ARM TR-020

Vaisala Ceilometer (Model CT25K) Handbook

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1. General Overview

The Vaisala ceilometer (VCEIL) is a self-contained, ground-based, active, remote-sensing device designed to measure cloud-base height at up to three levels and potential backscatter signals by aerosols. Model CT25K has a maximum vertical range of 25,000. The ceilometer transmits near-infrared pulses of light, and the receiver telescope detects the light scattered back by clouds and precipitation.

2. Contacts

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3. Deployment Locations and History

The instrument is used at all Tropical Western Pacific, North Slope of Alaska sites and the boundary facilities at the Southern Great Plains (SGP). In the summer of 2000, it replaced the Belfort Laser Ceilometer at the SGP in the summer of 2000.

4. Near-Real-Time Data Plots

See General Quick Looks.

5. Data Description and Examples

The figure below shows an example of the output analysis software package available for the Vaisala Ceilometers (CTVIEW). This particular example shows a false color intensity depiction of the backscattering profile for 28 September 1995. These data were taken at Sandia National Laboratory in Albuquerque, New Mexico during the early phase testing for the Atmospheric Radiation and Cloud Station (ARCS) for the Tropical Western Pacific (TWP).

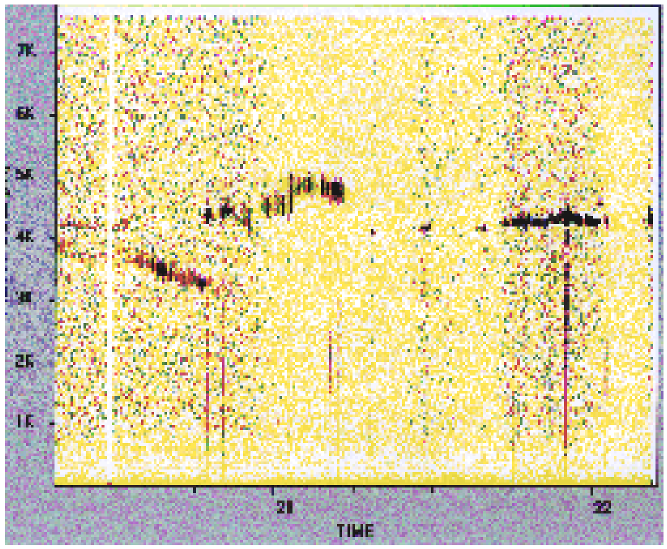

Figure 1.

5.1 Data File Contents

5.1.1 Primary Variables and Expected Uncertainty

The Vaisala ceilometers measure the backscattered light intensity from a pulsed InGaAs diode laser (905 nm) as a function of distance (15-m resolution CT25K). These measurements are used to produce derived products that are recorded. These products include:

1. The backscatter profile with 15-m resolution.
2. The cloud-bottom height determined with an algorithm to define cloud bottom as the height corresponding to a visibility reduction to 100 m.
3. Secondary cloud-bottom heights from a cloud above the lowest cloud.
4. Tertiary cloud-bottom heights from an even higher cloud.

5.1.1.1 Definition of Uncertainty

The CT25K is recalibrated every year at the Tropical Western Pacific site to ensure a range resolution of 15 m. The instrument derived product of cloud-ceiling height may drift with time if the relative sensitivity of the instrument degrades considerably. In the worst case, this change would not be observed until differences with the Micro-Pulse lidar (MPL) are observed. This would lead to an uncertainty equal to the range resolution of the MPL (300 m for older systems, 75 m for newer).

A comparison was performed between the Belfort Laser Ceilometer (BLC) and the Vaisala 25K at the SGP in September and October 1997. This comparison showed a similar shape to cloud features observed by the two systems with the BLC offset about 100 to 120 m higher than the Vaisala 25K. Below is an example of the comparison using ncexplorer of lowest cloud heights from the two instruments on one of the 9 days.

