

VAISALA

USER'S GUIDE

Vaisala Ceilometer CL51



M210801EN-A

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CHAPTER 1

GENERAL INFORMATION

This chapter provides general notes for the manual and the product.

About This Manual

This manual provides information for installing, operating, and maintaining the Vaisala Ceilometer CL51.

Version Information

Table 1 Manual Revisions

Manual Code	Description
M210801EN-A	January 2010 - This manual

Related Manuals

Table 2 Related Manuals

Manual Code	Manual Name
M210310EN-A	Termination Box User's Guide
M210717EN-B	CL-VIEW User's Guide

Contents of This Manual

This manual consists of the following chapters:

- Chapter 1, General Information, provides general notes for the manual and the product.
- Chapter 2, Product Overview, introduces the features, advantages, and the product nomenclature.
- Chapter 3, Installation, provides information that is intended to help with installing the product.
- Chapter 4, Functional Description, provides information on the measurement principles of the product.
- Chapter 5, Operation, contains information that is needed to operate this product.
- Chapter 6, Maintenance, provides information that is needed in basic maintenance of the product.
- Chapter 7, Troubleshooting, describes common problems, their probable causes and remedies, and provides contact information for technical support.
- Chapter 8, Repair, provides information on how to remove and replace different parts of the product.
- Chapter 9, Technical Data, provides the technical data of the product.
- INDEX

Abbreviations and Acronyms

Abbreviation/Acronym	Description
ESD	Electrostatic Discharge
LED	Light Emitting Diode
LIDAR	Light detection and ranging
MOR	Meteorological Optical Range
VV	Vertical visibility
WMO	World Meteorological Organization

General Safety Considerations

Throughout the manual, important safety considerations are highlighted as follows:

WARNING Warning alerts you to a serious hazard. If you do not read and follow instructions very carefully at this point, there is a risk of injury or even death.

CAUTION Caution warns you of a potential hazard. If you do not read and follow instructions carefully at this point, the product could be damaged or important data could be lost.

NOTE Note highlights important information on using the product.

WARNING Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the instrument. Vaisala Oyj assumes no liability for the customer's failure to comply with these requirements.

Product Related Safety Precautions

The Vaisala Ceilometer CL51 delivered to you has been tested for safety and approved as shipped from the factory. The following safety precautions must be observed during all phases of operation, service, and repair of this instrument:

WARNING Ground the product, and verify outdoor installation grounding periodically to minimize shock hazard.

CAUTION Do not modify the unit. Improper modification can damage the product or lead to malfunction.

WARNING To minimize shock hazard, the instrument chassis and cabinet must be connected to an electrical ground. The instrument is equipped with a three-conductor AC power connector. The power cable must either be plugged into an approved three-contact electrical outlet or the instrument must be carefully grounded to a low-resistance safety ground.

WARNING Do not operate the instrument in the presence of flammable gases or fumes. Operation of any electrical instrument in such an environment constitutes a definite safety hazard.

WARNING Do not attempt internal service or adjustment unless another person, capable of rendering first aid and resuscitation, is present.

WARNING Because of the danger of introducing additional hazards, do not install substitute parts or perform any unauthorized modification to the instrument. Return the instrument to a Vaisala office or authorized Depot for service and repair to ensure that safety features are maintained.

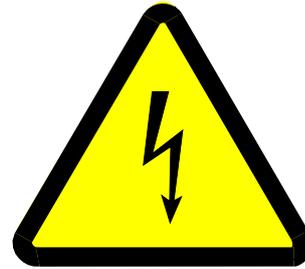
WARNING Operating personnel must not remove instrument covers. Component replacement and internal adjustments must be made by qualified maintenance personnel. Do not replace components with the power cable connected. Under certain conditions, dangerous voltages may exist even with the power cable removed. To avoid injuries, always disconnect power and discharge circuits before touching them.

WARNING High voltage will be present when the Laser Transmitter CLT521 or Receiver CLR321 covers are removed and they are connected to a powered unit. High voltage is present in the AC Power Unit CLP311, Internal Heater CLH311, Ceilometer Engine Board CLE321, and the Window Blower CLB311 at the top of the Shield.

The Laser Transmitter CLT521, Receiver CLR321, and AC Power Unit CLP311 are equipped with the following warning label:

WARNING! HIGH VOLTAGE INSIDE THIS ENCLOSURE

The Internal Heater CLH311 can be hot and is equipped with the following warning labels:



Terms Used in Groundings

Table 3 Specifications for the Grounding Terms

Term	Description
GND	Electronics common return, used only for signal and data circuits
SGND	Shield Ground for signal cables shields
PE 	Protective Earth, connects touchable metal structures to safe potential. Recognized by Earth symbol (on the left) and green or yellow-green wire insulation.

Laser Safety

The Vaisala Ceilometer CL51 is classified as a Class 1M laser device in accordance with International Standard IEC/EN 60 825-1. The CL51 complies with 21 CFR 1040.10 and 1040.11 except for the deviations pursuant to the Laser Notice No. 50, dated July 26, 2001. This means that when the CL51 is installed in a field environment with instrument covers on and pointed vertically or near-vertically, it poses no established biological hazard to humans.

The device is equipped with the following label:



The Ceilometer CL51 is intended for operation in an area restricted from public access, and to be pointed vertically or near-vertically.

Invisible laser radiation is emitted through the aperture on top of the ceilometer. The location of the laser aperture is shown in Figure 1 below.

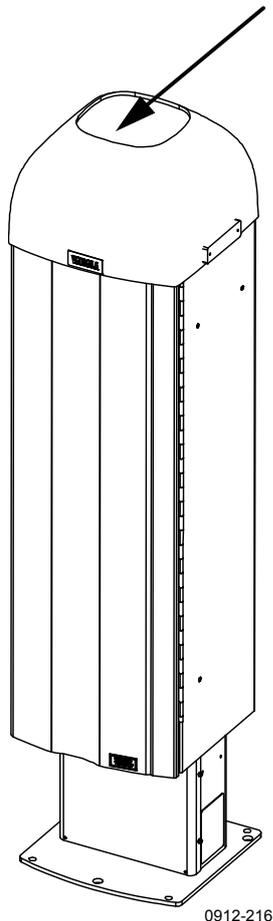


Figure 1 **Location of Laser Aperture on Ceilometer CL51**

The following precautions must be followed during the service and maintenance of the instrument:

WARNING Never look directly into the Ceilometer Transmitter or Ceilometer Optics with magnifying optics (such as glasses, binoculars, and telescopes). Never remove the Ceilometer Transmitter from its normal position without first switching off both the line and the battery power and detaching the transmitter ribbon cable from the Ceilometer Engine Board.

When operating, avoid looking at the ceilometer unit from the beam direction. When tilting the unit, make sure that it is not being viewed from the beam direction with magnifying optics.

Only trained personnel should perform maintenance functions. Access to the work area by unauthorized persons during service operations must be prevented.

ESD Protection

CAUTION The equipment contains parts and assemblies sensitive to damage by Electrostatic Discharge (ESD). Use ESD precautionary procedures when touching, removing or inserting any objects inside the equipment housing.

Electrostatic Discharge (ESD) can cause immediate or latent damage to electronic circuits. Vaisala products are adequately protected against ESD for their intended use. However, it is possible to damage the product by delivering electrostatic discharges when touching, removing, or inserting any objects inside the equipment housing.

To make sure you are not delivering high static voltages yourself:

- Handle ESD sensitive components on a properly grounded and protected ESD workbench. When this is not possible, ground yourself to the equipment chassis before touching the boards. Ground yourself with a wrist strap and a resistive connection cord. When neither of the above is possible, touch a conductive part of the equipment chassis with your other hand before touching the boards.
- Always hold the boards by the edges and avoid touching the component contacts.

Recycling



Recycle all applicable material.



Dispose of batteries and the unit according to statutory regulations. Do not dispose of with regular household refuse.

Regulatory Compliances

Vaisala Ceilometer CL51 complies with the Low Voltage Directive (2006/95/EC) and the EMC-Directive (2004/108/EC). The the conformity is shown by compliance with the following standards:

- EN 60950-1:2006 Information technology equipment - Safety - Part 1: General requirements
- EN 61326-1:2006-04 Electrical equipment for measurement, control and laboratory use - EMC requirements - Basic immunity test requirements.
- EN 55022:2006 + Am 1:2007 to EN55022:2006 Class B. Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement.
- EN 61000-3-2 (2006) Limits for harmonic current emissions
- EN 61000-3-3 (2008) Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems.

License Agreement

All rights to any software are held by Vaisala or third parties. The customer is allowed to use the software only to the extent that is provided by the applicable supply contract or Software License Agreement.

Warranty

For certain products Vaisala normally gives a limited one-year warranty. Visit our Internet pages for more information and our standard warranty terms and conditions: www.vaisala.com/services/warranty.html.

Please observe that any such warranty may not be valid in case of damage due to normal wear and tear, exceptional operating conditions, negligent handling or installation, or unauthorized modifications. Please see the applicable supply contract or Conditions of Sale for details of the warranty for each product.

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CHAPTER 2

PRODUCT OVERVIEW

This chapter introduces the features, advantages, and the product nomenclature.

Introduction to Vaisala Ceilometer CL51

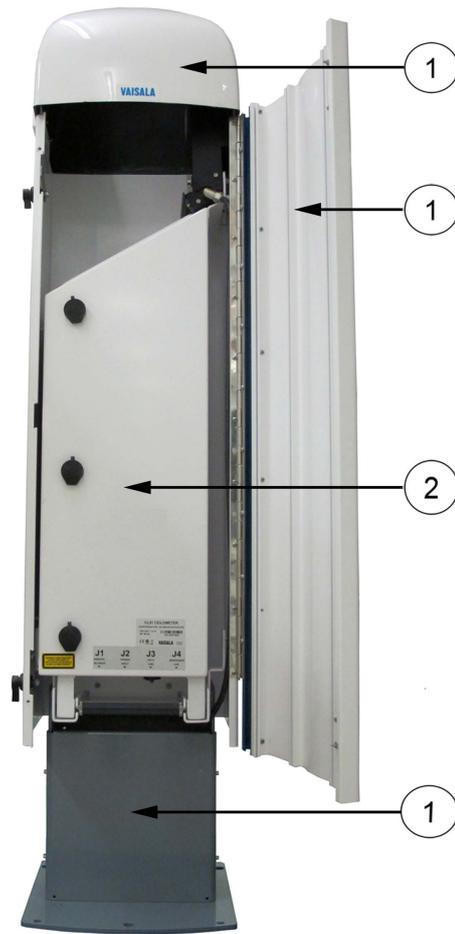
The Vaisala Ceilometer CL51 measures cloud height and vertical visibility.

The Ceilometer CL51 employs pulsed diode laser LIDAR technology (LIDAR = Light Detection and Ranging), where short, powerful laser pulses are sent out in a vertical or near-vertical direction. The reflection of light, backscatter – caused by haze, fog, mist, virga, precipitation, and clouds – is measured as the laser pulses traverse the sky. The resulting backscatter profile, that is, the signal strength versus the height, is stored and processed, and the cloud bases are detected. The time delay between the launch of the laser pulse and the detection of the backscatter signal indicates the cloud base height.

The Ceilometer CL51 is able to detect three cloud layers simultaneously. If the cloud base is obscured due to precipitation or ground-based fog, the CL51 reports Vertical Visibility. There is no need for adjustments in the field. The embedded software includes several service and maintenance functions and gives continuous status information from internal monitoring. The software is designed to give the full backscatter profile.

The CL51 includes data messages used in the CL31 and LD40. Therefore it is easy to transfer from older ceilometer versions to the CL51.

The Ceilometer CL51 is shown in Figure 2 on page 20.



0912-229

Figure 2 Vaisala Ceilometer CL51

The following numbers refer to Figure 2 above:

- 1 = Shield
- 2 = Measurement Unit

Product Nomenclature

Main parts of the Ceilometer CL51 are listed in Table 4 and optional parts in Table 5 below.

Table 4 Vaisala Ceilometer CL51 Main Parts

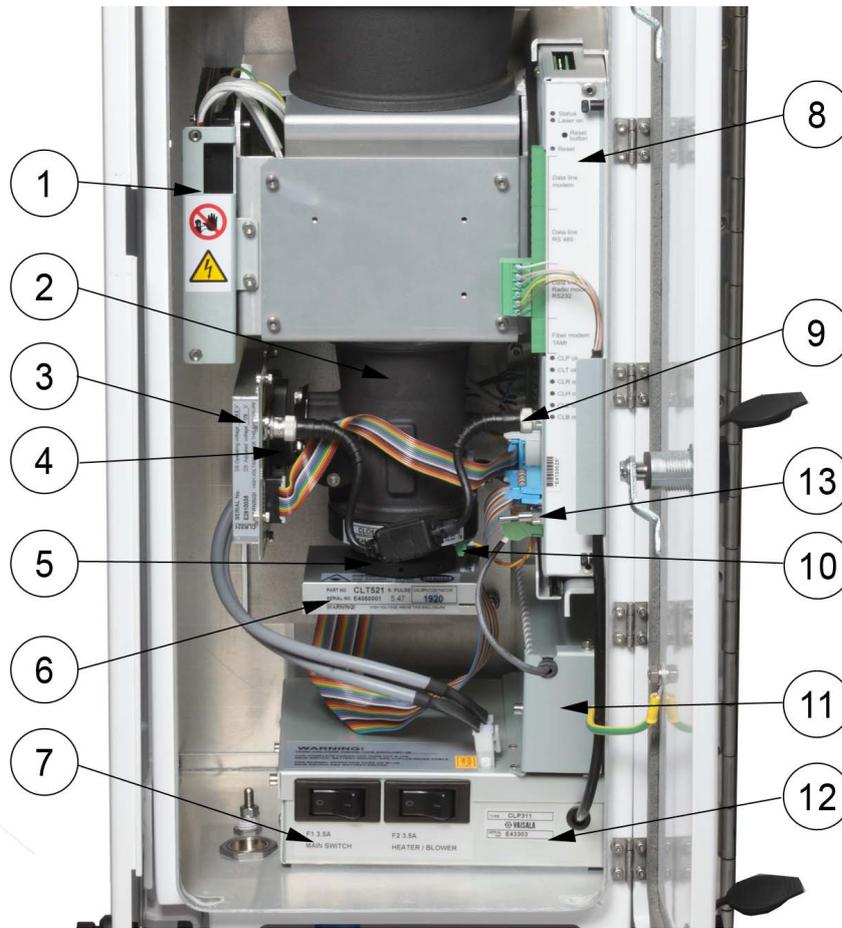
Code	Common Name
CLO511	Optics Unit
CLW511	Window
CLT521	Transmitter
CLR321	Receiver
CLM311	Laser Monitor Board
CLE321	Engine Board
CLP311	AC Power Unit
4592	No-break Battery
CLH311-115	Inside Heater (100 ... 115 VAC)
CLH311-230	Inside Heater (220 ... 240 VAC)
CLB311-115	Window Blower (100 ... 115 VAC)
CLB311-230	Window Blower (220 ... 240 VAC)
CT3839	Power cable (230 V)
CT35324	Power cable (115 V)
CT3838	Data cable
226296	Coaxial Cable

Table 5 Vaisala Ceilometer CL51 Optional Parts

Code	Common Name	Description
CL51BIRDKIT	Bird Deterrent	
DMX501	Modem Module	
CL51RADIOKIT	Radio Modem Installation Kit	Excl. radio modem and antenna
TERMBOX-1200	Termination box, Mains and signal	For extended surge and overvoltage protection
CLTERMBOX	Termination boxes for Mains and Signal	Without surge and overvoltage protection
QMZ101	Maintenance cable	
CL51TERMHOOD	Optical Termination Hood	
CT35022	Shock Absorber	For ship installations
CL51HUMITTER	Internal Humitter and Assembly Kit for CL51	

The complete delivery also includes mating cables with connectors for power and communication, installation hardware, a key for the measurement unit door, and this CL51 User's Guide.

Main parts of the CL51 Measurement Unit are shown in Figure 3 below.



0912-209

Figure 3 Ceilometer CL51 Measurement Unit Main Parts

The following numbers refer to Figure 3 above:

- 1 = Internal heater CLH311
- 2 = Optics unit CLO511
- 3 = Ceilometer Receiver CLR321
- 4 = Receiver ring
- 5 = Transmitter ring
- 6 = Ceilometer Transmitter CLT521
- 7 = F1 Main circuit breakers
F2 Window blower and internal heater circuit breaker
- 8 = Ceilometer Engine Board CLE321
- 9 = Coaxial cable 226296
- 10 = Laser Monitor Board CLM311
- 11 = Battery Cage (for Battery 4592)
- 12 = AC Power CLP311
- 13 = Battery switch

CHAPTER 3

INSTALLATION

This chapter provides you with information intended to help you with installing this product.

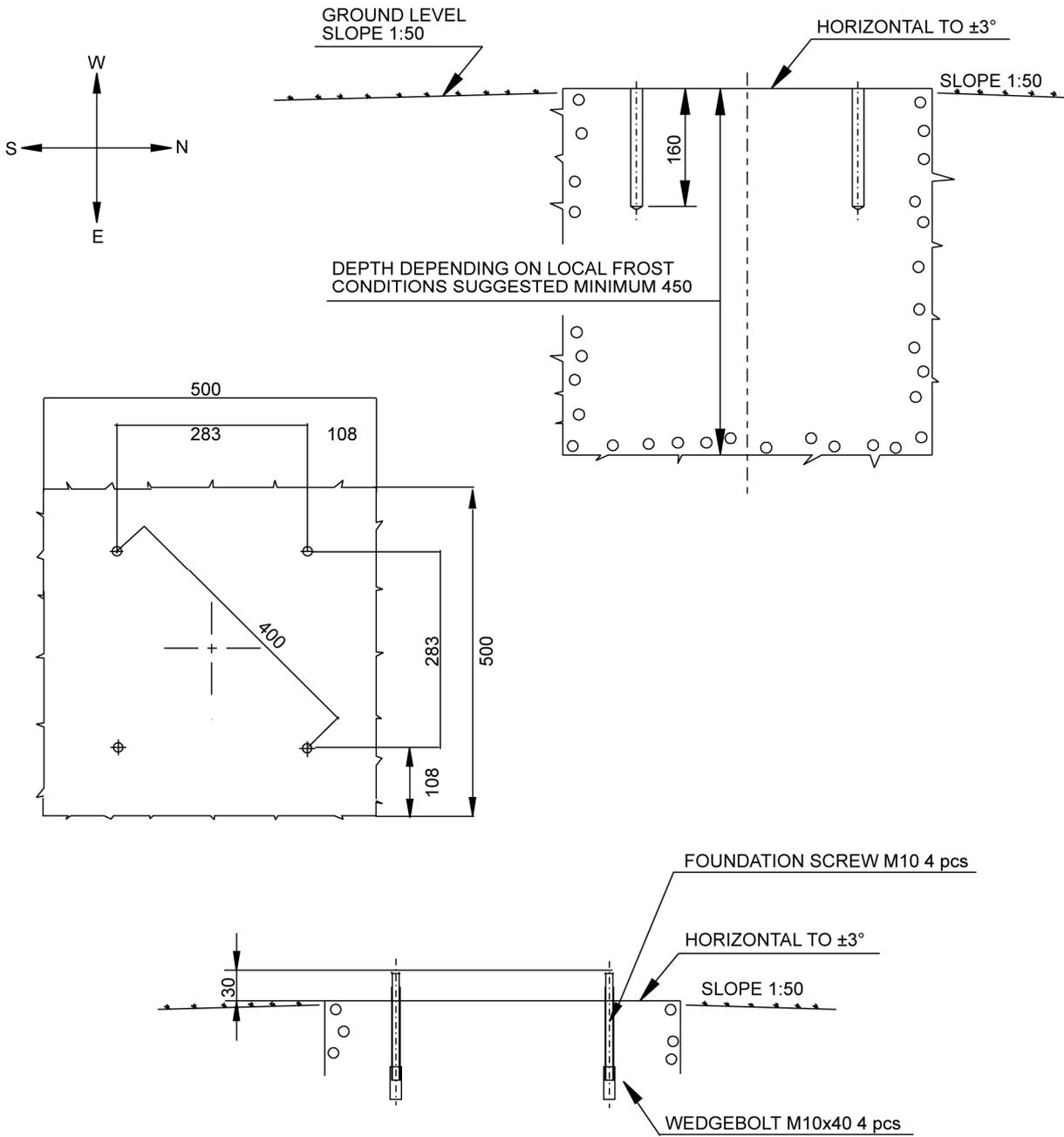
Preparing Foundation

When choosing an installation site it is recommended to use a wide open place where there are no tall trees, overhead lines, or antennas nearby. Proximity to powerful radars should also be avoided.

The standard foundation for the CL51 ground installation is a concrete foundation. The recommended minimum dimensions suggested are presented in Figure 4 on page 24. Mounting screws and bolts are included in the delivery.

NOTE

In case the CL51 replaces another ceilometer (CL31, CT25K, CT12K, LD40, LD25, or LD12) the existing foundation and foundation screws can be used.



0606-215

Figure 4 Foundation Construction

There are two ways to create a concrete foundation for the Ceilometer CL51: an existing concrete foundation can be used, or a new one created.

NOTE

If the tilt feature will be used (see section Using Tilt Feature on page 29), observe this in the layout of the foundation screws and shield placement.

Creating New Concrete Foundation

1. Fasten the M10 × 40 wedge bolts to the lower ends of the foundation screws (four each).
2. Fix a drilling template to the upper ends of the foundation screws with nuts.
3. Place the template with the attached foundation screws into the hole in such a way that approximately 30 mm (1.25 inches) of the foundation screw threads stand above the surface. Note the cardinal points indicated in Figure 4 on page 24.
4. Pour in the concrete and finish the foundation.

