transmissometer site in August 1988. Approval for installation of this system was received from the Forest Service in late February. Installation of the transmissometer system is scheduled for late March 1989.

HAWAII - The installation has been postponed by the COTR pending further review of technical, theoretical, and cost considerations.

CRATER LAKE - A system was fully installed and capable of operating on 9/1/88. Severe weather has made servicing of the receiver station and a site re-configuration visit impossible. ARS will request return of the system in March for servicing. An ARS technician will install a calibrated system for summer monitoring when weather conditions permit a site visit.

VOYAGEURS - A system was fully installed and capable of operating on 6/16/88. An operator was not assigned to service the site during most of the summer and fall. Severe weather has made servicing and a site re-configuration visit impossible. ARS will request return of the transmissometer system in early March. The system will be serviced, calibrated, and installed by an ARS technician when conditions permit a site visit.

YELLOWSTONE - Severe forest fires in the Park forced postponement of site selection and installation. Shelters and support equipment for this site have been prepared. A site selection visit will be made as soon as weather conditions permit. The installation will be performed as early in the summer as possible.

Table 2-1

Operational Transmissometer Network
by March 1, 1989

	LOCATION	NETWORK
1.	Acadia National Park	IMPROVE
2.	Badlands National Park	PROTOCOL
3.	Bandelier National Monument	PROTOCOL
4.	Big Bend National Park	IMPROVE
5.	Bridger Wilderness	IMPROVE
6.	Canyonlands National Park	IMPROVE
7.	Chiricahua National Monument	IMPROVE
8.	Glacier National Park	IMPROVE
9.	Grand Canyon National Park	IMPROVE
10.	Guadalupe National Park	PROTOCOL
11.	Mesa Verde National Park	IMPROVE
12.	Petrified Forest National Park	PROTOCOL
13.	Pinnacles National Monument	PROTOCOL
14.	Rocky Mountain National Park	IMPROVE
15.	Shenandoah National Park	IMPROVE
16.	Yosemite National Park	IMPROVE

A report will be issued in March 1989 summarizing all data collected at these sixteen sites from their initial installation date through March 1, 1989. These data will be included in the transmissometer database. Operational data collection and reporting will begin on March 1, 1989, and will be reported quarterly starting with the Spring 1989 Seasonal Summary Report.

2.2.2 Data Analysis and Reporting

Transmissometers calculate and report average atmospheric extinction over the path length of the instrument. Data are recovered daily from satellite data collection platforms. Along with extinction, ambient temperature and relative humidity are also monitored. The data represent one ten-minute average value for each hour. The measurement interval begins three minutes after the hour. After collection and editing (only removing times when the monitoring equipment was malfunctioning), the data are reduced to six-hour average values. The time periods of the four daily six-hour average values are:

1 - 0000 to 0559 hrs
2 - 0600 to 1159 hrs
3 - 1200 to 1759 hrs
4 - 1800 to 2359 hrs

The number of valid ten-minute averages in each six-hour average is recorded and kept in the database.

Data editing consists of removing measurements when the system was known to be inoperative or delivering questionable data due to non-standard operational parameters noted by on-site operators on the Log Sheets. These conditions include optical misalignment, unknown window transmission due to exceptionally dirty, broken, or missing window glass, or questionable data logging and transmission.

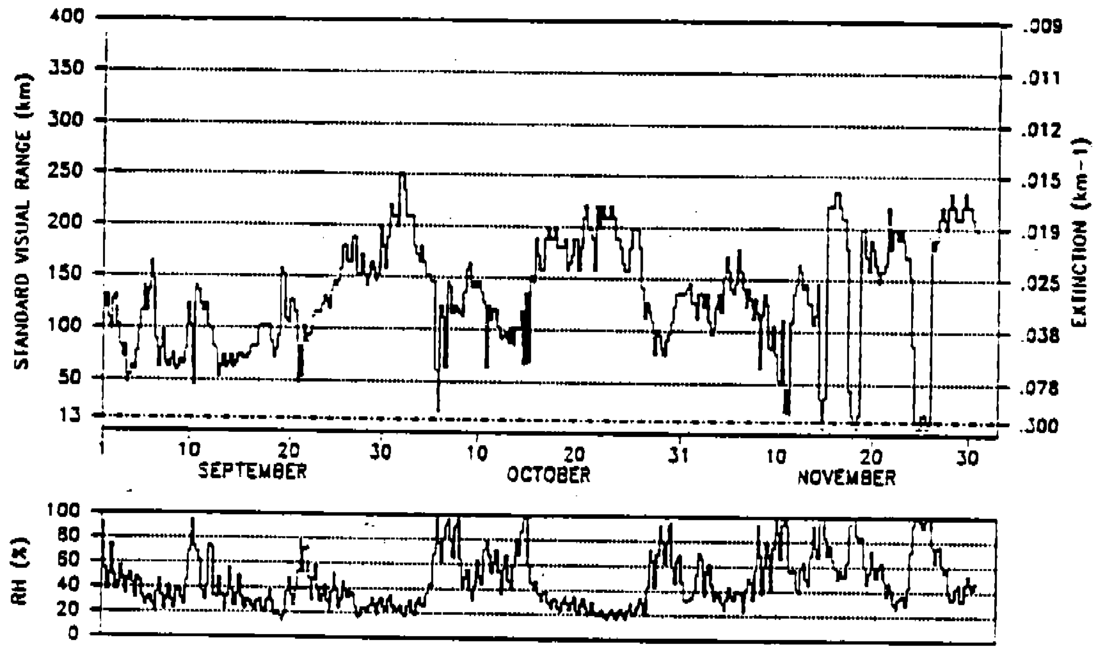
The data will be released in quarterly Seasonal Summary Reports. Figure 2-1 is a draft example of the Fall 1988 seasonal summary for Grand Canyon National Park. The report contains data collected from September 1, 1988, through November 30, 1988. Comments on the organization and data presentation of the report are being collected and will be incorporated into the final version.