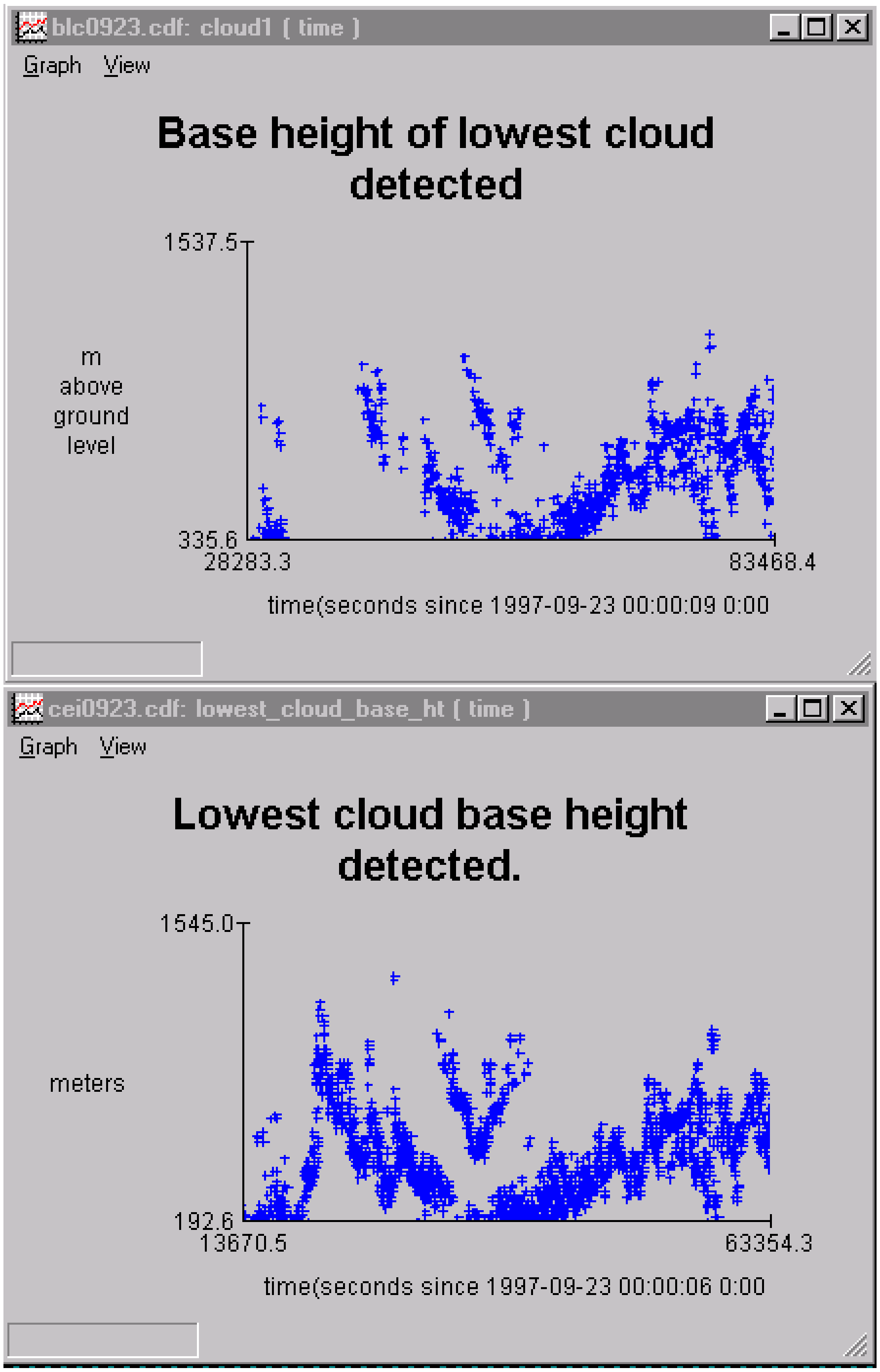

Figure 2.

5.1.2 Secondary/Underlying Variables

This section is not applicable to this instrument.

5.1.3 Diagnostic Variables

This section is not applicable to this instrument.

5.1.4 Data Quality Flags

Cloud base heights above 7620 m or below 0 m.