Using Existing Concrete Foundation

1. Drill four holes with a diameter of 12 mm and a depth of 165 mm (0.5 × 6.5 inches) into the concrete. Note the cardinal points indicated in Figure 4 on page 24.
2. Fasten the M10 × 40 wedge bolts to the lower ends of the foundation screws (four each).
3. Place the wedge bolt and foundation screw combinations into the holes, with the wedge bolts down, and hammer the protruding threads down.
4. Tighten the foundation screws a few turns to attach the wedge bolts to the hole walls.

Grounding

The CL51 is equipped with a separate grounding screw for external grounding at the bottom of the shield.

CAUTION

At the installation site, a connection to a solid earth ground is mandatory for adequate lightning and transient protection.

Unloading and Unpacking Instructions

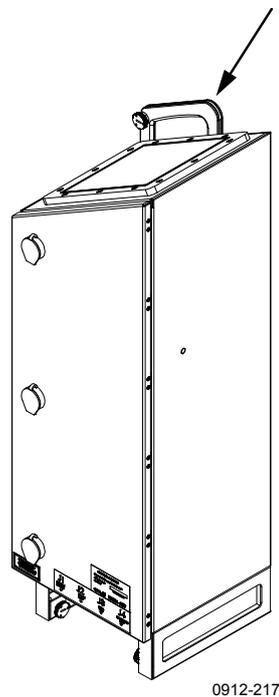
The CL51 is shipped in one container that contains the shield, the measurement unit inside the shield, and all the equipment, accessories, and documentation needed for carrying out the installation. Store the original packaging for a possible later transportation need.

NOTE

The device is quite heavy. Therefore it would be ideal if the unloading and unpacking were carried out by two people instead of one.

For opening, the package should be placed on a flat surface with the indicated top side up. Open the container from the top side and carefully remove the ceilometer and all other equipment.

- Use proper gloves for protection against sharp edges.
- Avoid touching the window or lens surfaces. Do not remove the protective sheet from the measurement unit window.
- Do not remove the integral protective caps from the unused external connectors (J4 Maintenance line).
- Use the measurement unit handle for lifting and carrying the measurement unit. See Figure 5 below.



0912-217

Figure 5 Measurement Unit Handle

If mishandling occurs during transportation or installation, the instrument should be returned to a Vaisala office or authorized Depot for inspection.

Mounting of Ceilometer CL51

The Ceilometer CL51 is delivered with the measurement unit attached to the shield. The shield can be mounted with the measurement unit attached, but it is recommended that you first remove the measurement unit, mount the shield onto the foundation, and then install the measurement unit into the shield.

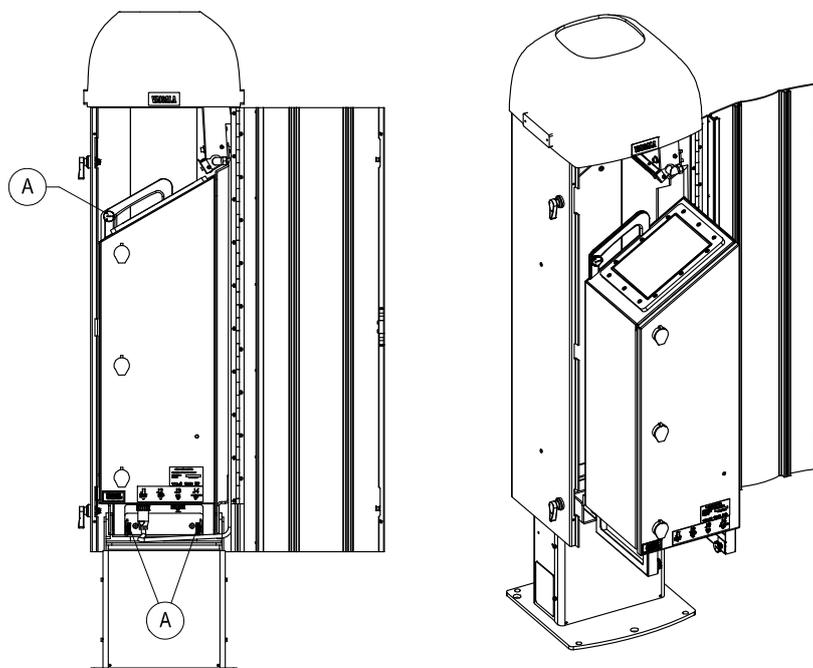
Mounting the Ceilometer CL51:

1. Remove the measurement unit from the shield. Loosen the three attachment screws (marked A in Figure 6 below), disconnect the blower cable from connector J1, and pull out the unit.
2. Place the shield on the foundation in such a way that the door faces North in the Northern hemisphere and South in the Southern hemisphere. See Figure 7 on page 28.
3. Place the flat washers on the foundation screws and tighten the nuts. See Figure 7 on page 28.

NOTE

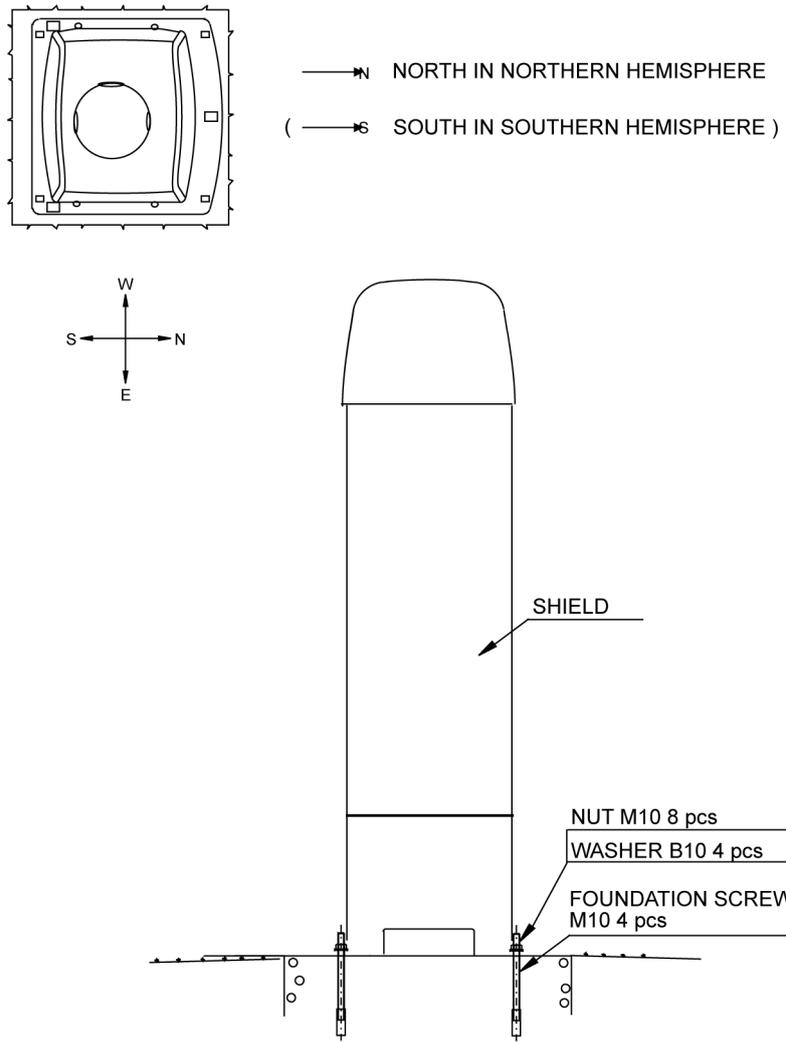
You can install an optional bird deterrent. For instructions, see section Mounting Optional Bird Deterrent on page 30.

4. Place the measurement unit inside the shield, connect the blower cable to connector J1, and tighten the three attachment screws (marked A in Figure 6 below.)



0912-218

Figure 6 Removing and Attaching the Measurement Unit



0606-211

Figure 7 Mounting the Shield

Using Tilt Feature

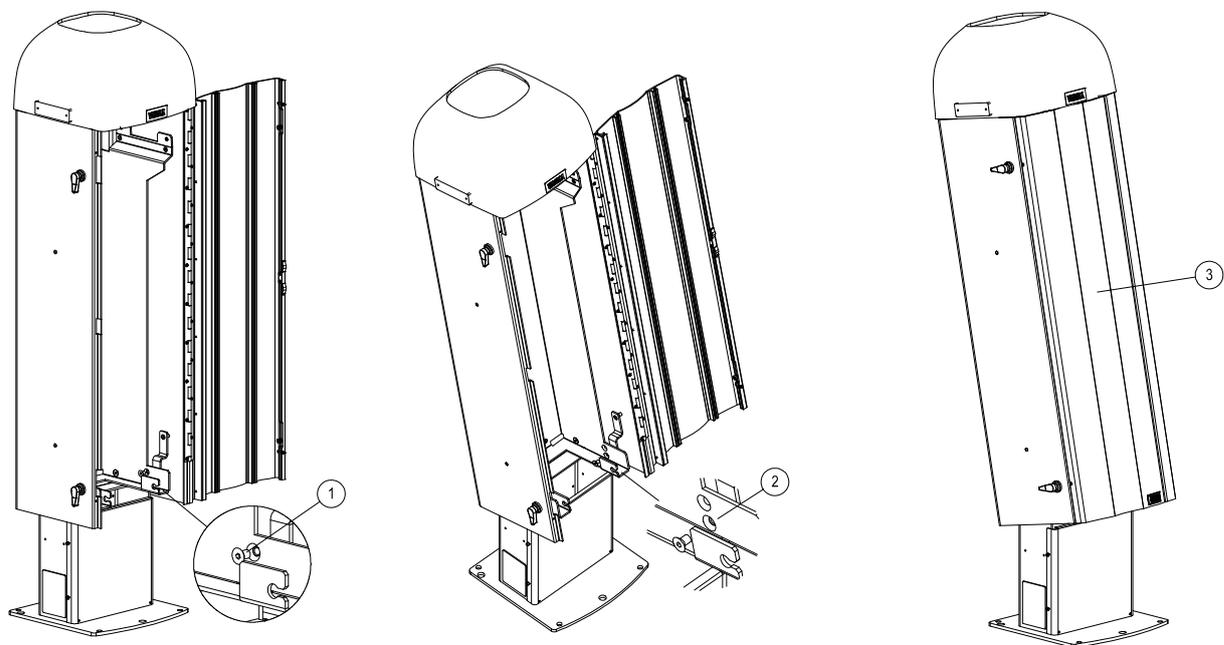
The Ceilometer CL51 can operate in a tilted position. The built-in sensor detects the tilt angle, that is, the deviation from vertical. The tilt feature allows three tilt angles: vertical, 12 degrees with the measurement unit door upwards, and 12 degrees with the measurement unit door downwards. The tilt angle is used for an automatic correction of the detected cloud base height, enabling accurate measurements also in a tilted position.

The tilt feature provides the following advantages:

- Protection in heavy weather conditions:
In heavy weather conditions, using a tilt angle of 12 degrees protects the measurement unit window from precipitation, thus enhancing performance.
- Precision in aircraft approach control:
The beam can be pointed towards the approach direction of an aircraft. This is useful, for example, for helicopter approaches, and at sites where the ceilometer cannot be located exactly at the desired spot.

Tilting Ceilometer

Remove the measurement enclosure. See Figure 6 on page 27. A 5 mm Allen-key is needed for tilting.



0912-219

Figure 8 Tilting the Ceilometer

Proceed as follows:

1. Loosen the tilting screws on both sides. See Figure 8 on page 29.
2. Tilt the ceilometer shield 12 degrees. It is recommended to tilt the ceilometer backwards, with the measurement unit door facing up. Lock it in place with the screws.

WARNING When the unit is operating in a tilted position, make sure that it is not being viewed from the beam direction with magnifying optics.

NOTE To avoid direct solar radiation, tilt the unit away from the Sun. That is, tilt it north in the northern hemisphere and south in the southern hemisphere. Pointing directly to the Sun will not damage the unit but may cause alarms and temporarily invalidate the data.

As the benefits of different tilting directions may be contradictory or cannot be realized simultaneously, the user must decide the direction of the final installation.

Mounting Optional Bird Deterrent

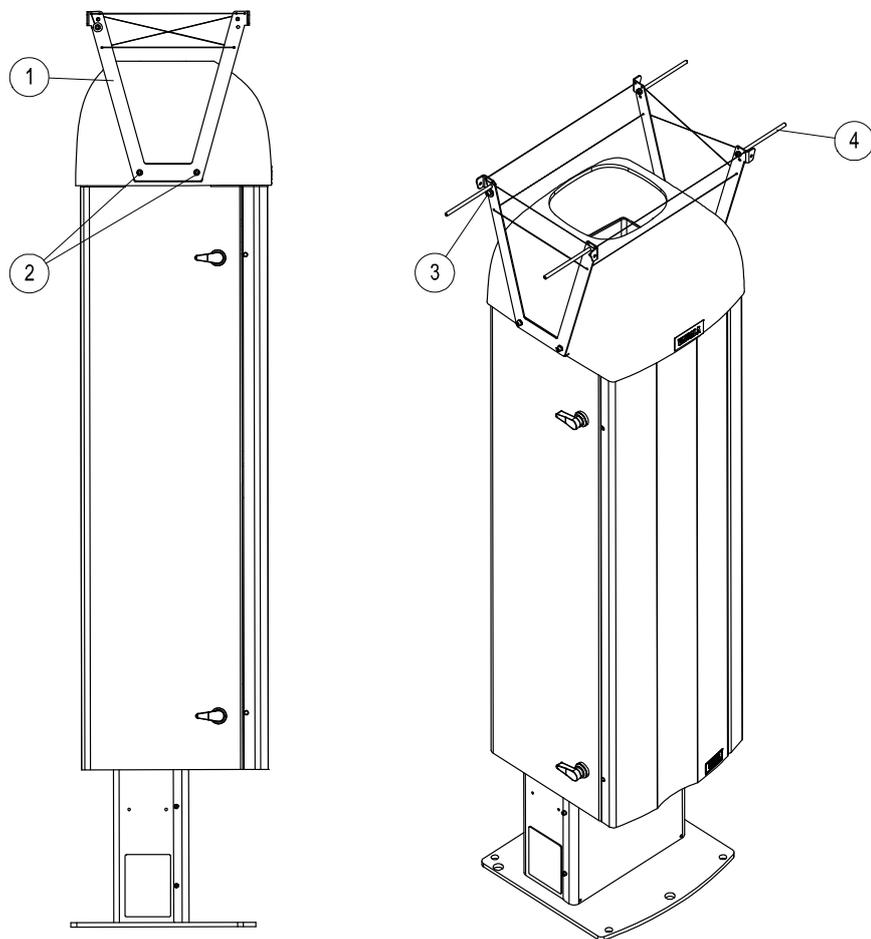
The Ceilometer CL51 can be ordered with an optional bird deterrent; see Figure 9 on page 31. When installed, it prevents birds from landing on the ceilometer which could interfere with the measuring.

The bird deterrent kit consists of two side plates, a piece of fluorocarbon line and two optional perches. To mount the bird deterrent, you need an 8 mm wrench and a 4 mm Allen-key.

Proceed as follows:

1. Place the sideplates on both sides of the ceilometer top cover and attach them with two washers and screws.
2. Slide a fluorocarbon line back and forth through the designated holes on the side plates, starting from the front of the ceilometer and continuing until the ends of the line meet on the back side of the ceilometer. See Figure 9 on page 31.
3. Adjust the line so that it is left slightly loose. Wrap both ends of the line around a screw, under the washer, and then tighten the screw.
4. Cut the remaining line ends short in order to avoid damage to the eyes when handling the device.

5. The optional bird perches can now be attached to the side plates.



0912-220

Figure 9 Ceilometer CL51 Bird Deterrent

The following numbers refer to Figure 9 above:

- 1 = Side plate
- 2 = Attachment screws
- 3 = Fluorocarbon line
- 4 = Bird perch

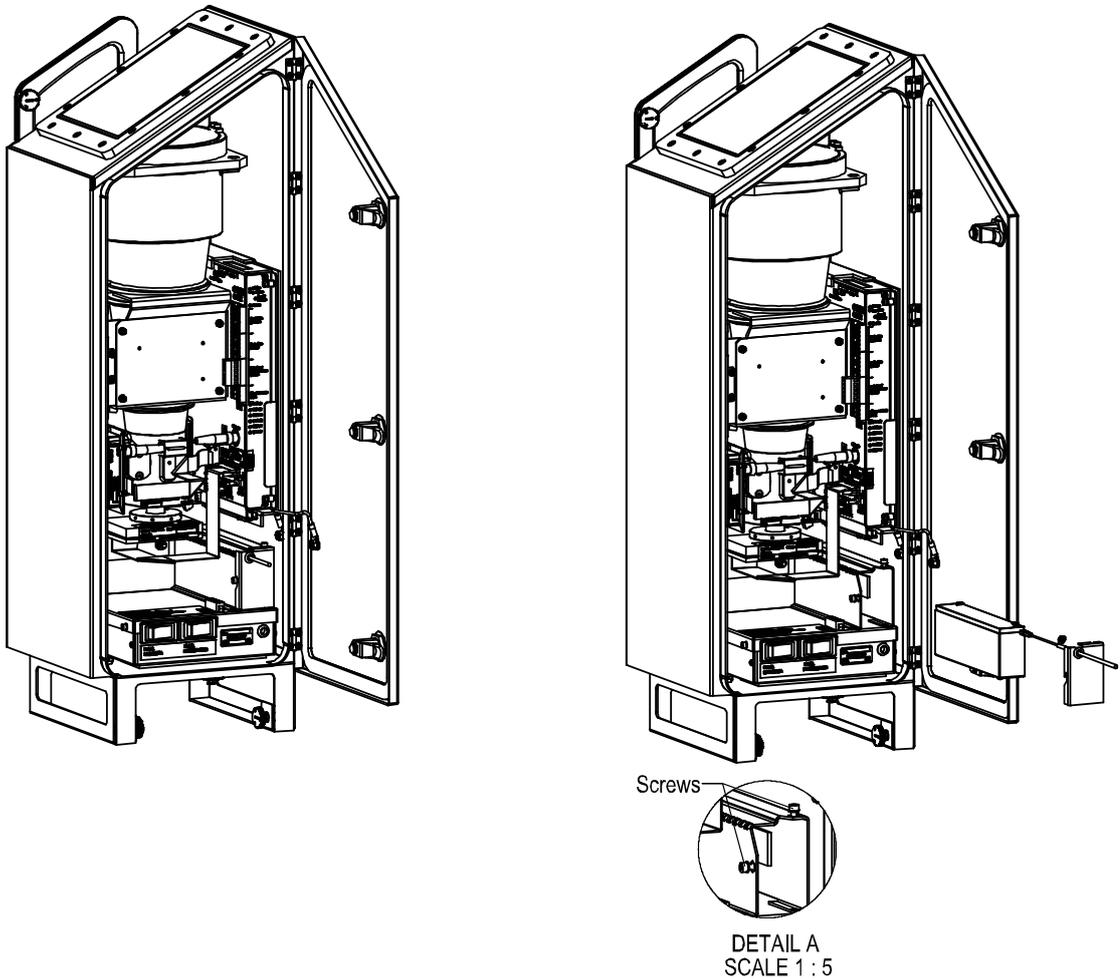
Startup

This section describes the different aspects of the Ceilometer CL51 that need to be considered before starting up the device.

Assembling Battery

The no-break battery is delivered in the same container with the Ceilometer CL51, but it does not come attached to the measurement unit. To attach the no-break battery, you need a crosshead screwdriver and a 3 mm Allen key.

Figure 10 below shows the location of the battery.



0912-221

Figure 10 Assembling the Battery

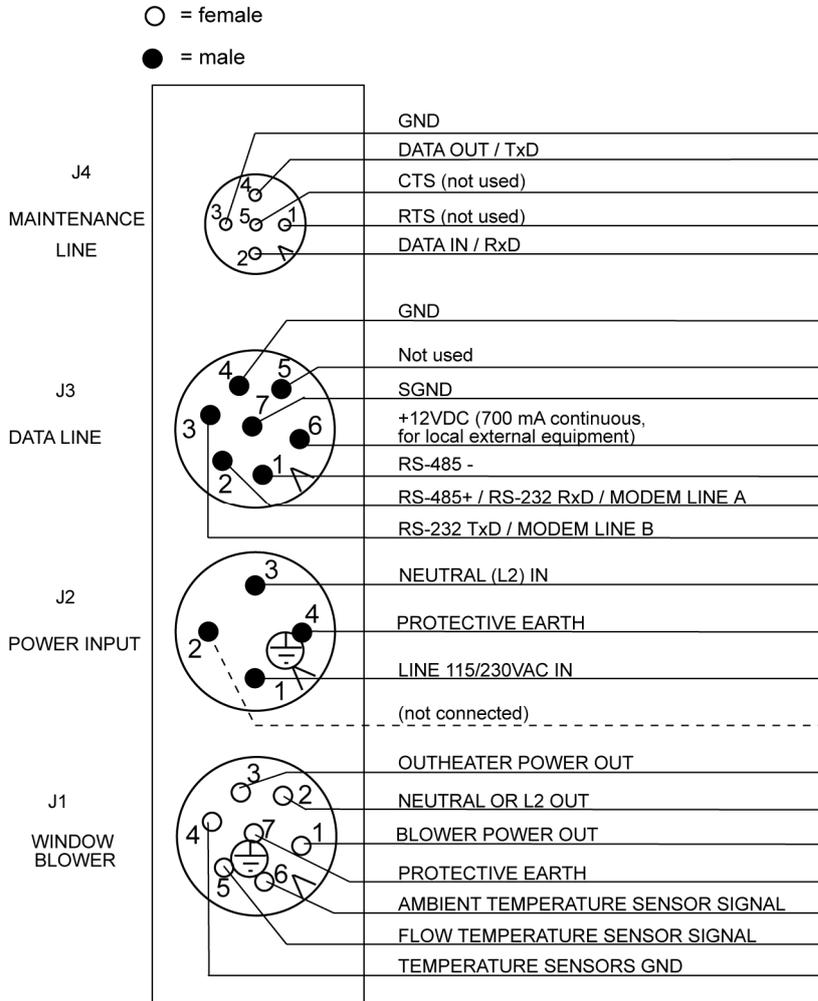
CAUTION Be carefull not to shortcircuit the battery.

