

Open-Air Integrating Nephelometer System For Visibility Monitoring

Technical Note 92-205

Introduction



Solar-Powered Installation at Joshua Tree National Monument

The Optec NGN-2 integrating nephelometer employs a unique open-air design that allows accurate measurement of the scattering coefficient (b_{scat}) of ambient air. With a direct, unobstructed path from the outside air to the optical measuring chamber, modification of the temperature, relative humidity, aerosols, and gases of the sampled ambient air are minimized. Using technology developed for the Optec LPV transmissometer, the NGN-2 features low power consumption, a rugged compact design, and easy installation and operation. The instrument is ideally suited for remote monitoring.

Air Resource Specialists, Inc. (ARS) has successfully deployed the NGN-2 to monitor b_{scat} in both urban and remote environments and is experienced in all aspects of successful monitoring, including installation, training, calibration, servicing, data reduction, analysis, and reporting.

Concept

Integrating nephelometers estimate the atmospheric scattering coefficient (b_{scat}) by directly measuring the light scattered by aerosols and gases in a sampled air volume.

Primary Features Optec NGN-2 Integrating Nephelometer

Open Air Design

- Continuous measurement of ambient b_{scat} at 550 nm
- Direct, unobstructed path from outside air to the measurement chamber
- Minimal modification to the temperature, relative humidity, aerosols, and gases of the sampled ambient air
- Well-defined optical response characteristics
- Modular design allows easy servicing and component replacement
- Flexible design can accommodate a heated or size-selective inlet

Solid-State Electronics

- Stable and repeatable clean air and span gas calibrations
- Low power requirements for remote solar power installation
- Internal computer monitors and controls operation, allows for flexible datalogger interface, and provides diagnostics
- Automatic clean air and span gas calibrations at user-selected intervals
- User-selectable sampling modes
- RS232 and analog outputs

Minimal Support Requirements

- Operates in ambient conditions; expensive climate-controlled sheltering is not required or recommended
- Ideally suited for remote applications
- Small size with minimal support requirements allow for easy installation on towers or existing shelter walls or rooftops
- Minimal servicing required. Annual preventive maintenance is recommended. Cost-effective method for continuous visibility monitoring.



Urban Installation Denver Visibility Monitoring Instrument Intercomparison Tests

Scattered radiation from an illumination source is integrated over a large range of scattering angles, in a defined band of visible wavelengths. Because the total light scattered out of a path is the same as the reduction of light along a path due to scattering, the integrating nephelometer gives a direct estimate of b_{scat} . Nephelometer concepts were developed during World War II, and commercially available instruments have been used in monitoring programs for the past twenty years. However, as documented by many researchers, a number of severe limitations compromise b_{scat} data collected by these instruments.



Line-Powered Installation at Amboy, California
Project MOHAVE Special Study

by instrument-related modification of sampled air due to sample chamber heating, aerosol sizing by the inlet, large scattering angle truncation error, poorly-defined optical response, and unstable electronics.

The Optec NGN-2 overcomes the sampling deficiencies of previous nephelometer designs to provide a method that continuously and accurately measures the scattering coefficient of ambient air. The NGN-2 features low-power operation, a rugged compact design, and digital electronics that ensure stable, linear performance over a wider range of environmental conditions. The complete, self-contained system operates under ambient conditions. The optical chamber features a large door that opens a complete side of the chamber to unrestricted, unmodified ambient air flow.

An environmentally-sealed compartment in the unit contains the CMOS computer, lamp assembly, motors, pumps, and electronics. The CMOS computer controls all operating functions of the NGN-2 which include:

- Scattered light measurement
- Clean-air, zero calibration
- Span gas calibration
- Moisture detection to close the optical chamber door during rain or snow conditions
- Optical chamber temperature measurement
- Initial data reduction
- Various error detection schemes
- Diagnostic tests

The operating system and run-time data acquisition programs, based on RTL-FORTH, reside in EPROM. Battery backed RAM maintains initial operator settings and the real time clock. A watchdog circuit monitors the proper operation of the computer and will reset the computer if static discharge or power surges interrupt operations. A simple diagnostic program, activated by an external terminal connected to the RS-232 interface, tests many of the NGN-2 functions.

Data are output from either the two-channel D/A or the Serial RS-232 interfaces. Two 12-bit D/A converters allow both the scattered light measurement and its associated status code to be recorded on separate channels by a voltage reading datalogger. Two output ranges are available: 0 to 5 volts, or 0 to 10 volts.

The RS-232 interface accommodates the logging of more information. Each line of data includes:

- Measurement status code
- Raw scattered light data
- Raw lamp brightness data
- Normalized scattered light data
- Integration time
- Chamber temperature
- Date and current time to the nearest minute

Baud rates can be set from 300 to 9600 with eight data bits, no parity, and one-stop bit.

Data collection is normally performed with an on-site datalogger. By using a modem, data collection and communication with the instrument can also be done remotely.