Additional information may be found at VCEIL25k Data Object Design Changes for ARM netCDF file header descriptions.

5.1.5 Dimension Variables

This section is not applicable to this instrument.

5.2 Annotated Examples

This section is not applicable to this instrument.

5.3 User Notes and Known Problems

This section is not applicable to this instrument.

5.4 Frequently Asked Questions

What is the difference between cloud height determination algorithms using the ceilometer and the Micro-Pulse Lidar (MPL)?

The MPL uses a threshold variation to identify the cloud bottom, and the ceilometers use a calculated vertical visibility threshold of 100 m. This means that the ceilometer will not classify thin cloud regions that the MPL would identify and usually give a slightly higher cloud bottom height.

Can direct sun damage the optics and detection systems of a ceilometer?

For the Tropical Western Pacific, because it is near the equator and direct sun focusing is difficult to avoid, the CT25K ceilometer comes with a narrow band window filter that excludes enough sunlight to avoid optics damage. At the Southern Great Plains and NSA, this filter window is not necessary as long as the instrument is pointed with the window opening pointing north to avoid direct sun.

Are the ceilometers eyesafe?

Yes, however the outgoing beam must never be viewed through magnifying optics such as binoculars or a camera.

Can the CT25K ceilometer returns be used to detect aerosol mixed layer depths in the absence of clouds?

Not yet, the CT25K presently processes out the raw data that would be needed to do this. We are working with the manufacturer to possibly make hardware and software changes that would allow this.

How does the CT25K compare with other ceilometers during low cloud conditions such as are often observed in the Arctic?

The CT25K uses overlapping transmitting and receiving optics so that beam overlap occurs at shorter distances so that detection of thin clouds only about 15-50 m above the ceilometer is improved.

6. Data Quality

6.1 Data Quality Health and Status

The following links go to current data quality health and status results.

- DQ HandS (Data Quality Health and Status)
- NCVweb for interactive data plotting using.

The tables and graphs shown contain the techniques used by ARM's data quality analysts, instrument mentors, and site scientists to monitor and diagnose data quality.

6.2 Data Reviews by Instrument Mentor

QC frequency: Several days each month

QC delay: Not specified.

QC type: Comparison to MPL and MWR measurements; data flags; graphical plots.

Inputs: Raw data files; maintenance logs

Outputs: Report to site scientists

Reference: N/A

VCEILs have been installed at the SGP, TWP and NSA for long-term, continuous operation. The most useful quality control check for the ceilometers is comparison with MPL measurements when one is located nearby. The MPL uses photon counting rather than photocurrent detection, and the ceilometer defines a cloud as a cloud droplet scattering that reduces visibility to a pilot to less than 100 m rather than the MPL procedure of identifying a sudden increase in backscatter. The increased sensitivity and looser definition of a cloud causes the MPL to often report clouds that are not reported by the ceilometer.

However, both instruments should normally report clouds and cloud bases that correspond closely. Another quality check involves comparing clouds detected by the ceilometer and liquid water measurement from the MWR. This only works for relatively low clouds where one is certain that the clouds are water and not ice clouds.

Instrument mentor Bill Porch recommends that these comparisons with MPL and MWR data should be accomplished for sample periods of a few days for each month. The rest of the data will be examined for internal consistency, namely whether clouds are observed at heights up to the limit of the system (7.62 km), the backscatter plot show expected variability, data gaps are minimal, and warning flags such as window dirt, dew, and frost minimal.

Once per 6 months or so, a calibration check will be performed that requires the instrument to be manually tipped to near horizontal and aimed at an object a know distance away. The results of this test will be logged as a part of maintenance. A summary report will periodically be provided to the SGP site scientist team.

6.3 Data Assessments by Site Scientist/Data Quality Office

All DQ Office and most Site Scientist techniques for checking have been incorporated within DQ HandS and can be viewed there.