Proceed as follows:

1. Open the measurement unit door and remove the two screws locking the lid of the no-break battery cage. See Figure 3 on page 22.
2. Connect the battery cable to the new battery, connecting the red end to the positive (+) end terminal and the black end to the negative (-) end terminal.
3. Open the battery cage lid and slide the battery into the battery cage.
4. Close the battery cage lid and tighten the two screws to their places.
5. Check that the battery switch on the CLE321 unit is in OFF position.
6. Connect the no-break battery cable to the CLE321 board.

Connecting External Cables

All external connectors are located at the bottom of the measurement unit. Figure 11 below shows the external connectors J1, J2, J3, and J4.



0606-210

Figure 11 External Connectors (Bottom View)

The window blower mounted into the shield is connected to J1. Line power is connected to J2. In normal use, remote communication is connected to J3. A local maintenance terminal, such as a laptop, can be connected to J4. A protective cap is included for covering J4 when it is not in use.

The power supply connector J2 provides a standard protective ground for the instrument chassis.

Power Supply Connection

1. Turn the main circuit breaker F1 to the OFF position (for location, see Figure 16 on page 41).
2. Plug in the line supply cable to connector J2 (for location, see Figure 11 on page 34) after checking the voltage of the power supply cable connector.

External mating connectors with 2 m (7 ft) cable are included for J2 and for J3. The power plug can be removed from the J2 cable when the unit is permanently installed at the final site.

The wire connections and cable glands of the optional Termination Box are presented in the Termination Box User's Guide (see section Related Manuals on page 9).

NOTE

When the permanent line power installation is made, the maximum size of the fuse protecting the power line is 10 A.

Data Line Connection

The Vaisala Ceilometer CL51 offers three possible options for the data line connection. These options are presented in Figure 12, Figure 13 and Figure 14 on the next pages.

Data Line Modem Connection

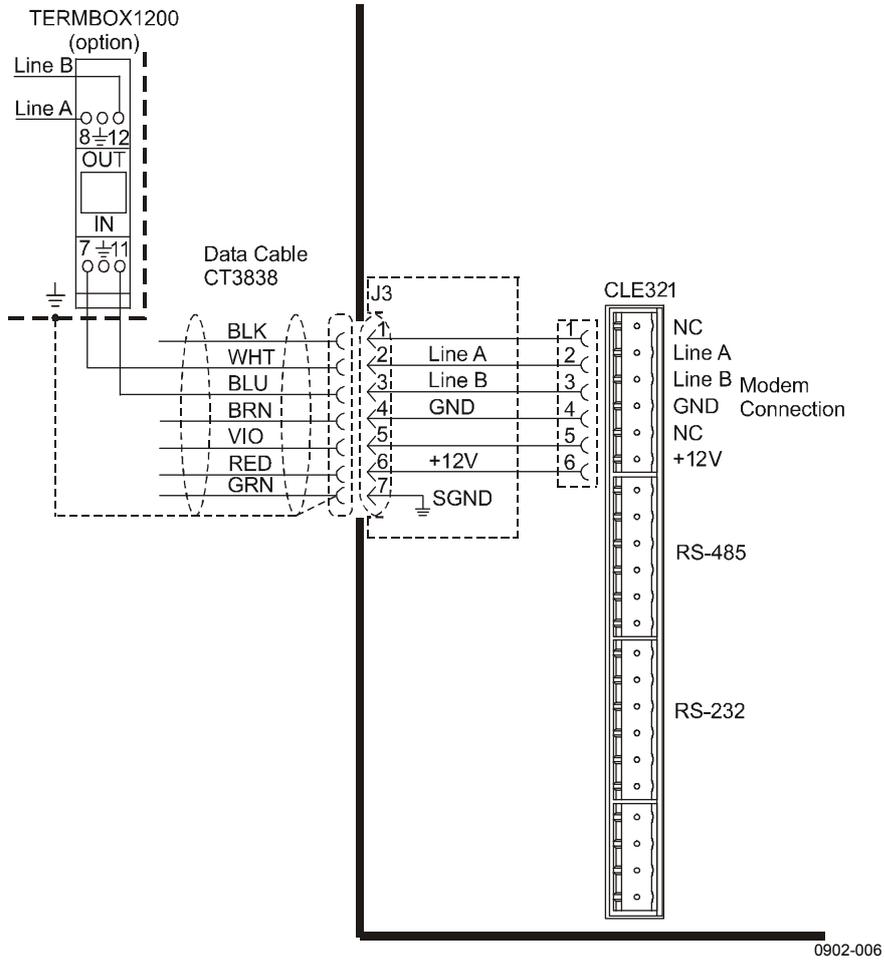
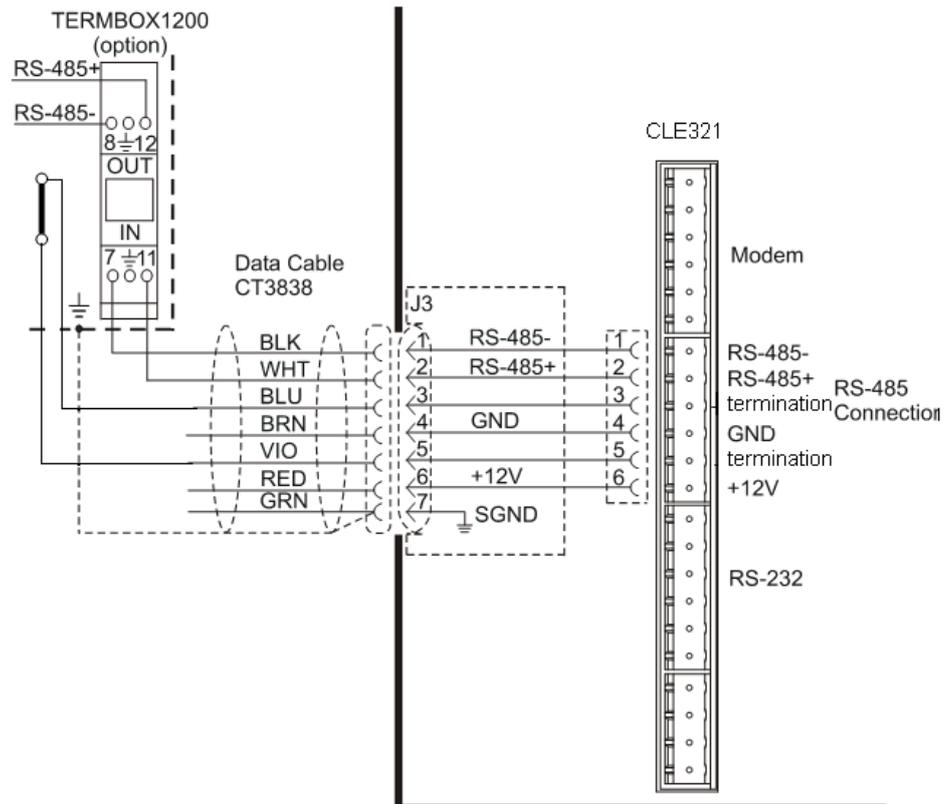


Figure 12 Data Line Modem Connection

Default Settings for the Data Line Modem Connection

Modem mode	V.22bis Answer
Bit rate	2400
Data bits	8
Stop bits	1
Parity	None

Data Line RS-485 Connection



0906-077

Figure 13 Data Line RS-485 Connection

The RS-485 connection is provided with a termination. If the ceilometer is connected to the end of a long line, it may be advantageous to connect the two signals marked "termination" as shown; this can improve data transmission speed, quality, and reliability.

Default Settings for the Data Line RS-485 Connection

Bit rate	19200
Data bits	8
Stop bits	1
Parity	None

Data Line RS-232 Connection

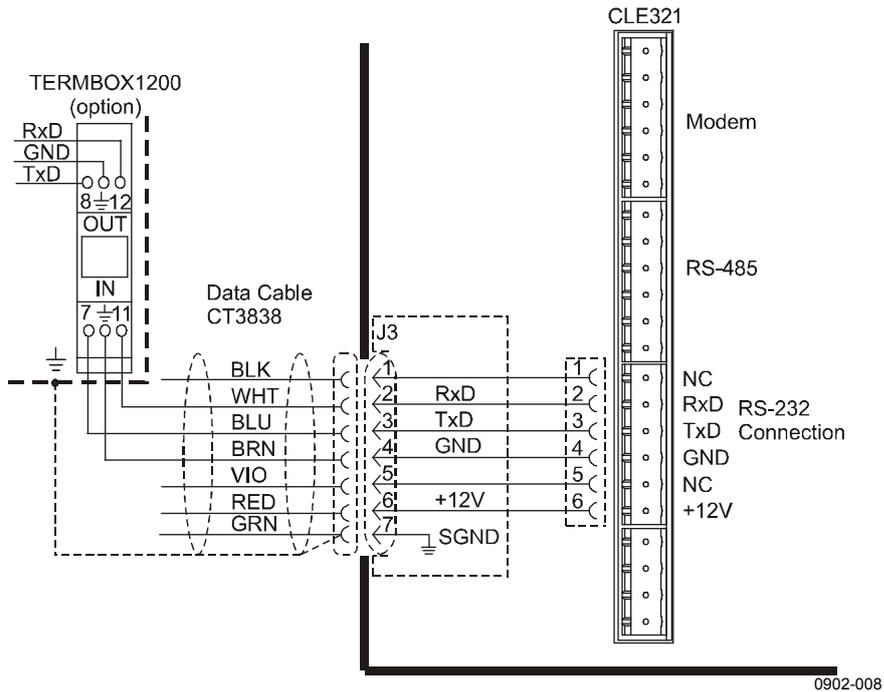


Figure 14 Data Line RS-232 Connection

Default Settings for the Data Line RS-232 Connection

Bit rate	19200
Data bits	8
Stop bits	1
Parity	None
Handshake	None

Maintenance Terminal Connection

Any terminal or PC with a serial interface and a terminal emulation program can be used for operating the Ceilometer CL51. The maintenance terminal connection is established with the QMZ101 maintenance cable, which connects the RS-232 port of the PC to the maintenance port of the ceilometer.

Setting up Maintenance Terminal Connection

1. Connect the RS cable to the ceilometer maintenance port (connector J4) and the terminal computer.
2. Configure the terminal as follows:

Bit rate	9600
Data bits	8
Stop bits	1

Parity	None
Handshake	None

Operation of Maintenance Terminal Connection

To operate the connection, do the following:

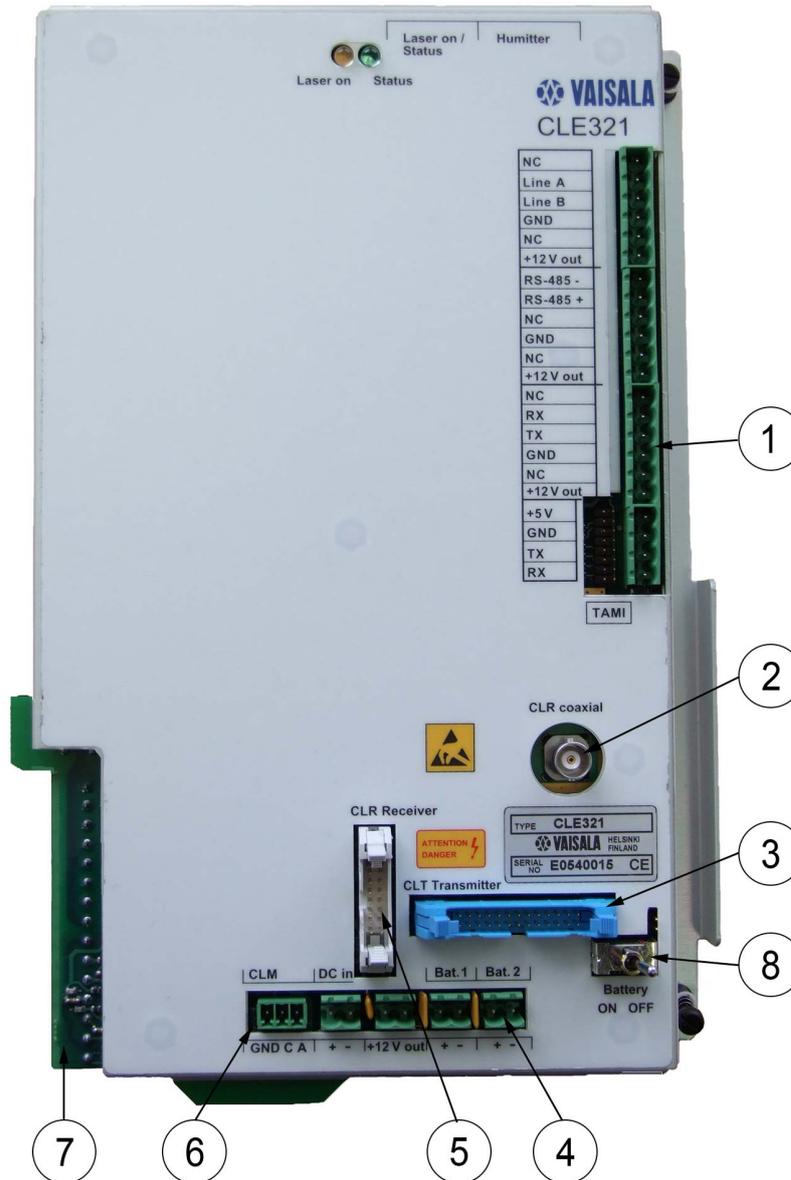
1. Turn the power on in CL51.
2. Open the CL51 maintenance with the **open** command.
3. The prompt `CEILO >` appears. For details, see Chapter 4, Functional Description.

Startup Procedure

Open the unit door and make a visual check of the internal connectors and subassemblies (see Figure 15 on page 40).

Turn the Main Circuit Breaker F1, the Window Blower Circuit Breaker F2, and the Battery Switch to the **On** position. After the initialization routines, the **Laser on** LED starts blinking at 6-second intervals. Also the six diagnostic LEDs light up. For location of the LEDs and switches, see Figure 16 on page 41.

WARNING Make sure that nobody is viewing the unit from the beam direction with magnifying optics.
--



0910-103

Figure 15 Ceilometer Engine Board CLE321

The following numbers refer to Figure 15 above:

- 1 = Data line connection to AC Power CLP311
- 2 = Coaxial cable connection to Ceilometer Receiver CLR321
- 3 = Connection to Ceilometer Transmitter CLT521
- 4 = Connection to Battery 4592
- 5 = Connection to Ceilometer Receiver CLR321
- 6 = Connection to Laser Monitor Board CLM311
- 7 = Connection to AC Power CLP311
- 8 = Battery Switch



0910-100

Figure 16 CL51 Switches

Settings for Normal Operation

The switch settings for normal operation are as follows:

Main circuit breaker F1	ON
Heater/Blower circuit breaker F2	ON
Battery switch	ON

The data message and interface configuration, as well as the configuration of measuring interval and transmission speed, are standard factory settings. The settings can be changed by giving commands from the terminal.

During the factory alignment procedure, the optical adjustments are carefully carried out to fulfill the requirements and specifications of the device. Optical adjustments have been made at the factory or depot, and there is no need to readjust them in the field.

NOTE

To switch the CL51 fully off, turn off the battery switch and the line power switch. Having the unit on with the battery supply will drain the battery.

Factory Settings of User Programmable Parameters

Table 6 below lists the factory defaults of user-programmable parameters. The prevailing parameter settings of the Ceilometer CL51 can be seen with the following command:

```
get params parameter_group
```

The user-programmable parameters can be changed with the following command:

```
set parameter_group parameter
```

Table 6 Factory Defaults of User-Programmable Parameters

Parameter	Factory Default
Control blower	Auto
Control inheater	Auto
Data_acq power_save	Disabled
Data_port baud	19200
Data_port mode	RS232
Data_port parity	8N1
Maint_port baud	9600
Maint_port parity	8N1
Message angle_corr	On
Message transmission	Periodic
Message transmission delay	100 ms
Message height_offset	0
Message interval	6 s
Message port	Data
Message profile scale	1.0
Message profile noise h2	Off
Message type	msg2_10x1540
Message units	Feet
Message vv_limit ceiling	2000 m (6562 ft)
Oper_mode	Normal
Port_timeout	2 min
Unit_id	0 (zero)

CHAPTER 4

FUNCTIONAL DESCRIPTION

This chapter provides information on the measurement principles of the product.

Theory of Operation

Basic Operating Principle

The operating principle of Ceilometer CL51 is based on the measurement of the time needed for a short pulse of light to traverse the atmosphere from the transmitter of the ceilometer to a backscattering cloud base and back to the receiver of the ceilometer.

The general expression connecting time delay (t) and backscattering height (h) is

$$h = ct/2$$

where c is the speed of light ($c = 2.99 \times 10^8$ m/s).

A reflection from 25 000 feet can be seen by the receiver after

$$t = 50.9 \mu\text{s}$$

Practical Measurement Signal

Generally, particles at all heights scatter light, so the actual return signal may look like that shown in Figure 17 on page 74.

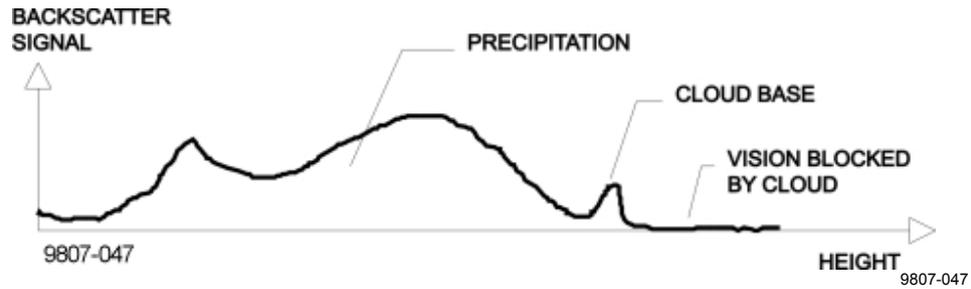


Figure 17 Typical Measurement Signal

The instantaneous magnitude of the return signal provides information on the backscatter properties of the atmosphere at a certain height. Information about fog and precipitation, as well as clouds, can be derived from the return signal. Fog and precipitation attenuate the return signal from a cloud. However, fog and precipitation backscatter signals also provide data that can be used in estimating this attenuation and computing the necessary compensation, up to a limit.

In its normal full-range operation, Ceilometer CL51 digitally samples the return signal from 0 to 100 μ s. The sampling is repeated every 67 ns, providing a spatial resolution of 10 meters from ground level up to 15 000 meters, i.e. 50 000 feet. This spatial resolution is adequate for measuring the atmosphere, since visibility in the densest clouds is of the same order. Note that the specified cloud height reporting range is 13 km, i.e. 43 000 feet.

Noise Cancellation

For safety and economic reasons, the transmitted laser power is so low that the noise of the ambient light exceeds the backscattered signal. To overcome this, a large number of laser pulses are sent, and the return signals are summed. The desired signal can be multiplied by the number of pulses, whereas noise, being random, partially cancels itself. The degree of cancellation for white (Gaussian) noise equals to the square root of the number of samples; thus, the resulting signal-to-noise ratio improvement is equal to the square root of the number of samples. However, this processing gain cannot be extended endlessly since the environment changes and, for example, clouds move.

Return Signal Strength

In general form, the instantaneous return signal power can be derived from the Lidar equation:

$$P_r(z) = E_o \cdot \frac{c}{2} \cdot \frac{A}{z^2} \cdot \beta(z) \cdot e^{-2 \int_0^z \sigma(z') dz'}$$

where

- $P_r(z)$ = Instantaneous power received from distance z
- E_o = Effective pulse energy (taking all optics attenuation into account) [Ws]
- c = Speed of light [m/s]
- A = Receiver aperture [m²]
- z = Distance [m]
- $\beta(z)$ = Volume backscatter coefficient at distance z [m⁻¹srad⁻¹, srad = steradian]
- $e^{-2 \int_0^z \sigma(z') dz'}$ = Two-way atmospheric transmittance, accounts for the attenuation of transmitted and backscattered power. The transmittance equals 1 in clear atmosphere, that is, with no attenuation.

Height Normalization

Assuming a clear atmosphere, the power of the return signal (P_r) is inversely proportional to the square of the distance, that is, the signal strength from 1 000 ft is generally a hundred times stronger than that from 10 000 ft.

The height dependence is eliminated by multiplying the measured signal value with the square of height (height normalization). Noise, however, being height-independent from a measurement point of view, will then be correspondingly accentuated with increasing height.

Backscatter Coefficient

The volume backscatter coefficient, $\beta(z)$, represents the portion of light reflected back towards the ceilometer from a distance z (for example, from water droplets). A dense cloud gives a stronger reflection. This can be expressed as follows:

$$\beta(z) = k \cdot \sigma(z)$$

where

k = Proportionality constant [1/srad].

$\sigma(z)$ = Extinction coefficient (the attenuation factor in forward direction) [1/m].

The extinction coefficient relates to *visibility* in a straightforward manner. If visibility is defined according to a 5 % contrast threshold (World Meteorological Organization definition for Meteorological Optical Range, MOR, equals daylight *horizontal* visibility), then the extinction coefficient is the following:

$$\sigma = 3 / V$$

where

V = MOR visibility (5 % contrast) [m]

The proportionality constant, k , also called the Lidar Ratio, has been subjected to a great deal of research. Although the Lidar Equation can be solved without knowing the ratio, it must remain constant with the height if accurate estimates of the extinction (or visibility) profile are to be made.