Instrument Specifications

The NGN-2 open-air integrating nephelometer is manufactured by Optec, Inc. The instrument has evolved to its present configuration through a series of laboratory tests and operational field trials designed to meet the needs of the Interagency Monitoring of Protected Visual Environments (IMPROVE), National Park Service, and other visibility monitoring programs.

Instrument specifications include:

Center Wavelength: 550 nm, with an 100 nm band pass

Scattering Angle Integration: 5 degrees to 175 degrees

Measurement Range: 0.01 km⁻¹ (Rayleigh) to over 20.00 km⁻¹
(0 to 32,768 counts)

Resolution: ± count (approx. ± 0.001 km⁻¹)

Accuracy Near Rayleigh: ± 10% (approx. ± 0.001 km⁻¹)

A single environmentally-sealed enclosure contains all components:

- Large inlet with motorized door
- Sampling chamber
- Pump and filter for clean air (zero) calibration
- Sample fan
- Solenoid activated inlet for span gas calibration
- Chamber temperature sensor
- CMOS control computer with real time clock
- Rain detector for closing the inlet door during precipitation events

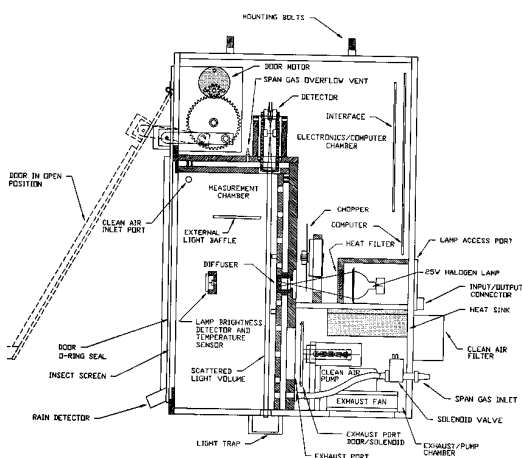
An internal CMOS computer controls all operating functions and outputs data in either digital or analog format.

- Power Requirements: 13.8 VDC, 5-amp power supply
Normal operating power consumption of approximately 45 watts
- Operating Temperature Range: -20 degrees C to 45 degrees C
- Operating Humidity Range: 0% to 100% RH
- Sample Chamber Temperature: Laboratory and operational field tests of the NGN-2 indicate that the average sample chamber heating is less than 0.5 degrees C over ambient under a variety of operational conditions.

Siting and Installation

The primary siting criteria is a location that represents the air mass of interest. The NGN-2 can be easily collocated with other monitoring instrumentation such as a fine particulate sampler, camera system, meteorological instrumentation, or a criteria pollutant monitoring station. Because the NGN-2 operates under ambient conditions, climate-controlled sheltering is not necessary, but a precipitation/solar radiation shield is suggested. The compact rugged design of the NGN-2 accommodates a variety of mounting alternatives.

An external power supply, calibration span gas supply, and data logging system are required. The low power requirements of the system accommodate solar applications. ARS has developed and field tested reliable mounting, power, span gas calibration, and logging systems that have successfully operated at the line power and solar installations. Installations can be easily performed by trained technical personnel.



Operation



Service of the NGN-2 Nephelometer

Once installed, minimal operator intervention is required. The CMOS computer controls all operating functions of the NGN-2 as defined by user-selectable monitoring program protocols. Periodic clean air (zero) and span gas calibrations are automatically performed and logged to document instrument response. No adjustments to the zero and span values are required. The operator, however, must install a new lamp every 750 operational hours. This task is easily performed. Factory-authorized preventive maintenance is suggested approximately once per year.

The sampling and calibration protocols are programmable. Three primary options are readily available:

1. Continuous 2-minute integrations
2. Single 10-minute integration starting at the beginning of each hour
3. 2-minute integration followed by a 3-minute, low-power vent mode

Any desired operational protocol is easily accommodated. For example, in urban areas, continuous 2-minute integrations of b_{scat} would be appropriate with clean-air zero calibrations at six-hour intervals and weekly span gas calibrations. In remote, pristine areas where air quality changes are less dynamic, the NGN-2 could be operated in a cycled mode, collecting a 10-minute integration of b_{scat} once an hour with daily clean-air zero calibrations and weekly span gas calibrations.

Should a system failure occur, diagnostic commands or a simple diagnostic program that can be activated by an external terminal connected to the RS-232 interface allow most NGN-2 functions to be tested for proper operation.

Data Recovery and Analysis

Data are output with associated instrument status codes and periodic calibration values. Typical data reduction can yield hourly, multi-hour, daily, monthly, or seasonal summaries of collected data.

ARS has been closely involved in the development, testing, and operational application of the Optec NGN-2 nephelometer. ARS has developed and operationally field tested installation and standard operating procedures for the NGN-2, and has successfully operated the NGN-2 in urban and remote rural environments.

The corporation specializes in supporting all phases of visibility-related monitoring and analysis from selecting of the best monitoring approach to site selection, installation, training, calibration, maintenance, data analysis, and reporting. ARS' scientists and field specialists are available to discuss your specific monitoring and analysis needs.

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