6.4 Value-Added Procedures and Quality Measurement Experiments

Many of the scientific needs of the ARM Program are met through the analysis and processing of existing data products into "value-added" products or VAPs. Despite extensive instrumentation deployed at the ARM CART sites, there will always be quantities of interest that are either impractical or impossible to measure directly or routinely. Physical models using ARM instrument data as inputs are implemented as VAPs and can help fill some of the unmet measurement needs of the program. Conversely, ARM produces some VAPs not in order to fill unmet measurement needs, but instead to improve the quality of existing measurements. In addition, when more than one measurement is available, ARM also produces "best estimate" VAPs. A special class of VAP called a Quality Measurement Experiment (QME) does not output geophysical parameters of scientific interest. Rather, a QME adds value to the input datastreams by providing for continuous assessment of the quality of the input data based on internal consistency checks, comparisons between independent similar measurements, or comparisons between measurement with modeled results, and so forth. For more information see VAPs and QMEs.

The most useful quality measurement experiment for the ceilometer is comparison of cloud heights detected with a micro-pulse lidar (MPL) and the ceilometer. However, it must be kept in mind that the MPL can detect backscatter from these thin clouds that is not discernible from the processed ceilometer backscatter. One reason for this includes the fact that the ceilometer is designed to detect clouds that obscure pilot visibilities to less than 100 m and is just not as sensitive as the MPL (photo-current vs. photon counting detection, respectively). Also, there is a change in daytime/nighttime sensitivity in the data. The ceilometer reports thin mid-level clouds at night that are not reported after sunrise. We have taken a corrective action by recording the processed data without the Vaisala noise reduction. However, the ceilometer will still not report the daytime thin clouds as clouds. The prevalence of thin scud type clouds at Manus, New Quinea makes this more of a problem there than at other sites, but thin mid-level clouds can occur anywhere. When there are both MPL and Ceilometer data the most sensitivity to thin clouds will always come from the MPL. The combination of the MPL and the ceilometer as a relatively low cost back-up is still valuable not only in maintaining a continuous data stream, but also the higher resolution of the ceilometer at Manus (TWP does not yet have the MPLHR) is useful for lower level cloud detection and possibly cloud-free mixing-depth estimates under some circumstances. 2. Another quality measurement experiment can be performed by comparing the ceilometer cloud base height and the calculated lifting condensation level from surface humidity and temperature measurements. The lifting condensation level temperature can be calculated as Tl = 1/[(1/(Tk-55)) - ln(U/100)/2840] where Tk is the absolute surface temperature (K) and U is the surface relative humidity (%). The height associated with the lifting condensation level can be calculated from an adiabatic lapse rate assumption.

7. Instrument Details

7.1 Detailed Description

7.1.1 List of Components

The system components consist of the following line replaceable units:

Table 1.

Component	Item #
CPU	DMC 50A
Transmitter	CTT21
Assembly	-
Receiver Board	CTR21
Blower Assembly	CT2688
DC Converter	DPS51
Power Cable	CT3839
Data Cable	CT3838
Backup Battery	4592

The separate mechanical parts include the following:

1. Ceilometer Measurement Unit
2. Shield
3. Pedestal
4. Maintenance Cable (1 meter with 9 pin D connector)
5. Data Cables (3 ft. with 9 pin D connector) CAB-000045, 50 ft. Twisted Pair RS422 CAB-000086, 50 ft. 12V power for RS422 Converter CAB-000087, and 10 ft. 9 pin RS232 cable to Computer in IVan CAB-000085)
6. Power Cable (50 ft.) CA-000044
7. Maintenance Terminal (Psion 3a)
8. Computer (connection for data terminal running OS2)
9. RS232 t0 RS422 and RS422 to RS232 converter boxes.
10. 4 Mounting Bolts and Hardware for Securing Pedestal to Cement Pad (4 nuts M10, washers B10, and foundation screws M10).

11. Spare Parts (spare connector cover, instrument door key, and manuals).

We do not presently stock individual system components as spares. This may change when replacement technical manuals become available. Presently, the only spare parts for the system include extra connectors for external cable wiring, two Psion remote terminals for data capture at the instrument, two null modem cables and two sets of keys for the instrument door access.