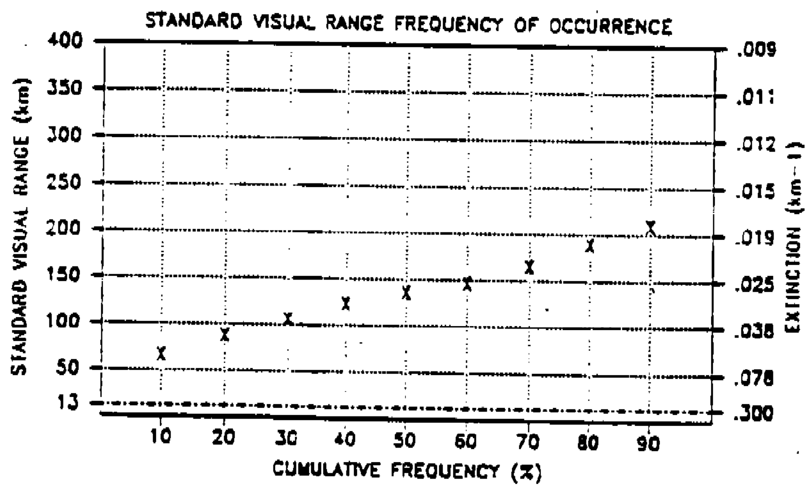
The top graph is a time line of all the collected six-hour average values. The dashed line at an SVR of 13 km (b_{ext}=0.3 km^{-1}) represents an optical depth of the transmissometer sight path of approximately 2 at the Grand Canyon. When the optical depth reaches this value, the error in measured extinction becomes relatively large. When b_{ext} is greater than 0.3 km^{-1}, the time line becomes dashed indicating an increased uncertainty in the measurement.

GRAND CANYON NATIONAL PARK

Transmissometer Data Summary -- 6 Hour Averages

September 1, 1988 - November 30,1988





%	b_{ext}	SVR
10	.059	66
50	.028	136
90	.018	209

FOR A GIVEN % OF THE TIME, THE SVR IS LESS THAN OR EQUAL TO THE CORRESPONDING SVR VALUE.

TRANSMISSOMETER DATA RECOVERY STATISTICS

CATEGORY	NUM	%
TOTAL POSSIBLE 6-HOUR AVERAGES IN THE TIME PERIOD	364	100
USABLE 6-HOUR AVERAGES IN THE TIME PERIOD	356	98

Figure 2-1. Example of Transmissometer Data Summary for Grand Canyon National Park.

The next graph presents a time line of six-hour average relative humidity measurements. This allows rapid determination of the effect of increasing relative humidity on measured b_{ext}. Long periods of relative humidity near 100% can be seen in Figure 2-1. This usually results in corresponding periods of high b_{ext}, and is probably associated with precipitation events. This assumption can only be verified by reviewing simultaneous photographic data.

The bottom plot is a rank-ordered cumulative frequency plot of six-hour average extinction values. The 10% to 90% values are plotted in 10% increments. All extinction values greater than 0.3 are placed into one bin at this level. The 10%, 50%, and 90% values are listed to the right of the plot.

The listing at the bottom contains data recovery statistics for the season.

A database will be developed to contain all b_{ext}, ambient temperature, and relative humidity six-hour average values. The number of 10-minute values in each six-hour average will be listed. All raw data will be kept in ASCII files by site.

2.2.3 Transmissometer Testing

Test shelters were installed at Christman Field on January 23, 1989; however, severe February weather prevented the installation of power. The following test station related actions were taken:

1. Instrument mounting posts and window/hood assemblies were installed.
2. Steps for shelter access were constructed and installed.
3. Meteorological sensors and support hardware were ordered.

4. Procedures for the first tests to be conducted were written. The first test will be the Lamp Stability of Intensity test.

Before any transmissometer test is conducted, a detailed test plan will be written. The test plan will include:

1. A brief narrative summary of the test describing objectives, procedures, instruments and support equipment, and test duration.

2. A schedule summarizing major test tasks, such as preparation, servicing intervals, and special checks. This will be made only for long-term tests.

3. Detailed step-by-step procedures for preparation of test instruments and equipment, servicing and special checks.

4. All Log Sheets to be used by servicing personnel.

5. A description of data collection formats.

Test plans will be reviewed prior to testing. Long-term tests, such as the transmitter lamp stability of intensity will start in March. Short-term tests that can be run concurrently will start in April.

2.2.4 Transmissometer Procurement

All ordered Optec LPV-2 transmissometers have been received. The location of each transmissometer is shown below:

Serial No.	Location
001	ARS, Ft. Collins
002	Shenandoah National Park
003	Petrified Forest National Park
004	Canyonlands National Park
005	Pinnacles National Park
006	Acadia National Park
007	Grand Canyon National Park
008	ARS, Ft. Collins
009	Rocky Mountain National Park
010	Glacier National Park
011	San Gorgonio Wilderness Area
012	Voyageurs National Park
013	Bridger Wilderness Area
014	ARS, Ft. Collins
015	Crater Lake National Park
016	Mesa Verde National Park
017	NPS, on loan to NOAA
018	NPS, on loan to NOAA
019	Bandelier National Monument
020	Badlands National Park
021	Guadalupe Mountains National Park
022	Non-NPS unit
023	Non-NPS unit
024	Big Bend National Park
025	Chiricahua National Monument
026	Yosemite National Park
027	ARS, Ft. Collins
028	ARS, Ft. Collins
029	ARS, Ft. Collins
030	ARS, Ft. Collins
031	ARS, Ft. Collins
032	ARS, Ft. Collins

2.3 Nephelometer Monitoring

Two locations--Great Smoky Mountains and Mount Rainier National Parks--will use nephelometers to monitor atmospheric scattering. Measurements from the nephelometer located at Look Rock, Great Smoky Mountains, will be collected for inclusion into the optical monitoring database. A nephelometer will be installed at Mount Rainier in late 1989. This nephelometer is currently being used to support transmissometer tests; it will not be available for installation until after completion of that program.