It has been discovered that in many cases, k can be assumed to equal 0.03, tending to be lower (down to 0.02) in high humidity, and higher (up to 0.05) in low humidity conditions. However, in precipitation conditions, k can have a wider range of values.

Assuming k value of 0.03 srad^{-1} , visibility in clouds in the range of 15 to 150 m (50 to 500 ft), gives the following range for β :

$$\beta = 0.0006 \dots 0.006 \text{ m}^{-1}\text{srad}^{-1} = 0.6 \dots 6 \text{ km}^{-1}\text{srad}^{-1}$$

Vertical Visibility

Any fog, precipitation, or similar obstruction to vision between the ground and the cloud base may attenuate the cloud base signal and produce backscatter peaks that far exceed that from the cloud. Virtually any backscatter height profile is possible, up to some physical limits. To distinguish a significant cloud return signal, the attenuation of, for example, fog or precipitation, has to be taken into account by normalizing with regard to extinction. The profile thus obtained is proportional to the extinction coefficient at various heights, and enables the use of a fairly straightforward threshold criteria to determine what is cloud and what is not.

By assuming a linear relationship between backscatter and extinction coefficient according to the previous formula and by assuming that the ratio, k , is constant over the observation range, it is possible to obtain an extinction coefficient profile through a mathematical computation. This is also called inverting the backscatter profile, and it basically answers the question of what kind of an extinction coefficient profile would produce the measured backscatter profile.

No assumption as to the absolute value of the ratio, k , needs to be made if k is constant in terms of height. The assumptions that have to be made are fairly truthful, and accurate enough for cloud detection purposes.

The backscatter profile inversion is also independent of several instrumental uncertainties including transmitted power and receiver sensitivity.

An estimate of vertical visibility can easily be calculated from the extinction coefficient profile because of the straightforward extinction coefficient-to-visibility relationship, assuming a constant contrast threshold. Visibility is simply the height where the integral of the extinction coefficient profile, starting from the ground, equals the natural logarithm of the contrast threshold, sign disregarded.

Tests and research have, however, shown that the 5 % contrast threshold widely used for horizontal measurement is unsuitable for vertical measurement if values close to those estimated by a ground-based observer are to be obtained.

Ceilometer CL51 uses a contrast threshold value which, through many tests, has been found to give vertical visibility values closest to those reported by ground-based human observers. A safety margin is obtained with regard to pilots looking down in the same conditions since the contrast between objects, especially runway lights, is much more distinct on the ground.

Sky Condition Algorithm

General

The Vaisala CL51 Sky Condition algorithm uses a time series of ceilometer data to calculate the cloud layer height and the amount of clouds in different layers. The purpose of the algorithm is to construct an image of the whole sky based on ceilometer measurements from a single point. The sky condition information is included in data message 2 and its subclass. The algorithm can report up to five cloud layers below 43 000 feet.

Option Code

You can activate the algorithm by entering an option code number to the ceilometer. The option code number is based on the CL51 ceilometer serial number. If the CL51 ceilometer is purchased with the sky condition activated, this has already been done at the factory. In case the sky condition option is purchased afterwards, you can find out the serial number by entering the following command::

```
CEILO > system

Vaisala Ceilometer CL51

Unit ID:      0
Serial Nro:   421202
SW Version:   1.010

HW Options
Modem:        N/A
Humitter:     N/A
```

The ceilometer serial number can also be found in the label on the measurement unit door. Send the CL51 serial number to Vaisala, and Vaisala returns the option code, for example, 63273 (see the example in the following section, Activation) .

Activation

After you have received the option code, activate the sky condition algorithm as follows:

```
CEILO > advanced
Service password accepted.
```

```
CEILO > set option sky_cond on 63273
OK.
```

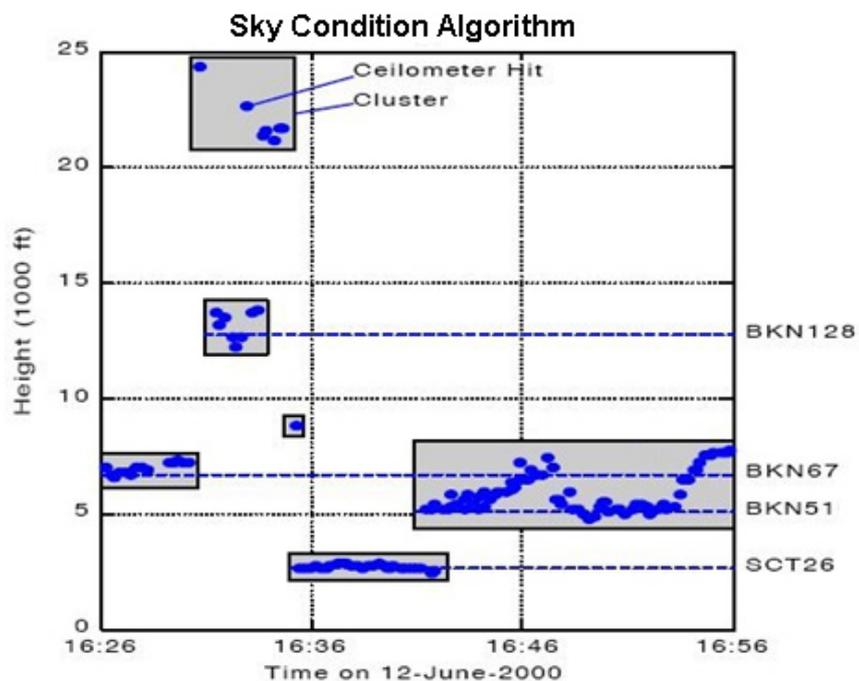
Select the sky condition message type (msg2_base or its subclass) to be reported:

```
CEILO > set message type msg2_base
OK
CEILO>close
```

Algorithm Overview

The sky condition algorithm is calculated every five minutes based on data collected during the last 30 minutes. The last 10 minutes are double-weighted to make the algorithm more responsive to variations in cloudiness.

Operation of the sky condition algorithm is shown in Figure 18 below. Instead of forming a histogram of hit heights, the algorithm uses both height and timing information to find hits close to each other. These hits are combined into clusters and a height value is calculated for each cluster. This height gives the base height of a cloud or cloud layer represented by the cluster. The algorithm reports layers by combining clusters whose heights are close to each other and then selecting clusters that cover the greatest amount of sky.



1001-132

Figure 18 Basic Operation of CL51 Sky Condition Algorithm in a 2D Time-Height Domain

The sky condition algorithm reports the total sky cover in octas with values between 0 and 9. (One octa equals one eighth.) Value 9 is reported only in a vertical visibility condition. In addition, the sky cover can have values of -1 and 99. The -1 is reported if the data is missing or the ceilometer is in stand-by mode. The value 99 is reported after the start-up of the ceilometer indicating there is not enough data for algorithm processing. Sky cover values are described in Table 7 below.

Table 7 Sky Cover Values from the Sky Condition Algorithm

Volume	Sky cover
0-8	Cloudiness in octas
9	Vertical Visibility (VV)
-1	Data missing or ceilometer in stand-by
99	Not enough data

Vertical Visibility (VV) hits are considered as cloud hits if they are above 1 500 feet. The cloud height is defined as $(VV + \text{signal range}) / 2$. Lower VV hits are assigned to a VV register during the last 10 minute period. If the percentage of VV hits in the register exceeds 60%, the sky condition algorithm reports VV. The VV height is the average height of the VV hits. Otherwise, the lower hits are also considered as normal cloud hits with cloud height $(VV + \text{signal range}) / 2$, that is, VV hits are assigned to cloud height categories.

The sky condition algorithm has been implemented using five independent modules. The algorithm control flow is shown in Figure 19 on page 51.

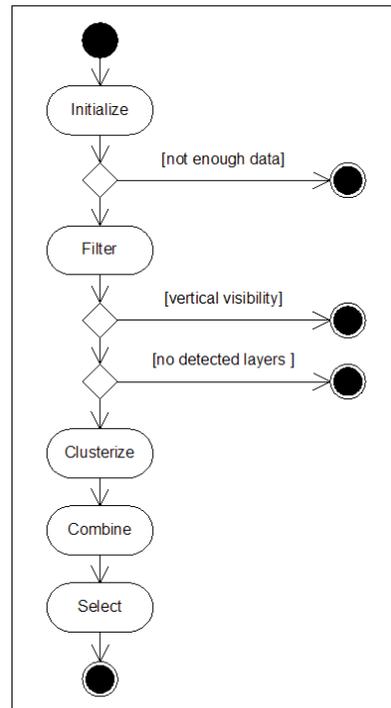


Figure 19 Control Flow of Sky Condition Algorithm

In the control flow, the **Initialize** module selects ceilometer measurements from the last 30 minutes, sorts them into time order and distributes them into specific data structures. After the ceilometer measurements have been distributed, the module checks whether the ceilometer has provided enough data for the algorithm. Two ratios are calculated: ratio of measurements during the last 30 minutes and ratio of measurements during the last few minutes. If either of these ratios exceeds a threshold value, the data is marked valid and will be used by the rest of the algorithm. Both of these ratios require a fixed sampling period that is automatically detected from the measurements. If there is no valid ceilometer data, 99 is returned as sky cover value, and if more than 30 minutes has elapsed, -1 is returned as sky cover value.

The **Filter** module converts ceilometer measurements into cloud hits. If the ceilometer measurement contains multiple cloud bases, the conversion results in multiple cloud hits. Vertical visibility measurements are also converted into cloud hits. After ceilometer measurements have been converted, the amount of clear sky, the amount covered by cloud hits and the amount covered by high clouds are determined for the unit. Total sky cover is adjusted using the value received from the **Initialize** module. The adjusted total sky cover gets the value of 8 only if no clear sky was detected and the measurements do not have any features that indicate there is no overcast condition.

The **Clusterize** module combines hits into clusters. First the cloud hits are combined into clusters, using an algorithm that looks for layers where

the horizontal difference between consecutive hits is small, and then by algorithm that allows large height differences between consecutive hits. These two algorithms are needed to make sure that in simple cases, separate layers are not combined and in difficult cases the algorithm does not report too many layers. After all hits have been combined into clusters, a height is assigned for each cluster. First, the height below which 10 % of all hits within the cluster are, is selected. Then, the height of the cluster is calculated as an average of selected hits around this height.

The **Combine** module combines clusters into a single list of layers. The module goes through all possible layer heights. A cover value is calculated for each height. The calculated value is the sum of the cover values of those clusters whose base height is between the height of the layer and the height of the layer plus vertical extent of the layer. Vertical extent of the layer is 100 feet or 10 % of the height of the layer, whichever is bigger. The height that has the largest cover value is used in forming a new layer. The height of the new layer is equal to a weighed sum of those clusters that were within the vertical extent of the layer. After the layer has been formed, the clusters are deleted and if there are any uncombined clusters left, the process will be repeated.

The **Select** module chooses the layers to be reported by the algorithm. The first step is to assign high cloud cover to a single cloud layer. If the highest layer is above the threshold height, high cloud cover is assigned to that layer; otherwise a synthetic layer is created at 43 000 feet. The second step is to determine which layer to report as the lowest one. After the lowest layer has been determined, the **Select** module rounds layer heights into 100 feet precision. Layers closer than 100 feet to the layer that is below them or whose sky cover is 1/16 or lower (less than 1/2 octas) are combined with the layers that are immediately below them. The height of the combined layer is the height of the lower layer. If the number of layers is still more than the number of layers requested, the algorithm combines the layer which covers the least amount of sky to the layer that is below it. This is done as many times as necessary to reduce the number of layers to the requested number. The lowest layer is not checked in either of the above two conditions.

The last phase of the **Select** module is to calculate the cumulative cloud cover for the reported layers. This value is simply the sum of the sky cover of the layer and all the layers below it converted into integer octas. However, the cumulative cover of 8 octas is only reported if the layer is the highest layer and if the total sky cover from the **Select** module is 8 octas.

CHAPTER 5

OPERATION

This chapter contains information that is needed to operate this product.

Operation Modes

There are two operation modes, normal and standby. The **set oper_mode normal** and **set oper_mode standby** commands are used to switch between the modes. In the normal mode, continuous measurement and message transmission occurs according to the chosen parameters. The standby mode, which involves turning off the wearing parts, can be used during periods when measurement is not needed. See Figure 20 below.

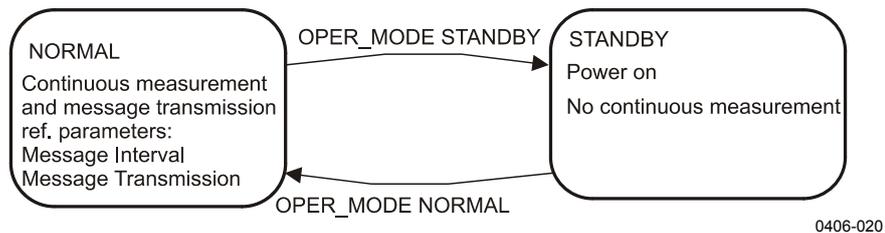


Figure 20 Operation Modes

Serial Lines - Open and Closed Port

As shown in Figure 11 on page 34, there are two line outputs in the CL51, the maintenance line (external connector J4) and the data line (external connector J3). The data line is intended to be used for measurement data communication and can be operated through a modem or a serial line (RS-232 or RS-485). The maintenance line is intended for on-site maintenance access, and is used only as a RS-232 serial line. Functionally the operation of the two lines is identical, that is, the same commands, operations, and messages operate through both lines.

The factory default setting is 8 data bits, no parity, 1 stop bit and 9600 bps (for maintenance line), 19200 bps (for data line). The bit rate can be selected from the user menu.

The lines use the 7-bit USASCII character format. Both the UPPER and lower letter cases can be used.

The standard operation of the serial lines requires no handshake signals.

A communication port, in other words the serial line, has the following two internal states (see Figure 21 below).

- **CLOSED**: This is the transmitting state of a measurement data message. In this state, messages are transmitted as a response to a polling input string or automatically at predetermined intervals, depending on the settings (message transmission). User commands are not accepted, except for the **open** command, which turns the line into the OPEN state.
- **OPEN**: This is the user dialog state. In this state, the device responds to user commands and command input is echoed. A command prompt `CEILO >` is displayed to indicate that the CL51 is ready for command input from the user. The commands are executed by pressing ENTER, for example, `OPEN 1 <enter>`. No automatic transmission of the measurement data message is executed in the open state. The port reverts to the closed state with the **close** command. An automatic, 2-minute time-out after the last character input is applied. A 2 to 30-minute time-out may be set with the **set port_timeout** command.

NOTE Only one of the ports can be open for commands at a time. Only one of the ports transmits measurement messages at a time. Additionally, in the RS-485 mode, a unit ID must be given with the **open** command.

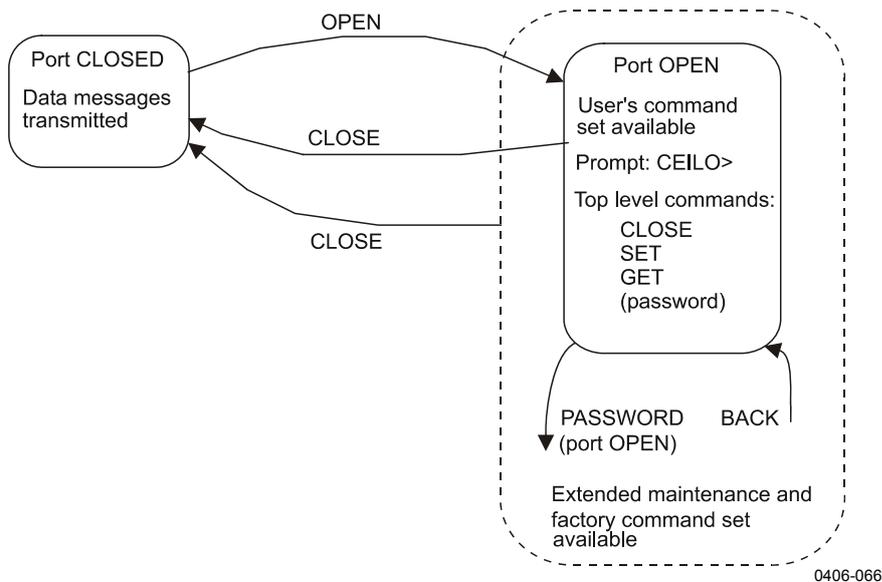


Figure 21 Open and Closed Port

User Commands

User commands are described in Table 8 below. User commands are accessible after opening the line with the **open** command. No password is needed.

The exact format of commands does not have to be remembered, as the command line interpreter provides interactive support. At each menu level, pressing ENTER provides an output of the available menu. Inserting a letter followed by ENTER outputs all commands starting with that letter. Inserting two letters followed by ENTER outputs all commands that start with those two letters, and so on, until only the desired command is left. This command is then executed by pressing the ENTER key.

In addition to the user menu and the user level command set, there is a second in-depth maintenance and service level menu and command set, which is intended for more profound system changes and diagnostics. These advanced level commands are presented in Table 9 on page 58. The password for this level is "advanced". The commands on this level should only be used according to the instructions in this manual.

Table 8 User Level Commands

Command	Description
close	Closes a user interface. Releases a port for message transmission.
get diag contamination	Prints diagnostic history of window contamination.
get diag angle	Prints diagnostic history of inclinometer angle.
get diag battery	Prints diagnostic history of battery voltage.
get diag int_temp	Prints diagnostic history of internal temperature.
get diag l_power	Prints diagnostic history of laser power.
get diag l_temp	Prints diagnostic history of laser temperature.
get failure history	Prints history of alarm and warning status.
get failure status	Shows active alarms and warnings.
get params data_acq	Prints data-acquisition related parameters.
get params factory	Prints factory calibration values.
get params message	Prints message related parameters.
get params port	Prints serial port and modem parameters.
get sensors	Prints data-acquisition values, tilt angles, and humidity, if available.
get temperatures	Displays temperatures.
get uptime	Displays uptime clock.
get voltages	Displays voltages.
name	Displays device type, name, and ID.
open	Opens a user interface.
reset	Resets the ceilometer using the watchdog reset.
set control blower on	Sets the window blower on.
set control blower off	Sets the window blower off.
set control blower manual	Sets manual control.
set control blower auto	Sets automatic control.
set control inheater on	Sets inheater on.
set control inheater off	Sets inheater off.

Command	Description
set control inheater manual	Sets manual control.
set control inheater auto	Sets automatic control.
set control outheater on	Sets outheater on.
set control outheater off	Sets outheater off.
set data_port baud 115.2 k	Data serial port speed.
set data_port baud 57.6 k	Data serial port speed.
set data_port baud 38.4 k	Data serial port speed.
set data_port baud 19.2 k	Data serial port speed.
set data_port baud 9600	Data serial port speed.
set data_port baud 4800	Data serial port speed.
set data_port baud 2400	Data serial port speed.
set data_port baud 1200	Data serial port speed.
set data_port baud 300	Data serial port speed.
set data_port mode RS-232	Data serial port mode.
set data_port mode RS-485	Data serial port mode.
set data_port parity 7E1	Data serial port settings.
set data_port parity 7O1	Data serial port settings.
set data_port parity 7N2	Data serial port settings.
set data_port parity 8N1	Data serial port settings.
set defaults	Restores the following default settings: Operation mode: normal Measurement mode: high_res Data acquisition autoadjustments: on Blower control: auto Inheater control: auto Diagnostics intervals: 2 min Power-save mode: disabled Power-save sleep interval: 60 s Message angle correction: on Message transmission: periodic Message transmission delay: 100 ms Message height-offset: 0 Message interval: 6 s Manual message: disabled Message port: data Message profile scale: 1.0 Message profile noise-h2: off Message type: msg2_10x1540 Message units: feet Message VV limit ceiling: 6562 ft (2000 m) Port timeout: 2 min Unit ID: 0
set diag interval angle	Sets diagnostic-data logging interval (min). 0 disables.
set diag interval battery	Sets diagnostic-data logging interval (min). 0 disables.
set diag interval contam	Sets diagnostic-data logging interval (min). 0 disables.
set diag interval int_temp	Sets diagnostic-data logging interval (min). 0 disables.
set diag interval l_power	Sets diagnostic-data logging interval (min). 0 disables.
set diag interval l_temp	Sets diagnostic-data logging interval (min). 0 disables.
set diag clear	Clears all diagnostic-data history.
set failure history clear	Clears failure history.
set maint_port baud 115.2 k	Maintenance serial port speed.
set maint_port baud 57.6 k	Maintenance serial port speed.
set maint_port baud 38.4 k	Maintenance serial port speed.
set maint_port baud 19.2 k	Maintenance serial port speed.
set maint_port baud 9600	Maintenance serial port speed.

Command	Description
set maint_port baud 4800	Maintenance serial port speed.
set maint_port baud 2400	Maintenance serial port speed.
set maint_port baud 1200	Maintenance serial port speed.
set maint_port baud 300	Maintenance serial port speed.
set maint_port parity 7E1	Maintenance serial port settings.
set maint_port parity 7O1	Maintenance serial port settings.
set maint_port parity 7N2	Maintenance serial port settings.
set maint_port parity 8N1	Maintenance serial port settings.
set message transmission delay	Sets request-based delivery response delay (ms).
set message transmission periodic	Sets periodic message transmission.
set message transmission request	Sets message request-based delivery.
set message interval 2 ... 120	Sets message delivery interval in seconds.
set message port data	Delivers messages into data port.
set message port maintenance	Delivers messages into maintenance port.
set message type msg1_10x1540	Sets Msg1 with 10x1540 profile (with 1540 samples and 10 m resolution).
set message type msg1_base	Sets Msg1 without a profile.
set message type msg2_10x1540	Sets Msg2 with 10x1540 profile (with 1540 samples and 10 m resolution).
set message type msg2_base	Sets Msg2 without a profile.
set message type status	Sets status message.
set message type ld40_std_tg	Sets LD40 Standard Telegram.
set modem v21 answer	Sets modem to answer with v21.
set modem v21 originate	Sets modem to call with v21.
set modem v22 answer	Sets modem to answer with v22.
set modem v22 originate	Sets modem to call with v22.
set modem v22bis answer	Sets modem to answer with v22bis.
set modem v22bis originate	Sets modem to call with v22bis.
set modem off	Disables the communication module and uses serial line communication.
set name <string>	Sets the unit name.
set oper_mode standby	Sets standby mode. Profile sampling is inactive.
set oper_mode normal	Sets normal operation.
set port_timeout 0 ... 30	Sets the command line time-out to 0 ... 30 minutes. Zero disables.
set unit_id <character>	Sets the unit ID.
status	Prints the status message.
system	Lists system information: type, ID, SW version, HW modules, serial number.
version	Displays the SW version.