7.1.2 System Configuration and Measurement Methods

The CT25K Ceilometers measure cloud-bottom heights and vertical visibilities. These instruments employ pulsed diode laser LIDAR (Light Detection and Ranging) technology, where short, powerful laser pulses are sent out in a vertical or slant direction. The directly backscattered light caused by haze, fog, mist, virga, precipitation and clouds is measured as the laser pulses traverse the sky. This is an elastic backscatter system and the return signal is measured at the same wavelength as the transmitted beam. The Raman Lidar looks at other wavelengths than those transmitted. The ceilometer backscatter profile, i.e., signal strength versus height, is stored and the cloud bases are detected. Knowing the speed of light (3×10^8 m/s it's not just a good idea, it's the law), the time delay between the launch of the laser pulse, and the detection of the backscatter signal gives the cloud-base height (see Theory of Operation, Section 7.2).

The CT25K is able to detect three cloud layers simultaneously. Besides cloud layers, it can detect whether there is precipitation or other obstructions to vision. The embedded software includes several service and maintenance functions and gives continuous status information from internal monitoring.

The instruments are placed on a foundation. The foundation should be a concrete pad at least 200-mm thick (the hole depth for the mounting bolts is 160 mm). The width should be 500 mm or larger (the whole spacing is a square pattern 283 mm on a side). The orientation of the pad ordinarily is made so that the one side of the pad points in a north-south direction. Because the Tropical Western Pacific site is near the equator, this layout is not as important as orienting the pad so that the instrument can be calibrated by tilting it near the horizon to hit a large object at least 200 m away for calibration (the ceilometer only tips to the horizon one way which is clockwise facing the tilting flange). Also, the 50-ft cables require that the pad be placed less than 30 ft from the cable opening of the instrument van containing the computer. The ceilometer must be at least 5 feet from the instrument van to allow tipping on both sides.

7.1.3 Specifications

Range: 7.5 km

Range resolution: 15 m

Wavelength: 905 nm @ 25 oC

Transmitter: Pulsed mode energy 1.6 microWatts +/- 5% Indium Gallium Arsenide

Receiver: Silicon APD Response @ 905 nm = 65 Amps/Watt 50% Pass = 35 nm @ 890 - 925 nm

Field of View: Divergence = +/- 0.66 mRadian

Optics: Focal length 377 mm, Lens diameter 145 mm, Transmittance 96% lens, Window 98%

Size: 672 x 308 x 244 mm (without stand)

Weight: 16 kg (without stand)

Power input 100/115/230 VAC (about 430 Watts)

7.2 Theory of Operation

Basic Principle of Operation

The operating principle of the CT25K ceilometer is based on 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. With the speed of light being:

c = 2.9929 x 108 m/s (= 186,010 miles per second)

A reflection from 25,000 ft will be seen by the receiver after t = 50.9 us.

The general expression connecting time delay (t) and backscattering height (h) is h = ct/2, where c is the speed of light.

Practical Measurement Signal

Generally, particles at all heights backscatter light, and so the actual return signal may look like that shown in the figure below.

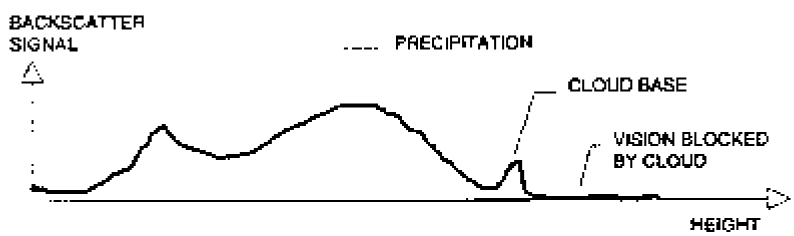

Figure 3.

The instantaneous magnitude of the return signal will provide information on the backscatter properties of the atmosphere at a certain height. From the return signal, information about fog and precipitation, as well as cloud, can be derived. Since fog and precipitation attenuate the light pulse, the cloud base signal will appear lower in magnitude in the return echo. However, the fog and precipitation information also provides data for estimating this attenuation and computing the necessary compensation, up to a limit. In its normal full-range operation, the CT25K ceilometer digitally samples the return signal every 100 ns from O to 50 us, providing a spatial resolution of 50 feet from ground to 25,000 feet distance. This resolution is adequate for measuring the atmosphere, since visibility in the densest clouds is in the order of 50 feet.