2.4 NPS IMPROVE Computer System and Data Processing

2.4.1 Database Development

The NPS Visibility Database System is operational and complete. All data through the Fall 1988 season are included, and all access programs are fully operational. The preparation of written documentation has begun.

An important component of the Database System is the Daily Average Database. The Daily Average Database is complete and will be the product that will be delivered to service general data requests. The database includes SVR daily averages, site history records, site and target specifications, and seasonal results records. A first draft of the documentation for this database, including the menu-driven data access and retrieval software instructions, was completed and is under review.

2.4.2 Computer Network Operations

The computer network and slide scanner system operated normally during the past month.

3.0 IMPROVE NETWORK

This section summarizes the status and schedule of the IMPROVE monitoring network.

3.1 Site Status

Table 3-1 summarizes the equipment status of all IMPROVE sites as of February 28, 1989. The following subsections describe the site-specific, operational status of transmissometer and camera installations.

3.1.1 Transmissometer Site Status

ACADIA - The system operated well during February. The operator left the flip mirror in the wrong position on 2/1, but corrected the problem on 2/2 resulting in minimal data loss.

BIG BEND - The system operated well during February. The operator changed lamps on 2/7, and dialed in a new calibration number. High winds caused periodic ground blizzards resulting in a few erratic readings.

CANYONLANDS - The system operated well during February. An annual site visit is planned for March.

CHIRICAHUA - The system was installed on 2/13-17 and operated well for the remainder of February.

CRATER LAKE - The system has operated erratically. Due to winter snowfall, no site operator inspection has taken place since October 20, 1988.

GLACIER - A newly-calibrated instrument was installed on 1/21 and site operators were trained. The system operated well during February. Local weather conditions, such as fog from the lake, have caused scatter in the readings and have interfered with the operator's ability to verify instrument alignment. An alignment aid (light with timer) will be sent to the Park in early March.

GRAND CANYON - The system operated well during February. An annual site visit is planned for March.

GREAT SMOKY MOUNTAINS - Two nephelometers are currently operating side-by-side at the Park. The NPS is operating one system and the EPA is operating the other. ARS is investigating how to best obtain the collected data for use by the IMPROVE Program.

Table 3-1

Network Status
IMPROVE Monitoring Sites
as of February 28, 1989

	Site Abrv.	Site Name	Cameras (Auto 35mm)	Transmissometer	Comments
1	ACAD	Acadia National Park	1	1	Trans. operational 11/14/87.
2	BIBE	Big Bend National Park	1	1	Trans. operational 12/2/88.
3	BRID	Bridger Wilderness	1	1	Trans. operational 7/22/88.
4	BRCA*	Bryce Canyon National Park	2		
5	CANY	Canyonlands National Park	1	1	Trans. operational 12/20/86.
6	CHIR	Chiricahua National Monument	1	1	Trans. operational 2/1/89.
7	CRLA	Crater Lake National Park	1	1	Trans. operational 9/2/88.
8	DENA	Denali National Park	1		Camera system removed for winter.
9	GLAC	Glacier National Park	1	1	Trans. operational 2/5/88.
10	GRCA*	Grand Canyon National Park	1	1	Trans. operational 12/20/86.
11	GRSM	Great Smoky Mountains National Park.	1		
12	JARB	Jarbidge Wilderness	1		
13	MEVE	Mesa Verde National Park	1	1	Trans. operational 9/16/88.
14	MORA	Mount Rainier National Park	1		
15	ROMM	Rocky Mountain National Park	1	1	Trans. operational 11/25/87.
16	SAGO	San Gorgonio Wilderness	1	1	Trans. operational 4/29/88.
17	SHEN	Shenandoah National Park	1	1	Trans. operational 3/4/88.
18	TONT	Tonto National Monument			
19	WEMI	Weminuche Wilderness	1		
20	YOSW	Yosemite National Park	1	1	Trans. operational 8/19/88.

*Also SCENES Sites

MESA VERDE - The system operated well during February. Due to the location of the receiver shelter (on top of a water tank), slight alignment adjustments are often necessary. An annual site visit is planned for March.

MOUNT RAINIER - A nephelometer will be installed in late 1989.

ROCKY MOUNTAIN - A newly-calibrated instrument and a new antenna with cable were installed on 1/26 and an operator was trained. The system operated well during February.

SAN GORGONIO - Erratic readings continue to be received from the system. Power, alignment, or a combination of problems are suspected. Site operator support is complicated by the fact that different operators service the transmitter and receiver. A visit to the site was planned for January 30, but was canceled by the Forest Service. On 1/30, ARS requested that the operator return the instrument to ARS for servicing. It took one month for the operator to find time to package the instrument for shipment. On 3/1, the operator informed ARS that the system was ready for shipment.

The Forest Service is reviewing its ability to support the site. A decision on whether or not they will be interested in providing continuing support is expected within a month. Unless further direction is received, ARS is considering the site down until the Forest Service reaches a decision.

SHENANDOAH - The system operated well during the first week of February. Erratic readings were received from 2/7-16; over-voltage resets are believed to be the cause of system timing drift resulting in the erratic readings. The operator reset the timing on 2/16; the system operated well for the remainder of February.

TONTO - The system will be installed in late March 1989.

YOSEMITE - An annual visit to the site was made on 1/30 to 2/2. The instrument was replaced with a newly-calibrated unit. Support equipment was adjusted and upgraded, and operators were re-trained. The system operated well for the first part of February. After a storm on 2/8, the readings became erratic and did not return to normal. The reason for the erratic readings is unknown; solutions for the problem are being studied. The site is being watched closely.

3.1.2 Camera Site Status

All camera systems operated normally except for the following site-specific events:

BRYCE CANYON - Film changes were occasionally late during February due to site inaccessibility (heavy snow).

NAVAJO - 35mm camera: A roll of film containing photos taken from 1/24-28 was lost at the site. Otherwise, the system has continued to operate smoothly.