Table 9 Advanced Level Commands

Command	Description
back	Go back one security level. Go back to the user level commands.
get failure diag	Show failure diagnostics data.
get params algorithm	Prints cloud algorithm related parameters.
service replace_instr battery	Prints service instructions for replacing a battery.
service replace_instr cle_engine_board	Prints service instructions for replacing a CLE321 engine board.
service replace_instr clp_ac_power	Prints service instructions for replacing a CLP311 power unit.
service replace_instr clr_receiver	Prints service instructions for replacing a CLR321 receiver.
service replace_instr clt_transmitter	Prints service instructions for replacing a CLT521 transmitter.
service self_check	Runs the self-check.
service spare_part cle_engine mark	Marks CLE spare part status.
service spare_part cle_engine clear	Clears CLE spare part status.
service spare_part clt_transmitter mark	Marks CLT spare part status.
service spare_part clt_transmitter clear	Clears CLT spare part status.
service spare_part show_state	Shows spare part status of CLE and CLT.
service sw_update	Updates the software.
set data_acq autoadj on	Sets SW-control of data acquisition parameters.
set data_acq autoadj off	Disables SW-control of data acquisition parameters.
set data_acq meas_mode standard	Activates CL31 emulation mode. Maximum range 7700 m, 10 m resolution, laser pulse rate 10 kHz.
set data_acq meas_mode high_res	Activates CL31 emulation mode. Maximum range 7550 m, 5 m resolution, laser pulse rate 7 kHz.
set data_acq meas_mode high_end	Activates standard CL51 mode. Maximum range 15 400 m, 10 m resolution, laser pulse rate 6.5 kHz.
set data_acq power_save disable	Disables power-save mode.
set data_acq power_save enable	Enables power-save mode.
set data_acq power_save interval 30 ... 30 000	Power-save interval in seconds. Default is 60.
set data_acq receiver gain low	Sets receiver to low gain.
set data_acq receiver gain high	Sets receiver to high gain.
set data_acq transmit length_of_p short	Sets transmitter to short pulse.
set data_acq transmit length_of_p long	Sets transmitter to long pulse.
set data_acq transmit inlaser 0 ... 4095	Sets control value for laser pulse.
set factory calibr_outlaser	Starts automatic calibration of target outlaser.
set factory cross_talk	Calibrates factory crosstalk.
set factory opt_sensit	Sets optics sensitivity.
set factory outlaser 0 .. 2500	Sets target outlaser.
set factory win_clean	Sets window clean status for window cond. calibration.
set message angle_corr on	Heights in messages are corrected for the tilt angle.
set message angle_corr off	Heights in messages are not corrected for the tilt angle.
set message height_offset <value>	Sets height offset in current units. (Range is -304 ... 304 m or -1000 ... 1000 ft.) Positive values are added to and negative values are subtracted from the measured height.
set message manual_msg <string>	Sets a manual message. Empty string disables.

Command	Description
set message profile scale	Scaling factor for range gate data (%).
set message profile noise_h2 on	Range gates data is always range normalized, even noise.
set message profile noise_h2 off	Range gates data is range normalized, if backscatter is contained.
set message type cl31_msg1_10x770	Sets CL31 Msg1 with 10x770 profile.
set message type cl31_msg1_20x385	Sets CL31 Msg1 with 20x385 sample profile with 385 samples and 20 m resolution.
set message type cl31_msg1_5x1500	Sets CL31 Msg1 with 5x1500 profile.
set message type cl31_msg1_5x770	Sets CL31 Msg1 with 5x770 profile.
set message type cl31_msg1_base	Sets CL31 Msg1 without a profile.
set message type cl31_msg2_10x770	Sets CL31 Msg2 with 10x770 profile.
set message type cl31_msg2_20x385	Sets CL31 Msg2 with 20x385 profile.
set message type cl31_msg2_ 5x1500	Sets CL31 Msg2 with 5x1500 profile.
set message type cl31_msg2_ 5x770	Sets CL31 Msg2 with 5x770 profile.
set message type cl31_msg2_base	Sets CL31 Msg2 without a profile.
set message units feet	Reported heights unit is feet.
set message units meters	Reported heights unit is meters.
set message vv_limit ceiling	Sets vertical visibility ceiling limit (meters/feet). No vertical visibility will be reported above this limit. (Default: 2000 m).
set option humitter on	Enables the humitter option.
set option humitter off	Disables the humitter option.
set option sky_cond off	Disables the sky condition option.
set option sky_cond on 0 .. 99999	Enables the sky condition option with an activation code.

Data Messages

To ease the use of the Ceilometer CL51 and to ease the transfer from old ceilometer versions to the new one, the CL51 includes data messages used in CL31 and LD40. The CL51 provides the following data messages:

- CL51 Data messages 1 and 2
- CL51 Status message
- CL31 Data messages 1 and 2
- LD40 Standard Telegram

Each port can be set to transmit a specified message automatically. Alternatively, the port can be set to transmit the set message only when polled by a predetermined polling string of characters, or the polling string can contain the message identification.

NOTE

All characters are 7-bit USASCII.

↵ symbolizes Carriage Return + Line Feed (2 characters) throughout this document.

Start-of-Header, Start-of-Text, End-of-Text, End-of-Transmission, Carriage Return, and Line Feed are non-printing characters in most practical terminal use.

CL51 Data Messages No. 1 and 2

Data message No. 1 contains cloud height/vertical visibility measurement and elementary status information that enables a host system or operator to see that no warnings or alarms are present. This message also includes a range and sensitivity normalized backscatter profile that is suitable, for example, for a graphical data presentation or research purposes. In addition to the content of data message No. 1, data message No. 2 also includes sky condition data. Data messages 1 and 2 are described in Table 10 on page 61.

The backscatter profile includes data up to 15 km (50 000 ft), but clouds are reported only up to 13 km (43 000 ft).

The data resolution is 10 m (33 ft) in distance, and 20 bits (five hex-ASCII characters) in signal magnitude.

An example of the CL51 data message No.1 is presented below:

☎CLA10016☺	1st line	12 char.
30 01230 12340 23450 FEDCBA987654	2nd line	35 char.
00100 10 1540 098 +34 099 12 0621 L0112HN15 139	3rd line	49 char.
00000111112222233333 ... (5 x 1540 bytes)	4th line	7702 char.
☺1a3f♦	5th line	8 char.
	Total	7806 char.

An example of the CL51 data message No. 2 is presented below:

☎CLA10026☺	1st line	12 char.
30 01230 12340 23450 FEDCBA987654	2nd line	35 char.
3 0055 5 0170 0 //// 0 //// 0 ////	3rd line	42 char.
00100 10 1540 098 +34 099 12 0621 L0112HN15 139	4th line	49 char.
00000111112222233333 ... (5 x 1540 bytes)	5th line	7702 char.
☺1a3f♦	6th line	8 char.
	Total	7848 char.

For data lines with low bandwidth, there is also a base version of each message. In the short version of message No.1, lines 3 and 4 are left out. In the base version of message No.2, lines 4 and 5 are left out. In the table below, the data message types are summarized with the minimum bit rates and storage capacity. The minimum reporting interval is 6 s.

Table 10 CL51 Data messages No. 1 and 2

Message Number and Subclass	Message Name	Length (bytes)	Min bps (6 s)	Data/Month (6 s)	Min bps (30 s)	Data/Month (30 s)
16	msg1_10x1540	7806	19.2k	3220 MB	4800	644 MB
18	msg1_base	55	300	23 MB	300	5 MB
26	msg2_10x1540	7848	19.2k	3240 MB	4800	647 MB
28	msg2_base	97	300	40 MB	300	8 MB

The interpretation of the message lines is as follows:

1ST LINE

Example: ☎CLA10016☺

where

- ☎ = Start-of-Heading character
- CL = Ceilometers' identification string; always CL
- A = Unit identification character 0 ... 9, A ... Z
- 100 = Software level ID 100 ... 999
- 1 = Message number; message without sky condition data is = 1, with sky condition data is = 2
- 6 = Character for subclasses of message
 - 6 = 10 m x 1540 samples, range 15400 m (*msg1_10x1540*)
 - 8 = without a backscatter profile (*msg1_base*)

where

- ☺ = Start-of-Text Character
- ↵ = Carriage Return + Line Feed

2ND LINE

Example: 30 01230 12340 23450 FEDCBA987654↵

where

- 3 = First digit of line:
 - 0 = Detection status as follows: No significant backscatter
 - 1 = One cloud base detected
 - 2 = Two cloud bases detected
 - 3 = Three cloud bases detected
 - 4 = Full obscuration determined but no cloud base detected
 - 5 = Some obscuration detected but determined to be transparent
 - / = Raw data input to algorithm missing or suspect

- 0 = Second digit of line:
 - 0 = Warning and Alarm information as follows: Self-check OK
 - W = At least one Warning active, no Alarms
 - A = At least one Alarm active

- 01230 = If detection status is 1, 2, or 3: Lowest cloud base height
 If detection status is 4: Vertical Visibility as calculated
 If detection status is 0 or 5: ////

- 12340 = If detection status is 2 or 3: Second lowest cloud base height
 If detection status is 4: Highest signal detected
 If detection status is 0, 1, or 5: ////

- 23450 = If detection status is 3: Highest cloud base height
 If detection status is 0, 1, 2, 4, 5: ////

- FEDC = Alarm (A), Warning (W), and internal status (S) information. Each character is
 BA98 a hexadecimal representation of four bits, i.e. values between 0 and 9 are
 7654 presented with respective numbers and values 10, 11, 12, 13, 14, and 15 are
 presented with letters A, B, C, D, E, and F, respectively. As each of the 12
 characters represent the sum of four individual bits, the total number of bits is
 48 (b00-b47), with the following breakdown and interpretation:
 - F: b47 (8000 0000 0000) Transmitter shut-off (A)
 - b46 (4000 0000 0000) Transmitter failure (A)
 - b45 (2000 0000 0000) Receiver failure (A)

	b44	(1000 0000 0000)	Voltage failure (A)
E:	b43	(0800 0000 0000)	(spare) (A)
	b42	(0400 0000 0000)	Memory error (A)
	b41	(0200 0000 0000)	Light path obstruction (A)
	b40	(0100 0000 0000)	Receiver saturation (A)
D:	b39	(0080 0000 0000)	(spare) (A)
	b38	(0040 0000 0000)	(spare) (A)
	b37	(0020 0000 0000)	(spare) (A)
	b36	(0010 0000 0000)	(spare) (A)
C:	b35	(0008 0000 0000)	(spare) (A)
	b34	(0004 0000 0000)	(spare) (A)
	b33	(0002 0000 0000)	Coaxial cable failure (A)
	b32	(0001 0000 0000)	Ceilometer engine board failure (A)
B:	b31	(0000 8000 0000)	Window contamination (W)
	b30	(0000 4000 0000)	Battery voltage low (W)
	b29	(0000 2000 0000)	Transmitter expires (W)
	b28	(0000 1000 0000)	High humidity (W)
A:	b27	(0000 0800 0000)	(spare) (W)
	b26	(0000 0400 0000)	Blower failure (W)
	b25	(0000 0200 0000)	(spare) (W)
	b24	(0000 0100 0000)	Humidity sensor failure (W)
9:	b23	(0000 0080 0000)	Heater fault (W)
	b22	(0000 0040 0000)	High background radiance (W)
	b21	(0000 0020 0000)	Ceilometer engine board failure (W)
	b20	(0000 0010 0000)	Battery failure (W)
8:	b19	(0000 0008 0000)	Laser monitor failure (W)
	b18	(0000 0004 0000)	Receiver warning (W)
	b17	(0000 0002 0000)	Tilt angle > 45 degrees warning (W)
	b16	(0000 0001 0000)	(spare) (W)
7	b15	(0000 0000 8000)	Blower is on (S)
	b14	(0000 0000 4000)	Blower heater is on (S)
	b13	(0000 0000 2000)	Internal heater is on (S)
	b12	(0000 0000 1000)	Working from battery (S)
6	b11	(0000 0000 0800)	Standby mode is on (S)
	b10	(0000 0000 0400)	Self test in progress (S)
	b09	(0000 0000 0200)	Manual data acquisition settings are effective (S)
	b08	(0000 0000 0100)	(spare) (S)
5	b07	(0000 0000 0080)	Units are meters if on, else feet (S)
	b06	(0000 0000 0040)	Manual blower control (S)
	b05	(0000 0000 0020)	Polling mode is on (S)
	b04	(0000 0000 0010)	(spare) (S)
4	b03	(0000 0000 0008)	(spare) (S)
	b02	(0000 0000 0004)	(spare) (S)
	b01	(0000 0000 0002)	(spare) (S)
	b00	(0000 0000 0001)	(spare) (S)

3RD LINE (4TH LINE IN MESSAGE NO. 2)

Example: 00100 10 1540 098 +34 099 12 621 L0112HN15 139␣

where

00100	=	Parameter SCALE, 100 (%) is normal (0 ... 99999 possible)
10	=	Backscatter profile resolution in meters.
1540	=	Length of the profile in samples.
098	=	Laser pulse energy, % of nominal factory setting (0 ... 999)
+34	=	Laser temperature degrees C (-50 ... +99)
099	=	Window transmission estimate % (0 ... 100)
12	=	Tilt angle, degrees from vertical (0 ... 90)
0621	=	Background light, millivolts at internal ADC input (0 ... 2500)
L0112HN15	=	Measurement parameters (pulse Long/Short, pulse qty 0112x1024, gain High/Low, bandwidth Narrow/Wide, sampling 15/30 MHz)
139	=	SUM of detected and normalized backscatter, 0 ... 999. Multiplied by scaling factor times 10 ⁴ . At scaling factor 1.0 the SUM range 0 ... 999 corresponds to integrated backscatter 0...0.0999 srad ⁻¹ .

NOTE

This line is omitted if the message subclass is 5 or 8.

4TH LINE (5TH LINE IN MESSAGE NO. 2)

Example: 00000111112222233333.....␣ (5 x 1540 + 2 bytes)

The two-way attenuated backscatter profile with sensitivity normalized units (100000·srad·km)⁻¹ unless otherwise scaled with the SCALE parameter. Each sample is coded with a 20-bit HEX ASCII character set; msb nibble and bit first, 2's complement. The length of this line is equal to 5 times the length of the profile + 2. Note that the profile is not corrected with the tilt angle.

Using the SCALE parameter a total dynamic range of 29 bits can be achieved for this message.

The line ends with Carriage Return and Line Feed characters.

NOTE

This line is omitted if the message subclass is 5 or 8

5TH LINE (6TH LINE IN MESSAGE NO. 2)

Example: ⊕1a3f◆↵

where

- ⊕ = End-of-Text character
- 1a3f = Checksum, see below for calculation procedure
- ◆ = End-of-Transmission character
- ↵ = Carriage Return + Line Feed

CRC16 Checksum

The CRC16 checksum can be calculated using the following algorithm written in the C programming language:

```
/* 16-bit type. */
typedef unsigned short Word16;

/* Calculate CRC-16 value as used in CL51. */
Word16 crc16(const unsigned char *buf, int len)
{
    Word16 crc;
    Word16 xmask;
    int    i, j;

    crc = 0xffff;

    for (i = 0; i < len; ++i)
    {
        crc ^= buf[i] << 8;

        for (j = 0; j < 8; ++j)
        {
            xmask = (crc & 0x8000) ? 0x1021 : 0;
            crc <<= 1;
            crc ^= xmask;
        }
    }

    return crc ^ 0xffff;
}
```

The calculation of the checksum starts after the Start-of-Heading character and ends after the End-of-Text character, that is, the first character included is C and the last one included is End-of-Text.

CL31 Data Messages No. 1 and 2

CL31 messages follow the same format as the CL51 messages. The data resolution is 5 m/10 m/20 m (16 ft/33 ft/66 ft). When a CL31 message is selected, the CL51 will automatically switch to CL31 emulation mode. The measurement range is then 7700m and the resolution is either 5m or 10m depending on message type. The available messages are listed in Table 11 and Table 12 .

Table 11 Messages with 10 m Resolution (Standard Mode)

Message Number and Subclass	Message Name	Length (bytes)	Min bps (2 s)	Data/Month (2 s)	Min bps (12 s)	Data/Month (12 s)
11	cl31_msg1_10x770	3956	28.8k	4890 MB	4800	815 MB
12	cl31_msg1_20x385	2031	14.4k	2510 MB	2400	418 MB
15	cl31_msg1_base	55	300	68 MB	300	11 MB
21	cl31_msg2_10x770	3993	28.8k	4940MB	4800	423 MB
22	cl31_msg2_20x385	2068	14.4k	2560 MB	2400	425 MB
25	cl31_msg2_base	92	600	114 MB	300	19 MB

Table 12 Messages with 5 m Resolution (High Resolution)

Message Number and Subclass	Message Name	Length (bytes)	Min bps (3 s)	Data/Month (3 s)	Min bps (15 s)	Data/Month (15 s)
13	cl31_msg1_5x1500	7606	28.8k	6267 MB	9600	1253 MB
14	cl31_msg1_5x770	3956	14.4k	3260 MB	4800	625 MB
15	cl31_msg1_base	55	300	45 MB	300	9 MB
23	cl31_msg2_5x1500	7643	28.8k	6230 MB	9600	1260 MB
24	cl31_msg2_5x770	3993	14.4k	3290 MB	4800	660 MB
25	cl31_msg2_base	92	600	76 MB	300	15 MB

The interpretation of the message lines is as described in the previous chapter.

CL31 Data messages 1 and 2 of subclass 5 (without profile data) may be used in both 10 m and 5 m resolutions. A selection of these messages always activates the 10 m resolution (standard mode). If needed, users can change into the 5 m resolution (high resolution) by typing the following advanced level command: **set data_acq meas_mode high_res**. Thus, the above messages will work in 5 m resolution.

CL51 Status Message

The Status message displays the internal monitoring of the entire unit. It is mainly meant for testing and maintenance purposes. The Status message can be displayed by giving the **status** command.

An example of the status message is presented below:

```

☎CL0100S0☺
10 00850 // // // // // 000000000080

Alarms
  Tmit Shutoff OK      Transmitter OK
  Receiver          OK      Voltages      OK
  Ext Memory       OK      Light Pth Obs OK
  Rec Saturat     OK      Coaxial Cable OK
  Engine           OK

Oper Mode:  normal   Autoadj:  on
Meas Mode:  high_end Interval: 6.0 s
Power Save: disabled Sleep Int: 60 s

Transmitter          Receiver
  Pulse Len: long    Gain:      high
  Inlaser:  1745     Bandwidth: narrow
  Pulse Cnt: 32768   Smpl Rate: 15 MHz
  Pulse Frq: 6.5 kHz

Window Cnd: 100 %   Outlaser: 1064
Backg Rad:  2.4     103 %

Tilt Angle: 0.4     Humidity: N/A

Temperatures
  Internal: 23.7     External: 8.7
  DC Power: 22.6    Inclinom: 28.9
  Laser:    25.6     Blower:   8.3

Internal heater: off (auto)
Blower:         on (auto)
Blower heater:  on
Batt Use:       off

System Status:  OK
Suspect Module: none
☺
    
```

Message interpretation:

1ST LINE

The first line of the CL51 status message is structurally identical to the first line of the CL51 data message No. 1 (see section CL51 Data Messages No. 1 and 2 on page 60), except that the second to last character that identifies the message number, is always S0☺┘.

2ND LINE

The second line of the CL51 status message is structurally identical to the second line of the CL51 data message No. 1 (see section CL51 Data Messages No. 1 and 2 on page 60).

LINES 4 ... 9

Lines four to nine display the alarm status of the Ceilometer CL51. Should an alarm be present, the CL51 will invalidate the cloud data.

11TH LINE

Line 11 displays the operation mode and autoadjustment settings of the CL51. In normal use, the operation mode should be set to **normal** and autoadjustment should be set to **on**.

12TH LINE

Line 12 displays the measurement mode and measurement interval settings of the CL51. In normal use, the measurement mode should be set to **high_end**. By default the measurement interval is 6.0 s.

13TH LINE

Line 13 displays the power-save mode status and sleep interval settings of the CL51. In normal use, the power-save mode is **disabled**. If the power-save mode is on, the sleep interval indicates the interval when the CL51 does not measure.

LINES 15 ... 19

Lines 15 to 19 display the transmitter and receiver settings of the CL51.

Transmitter	Pulse Len	=	Pulse length, long in normal use (100 ns)
	Inlaser	=	Controls the peak laser power
	Pulse Cnt	=	Pulse count, the number of pulses during a single measurement cycle, 32768 by default
	Pulse Frq	=	Laser pulsing frequency (6.5 kHz)
Receiver	Gain	=	High by default, may be low in fog or heavy snow
	Bandwidth	=	Narrow by default
	Smpl Rate	=	Receiver signal sampling rate, defines the vertical resolution of the measurement. Default is 15 MHz which corresponds to a 10 m resolution.