Noise Cancellation

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

Height Normalization

Assuming a clear atmosphere, it can be seen that the power is inversely proportional to the square of the distance or height i.e., the strength of a signal from 10,000 ft is generally one hundredth of that from 1,000 ft. The height square dependence is eliminated by multiplying the value measured with the square of the height (height normalization). However, noise, being height independent from a measurement point of view, will then be correspondingly accentuated with increasing height.

The Backscatter Coefficient

The volume backscatter coefficient, b(z), represents the portion of light which is reflected back towards the ceilometer from a distance z (e.g., by water droplets). It is obvious that the denser a cloud is, the stronger the reflection will be. The relationship can be expressed as: $b(z) = k*S(z)$

where

k is a "constant" of proportionality.
S(z) is the extinction coefficient (i.e., the attenuation factor in a forward direction).

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 $S = 3 / V$

where

S is the extinction coefficient
V is MOR visibility (5 % contrast)

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

It has been found that in many cases, k can be assumed to equal 0.03, tending to be lower in high humidities, to 0.02; and higher in low humidities, to 0.05. However, in e.g. precipitation of various kinds, k will have a wider range of values. Assuming a value 0.03 (srad-1) for k and visibility in clouds being in the range 15...150 m (50...500 ft) gives the range of value for B:

B = 0.0006...0.006 m-1srad-1' = 0.6...6 km-1srad-1

Extinction Normalization and Vertical Visibility

Any fog, precipitation, or similar obstruction to vision between ground and 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 fog, precipitation, etc., 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 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 that the ratio, k, is constant over the range observed, it is possible to obtain an extinction coefficient profile through a mathematical computation. This is also called inverting the backscatter profile to obtain the extinction coefficient profile, and answers the question, "What kind of extinction coefficient profile would produce the backscatter profile measured?"

No assumption as to the absolute value of the ratio, k, needs to be made if k is constant with height. The assumptions that have to be made are fairly truthful, and in any case accurate enough for the purpose of cloud detection. Likewise, the 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, provided that a constant contrast threshold is assumed. Visibility will simply be that height where the integral of the extinction coefficient profile, starting from 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. The CT25K 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 wide safety margin is obtained with regard to pilots looking down in the same conditions since the contrast objects, especially runway lights, are much more distinct on the ground.

7.3 Calibration

7.3.1 Theory

The calibration procedure is based on the ability of the instrument to tip parallel to the ground. Comparison with MPL heights during low cloud situations can also be informative. The calibration of the CT25K is performed by tilting the instrument horizontally and detecting the return from a solid object of known distance more than 100 m from the ceilometer.

7.3.2 Procedures

This section is not applicable to this instrument.

7.3.3 History

Table 2.

ARCS Calibration Form	**Field Calibration**	**CAL Record CAL (CEIL)- 0001**			
Date:	GMT Begin Time:	GMT End Time:			
9/12/95	21:00	23:00			
Instrument/ System:	Ceilometer				
Mfg or TWP Model or Part No.:	CT25K				
Serial Number:	p0110009				
Location (Example PNNL):	-				
Participants:	Sandia				
Author	W. Porch (Originator)				
Initials:	WMP				
II. Initial Values					
Reference Distance m	Reading	Reference	Reading	Reference	Reading
525	525	345	345	135	135
III. Final Values					
Reference Distance m	Reading	Reference	Reading	Reference	Reading
525	525	345	345	135	135
IV. Calibration Change (if applicable)					
Original Sensitivity (Distance Correction Factor):	None				
V. Documents Referenced:	Calibration Procedure PRO(CEI) - 002.000				
Documents Updated:					
Problems:	None				

FM(CAL)001.00

7.4 Operation and Maintenance

7.4.1 User Manual

This section is not applicable to this instrument.

7.4.2 Routine and Corrective Maintenance Documentation

This section is not applicable to this instrument.