NAVAJO - 8mm camera: The 2X neutral density filter now attached to the camera is providing improved exposures.

CRATER LAKE - No photos were taken between 12/24 and 1/3 due to a very late film change. Very few valid photos were taken from 1/3-17 because snow and ice covered the enclosure window.

GRAND CANYON - TRUMBULL 35mm camera: A replacement camera was sent on 1/27 in response to continuing overexposure problems. The camera was installed by Park personnel on 2/17. No film has been received to verify if exposures have improved.

NAVAJO AND TRUMBULL 8mm cameras: Both movie cameras continue to operate well.

JARBIDGE - Most photos taken from 1/3-24 are invalid because snow and ice covered the enclosure window.

3.2 IMPROVE Schedules and Milestones

3.2.1 Field Service Schedule (March and April 1989)

The following IMPROVE sites will be visited during the next two months to perform annual transmissometer system servicing. The actual visitation dates will depend on instrument availability, weather, operator schedules, and the ability to calibrate replacement systems.

Canyonlands National Park
Grand Canyon National Park

San Gorgonio may or may not be visited depending on the pending Forest Service decision whether to continue site support.

A transmissometer installation visit is planned for:

Tonto National Monument

An automatic camera installation visit is scheduled for:

Bryce Canyon National Park

3.2.2 Task Schedules (March and April 1989)

The following IMPROVE-specific milestones will be met:

- o Review of day-to-day patterns, trends, and variations in transmissometer data (weekly meetings).
- o Continue coordinating, scheduling, contacting parks, and procuring supplies for the remainder of the transmissometer installations.

4.0 NON-IMPROVE SITES TO BE OPERATED ACCORDING TO IMPROVE PROTOCOLS

This section summarizes the status and schedules of the non-IMPROVE sites to be operated according to IMPROVE Protocols.

4.1 Site Status

Table 4-1 summarizes the equipment status of all sites as of February 28, 1989. The following subsections describe the site-specific operational status of transmissometer and camera installations.

4.1.1 Transmissometer Site Status

BADLANDS - The system operated well during February.

BANDELIER - The system operated well during February. The operator changed lamps and dialed in a new calibration number on 2/2.

GUADALUPE - The system operated well for the first part of February. The operator left the transmitter flip mirror in the wrong position from 2/7-8, and then left the receiver flip mirror in the wrong position from 2/8-14. This resulted in data loss for a one-week period. The system operated well for the remainder of February.

HAWAII VOLCANOES - If approved, system installation will occur in late 1989.

PETRIFIED FOREST - The system operated well during February. An annual site visit is planned for March.

PINNACLES - The system operated well during February. Wet weather and ground settling are suspected to be causing intermittent alignment problems. A site visit to install a new receiver mounting pier may be necessary.

VOYAGEURS - Erratic readings were received during February. Power problems and system timing are suspected causes. A site visit will be scheduled as soon as weather permits.

YELLOWSTONE - Installation is scheduled for Summer 1989.

Table 4-1

Network Status
Non-IMPROVE to be Operated Under IMPROVE Protocol Sites
as of February 28, 1989

	Site Abrv.	Site Name	Cameras Auto 35mm	Cameras Auto 8mm	Transmissometer	Comments
1	ARCH	Arches National Park	1			
2	BADL	Badlands National Park	1		1	System operational as of 1/15/88.
3	BAND	Bandelier National Monument	1		1	System operational as of 10/7/88.
4	GRSA	Great Sand Dunes National Monument	1			
5	GUMO	Guadalupe Mountains National Park	1		1	System operational as of 11/18/88.
6	HALE	Haleakala National Park	1			
7	HAVO	Hawaii Volcanoes National Park	1			
8	ISRO	Isle Royale National Park	1			
9	LAVO	Lassen Volcanic National Park	1			
10	NACA	National Capital Region	1			Installed on 12/5/88.
11	PEFO	Petrified Forest National Park	1		1	Trans. operational 4/17/87.
12	PINN	Pinnacles National Monument	1		1	Trans. operational 3/25/88.
13	PORE	Point Reyes National Seashore	1			
14	REDW	Redwood National Park	1			
15	VIIS	Virgin Islands National Park				
16	VOYA	Voyageurs National Park	1		1	Trans. operational 7/13/88.
17	YELL	Yellowstone National Park	1			

4.1.2 Camera Site Status

All camera systems operated normally except for the following site-specific events:

ARCHES - The new site operator failed to load the film properly for two consecutive periods. No photos were taken from 1/9 to 1/30.

BANDELIER - A repaired camera system was installed on 2/2. No photos have been taken since 11/15 due to a combination of operator errors, equipment malfunctions, and delayed communication from the Park to ARS concerning problems. The system appears to have worked properly from 2/2 to 2/24, although film is not yet back from processing.

HALEAKALA - No photos were taken from 1/12-23 because the film was incorrectly loaded.

HAWAII VOLCANOES - A request for an alignment adjustment was sent to this site on 1/23. The adjustment was made on 2/10 and will include more of the mountain range in the view.

YELLOWSTONE - Continual overexposures prompted a replacement camera to be sent on 2/1. It was installed on 2/13, but to date, no processed film is available to check if exposures have improved.

4.2 Schedules and Milestones

4.2.1 Field Service Schedules

The following NPS IMPROVE Protocol sites will be visited during the next two months to perform annual transmissometer system servicing. The actual visitation dates will depend on instrument availability, weather, operator schedules, and the ability to calibrate replacement systems.

Petrified Forest National Park
Pinnacles National Monument

A visit to Voyageurs National Park will be made as soon as weather permits. It may not be practical to visit the site before late spring.

4.2.2 Task Schedules

Major task schedules parallel the IMPROVE schedules presented in Section 3.2.2.

5.0 AUXILIARY MONITORING SITES

This section summarizes the status and schedules of all Auxiliary monitoring sites.