21ST LINE

Line 21 displays the window contamination status and outlaser settings of the CL51. The estimated transparency of 90 % to 100 % means that the window is clean. It is recommended that the window is cleaned whenever there is a window contamination warning, that is, the transparency is estimated as 70 % or lower.

Outlaser is the laser pulse energy measured with the CLM311 Laser Monitor Board. The value underneath the outlaser value (on line 22) refers to the percentage of the laser power relative to the factory setting. The embedded software will maintain this value between 95 % and 105 %.

22ND LINE

Line 22 displays the background radiance value of the CL51. The background radiance varies according to the background luminance condition and temperature. The following value, outlaser percentage, is described above.

24TH LINE

Line 24 displays the tilt angle in degrees from vertical. Humidity measurement is visible if the option is activated.

LINES 26 ... 29

Lines 26 to 29 display temperature values in degrees centigrade. These values are used for the automatic control of the internal heaters and the blower, and for status monitoring.

LINES 31 ... 34

Lines 31 to 34 display the status of the internal heater, the blower, the blower heater, and the battery.

36TH LINE

Line 36 displays a summary of the system status. It should be **OK**. Alternatively, it can display the texts **Warning** or **Alarm/Fail**, if there are warnings or alarms present.

37TH LINE

Line 37 displays the automatic diagnosis in case of a failure. The system suggests a module to be replaced. If there is a secondary option, it will be stated in parentheses.

38TH LINE

Example: ☹␣

where

- ☹ = End-of-Text character
- ␣ = Carriage Return + Line Feed

The status message can also be used in the CL31 emulation mode, with 7700 m measurement range and 5 m or 10 m resolution. The CL31 emulation mode is activated using one of the commands `set data_acq meas_mode standard` (10 m resolution) or `set data_acq meas_mode high_res` (5 m resolution).

LD40 Standard Telegram

The Ceilometer CL51 includes one Ceilometer LD40 data message. This is the standard telegram 'X1TA'. This message is given in clear text and includes cloud heights and additional meteorological data, date, time, sensor address, and status information of the instrument.

An example of the 'X1TA' telegram and a message interpretation are presented below:

```
ⓈX1TA_8_015_00.00.00_00:00_00875_11150_NODET_0100_0325_NOD
T_11300_11600_+025_ft_01_00000000_96 ↵ Ⓢ
```

where

Ⓢ	= Start-of-text character
X	= Sensor type (X LD40)
1	= Sensor ID number (0 to 9..ABC..MN)
TA	= Text telegram
8	= Instrument type, Always 8 = LD40
015	= Telegram update time or message interval in seconds
00.00.00	= Always (Date N/A)
00:00	= Always (Time N/A)
00875	= First cloud layer
11175	= Second cloud layer
NODET	= Third cloud layer (in this case: not detected)
0100	= Penetration depth of laser beam into first cloud layer
0325	= Penetration depth of laser beam into second cloud layer
NODT	= Penetration depth of laser beam into third cloud layer
11300	= Vertical visibility
11600	= Maximum range of detection
+025	= Cloud height offset (in this case the ceilometer is situated 25 ft above the runway level)
f	= Dimensions of all values between byte 26 and byte 76 (ft or m_)
00	= Always (Precipitation index. N/A)
00000000	= System status and messages
96	= Checksum (This value is only an example; the correct value may be different from this one.)
↵	= Carriage return + Line feed
Ⓢ	= End-of-transmission character

NOTE

The notation '_' stands for a space character.

Telegram Structure Remarks

- a. Spaces (20 hex) always appear with the following bytes: 5, 7, 11, 20, 26, 32, 38, 44, 49, 54, 59, 65, 71, 76, 79, 82, 91.

The only other byte that may contain a <SPACE>, is byte 78, provided that the dimension is in meters.

Numbers are always given with the leading zeros as in bytes 27 to 31 in the example.

- b. NODET (and NODT) indicates that the value in question has not been detected because there was only one cloud layer or no cloud layer at all, for example.

Like any measured value, NODET also contains information about the result of the measurement.

NODET may appear instead of cloud layers, minimum vertical extensions of clouds, and vertical visibility.

- c. When bytes 83 to 90 signal a CL51 alarm, all cloud detection values within the telegram are replaced by minus signs (-, 2D Hex). For example:

----- is shown instead of bytes 27 to 31.

- d. All values given are height above the runway level; the Ceilometer CL51 itself might be located above or below the runway level. Therefore, byte 72 must always contain a sign byte, either + or -.

Failure and Warning Messages

Bytes 83 to 89 of the LD40 standard telegram inform about warnings and errors. A '0' signifies that no error of that error group has happened.

An alarm will lead to data telegrams to contain invalid data. A warning status does not cause invalid data.

The following tables describe how the CL51 is mapped to the LD40 error groups. See Table 13 below for the definition of the different error groups.

Table 13 Error Group Definition

Error Group	Byte No.	Description
1	83	Engine board and voltages
2	84	Light path, receiver saturation and window condition.
3	85	Receiver and coaxial cable
4	86	Transmitter

Error Group	Byte No.	Description
5	87	Memory failure and general warnings
6	88	Temperature regulation
7	89	Always 0. Not used.

Tables from Table 14 to Table 20 describe each single error code in different error groups.

Table 14 Error Group 1 (Byte 83)

Error Code	Description
0	Status OK
1	Engine or voltage failure (A)
2	Not used
3	Not used
4	Not used
5	Not used
6	Not used

Table 15 Error Group 2 (Byte 84)

Error Code	Description
0	Status OK
1	Light path obstruction (A) or Window contamination warning (W)
2	Receiver saturation (A)

Table 16 Error Group 3 (Byte 85)

Error Code	Description
0	Receiver OK
1	Not used
2	Not used
3	Not used
4	Receiver failure (A) or Coaxial cable failure (A) or Receiver warning (W)
5	Not used
6	Not used

Table 17 Error Group 4 (Byte 86)

Error Code	Description
0	Transmitter OK
1	Transmitter expires (laser power low) (W)
2	Transmitter failure
3	Not used
4	Not used
5	Not used
6	Transmitter shutoff (laser temperature too high) (A)

Table 18 Error Group 5 (Byte 87)

Error Code	Description
0	Status OK
1	Laser monitor failure (W) or Blower failure (W) or High radiation warning (W) or Engine warning (W) or Tilt angle warning (angle is > 45 degrees) (W) or Battery voltage low (W) or Battery failure (W) or Humidity high (option) (W) or Humidity Sensor failure (option) (W)
2	Not used
3	Memory failure (A)
4	Not used

Table 19 Error Group 6 (Byte 88)

Error Code	Description
0	Temperature regulation OK
1	Heater failure (W)

Table 20 Error Group 7 (Byte 89)

Error Code	Description
0	Always 0 (Data transmission. N/A)
1	Not used
2	Not used
3	Not used
4	Not used
5	Not used
6	Not used
7	Not used
8	Not used

Checksum Calculation

The checksum of a data or a command telegram is calculated by computing the sum of all signs (alphanumerical signs and control codes such as STX, EOT CR, LF, except the checksum bytes itself), build the two's complement and take the lower byte of this result.

The higher half-byte and the lower half-byte - converted to a visible ASCII character - is the checksum.

See the following example with the **polling** command:

Telegram:

STX H0C!X1P-----83 EOT

1. Compute the sum:

$$\text{Sum} = \text{STX} + \text{'H'} + \text{'0'} + \text{'C'} + \text{'!'} + \text{'X'} + \text{'1'} + \text{'P'} \\ + 10 \times \text{'-'} + \text{EOT}$$

$$\text{Sum} = 0x02 + 0x48 + 0x30 + 0x43 + 0x21 + 0x58 \\ + 0x31 + 0x50 + 10 \times 0x2D + 0x04$$

$$\text{Sum} = 0x037D \text{ HEX} = 893 \text{ DEZ}$$

2. Building the two's complement:

The two's complement is built by inverting the binary representation of the sum and adding 1:

$$2\text{Com} = \neg \text{Sum} + 1 = \neg 0x037D + 0x01 = 0x0C83 \text{ HEX} \\ = 3203 \text{ DEZ} .$$

3. Take lower byte and build ASCII-character:

The lower byte of 2Com is 0x83 HEX, so the high byte of the checksum is 8 and the low byte is 3:

$$\text{Checksum} = 83$$

Manual Message

The ceilometer can be set to transmit user defined cloud heights and status information. User can set a cloud message in the format of line 2 of any real cloud message (for example, Message No. 1). The message is a string and the maximum length is 33 characters. If the length is less than 33 characters, the remaining length will be padded with spaces. The end of a string is determined by a new line and the leading spaces are omitted. This message is volatile. The manual message command is behind the password "advanced". Below is an example of a manual message:

```
CEILO > advanced
Service password accepted.
CEILO > set message manual_msg "30 00200 01000 05000
000000000000"
OK
```

The **get params message** command displays the current manual message.

To return to the normal messages, give an empty string:

```
CEILO > set message manual_msg
```

```
OK
```

The manual message is intended for testing purposes. After reset, the normal message takes effect.

Polling Mode

A port can be set to transmit a message only when polled by a predetermined polling string of characters. The polling string can contain the message identification.

The CL51 unit can be assigned an identification of one-character digit or letter. The factory setting is 0 (zero).

The polling mode is activated with the following command:

```
CEILO > set message transmission request
```

Returning to the normal autosend mode is done using the following command:

```
CEILO > set message transmission periodic
```

The polling string format is as follows:

```
<Enq> CLIdNo ↵
```

where

- Enq = Character ENQUIRE = ASCII 05H = control-E.
- CL = Fixed ceilometer identifier; CL for CL51 or CL31 messages.
- Id = Identification character, 7-bit printable ASCII character.
- No = Optional message identifier; 1, 2. The identifier 1 returns the default option for data message No. 1. To return a particular subclass message, use one of the following identifiers: 11, 12, 13, 14, 15, 16 or 18. Data message No. 2 is requested similarly: 2, 21, 22, 23, 24, 25, 26 or 28. The identifier S returns the Status message.
- ↵ = ENTER (Carriage Return) + Line Feed.

The following are examples of the polling command:

```
<Enq> CL116<Enter>    Message 1, subclass 6 from Ceilometer  
                        No.1
```

NOTE

If the *id* character in a polling string is replaced with a blank space, all ceilometers on the line will respond. Accordingly, if *No* is a blank space, the CL51 sends the default message. In the RS-485 mode *id* is always needed, the blank space is ignored.

The LD40 message is polled by sending an LD40 Command Telegram. See Table 21 below for a description of the command telegram frame of a polling request.

Table 21 Command Telegram Description 'Polling Request'

Byte	Example	Description
0	<STX>	02 HEX (Start of text)
1	H	Command telegram header
2	0	Command telegram header
3	C	Command telegram header
4	!	Command telegram header
5	X	Instrument type --> Ceilometer
6	1	Sensor Id number (0 to 9..ABC..MIN). In this case --> 1
7-17	P-----	Command indicator --> P (polling), byte 8-17 not used and filled with '-'
18-19	83	Checksum (Hex-coded two's complement of the sum of bytes from 0 to 20, excluding bytes 18 and 19.
20	<EOT>	04 Hex (End of transmission)

CHAPTER 6

MAINTENANCE

This chapter provides information that is needed in basic maintenance of the Ceilometer CL51.

Periodic Maintenance

Periodic maintenance is normally limited to window cleaning. In addition, warnings and alarms should be checked regularly with the maintenance terminal or another terminal or PC with a serial connection (see section CL51 Status Message on page 68). Proper function of the window blower, the only mechanically moving part, is automatically checked once an hour. Any malfunction is reported in the data and status messages.

Alarms and Warnings

The data message has to be checked for alarms and warnings on a regular basis. The second character in line two contains warning and alarm information indicating the present device status as follows:

0	Self-check OK
W	At least one warning active, no alarms
A	At least one alarm active

In case there is an active alarm or warning, more information is given at the end of the second line as a binary code indicating the cause. The status message gives detailed information about the failure. See section Data Messages on page 60.

Repair and service must be done according to the instructions in Chapter 7, Troubleshooting on page 83 and Chapter 8, Repair on page 91.

Cleaning

Data messages include a warning that informs when the window is contaminated. After the system has detected contamination on the window, it will start the blower, which is designed to remove light contaminants and dry off rain drops. If the blower cannot remove the contamination, the CL51 will issue a **Window Contaminated** warning indicating that the window must be manually cleaned.

To clean the window, proceed as follows:

1. Flush the window with clean water to remove coarse grains. Remember to keep the enclosure door closed. Do not use pressure cleaners.
2. Clean the window with a soft, lint-free cloth moistened with a mild detergent. Be careful not to scratch the window surface.

While cleaning the window, you can also check the operation of the window blower. Unless it is already running, the blower should start when you block the laser beam with the cleaning cloth for some 15 seconds or more. This will verify that the blower is functional. If there are no low clouds, precipitation, or fog present, the blower should stop after the window is cleaned. In case of a malfunction, the window blower has to be replaced.

Window Contamination Measurement Calibration

After 5 years of operation, calibrate the window contamination measurement.

In addition, if the CL51 system starts issuing **Window Contamination** warnings frequently without a real reason, this may indicate that the window is worn out or the window contamination measurement has drifted. In that case, the window contamination measurement can be calibrated to ensure proper functioning.

To calibrate, do the following:

1. Check the sky condition. In case of fog, smoke, precipitation or an otherwise unclear sky, use the termination hood (CL51TERMHOOD) in calibration.
2. Make sure that the window is cleaned.
3. Open the command line and enter the Advanced level by giving the **advanced** command.
4. Give the **set factory win_clean** command.

The calibration is carried out automatically.

NOTE

If the window is visibly worn out, replace it.

Checking Door Gasket

The measurement unit door utilizes an electrically conductive gasket to suppress electromagnetic radiation. When the door is opened, check that the gasket and the opposite contact surfaces are clean. If necessary, use a wet cloth for cleaning.

Checking Battery

Check the battery condition annually. If any signs of aging such as a bulging battery case, white powder or residue near the battery vent, leaking electrolyte, or corroded terminals are observed, replace the battery. Lead acid batteries may age in 3 to 5 years time and result in a rupture and loss of electrolyte.

NOTE

When disposing of old batteries, be sure to follow local environmental regulations.

NOTE

In freezing temperatures there is a danger of battery rupture if the battery is completely discharged. Do not store empty batteries in freezing temperatures. Replace the battery if signs of mechanical rupture are observed.

Storage

If the CL51 is stored unpacked for extended times in an unconditioned area, keep caps on all external connectors. Keep the measurement unit door closed and also keep a dust cover on the window during long periods of storage.

Save the container for future transport use. For transportation, the equipment must be placed and padded into the container in the same way as initially received.

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CHAPTER 7

TROUBLESHOOTING

This chapter describes common problems, their probable causes and remedies, and contact information for technical support.

Troubleshooting Procedure

The goal of troubleshooting is to locate the cause for the potential problem. Failure situations usually are caused by dirt in optics or unclarity of the optical path. Also external conditions or the following replaceable subassemblies may be the source of problems:

- CLE321 Ceilometer Engine Board
- CLT521 Ceilometer Transmitter
- CLR321 Ceilometer Receiver
- CLM311 Laser Monitor Board
- CLP311 AC Power
- CLB311-115/230 Blower
- CLH311-115/230 Heater
- 226296 Coaxial cable
- 4592 Battery

If damage is suspected in a subassembly or a board, replace it with a spare part and send the defective part to Vaisala for repair/replacement.

NOTE

Replacements must only be performed by qualified maintenance personnel, and they must be done according to the instructions in Chapter 8, Repair. As a principle, customer made repairs are restricted to the replacement of subassemblies.

Accessing Diagnostic Information

During normal operation, the CL51 continuously monitors its internal status and regularly checks the blower and the heater. The CL51 automatically analyzes the diagnostic test results and reports potential failures with every data message.

The CL51 automatically identifies the potentially faulty subassemblies. If this does not help, see Table 22 on page 87, Table 23 on page 88 and Table 24 on page 89 for probable causes for warnings, alarms, and other typical faults. You also can use these tables to rule out any problems related to cable connections or the clarity of the window or optical path.

Equipment for Troubleshooting

To establish a service connection to the CL51 you need to have a maintenance terminal which can be a palmtop computer with an RS-232 Interface or a PC with serial interface, Maintenance cable QMZ101, and any terminal program. The CL-VIEW software can be used for this purpose. If you perform the operation check indoors, you need to have an Optical Termination Hood (CL51TERMHOOD) which absorbs the laser light that would otherwise reflect from the ceiling and possibly saturate the receiver.

NOTE

The maintenance connection can also be established through the data line if, for example, the ceilometer is out of use. This will stop the data flow for as long as the command line is kept open.

Troubleshooting Instructions

To check the normal operation of the CL51, proceed as follows:

1. Clean the window carefully with a soft, lint-free cloth moistened with a mild detergent. Be careful not to scratch the window surface.
2. If you are indoors, put the optical termination hood (CL51TERMHOOD) on the ceilometer window. To the ceilometer, this represents a clear, nighttime sky.
3. Connect the maintenance terminal to the maintenance port at the bottom of the CL51. Turn on both the CL51 and the maintenance terminal. If you are using the palmtop or the CL-VIEW program for the first time, make the necessary installations according to the manuals of these products.

4. Verify that the ceilometer starts operating properly. A quick status check can be made by looking at the LEDs on the CLE321 board (see Figure 26 on page 99). After the initialization routines, the **Laser on** LED should start blinking at 6-second intervals. If all the key modules are ok, all six diagnostic LEDs should light up.
5. A blower check is done during the first 5 minutes, during which the blower is running. The automatic check also verifies the functioning of the blower heater. The result of this check is available 5 minutes after starting the unit and it is indicated by the **CLB ok** LED. It also is displayed in the status message.
6. To get the failure status message, type the **open** command and press ENTER on the maintenance terminal (PC) keyboard.

A CEILO > prompt should appear. Give the **get failure status** command and press ENTER.

An example of the response is as follows:

```
Alarms
Tmit Shutoff  OK      Transmitter  ALRM
Receiver      OK      Voltages    OK
Ext Memory   OK      Light Pth Obs OK
Rec Saturat  OK      Coaxial Cable OK
Engine       OK

Warnings
Window Contam OK      Battery Low  OK
Transm Expire OK      Humid High   OK
Blower       OK      Humid Sensor OK
Int Heater   OK      High Rad     OK
Engine       OK      Battery      OK
Laser Monitor OK      Receiver     OK
Tilt Angle   OK

System Status:  FAIL
Suspect Module: CLT
```

The two last lines in the status message will indicate if there are warnings or alarms present. The **Suspect module** line indicates the sub unit that is suspected to be faulty. In this example, it is the Ceilometer Transmitter CLT521.

7. Wait until the 5-minute blower check is over and check the result from the status message. After this, place a piece of white paper on the ceilometer window. The blower should start within 1 minute. Remove the paper. The blower should stop within 8 minutes.
8. If there are clouds present, compare the ceilometer measurement with a qualified weather observer's height approximation.
9. In case there are no clouds present and if the site is suitable, do a hard target test. Turn the measurement unit 90 degrees and aim it on a fixed target (such as a wall or a forest front).

The minimum distance to a hard target should be 300 meters (1000 ft). The backscatter signal from a hard target is very strong compared to the signal from a cloud. The receiver may saturate if the distance is too short.

CAUTION

When tilting the unit, make sure that nobody is watching the beam with binoculars or other magnifying optics.

Disable the automatic angle correction with the following commands:

```
CEILO > SET MESSAGE ANGLE_COR OFF
```

```
CEILO > CLOSE
```

Compare the ceilometer's distance reading to a reference measurement.

Warning and Alarm Messages

This section describes different warning and alarm messages.

Table 22 CL51 Status, Warnings

Status Message Info	Reason	Instructions
Window contamination warning (appears from time to time and lasts < 5 min).	Usually drizzle drops on the window.	The blower will clean the window. If clouds are detected, the height information is correct. If no clouds are detected, it is possible that high clouds are missed.
Window contamination warning (continuous).	Bird droppings, leaves, dust etc. have contaminated the window.	Clean the window.
Battery low warning	The unit has been powered too long using the backup battery.	Connect the line voltage or replace the battery.
	Recharging of the battery has failed.	If the battery is old, replace it. If the battery is OK, check the operation of Ceilometer Engine Board CLE321.
Transmitter expires warning.	Laser diode is too old.	Replace Transmitter CLT521. The measurement data is valid, but it is possible that some clouds are missed.
High humidity warning (option)	Relative humidity > 85 %. Water has been condensed inside the ceilometer. Leakage in the enclosure or leakage in the door.	Take the ceilometer inside, open the maintenance door and let it dry in a warm air conditioned place. Condensed water on optical surface may disturb the measurement. There is a danger of short circuits.
Blower failure warning.	Blower cable is not connected.	Check that the blower cable is connected.
	Window blower circuit breaker is not ON.	Check that the window blower circuit breaker is ON.
	Line voltage level is not correct.	Check that the line voltage is present and correct.
	Blower is stuck.	Check if visible obstacles disable blower operation.
	Blower is damaged.	Replace the blower.
Humidity sensor failure warning (option)	Humidity sensor is not connected.	Connect the humidity sensor or disable the option in the software.
	Humidity sensor is damaged.	Replace the humidity sensor.
Heater fault warning	Window blower circuit breaker is not ON.	Check that the window blower circuit breaker is ON.
	Line voltage level is not correct.	Check that the line voltage is present and correct.
	Heater is damaged.	Replace the heater.
High background radiance warning	Ceilometer is pointing directly to the Sun.	In case there are no alarms, the measurements are OK. If there is an alarm, the measurements are invalid.
Ceilometer Engine Board failure warning	Non-critical fault in Ceilometer Engine Board CLE321.	Replace Ceilometer Engine Board CLE321.
Battery failure warning	Battery is dead.	Replace the battery.