7.4.3 Software Documentation

ARM netCDF file header descriptions may be found at VCEIL 25k Data Object Design Changes.

7.4.4 Additional Documentation

A. Calibrations and Related Performance Checks:

1. What are factory recommended calibration procedures? There are two calibration procedures used to verify and/or optimize performance of the CT25K ceilometers. Factory calibrations include testing output and received laser power, optical alignment, and pulse timing electronics. The results of these tests are available from the instrument microprocessor by typing "GET FACTORY" and "GET STATUS".

2. What are the factories recommended performance checks? All performance checks of this instrument are automatic. The "instrument health" data appears in the instrument output data files.

3. What are the mentor calibration procedures? The mentor (or the RESET team in the case of the TWP sites) calibrates the ceilometers by tipping the instrument to a near horizontal position and aims the beam at a known object more than 100 m distant.

4. What are the mentor performance checks? The instrument mentor or site operator checks the "instrument health" data in the output data files to diagnose a possible instrument malfunction. The "instrument health" data are of sufficient detail to pinpoint a failing or failed component or subsystem.

5. How are calibration and related performance checks documented? Performance checks of CT25K systems are documented in the TWP Site Data Log by the TWP weather observers. Field calibrations are logged on a ceilometer field calibration form (see example in Calibration History, Section 7.3.3).

   a. Where are procedures documented? Performance checks and calibration of ceilometer operation are documented in TWP calibration procedures and a CT25K user's manual translation written for the TWP.

   b. Have major changes to calibration procedures occurred? If so, for which components and when? To our knowledge, Vaisala has not issued any calibration procedure changes since the instrument was purchased and installed in 1996.

   c. Are major changes to calibration procedures expected to occur? If so, for which components and when? No major changes to calibration procedures are anticipated.

6. Who implements (mentor) calibration and performance checks? Mentor: The mentor implemented field calibration at the TWP ARCS Integration Site at Sandia Natl' Lab, Albuquerque, New Mexico. The RESET team will perform instrument performance checks and instrument calibration at the ARCS site in the TWP. Site Ops: Site ops personnel will support

the instrument mentor in instrument performance checks and calibration procedures at the SGP.

7. What is standard schedule of calibrations and checks? The instrument mentor recommends instrument calibrations be performed upon delivery of the instrument and every 6-months thereafter.

8. How are the calibration and check procedures initiated (queued)?
   Scheduled Calendar Event: These are to be performed at each RESET visit
   Work Order: Routine by RESET
   Data Inspection: Routine by Weather Observers at TWP and remotely by mentor and site scientist
   Instrument Failure: CT25K performance checks are generally initiated upon observation of instrument malfunction or a perceived degradation in instrument performance.

9. How long does it take to perform calibration and performance check procedures? Performance checks require 1 data cycle (every 15 seconds) CT25K calibration requires 2 hours in the field.

10. Are any data affected or lost during calibration or performance check procedures? No data are lost during instrument performance checks because the performance data appear in each data packet. Since CT25K calibration requires placement of the tilting of the ceilometer, cloud base height data cannot be acquired during this procedure.

11. What are corrective procedures when calibrations and or performance checks fall behind schedule? No corrective procedures have been implemented.

B. Calibration Data:

1. Where are calibration data documented?
   Site Data System: No
   Site Ops Data base - Hard Copy: No
   Site Ops Data base - Electronic Copy: No
   Instrument Mentor - Hard Copy: Yes
   Instrument Mentor - Electronic Copy: Yes
   Data Logger: No
   netCDF file: No
   Special Archive Database: Yes (TWP calibration records)
   Special Databases accessible via the WWW: No
   Other: In the CT25K lidar unit (EEPROM) which is accessible by the portable maintenance terminal (PSION handheld or laptop computer).

2. Where are calibration coefficients and algorithms applied to convert data to geophysical units? Conversion of raw lidar data to cloud base height and visibility occurs in the CT25K transmitter/receiver module. These data may be accessed via modem or local area network.

C. Maintenance Procedures:

1. What are the factory recommended maintenance procedures: (preventive and corrective)? The ceilometer transmitter and receiver windows should be cleaned at least every three weeks using Windex or Glass-Plus.