5.1 Site Status

Table 5-1 summarizes the equipment status of all sites as of February 28, 1989. During February the following camera-related site-specific events occurred:

<u>NPS SITES</u>

CARLSBAD CAVERNS - After repeated attempts to resolve problems with the Park staff, ARS sent a memorandum to the COTR regarding this site on 1/23. To date, no film has been received from the site and no one at the Park has responded to ARS' phone messages. ARS will not take any further action with the Park until directed to do so by the COTR.

DEATH VALLEY - The camera system was not serviced from 12/31/88 to 1/20/89 due to a lack of personnel. Film has been received for 1/21 to 2/13, but is not back from processing.

GRAND TETON - No photographs were taken from 12/14/88 - 1/13/89 due to a lack of personnel.

WIND CAVE - No photographs were taken from 1/20 to 2/9. A blank roll of film was followed by a roll that did not advance past the documentation photo. The operator has been instructed to follow trouble-shooting procedures and to review instructions for loading film.

<u>BLM SITES</u>

CRAIG - No photographs were taken from 1/21 to 1/29. Extremely low temperatures at this site made operation of the system impossible.

<u>FOREST SERVICE SITES</u>

Forest Service visibility monitoring will no longer be administered through the NPS contract office. The Forest Service has awarded a separate contract to support their monitoring efforts.

Table 5-1

Network Status
Auxiliary Monitoring Sites
as of February 28, 1989

	Site Abrv.	Site Name	Cameras (Auto 35mm)	Cameras (8mm time lapse)	Comments
NPS					
1	BURI	Buffalo National River	1		
2	CACA	Carlsbad Caverns National Park	1		
3	CARE	Capital Reef National Park	1		
4	CAMO	Capulin Volcano National Mon.	1		
5	CHCU	Chaco Culture National Historic Park	1		
6	COLM	Colorado National Monument	1		
7	CRMO	Craters of the Moon National Monument	1	1	
8	DEVA	Death Valley National Monument	1		
9	DINO	Dinosaur National Monument	1		
10	EVER	Everglades National Park	1		
11	GRTE	Grand Teton National Park	1		
12	JOTR	Joshua Tree National Monument	1		
13	LABE	Lava Beds National Monument	1		
14	LECA	Lehman Caves National Monument	1		
15	MOOS	Moosehorn National Wild. Refuge		1	
16	NOCA	North Cascades National Park	1		
17	OLYA	Olympic National Park	1		
18	SAGU	Saguaro National Monument		1	
19	THRO	Theodore Roosevelt National Park	1		
20	WICA	Wind Cave National Park	1		
21	ZION	Zion National Park	1		
BLM					
1	CRAI	Craig	1		
2	BLCA	Black Canyon of the Gunnison National Monument	1		
3	GRRI	Green River Resource Area	1		Site name changed from Big Sandy to Green River Res. Area (GRRI).
4	KEMM	Kemmerer	1		

5.2 Schedules and Milestones

5.2.1 Task Schedules

Major task schedules parallel the IMPROVE schedule presented in Section 3.2.2.

6.0 SCENES SITES

This section summarizes the status and schedules specific to the SCENES monitoring sites.

6.1 Site Status

Table 6-1 summarizes the equipment status of all sites as of February 28, 1989. Note that Grand and Bryce Canyons are also IMPROVE sites; they are discussed in Section 3.0. The following site-specific events occurred in February:

LAKE MEAD - Only 65 photographs out of a possible 160 were taken from 11/14/88 to 1/4/89 due to the following:

11/14 - 11/30	alarms turned off
12/11 - 12/15	late film change
12/27 - 01/04	late film change

The exposed film for the period 11/14 - 1/4 was not received at ARS until 1/18 and was not back from processing until 1/31.

Table 6-1

Network Status
SCENES Monitoring Network
as of February 28, 1989

	Site Abrv.	Site Name	Cameras Auto 35mm	Cameras Auto 8mm	Trans-missometer	Tele-radiometer	Comments
1	BRCN*	Bryce Canyon National Park	2	1**			
2	GLCA	Glen Canyon National Recreation Area	1	1**			
3	GRCT*	Grand Canyon National Park	1	1**	1		
4	LAME	Lake Mead National Recreation Area	1				

* Also an IMPROVE Monitoring Site
**Special winter photography program (see Section 7.2)

7.0 OTHER CONTRACT SUPPORT

This section summarizes additional support provided within the contract.

7.1 Data/Equipment Requests

Persons or organizations requesting data submit their request in writing to the COTR. ARS responds to each request approved by the COTR. The following requests were serviced during February.

Individual	Agency	Request
D. Morse	NPS, Denver	At the request of D. Morse, duplicate slides of Yosemite--Telegraph Hill--from the slide spectrum archive were sent to J. Goldsmith (NPS-AIR, Western Region) on 2/28.
M. Scruggs	NPS, Denver	A variety of cumulative frequency analyses for time of day and combined seasons were performed on Voyageurs data. The data analyses were delivered to M. Scruggs on 2/22.

The following standard procedure for slide requests will be followed. If a park of other interested parties call ARS to request representative ranges of visibility conditions, the caller will be referred to Dee Morse (NPS-Denver). Data or other special requests will be referred to the COTR. ARS will fill no request unless it is approved by the COTR.

7.2 Winter Photographic Monitoring at Grand, Bryce, and Glen Canyons.

Intensive photographic monitoring will be conducted from November 1988 through March 15, 1989 at Grand, Bryce, and Glen Canyons to enhance the winter visibility database for these Colorado Plateau sites. Slides will be taken 9 times a day, and 8mm time-lapse photography will be taken from sunrise to sunset. The following views will be documented.

Grand Canyon	Navajo Mountain Mt. Trumbull
Bryce Canyon	Navajo Mountain
Glen Canyon	Navajo Mountain

The equipment was installed in November and continues to operate. Site-specific details for Grand Canyon and Bryce Canyon are provided in Section 3.1.2, and for Glen Canyon in Section 6.1.

8.0 CONTRACT ADMINISTRATION

The NPS notified ARS of its intentions to exercise the contract option for Year 3. ARS will prepare a Work Plan and Cost Proposal by March 10, 1989.