Status Message Info	Reason	Instructions
Laser monitor failure warning	Laser power monitor board CLM311 has failed.	Replace CLM311.
	Laser power measurement on Ceilometer Engine board CLE321 has failed.	Replace CLE321.
Receiver warning	A non-critical CLR321 Receiver failure.	Replace CLR321.
Tilt angle > 45° warning	The unit is not correctly installed or the tilt angle is larger than 45°.	Check the installation. The height measurement accuracy is lost with tilt angles greater than 45°.

Table 23 CL51 Status, Alarms

Problem	Reason	Instructions
Transmitter shut-off alarm (Laser temperature > 85°C)	Direct sunlight has heated the laser.	Wait for the Sun to exit the field-of-view. CL51 will return to normal operation.
	Environment temperature too high.	Check if there is a specific reason for the high temperature.
Transmitter failure alarm	Laser is worn out or damaged.	Replace Laser Transmitter CLT521.
	Laser does not get electrical power.	Check from the status message that the line Voltages is marked OK .
Receiver failure alarm	Receiver CLR321 is damaged.	Replace CLR321.
	Loose cable connection.	Check that the cables from Receiver CLR321 and Ceilometer Optics Unit CLO511 are undamaged and correctly connected.
	Receiver test not operating.	Check that the Optics Unit CLO511 is not misplaced or damaged.
Voltage failure alarm	Ceilometer Engine Board CLE321 is damaged.	Replace CLE321.
Memory error alarm	A failure in the CLE321 memory.	Replace CLE321.
Light path obstruction alarm	Window is badly contaminated or severely scratched.	Clean the window or in case of damage, replace CLW511.
	Something blocks the laser beam.	Check the clarity of the optical path.
Receiver saturation alarm	Ceilometer is pointing directly to the Sun.	Wait for the Sun to exit the field-of-view. CL51 will return to normal operation.
	Something is partially blocking the laser beam.	Check the clarity of the optical path.

Table 24 CL51 Status, Miscellaneous Problems

Problem	Reason	Instructions
CL51 does not start, no LEDs are lit	Power is not connected.	Check that both the main and the battery switches are in the ON position. Check the presence and correctness of the line voltage. Also check that the battery is OK.
	Loose cable connection.	Check the cable connections.
Laser on LED is not blinking but the Status LED is lit.	Operation mode is standby.	Connect the maintenance terminal and check if the operation mode is normal.
	CLE321 is damaged.	Replace CLE321.
Data message is missing.	Dialogue is not operating.	Check the cable connections. Open the terminal.
	Wrong communication parameters.	Check the communication parameters (number of bits, parity, etc.).
	Wrong data port.	Open the terminal program and give open command and then get params message command. Check that the PORT is set to DATA.
	Operation mode is standby.	Open the terminal program and first give the open command and then the status command. Check that the OPERATION MODE is NORMAL.
Cloud detection is missing.	Equipment failure.	Open the terminal program and give open command and then get failure status command. Check the alarms and warnings. If there are no alarms or warnings in the data message, contact Vaisala.
The capability to detect high clouds is reduced.	Low receiver gain (no fog or snow).	Check the automatic receiver gain setting in the status message. If it is low, check that the window is clean. Check that the optical path is clear. Visually check that the lens is clean.
	Extensive amount of dirt or water droplets on the window and a failure in the diagnostics.	Check the window clarity. Check the blower operation by giving the service self_check command and check that the blower works.

Technical Support

For technical questions, contact the Vaisala technical support via e-mail at helpdesk@vaisala.com.

For contact information of Vaisala Service Centers, see www.vaisala.com/services/servicecenters.html.

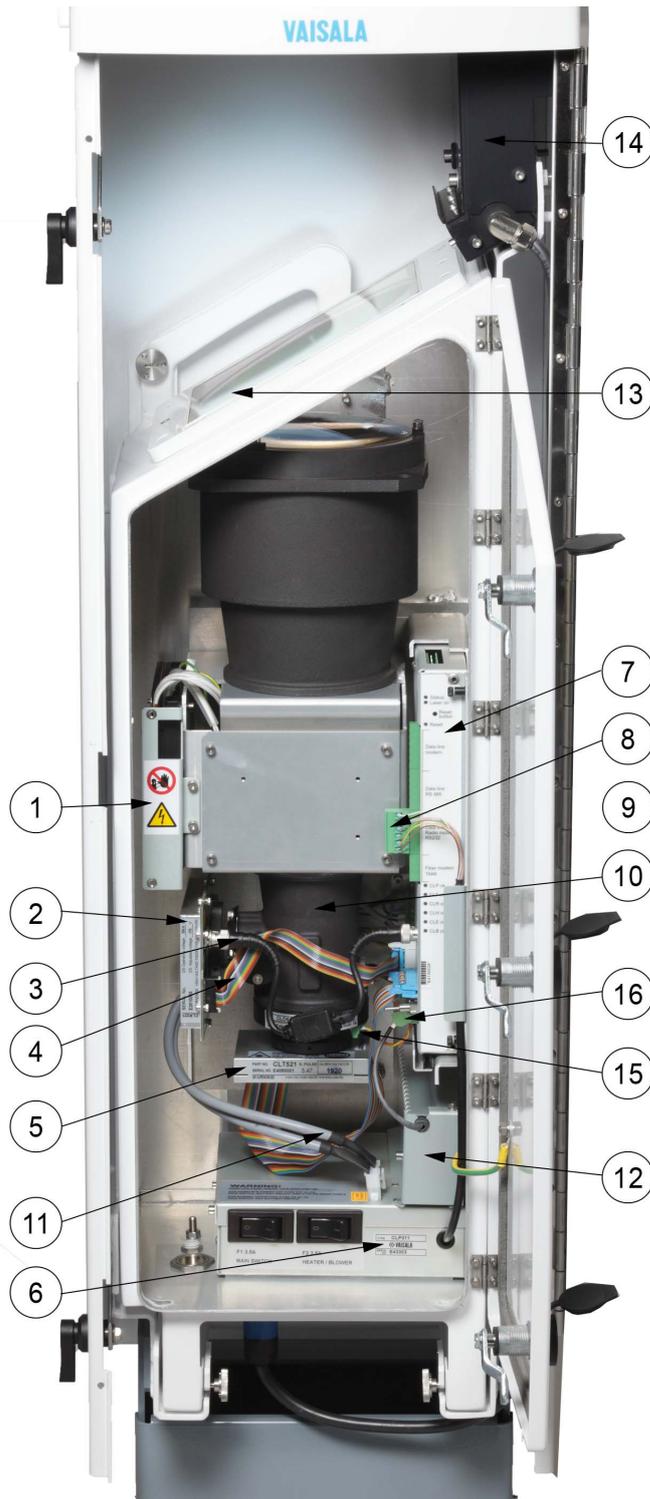
CHAPTER 8

REPAIR

This chapter provides information on how to remove and replace different parts of the product.

Table 25 Available Spare Parts

Spare Part Code	Common Name
226116	Battery (Lead Dry, 12V 2.1Ah)
CLB311-115SP	Window Blower 115VAC
CLB311-230SP	Window Blower 230VAC
CLE321HRSP	Engine board CLE321 for CL51
CLH311-115SP	Inside Heater 115VAC
CLH311-230SP	Inside Heater 230VAC
CLHUMITTERSP	Humitter
CLM311SP	Laser Monitor Board
CLP311SP	AC Power
CLR321SP	Ceilometer Receiver CLR321
CLT521SP	Ceilometer Transmitter CLT521
CL51TERMHOODSP	Optical Termination Hood
CLW511SP	Window Assembly
CT35022SP	Shock Absorber Kit
CT35324SP	Power cable (115V)
CT3838SP	Data Cable
CT3839SP	Power cable (230V)
DMX501SP	Modem Module
226296SP	Coaxial Cable
TERMBOX-1200SP	Termination Box with overvoltage protection
CLTERMBOXSP	Termination Box
QMZ101SP	Terminal Cable for MAWS
CL31USBCABLESP	CL31 USB Cable
CL51RADIOKITSP	Radio Modem Kit
CL51BIRDKITSP	Bird deterrent (223133)



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Figure 22 CL51 Maintenance Parts

The following numbers refer to Figure 22 above:

- 1 = Internal heater CLH311
- 2 = Ceilometer Receiver CLR321

The following numbers refer to Figure 22 above:

- 3 = Coaxial cable
- 4 = Receiver ribbon cable
- 5 = Ceilometer transmitter CLT521
- 6 = Ceilometer AC power CLP311
- 7 = Ceilometer engine board CLE321
- 8 = Data line connector
- 9 = Optics Unit CLO511
- 10 = Transmitter ribbon cable
- 11 = AC power cables
- 12 = No-break battery 4592
- 13 = Window CLW511
- 14 = Window Blower CLB311
- 15 = Laser Monitor Board CLM311
- 16 = Battery cable

Replacing Window CLW511

Refer to number 13 in Figure 22 on page 92.

NOTE

The Ceilometer Window CLW511 is recommended to be replaced indoors to prevent water and other contamination from getting into the measurement unit.

To replace the Ceilometer Window CLW511, you need a 2.5 mm Allen-key and a screwdriver.

Then proceed as follows:

1. Open the measurement unit door with the special key provided with the unit. Then switch off the power with all three switches (F1, F2, and Battery). For the location of the switches, see Figure 15 on page 40 and Figure 16 on page 41.

WARNING

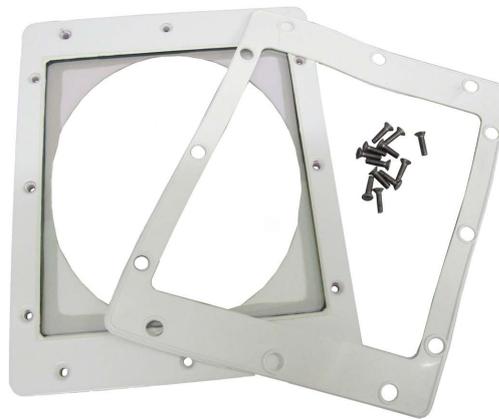
Disconnect the power cable from connector J2 before continuing!

2. Close the door and remove the measurement unit. To do this, loosen the three attachment screws (marked A in Figure 6 on page 27) on the back of the measurement unit, disconnect the blower cable from connector J1 (see Figure 11 on page 34) and pull out the unit.

3. Loosen the 12 screws on the frame of the window and remove the window by lifting it out with the screws attached. Also remove any pieces of the old gasket.
4. Use some solvent to clean the surface of the measurement unit before attaching the new window. Also check that the gasket on the window is undamaged and in place.

NOTE

Avoid touching the new window with your bare hands as it may get scratched. Also avoid touching the clean window surface as it may get contaminated.



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Figure 23 Window CLW511

5. Place the window on the measurement unit and attach the 12 screws with your fingers to prevent the window from sliding off its place.
6. Then tighten the screws in a crosswise order to allow the window gasket to tighten evenly. For example, you can first tighten the screw on top of the window frame, then the one on the bottom, then the one on the left, and the one on the right. Tighten the remaining eight screws in a clockwise order, in such a way that you first tighten one screw and then the one opposite to this, then the one next to the first screw and so forth. After tightening these eight screws, you should retighten the first four screws.

NOTE

Remember to use a thread-locking compound to the window screws before final tightening.

7. After attaching the window, clean it properly. See section Cleaning on page 80.

8. Place the measurement unit inside the shield, reconnect the blower cable to connector J1, and tighten the three attachment screws (marked A in Figure 6 on page 27).
9. Connect the power cable to connector J2.
10. Switch on the power with all three switches. Wait until the **Laser on** LED starts blinking at 6-second intervals. Make sure that all six diagnostic LEDs are lit. Refer to Figure 26 on page 99.

The ceilometer unit should now return to normal operation. Verify that the unit is working properly and that there are no failures with the system. If failures exist, separate troubleshooting may be necessary.

Replacing Ceilometer Laser Transmitter CLT521

Refer to number 5 in Figure 22 on page 92.

WARNING The Ceilometer Transmitter CLT521 emits invisible laser radiation which is harmful to the eye if viewed at a short distance. Never remove the Ceilometer Transmitter from its normal position without first switching off both the line and the battery power and detaching the transmitter ribbon cable from the Ceilometer Engine Board CLE321.

CAUTION Servicing the equipment must only be performed by qualified maintenance personnel.



Figure 24 Laser Transmitter CLT521

The transmitter should be replaced if the ceilometer unit has been generating warnings and alarms, and a malfunction with the operation of the transmitter has been detected.

To replace the Ceilometer Laser Transmitter CLT521, you will need a 2.5 mm Allen-key.

Then proceed as follows:

1. Open the measurement unit door and confirm that there is an active transmitter failure. In case of a transmitter failure, the **CLT ok** LED will be turned off. Refer to Figure 26 on page 99.
2. Switch off the power with all three switches (F1, F2, and Battery). For the location of the switches, see Figure 15 on page 40 and Figure 16 on page 41.

WARNING Disconnect the power cable from connector J2 before continuing!
--

3. Detach the transmitter ribbon cable (refer to number 10 in Figure 22 on page 92) from the Ceilometer Engine Board CLE321.
4. To detach the transmitter, loosen the transmitter ring by turning it to the right (counterclockwise seen from the direction of the ceilometer window). As the transmitter ring is not knurled use the 2.5-mm Allen key as a lever. Remove the transmitter from the unit.
5. If the new transmitter has its laser and attachment ring protected by a plastic cap, remove it carefully by rotating the cap counterclockwise and pulling it outwards. Avoid using much force. Check that no plastic remains are left on the threads or on the laser.
6. Place the new transmitter to its place and tighten the transmitter ring in such a way that the labels of the transmitter face the measurement unit door.

CAUTION When tightening the transmitter, avoid applying force to the transmitter enclosure. If the transmitter starts to rotate along when the ring is tightened, stop the transmitter from rotating by hand, but do not apply any unnecessary force. Otherwise the optical centering of the laser diode may be lost, resulting in loss of cloud detection.
--

7. Connect the transmitter ribbon cable to the CLE321 board.
8. Connect the power cable to connector J2.
9. Switch on the power with all three switches. Wait until the **Laser on** LED starts blinking at 6-second intervals. Ensure that all six diagnostic LEDs are lit. Refer to Figure 26 on page 99.

The ceilometer unit should now return to normal operation. Verify that the unit is working properly and that there are no other failures with the system. If other failures exist, separate troubleshooting may be necessary.

Replacing Ceilometer Receiver CLR321

Refer to number 2 in Figure 22 on page 92.

CAUTION Servicing the equipment must only be performed by qualified maintenance personnel.

The receiver should be replaced if the ceilometer unit has been generating warnings and alarms, and a malfunction with the operation of the receiver has been detected.



Figure 25 Receiver CLR321

To replace the Ceilometer Receiver CLR321, you will need a 2.5 mm Allen-key. Then proceed as follows:

1. Open the measurement unit door and confirm that there is an active receiver failure. In case of a receiver failure, the **CLR ok** LED will be turned off. Refer to Figure 26 on page 99.
2. Switch off the power with all three switches (F1, F2, and Battery). For the location of the switches, see Figure 15 on page 40 and Figure 16 on page 41.

WARNING Disconnect the power cable from connector J2 before continuing!

3. Detach the coaxial cable (refer to number 3 in Figure 22 on page 92) from the receiver. Also detach the receiver ribbon cable (refer to number 4 in Figure 22 on page 92) from the Ceilometer Engine Board CLE321.
4. To detach the receiver, loosen the receiver ring by turning it downwards. If necessary, you can use a 2.5-mm Allen key as a lever. Remove the receiver from the unit.
5. Place the new receiver to its place and tighten the receiver ring in such a way that the labels of the receiver face the left wall of the enclosure.

CAUTION

When tightening the receiver, avoid applying force to the receiver enclosure. If the receiver starts to rotate along when the ring is tightened, stop the receiver from rotating by hand, but do not apply any unnecessary force. Otherwise the optical centering of the photo diode may be lost, resulting in loss of cloud detection.

6. Connect the receiver ribbon cable to the CLE321 board. Also connect the coaxial cable to the receiver.
7. Connect the power cable to connector J2.
8. Switch on the power with all three switches. Wait until the **Laser on** LED starts blinking at 6-second intervals. Ensure that all six diagnostic LEDs light up after the self-test. Refer to Figure 26 on page 99.

The ceilometer unit should now return to normal operation. Verify that the unit is working properly and that there are no other failures with the system. If other failures exist, separate troubleshooting may be necessary.

Replacing Ceilometer Engine Board CLE321

Refer to number 7 in Figure 22 on page 92.



0910-104

Figure 26 Ceilometer Engine Board CLE321

CAUTION

Servicing the equipment must only be performed by qualified maintenance personnel.

Ceilometer Engine Board CLE321 should be replaced if the ceilometer unit has been generating warnings and alarms, and a malfunction with the operation of the CLE321 board has been detected.

To replace the Ceilometer Engine Board CLE321, you need a screwdriver.

Then proceed as follows:

1. Open the measurement unit door and confirm that there is an active CLE321 board failure. In case of a CLE321 board failure, the **CLE ok** LED will be turned off. Refer to Figure 26 on page 99 above.
2. Switch off the power with all three switches (F1, F2, and Battery). For the location of the switches, see Figure 15 on page 40 and Figure 16 on page 41.

WARNING Disconnect the power cable from connector J2 before continuing!
--

3. Detach the transmitter ribbon cable, the receiver ribbon cable, and the coaxial cable from the Ceilometer Engine Board CLE321. (Refer to numbers 10, 4, and 3 in Figure 22 on page 92, respectively.)
4. Memorize the position of the data line connector (RS-232/RS-485/Modem; refer to number 8 in Figure 22) in front of the CLE321 board and detach it. Refer to Figure 26.
5. Loosen the hand screws to release the CLE321 board from the frame. Gently pull the CLE321 board halfway out of the measurement unit and detach the battery cable (refer to number 16 in Figure 22) and the CLM311 cable (refer to number 15 in Figure 22). Then remove the entire CLE321 board. Refer to Figure 26.
6. Place the new CLE321 board onto the frame in such a way that you can reconnect the battery cable and the CLM311 cable.
7. Reattach the receiver ribbon cable, the transmitter ribbon cable, and the coaxial cable when the board is pushed halfway in.
8. Push the new CLE321 board in such a way that it connects to the back plane connector. Tighten the hand screws to lock the board position.
9. Connect the data line connector to the same position as it was connected to on the previous board.
10. Connect the power cable to connector J2.
11. Switch on the power with all three switches. Wait until the **Laser on** LED starts blinking at 6-second intervals. Make sure that all six diagnostic LEDs light up after the set-test. Refer to Figure 26 on page 99.

The ceilometer unit should now return to normal operation. Verify that the unit is working properly and that there are no other failures with the system. If other failures exist, separate troubleshooting may be necessary.

Replacing No-break Battery 4592

Refer to number 12 in Figure 22 on page 92.

CAUTION Servicing the equipment must only be performed by qualified maintenance personnel.



0910-110

Figure 27 No-break Battery 4592

The no-break battery should be replaced when it is damaged or can otherwise no longer be recharged.

To replace the no-break battery, you will need a crosshead screwdriver and a 3 mm Allen-key.

Then proceed as follows:

1. Open the measurement unit door and switch off the power with all three switches (F1, F2, and Battery). For the location of the switches, see Figure 15 on page 40 and Figure 16 on page 41.

WARNING Disconnect the power cable from connector J2 before continuing!

2. Disconnect the battery cable (refer to number 16 in Figure 22 on page 92) from the CLE321 board.

3. Remove the two screws locking the lid of the battery cage. One of the screws is located on top of the battery cage, the other is on the left side near the top of the cage.
4. Open the lid of the battery cage and slide out the battery. Disconnect the battery cable.
5. Connect the battery cable to the new battery, connecting the red end to the positive (+) pin and the black end to the negative (-) pin.
6. Slide the new battery into the battery cage and close the lid. Tighten the two screws back to their places.
7. Reconnect the battery cable to the CLE321 board.
8. Connect the power cable to connector J2.
9. Switch on the power with all three switches. Wait until the **Laser on** LED starts blinking at 6-second intervals. Make sure that all six diagnostic LEDs light up after the self-test. Refer to Figure 26 on page 99.

The ceilometer unit should now return to normal operation. Verify that the unit is working properly and that there are no other failures with the system. If other failures exist, separate troubleshooting may be necessary.

Replacing AC Power Supply CLP311

Refer to number 6 in Figure 22 on page 92.

CAUTION Servicing the equipment must only be performed by qualified maintenance personnel.

The AC power supply CLP311 should be replaced if the ceilometer unit has been generating warnings and alarms, and a malfunction with the operation of the power unit has been detected.



0910-106

Figure 28 AC Power Supply CLP311

To replace the AC power, you will need an Allen-key.

Then proceed as follows:

1. Open the measurement unit door and confirm that there is an active AC power unit failure. In case of an AC power unit failure, the **CLP ok** LED will be turned off. Refer to Figure 26 on page 99.
2. Switch off the power with all three switches (F1, F2, and battery). For the location of the switches, see Figure 15 on page 40 and Figure 16 on page 41.

WARNING Disconnect the power cable from connector J2 before continuing!