2. What are the mentor preventative and corrective maintenance procedures? There are no documented preventative maintenance procedures. Corrective maintenance is performed at the component-level (i.e., by replacing the circuit board or component containing the defective component(s)).

3. How are maintenance procedures documented?

   a. Where are procedures documented? Maintenance procedures are documented in the CT25K Users guide manual and Manual translation for the TWP.

   b. Have major changes to maintenance procedures occurred? If so, for which components and when? No significant changes have been made to instrument maintenance procedures since the CT25K was purchased and delivered in 1996.

   c. Are major changes to maintenance procedures expected to occur? If so, for which components and when? No major changes to maintenance procedures are anticipated.

4. What is the procedure schedule? Part of ARCS daily rounds.

5. How are the procedures initiated (queued)?
   Scheduled Calendar Event: Maintenance schedule and RESET visits
   Work Order: No
   Data Inspection: Yes
   Instrument Failure: Instrument maintenance procedures are initiated either by instrument failure or by a perceived degradation in instrument performance.

6. How long does it take to perform maintenance procedure? Variable, 1-8 hours.

7. Are any data affected or lost during maintenance procedure? CT25K data are unavailable during performance of maintenance procedures.

8. How are potential affects to data documented? The time period during which the instrument was shut down for maintenance will be documented in the Site Operations Log.

9. What are corrective procedures when maintenance falls behind schedule? The only regular, periodic maintenance required for the CT25K is cleaning of the transmitter and receiver windows. If the windows are overly dirty, this will be noticed by one of the Weather Observers and corrected on the spot.

10. Where is actual maintenance work documented? In the Site Operations Log.

D. Data Integrity and Quality Inspections:

1. What nodes or activities along the data pipeline affect (or can potentially affect) the data stream?
   Controller Boxes: No
   Microprocessors: Yes
   Data Logger: No
   Communication lines/links: Yes
   Calibration Data files: No
   Ingest Modules: Yes.

2. What are current difficulties? We have found that the CT25K is having difficulty detecting thin clouds during the day between 2 and 7 km because of the bright shy in the tropics and Vaisala's nise reduction algorithm at the microprocessor level. We are turning off the noise reduction algorithm.

3. List and describe any standard or non-standard data inspections (active or planned) under each of the following categories:
   Data Existence check: This check is performed during and after ingest by the Experiment Center at PNNL. This check is also performed periodically by Jim Mather at the Pennsylvania State University.
   Mentor QC checks (during ingest): This check is the responsibility of the instrument mentor but has not yet been implemented on a regular basis.
   Mentor QC checks (outside of ingest): Yes
   Within Platform Check: No
   Multiple Platform Check: No
   Other automated netCDF file checks: No
   Other analytic tools or algorithms: No.

4. Does storage media exist on the instrument system to back up data and store it for delayed data ingest? Please identify media and the maximum period of time that the data can be backed up on the media: Data may be temporarily stored on the hard disk of the CT25K Linebacker Computer located in the TWP instrument van Trailer. The maximum amount of data which can be backed up on this laptop computer is about 1 month.

7.5 Glossary

Ceilometer - an instrument for observing the height of cloud bottoms that degrade horizontal visibility for aircraft to less than 100 m.

Lidar - an instrument that uses laser ranging and detection to determine the direct backscattering profile in the atmosphere

um - a micrometer (10-6 m)

Also see the ARM Glossary.

7.6 Acronyms

LIDAR: Light Detection and Ranging
MPL: Micro-Pulse Lidar
MWR: MicroWave Radiometer
SGP: Southern Great Plains
TWP: Tropical Western Pacific
WSI: Whole-Sky Imager

Also see the ARM Acronyms and Abbreviations.

7.7 Citable References

Lonnqvist, J. 1995: Experiences with a Novel Single-lens Cloud Height Lidar. *Preprints, Ninth Symposium on Meteorological Observations and Instrumentation*, March 27-31, 1995, Charlotte, NC, Amer. Meteorol. Soc., Boston, MA, pp. 106-109.