Appendix H

Monitoring for Reasonably Attributable Impact of Local Sources at Voyageurs National Park Petrified Forest National Park and Moosehorn Wilderness

MONITORING FOR REASONABLY ATTRIBUTABLE IMPACT OF LOCAL SOURCES AT

VOYAGEURS NATIONAL PARK
PETRIFIED FOREST NATIONAL PARK AND
MOOSEHORN WILDERNESS

Submitted to

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Prepared by

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May 5, 1988

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1.0 INTRODUCTION

The IMPROVE Committee directed Air Resource Specialists, Inc. (ARS) to install 8mm time-lapse and 35mm color-slide camera systems at Voyageurs and Petrified Forest National Parks to access the possible visual air quality impact in class I areas by plumes from local sources. ARS personnel traveled to Petrified Forest National Park with W. Malm, of the National Park Service, to select and install the monitoring systems. W. Malm traveled to Voyageurs to select the monitoring site; the equipment was supplied and shipped by ARS. National Park Service personnel installed the camera systems after phone conversations with ARS staff.

The IMPROVE Committee also directed ARS to provide an 8mm time-lapse system for installation at Moosehorn National Wilderness. Bud Rolofson, of the Fish and Wildlife Service, traveled to Moosehorn Wilderness to site the 8mm time-lapse system. The system was shipped to Moosehorn and installed by Fish and Wildlife personnel. No systematic, 35mm color-slide photography was initiated at the Moosehorn site.

The following sections describe the collected data from each site.

2.0 PETRIFIED FOREST NATIONAL PARK

The combined 8mm time-lapse and 35mm color-slide system began operation on March 13, 1987. The system was installed with the 8mm and 35mm cameras viewing the same sight path. The view was southeast overlooking the length of the Park toward Blue Mesa. The system operated at this location until July 31, 1987. Figure 2-1 is a photograph of the monitoring view.

During this time period, no visible plumes were recorded by either the 8mm time-lapse or 35mm slide systems. The IMPROVE Committee directed ARS to move the monitoring systems to another location in the Park looking southwest outside of the Park boundaries toward the Cholla Generating Station (a coal-fired power plant located approximately 40 km from the Park boundaries). The power plant is to the right of the center-of-view, located just over the horizon and not directly visible in the photographic record. Figure 2-2 is a photograph of the new monitoring vista.

The system operated until March 1, 1988. During this monitoring period, no visible plumes were recorded entering National Park areas. Occasional discoloration on the horizon was visible, but not readily identifiable or traceable to any specific source. Figure 2-3 is an example of this distant, elevated layer of haze. Thus, the IMPROVE Committee decided to discontinue any further special photographic monitoring at Petrified Forest and directed ARS to remove the equipment which was accomplished in early April 1988.

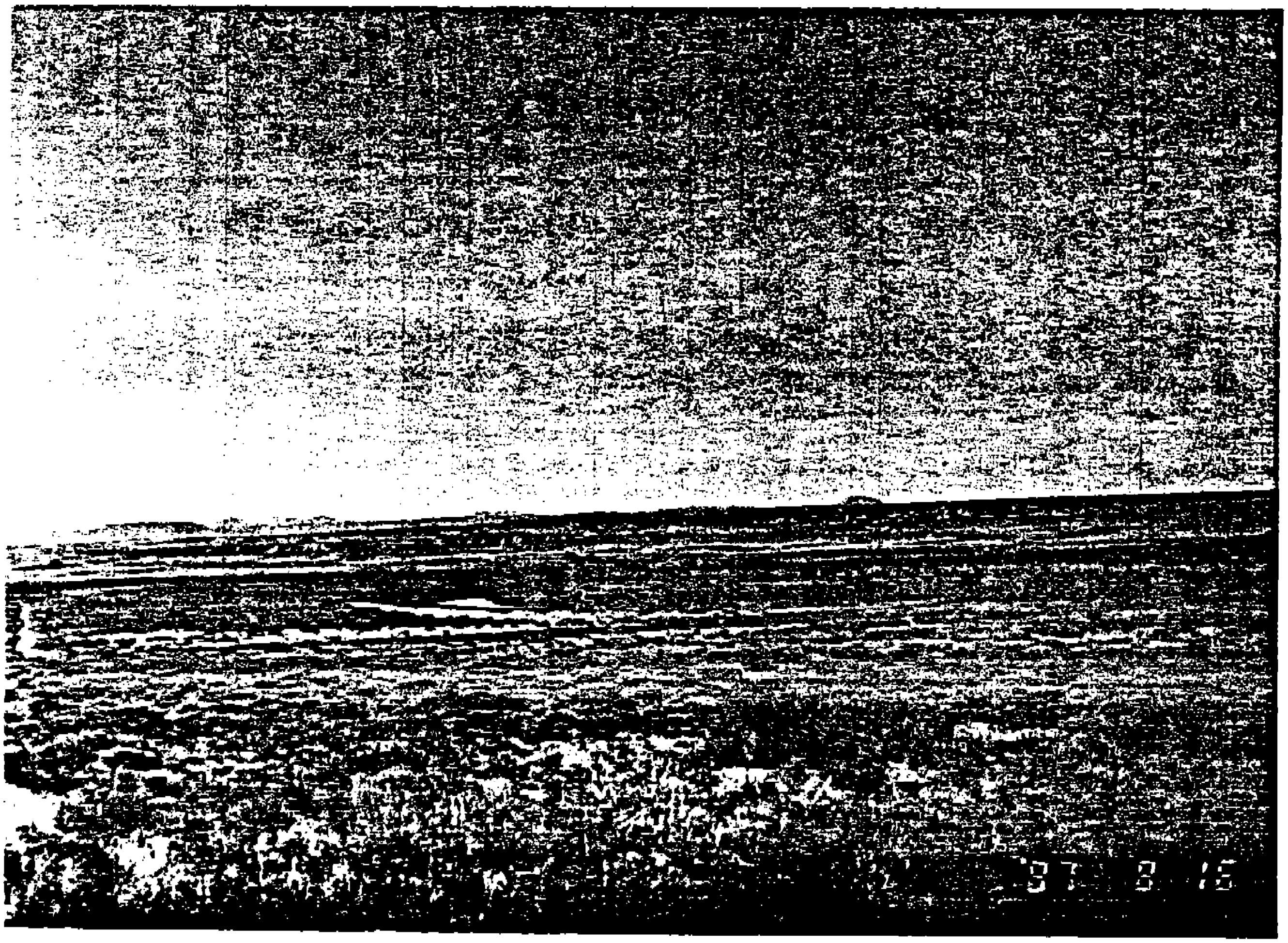

Figure 2-1. Petrified Forest National Park - Initial Monitoring View Southeast Toward Blue Mesa.