3. Disconnect the battery, transmitter, receiver, laser monitor board, and data cables (refer to numbers 3, 4, 8, 10 and 16 in Figure 22 on page 92) from the CLE321 board.
4. Detach the CLM311 twisted pair cable (refer to number 15 in Figure 22) from the CLE321 board.
5. Remove the no-break battery. Refer to steps 3 to 5 in section Replacing No-break Battery 4592 on page 101.
6. Detach the data line cable from the connector J3.
7. Remove the six CLP311 attachment screws from the bottom of the ceilometer measurement unit. Also disconnect the AC power cable (refer to number 11 in Figure 22). Lift the AC power unit from the ceilometer measurement unit.
8. Put the new AC power unit in place of the old one and connect the AC power cable. Tighten the six attachment screws back to their places.
9. Reattach the data line connector.
10. Attach the CLM311 twisted pair cable to the CLE321 board.
11. Snap the internal heater connector to its place.
12. Place all heater cables behind the holder and tighten the four holder screws.
13. Reconnect the battery, transmitter, receiver, laser monitor board, and data cables to the CLE321 board.
14. Insert and reconnect the battery as you removed it. Refer to steps 6 to 8 in section Replacing No-break Battery 4592 on page 101.
15. Connect the power cable to connector J2.
16. Switch on the power with all three switches. Wait until the **Laser on** LED starts blinking at 6-second intervals. Ensure that all six diagnostic LEDs light up after the self-test. Refer to Figure 26 on page 99.

The ceilometer unit should now return to normal operation. Verify that the unit is working properly and that there are no other failures with the system. If other failures exist, separate troubleshooting may be necessary.

Replacing Window Blower CLB311

Refer to number 14 in Figure 22 on page 92.

CAUTION Servicing the equipment must only be performed by qualified maintenance personnel.

CAUTION Be careful not to contaminate or scratch the window.

The window blower should be replaced if the ceilometer unit has been generating warnings and alarms, and a malfunction with the operation of the blower has been detected.

To replace the Ceilometer Window Blower CLB311, you will need a 5 mm Allen-key.

Then proceed as follows:

1. Open the measurement unit door and confirm that there is an active window blower failure. In case of a window blower failure, the **CLB ok** LED will be turned off. Refer to Figure 26 on page 99.
2. Switch off the power with all three switches (F1, F2, and Battery). For the location of the switches, see Figure 15 on page 40 and Figure 16 on page 41.

WARNING Disconnect the power cable from connector J2 before continuing!



0910-105

Figure 29 Window Blower CLB311-115 / CLB311-230

3. As the blower is attached to the shield of the ceilometer, you will first have to remove the measurement unit from the shield to get to the blower. To remove the measurement unit, loosen the three attachment screws (marked A in Figure 6 on page 27) on the back of the measurement unit, disconnect the blower cable from connector J1 (see Figure 11 on page 34) and pull out the unit.
4. Use an Allen key to loosen the two screws on the side of the window blower, then pull out the blower.
5. Use the same Allen screws to attach the new window blower.
6. Reattach the measurement unit by placing it inside the shield, reconnecting the blower cable to connector J1, and tightening the three attachment screws.
7. Connect the power cable to connector J2.
8. Switch on the power with all three switches. Wait for 5 minutes after the start-up until self-check is completed. Ensure that all six diagnostic LEDs are lit. Refer to Figure 26 on page 99.

The ceilometer unit should now return to normal operation. Verify that the unit is working properly and that there are no other failures with the system. If other failures exist, separate troubleshooting may be necessary.

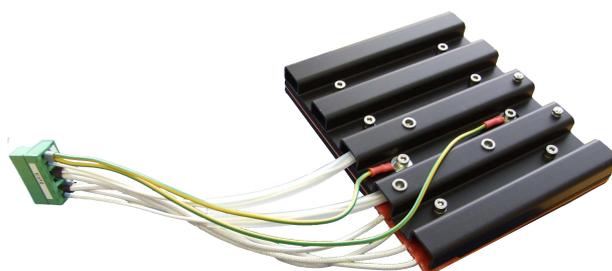
Replacing Internal Heater CLH311

Refer to number 1 in Figure 22 on page 92.

CAUTION Servicing the equipment must only be performed by qualified maintenance personnel.

NOTE The Internal Heater CLH311 is recommended to be replaced indoors.

The internal heater should be replaced if the ceilometer unit has been generating warnings and alarms, and a malfunction with the operation of the heater has been detected.



0910-107

Figure 30 Internal Heater CLH311-115 / CLH311-230

To replace the Internal Heater CLH311, you will need a 3 mm Allen-key. The Optics unit has to be removed before replacing CLH311.

Then proceed as follows:

1. Open the measurement unit door and confirm that there is an active internal heater failure. In case of an internal heater failure, the **CLH ok** LED will be turned off. Refer to Figure 26 on page 99.
2. Switch off the power with all three switches (F1, F2, and battery). For the location of the switches, see Figure 15 on page 40 and Figure 16 on page 41.

WARNING Disconnect the power cable from connector J2 before continuing!

3. Close the enclosure door and remove the measurement unit. To do this, loosen the three attachment screws (marked A in Figure 6 on page 27 on the back of the measurement unit, disconnect the blower cable from connector J1 (see Figure 11 on page 34) and pull out the unit.
4. Remove the metal plate protecting the heater by loosening its two screws.
5. Disconnect the battery, transmitter, receiver, and data cables (refer to numbers 3, 4, 8, 10 and 16 in Figure 22 on page 92) from the CLE321 board.
6. To remove the Optics Unit (refer to number 9 in Figure 22), first remove the holder plate by loosening the four Allen screws on its front cover.
7. Detach the internal heater connector and holding the cable aside, carefully pull out the Optics Unit upper end first.

NOTE

Do not touch the lens of the Optics Unit. Place the Optics Unit aside in a way that it is not leaning on the receiver or the transmitter.

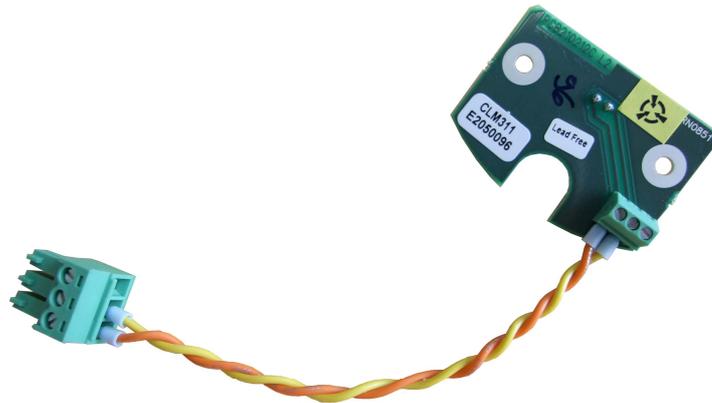
8. Detach the CLM311 twisted pair cable (refer to number 15 in Figure 22) from the CLE321 board.
9. To remove the internal heater, use an Allen key or a short screwdriver and loosen the three screws attaching the heater to the left wall of the measurement unit enclosure. Then slide out the internal heater.
10. Slide the new internal heater into its place and hold it there while tightening the three screws.
11. Attach the CLM311 twisted pair cable to the CLE321 board.
12. Slide the optics tube into its place with the bottom end first making sure no cables get stuck between the optics tube and other ceilometer components.
13. Snap the internal heater connector to its place.
14. Place all heater cables behind the holder and tighten the four holder screws.
15. Reconnect the battery, transmitter, receiver, and data cables to the CLE321 board.
16. Reattach the metal plate protecting the internal heater.
17. Insert the measurement unit inside the shield, reconnect the blower cable to connector J1, and tighten the three attachment screws.
18. Connect the power cable to connector J2.
19. Switch on the power with all three switches. Wait until the **Laser on** LED starts blinking at 6-second intervals. Ensure that all six diagnostic LEDs are lit. Refer to Figure 26 on page 99.

The ceilometer unit should now return to normal operation. Verify that the unit is working properly and that there are no other failures with the system. If other failures exist, separate troubleshooting may be necessary.

Replacing Laser Monitor Board CLM311

Refer to number 15 in Figure 22 on page 92.

CAUTION Servicing the equipment must only be performed by qualified maintenance personnel.



0910-109

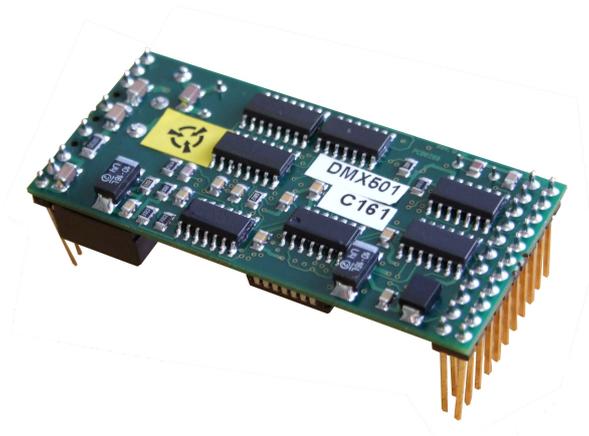
Figure 31 Laser Monitor Board CLM311

Under normal circumstances there should be no need to replace the Laser Monitor Board CLM311. If it must be replaced, the whole CLO511 must be calibrated to ensure proper operation of the ceilometer. This can be done only in qualified service depot or in Vaisala where all necessary tools are available to do this.

Replacing Modem Module DMX501 (Optional)

CAUTION Servicing the equipment must only be performed by qualified maintenance personnel.

Always replace the modem module indoors.



0910-108

Figure 32 Modem Module DMX501

To replace the Modem Module DMX501, you will need a screwdriver. As the DMX501 module is located inside the CLE321 module, you will have to remove the CLE321 board to get to the DMX501 module.

Proceed as follows:

1. Open the front door of the ceilometer enclosure and switch off the power with all three switches (F1, F2, and battery). For the location of the switches, see Figure 15 on page 40 and Figure 16 on page 41.

WARNING Disconnect the power cable from connector J2 before continuing!

2. Detach the transmitter ribbon cable, the receiver ribbon cable, and the coaxial cable from Ceilometer Engine Board CLE321. (Refer to numbers 10, 4, and 3 in Figure 22 on page 92, respectively.).
3. Memorize the position of the data line connector (RS-232/RS-485/Modem; refer to number 8 in Figure 22) in front of the CLE321 board and detach it. Refer to Figure 26.

4. Loosen the hand screws to release the CLE321 board from the frame. Carefully pull the CLE321 board halfway out of the measurement unit and detach the battery cable (refer to number 16 in Figure 22) and the CLM311 cable (refer to number 15 in Figure 22). Then remove the entire CLE321 board. Refer to Figure 26.

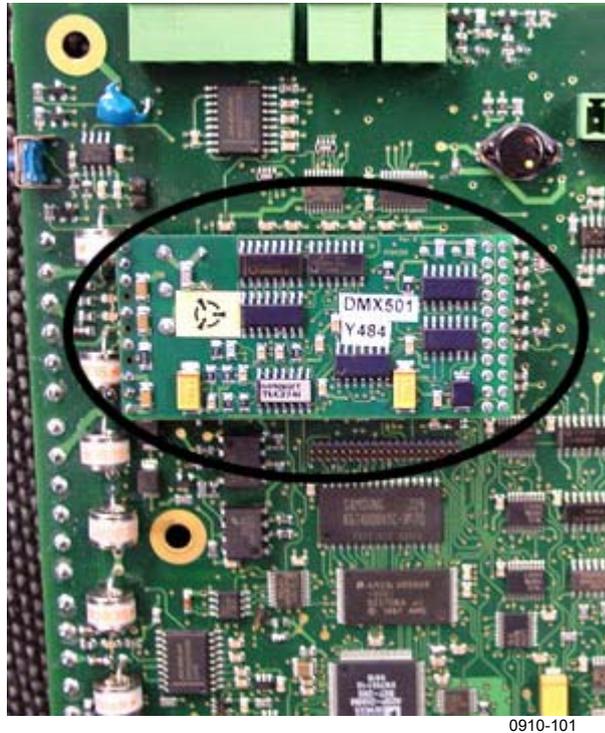


Figure 33 DMX501

WARNING

Ground yourself before touching the DMX501 module. You can do this, for example, by touching a conductive part of the equipment chassis with your other hand before touching the DMX501 module.

5. Pull the DMX501 module gently out of its place on the CLE321 board to avoid bending its legs.
6. Check that the legs of the new DMX501 module are straight before placing it on the CLE321 board. Once the DMX501 module is in its place, push it gently to the CLE111 board.
7. Place the new CLE321 board onto the frame in such a way that you can reconnect the battery cable and the CLM311 cable.
8. Reattach the receiver ribbon cable, the transmitter ribbon cable, and the coaxial cable when the board is pushed halfway in.
9. Push the CLE321 board in such a way that it connects to the back plane connector. Tighten the hand screws to lock the board position.

10. Connect the data line connector to the same position as it was connected to on the previous board.
11. Connect the power cable to connector J2.
12. Switch on the power with all three switches. Wait until the **Laser on** LED starts blinking at 6-second intervals. Make sure that all six diagnostic LEDs light up after the self-test. Refer to Figure 26 on page 99.

The ceilometer unit should return to normal operation. Verify that the unit is working properly and that there are no failures with the system. If failures exist, separate troubleshooting may be necessary.

CHAPTER 9

TECHNICAL DATA

This chapter provides the technical data of the product.

Specifications

This section describes the different technical specifications of Vaisala Ceilometer CL51.

Mechanical Specifications

Table 26 Ceilometer CL51 Mechanical Specifications

Property	Description / Value
Dimensions:	
Measurement unit	834 x 266 x 264 mm (33 x 10 1/2 x 8 1/3 in.)
Height with shield	1531 mm (61 in.)
Weight:	
Measurement unit	18.6 kg (41 lbs)
Shield and blower	27.4 kg (60.4 lbs)
Housing classification	IP65
Plywood transport container:	
Container size	1650 x 540 x 480 mm (65 x 21 1/4 x 19 in.)
Container weight	66 kg (145.5 lbs)

External Connector J1 - Window Conditioner

Table 27 Window Conditioner

Property	Description / Value
Connector J1	Type Binder series 693, 09-4228-00-07 (female)
Mating connector type	Type Binder series 693, 99-4225-70-07 7-pin (male) elbow

External Connector J2 - Power Input

Table 28 Power Input

Property	Description / Value
At nominal line voltage	100V or 115 V or 230 V
Power consumption (typical):	
Total	310 W
Measurement unit	15 W
Internal heater	100 W
Window conditioner heater	175 W
Window blower	20 W
Frequency	45-65 Hz
Power connector (J2)	Type Binder series 693, 09-4223-00-04 4-pin (male)
Mating connector type	Type Binder series 693, 99-4222-70-04 (female) elbow
No-break power supply	12 V Sealed Lead Acid Battery, 2 Ah
Overvoltage protection	Low-pass filter , VDR

Output Interface

The data port can operate according to the following serial line standards:

RS-232

RS-485, multidrop, 2-wire

The data port can also be operated through a DMX501 modem module. The maintenance port is an RS-232 serial line.

External Connector J3 - Data Line

The data line is intended to be used for measurement data communication, but it can also be used with a Ceilometer Maintenance Terminal, PC, or other terminals. Data line properties are described in Table 29 on page 115.

Table 29 Data Line

Property	Description / Value
Connector (J3)	Type Binder series 693, 09-4227-00-07 7-pin (male)
Mating connector type	Type Binder series 693, 99-4226-70-07 (female) elbow
Baud rate	19200 bps standard with RS-232 300, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115 200 bps available 300, 1200 or 2400 bps available with modem DMX501
Max. distance to operate	300m (1000 ft) with RS-232, 1.2 km (4000 ft) with RS-485, all at 2400 bps with typical communication cables 10 km (6.2 mi.) with Modem
Standard character frame	1 Start Bit 8 Data Bits No Parity 1 Stop Bit
Standard character code	USASCII
Pin connections	1 RS485 -/RTS# (no SW support) 2 RS485+/RS-232 RxD/ Modem Lead A 3 Modem Lead B /RS-232 TxD 4 Ground 5 CTS# (no SW support) 6 +12 V DC (700 mA continuous, for local external equipment)

Modem circuits are non-polar and symmetrical. All modem circuits are electrically floating to overvoltage protection rating (300 V - 500 V).

Overvoltage protection in each circuit	Primary Noble Gas Surge Arrester Secondary VDRs, Transient Zener Diodes or normal Diodes
--	---

NOTE

For information on data line connection options, see Figure 12 on page 36, Figure 13 on page 37, and Figure 14 on page 38.

External Connector J4 - Maintenance Line

Maintenance line is intended for on-site maintenance and can be used with a Ceilometer Maintenance Terminal, PC, or other terminal.

Table 30 Maintenance Line

Property	Description / Value
Connector (J4)	Female five (5) pin M12 connector (e.g. Lumberg RKF 5 / 0,5 M)
Mating connector type	Male five (5) pin M12 connector (e.g. Lumberg RST 5-644)
Baud rate	9600 default and standard 300, 2400, 4800, 9600, 19200, 38400, 57600, 115 200 bps available
Distance to operate	300 m (1000 ft) at 2400 baud with typical communication cables
Standard character frame	1 Start Bit 8 Data Bits No Parity 1 Stop Bit
Standard character code	USASCII
Pin connections	See Figure 34 on page 116 above (RTS/CTS not used).

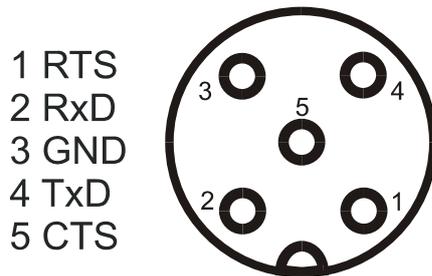


Figure 34 Pin Connections of Connector J4

Overvoltage protection in each circuit	Primary Noble Gas Surge Arrester Secondary VDRs, Transient Zener Diodes or normal Diodes
--	---

Modem Module DMX501

Table 31 Modem Module DMX501 Specifications

Property	Value / Description
Data rate	300, 1200, 2400 bps
Modem standards supported	V.21, V.22, V.22bis
Supply voltage	5 V (+4.75 V to 5.5 V)
Current consumption	Reset / power-down 9 mA, operation 26 mA
Modem chip crystal frequency	11.0592 MHz
USART clock frequency	11.0592 MHz / 2 (Modem xtal freq. divided by 2)
Line interface	Matched to 600 Ω
Max. operation distance	10 km (approx. 6 miles)

Transmitter Specifications

Table 32 Transmitter Specifications

Property	Description / Value
Laser source	Indium Gallium Arsenide (InGaAs) Diode Laser
Center wavelength	910 \pm 10 nm at 25 °C (77 °F)
Operating Mode	Pulsed
Nominal pulse properties at full range measurement:	
Energy	3.0 μ Ws \pm 20% (factory adjustment)
Peak power	27 W typical
Width, 50%	110 ns typical
Repetition rate	6.5 kHz
Average power	19.5 mW
Max Irradiance	520 μ W/cm ² measured with 7 mm aperture
Laser classification	Classified as Class 1M laser device in accordance with IEC/EN 60 825-1 Complies with 21 CFR 1040.10 and 1040.11 except for the deviations pursuant to the Laser Notice No. 50, dated July 26, 2001.
Beam divergence	\pm 0.15 x \pm 0.25 mrad

Receiver Specifications

Table 33 Receiver Specifications

Property	Description / Value
Detector	Silicon Avalanche Photodiode (APD)
Surface diameter	0.5 mm (0.02 in.)
Receiver bandwidth	3 MHz (-3db)
Interference filter	Center wavelength 915 nm typical
50% pass band	36 nm
Transmissivity at 913 nm	80 % typical

Property	Description / Value
Field-of-view divergence	± 0.56 mrad

Optical System Specifications

Table 34 Optical System Specifications

Property	Description / Value
Optics System Focal Length	450 mm (17.7 in.)
Effective lens diameter	148 mm (5.75 in.)
Lens transmittance	98 % typical
Window transmittance	97 % typical, clean

Performance Specifications

Table 35 Performance Specifications

Property	Description / Value
Cloud detection range	0 ... 13 km (0 ... 43 000 ft)
Measurement range	0 ... 15 km (0 ... 50 000 ft)
Measurement resolution	10 m (33 ft)
Cloud reporting resolution	5 m or 10 ft., units selectable
Reporting interval	6 ... 120 s, selectable
Measurement interval	6 s

Environmental Conditions Specifications

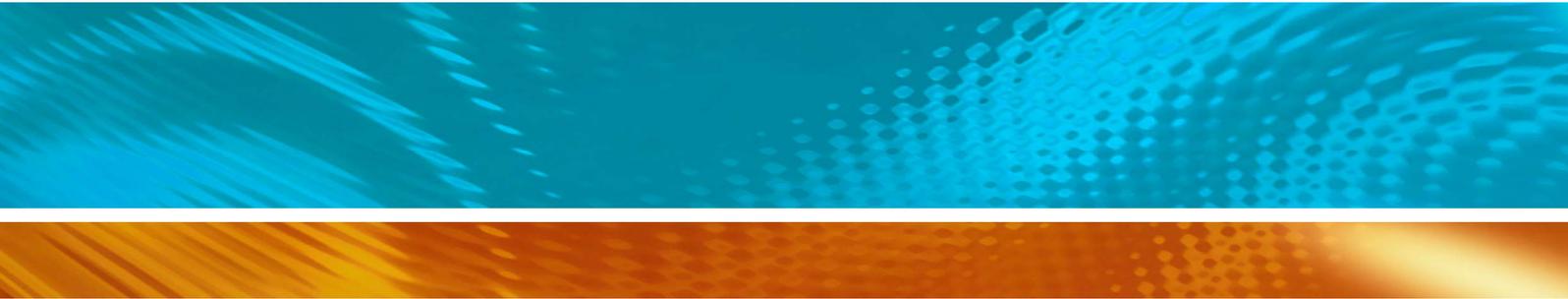
Table 36 Environmental Conditions Specifications

Property	Description / Value
Ambient temperature	-40 ... +60 °C (-55 ... +60 °C optional)
Humidity	to 100 %RH
Wind	to 110 kt (55 m/s)
Vibration	5 - 13.2 Hz, ± 1.0 mm 13.2 - 100 Hz, ± 0.7 g

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