Figure 2-2. Petrified Forest National Park - Second Monitoring View Southwest Toward Cholla Power Plant.

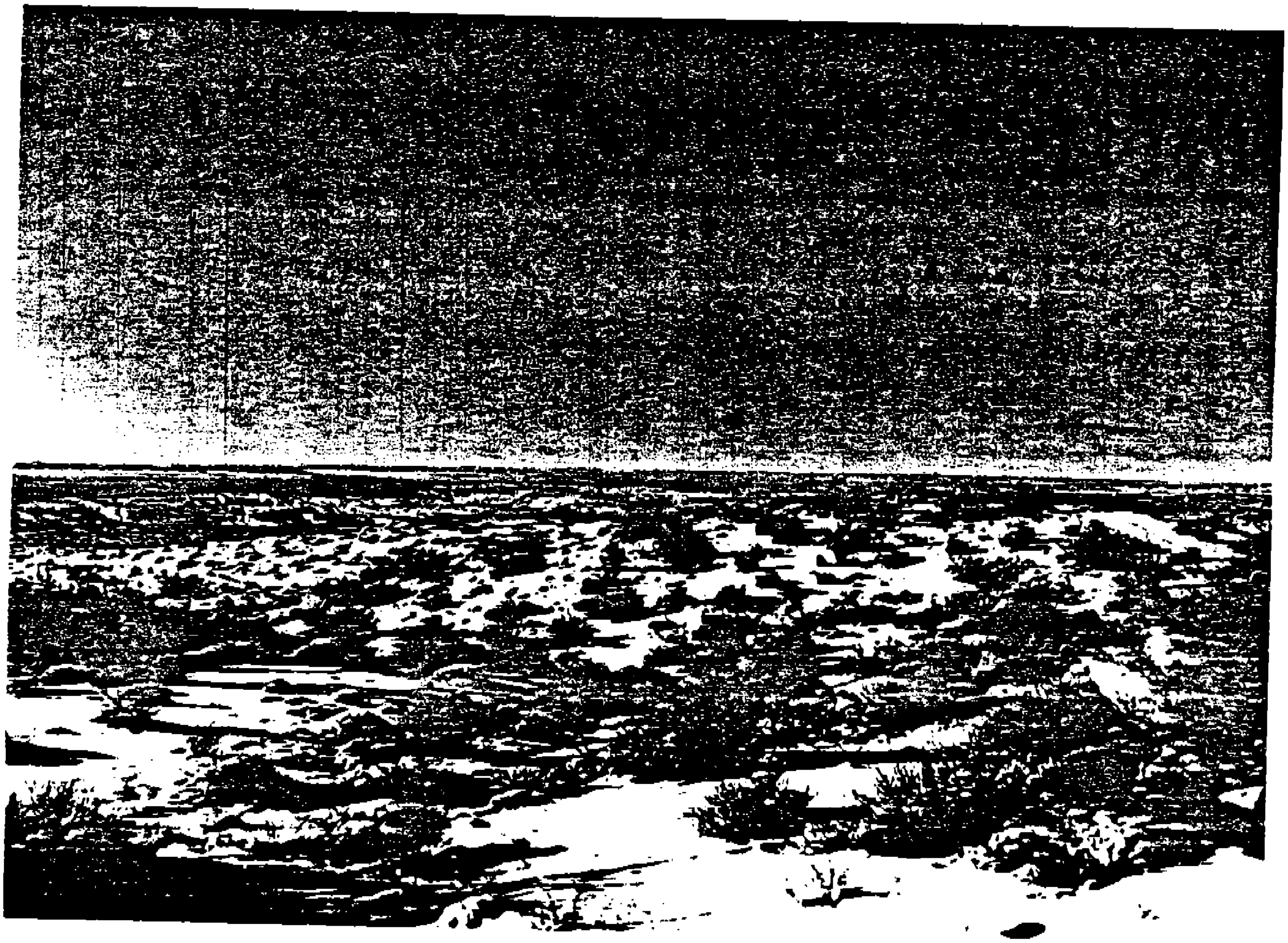

Figure 2-3. Petrified Forest National Park - View of Layered Haze on the Distant Horizon.

3.0 VOYAGEURS NATIONAL PARK

The 8mm time-lapse system began operation on October 24, 1986, viewing north across Kabetogama Lake. The nearest sources were approximately 30 km west-northwest of the vista. The 35mm camera was sited by Park personnel to view east through the Park to a more distant horizon feature. The new vista has a more appropriate target for microdensitometry visual air quality analysis. Figure 3-1 is a photograph of this monitoring view.

The systems were in operation until April 1988. During this period, no distinct, easily-identifiable plumes were visible in either the 8mm time-lapse or 35mm slide data. The IMPROVE Committee directed ARS to have Park personnel discontinue operation of the camera systems as of April 20, 1988.

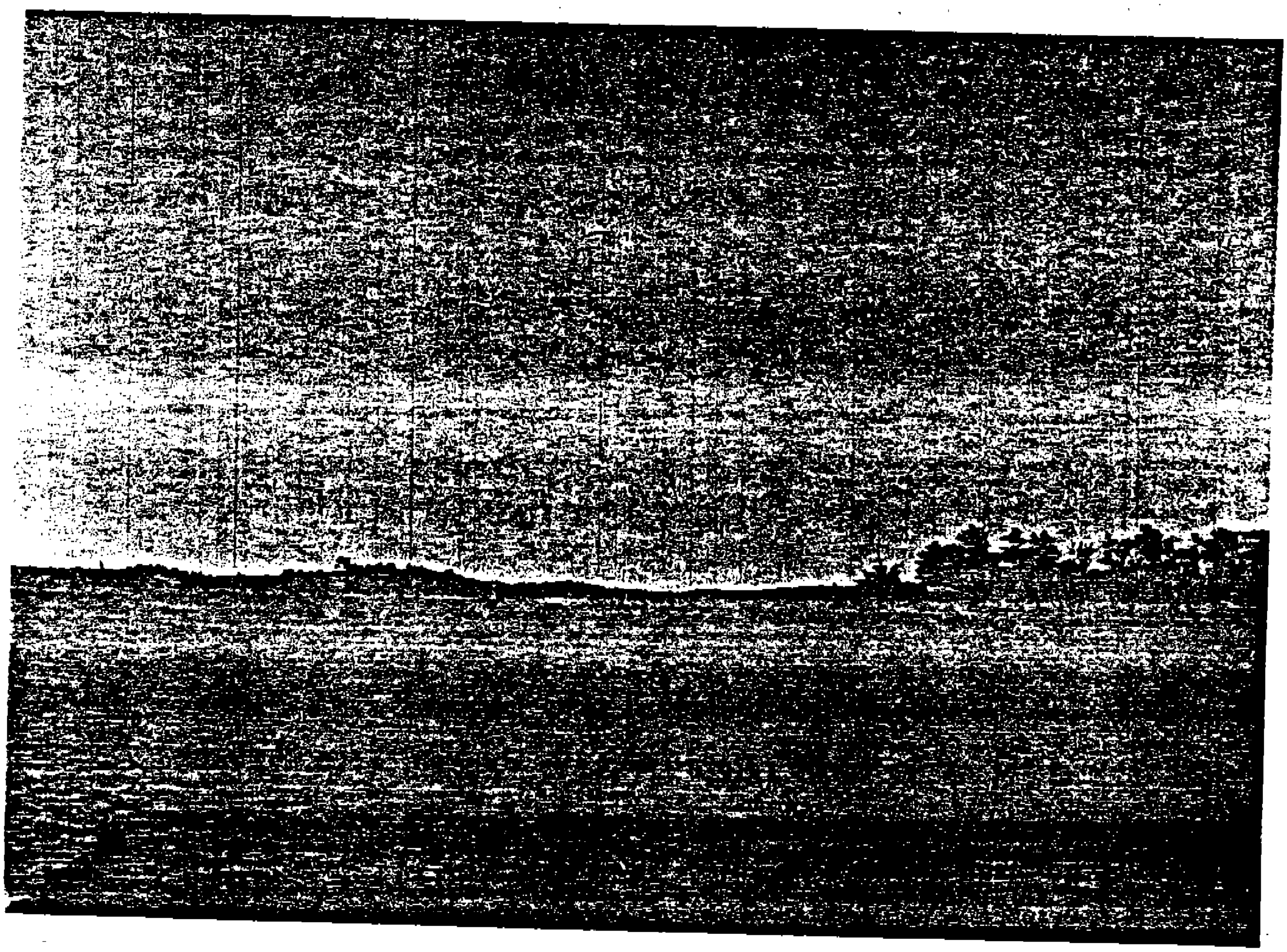

Figure 3-1. Voyageurs National Park - 35mm Camera View.

4.0 MOOSEHORN NATIONAL WILDERNESS

An 8mm time-lapse camera system has been in operation at Moosehorn Wilderness. Due to difficult winter access, the camera was relocated. The two locations are detailed below:

Location 1

October 5, 1987 -	November 15, 1987
Camera Location	Magurrewock Mountain
Vista Photographed	Woodland Georgia Pacific Mill Azimuth 264 degrees

Location 2

November 16, 1987 -	February 14, 1988
Camera Location	Clearcut End of McConvet Road
Vista Photographed	Woodland Georgia Pacific Mill Azimuth 292 degrees

The 8mm time-lapse has shown a visible plume being emitted from the pulp mill nearly every day. The majority of the time, the plume appears to cross over the Wilderness boundary. Since no 35mm photography is available, the time-lapse film has been transferred to video tape which accompanies this report. The camera continues in operation and film is being processed and archived by ARS.

5.0 CONCLUSIONS

Photographic monitoring at Petrified Forest and Voyageurs National Parks for a period of one year has not been able to discern any identifiable plumes entering class I areas. The photographic record has been archived and the special monitoring discontinued as of April 1988 at both Parks.

Time-lapse monitoring of emissions from a pulp mill located near Moosehorn Wilderness has identified many cases of visible plumes entering the class I area. The 8mm time-lapse from October 5, 1987, to February 14, 1988, has been transferred to video tape for distribution with this report. Photographic monitoring with the 8mm time-lapse camera continues.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

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16. ABSTRACT

In Section 169A of the Clean Air Act as amended August 1977, Congress declared as a national goal "the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory class I Federal areas which impairment results from manmade air pollution."[1] Mandatory class I Federal areas are national parks greater in size than 6000 acres, wilderness areas greater in size than 5000 acres and international parks that were in existence on August 7, 1977.[2] This section required the Environmental Protection Agency (EPA) to promulgate regulations requiring States to develop programs in their State Implementation Plans (SIPs) providing for visibility protection in these areas. EPA promulgated these regulations on December 2, 1980.[3]

This report summarizes the progress made to date in developing and implementing the interagency monitoring network which supports the effort, Interagency Monitoring of Protected Visual Environments (IMPROVE).

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Visibility monitoring State Implementation Plans (SIP) Class I Federal Areas		

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
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