OPERATING MANUAL

VPF Series

Present Weather
Sensors

EN
102186.08F

senseca
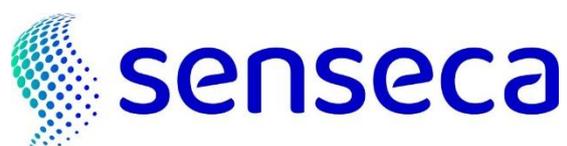
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Contents

1   GENERAL INFORMATION

The sensors covered in this manual:

Sensor Model	Capability
VPF-710	Visibility

This model has an extra backscatter receiver for:

VPF-730	Visibility
	Precipitation type identification

Rain rate

Snowfall rate

Precipitation accumulation

VPF-750	Visibility
	Precipitation type identification

This model has an extra precipitation sensor and an extra high accuracy temperature and humidity sensor for:

50 weather codes (from WMO

Code Table 4680), including:

Past Weather

Freezing Rain

Ice Pellets

CE   UK CA   RoHS Compliant

Thank you for choosing Senseca as your supplier of Present Weather Sensors

A great deal of time has been invested at Senseca to offer the best combination of sensor performance and value and almost three decades of experience and knowledge have been incorporated into the VPF Sensors. We are confident that they will provide you with many years of reliable, accurate operation.

Features of the VPF Sensors:

- Flexibility to connect to a wide range of data collection/processing units with a choice of RS232, RS422 or RS485 serial outputs.

- Easy installation due to its light weight and small footprint.

- Identification of precipitation type as well as accumulation totals (Not VPF-710).

- Identification of 50 weather codes (from WMO Code Table 4680) (VPF-750 only).

There are currently three sensors in Senseca's VPF sensor range. These are the VPF-710, the VPF-730 and the VPF-750. Throughout this manual, the term 'VPF-700 Series of Sensors' is used to refer to features common to all three of these sensors. Senseca may introduce other VPF sensors based on the original VPF designs, which fulfil alternative functions, but do not form part of the VPF-700 series and are not covered by this User manual.

Customer Satisfaction

At Senseca we set our standards high and only your complete satisfaction is acceptable to us. If you believe your experience has not met these standards, we would be grateful if you would contact us so we can rectify any issues you may have. Equally, if you have any positive experiences you would like to share, please contact us.

After Sales Support

Senseca offers support by telephone and email for the lifetime of these sensors, even if there has been a change of ownership, so please get in touch if you require help. Similarly, if you have any questions about your new equipment, we are only a mouse-click or telephone call away. Our contact details are given below.

For your convenience, our contact details are also on the label fixed to your sensor.

Contacting Senseca

If you would like technical assistance, advice or you have any queries regarding the operation of the sensor please do not hesitate to contact us.

For enquiries and technical support:
Contact us by telephone on: + 44 (0)1275 847787
Contact us by e-mail at: info.bristol@senseca.com

Five year warranty

The VPF Present Weather Sensors come with a five-year limited warranty against defective materials and workmanship. If you have any questions about the warranty, please contact Senseca.

If you need to technical support

The VPF sensors should give you many years of trouble-free service but in the unlikely event that the equipment requires attention contact Senseca UK.

In order to help us to assist you please be sure to include the following information:

- Model of equipment
- Serial number of equipment
- Nature of defect
- Data Output Strings
- Responses to R? command
- Relevant application details
- Your full name, address and contact details

CE Certification - Safety

All Senseca's VPF sensors comply with the requirements for CE marking. Once installed, it is the user's responsibility to ensure that all connections made to the sensor comply with all Local and National safety requirements.

In order for the mains version of any sensor to comply with the requirements of EN 61010-1:2010, 'Safety requirements for electrical equipment for measurement, control, and laboratory use', the following should be observed:

A switch or circuit breaker must be included in the installation. This switch or circuit breaker must be suitably located and easily reached. It must be marked as the disconnecting device for this equipment.

⚠ WARNING

This product **MUST BE EARTHED**. Failure to install a suitable earth may result in inaccurate readings and damage to the product and attached equipment.

Failure to install an earth will make the unit potentially unsafe when hazardous voltages are used.

2   SENSOR SET-UP

The format of this section is such that it logically follows these recommended procedural steps:

Step 1 - Unpack equipment and ensure that all required parts are supplied and identified.

Step 2 - Make electrical connection as required for testing and configuration.

Step 3 - Power up and test equipment on bench.

Step 4 - Configure equipment as required for site installation.

Step 5 - Installation including siting considerations, height, orientation, mounting and electrical grounding.

Step 6 - Carry out commissioning test procedure.

NOTE

Many of the tests specified within this manual require the use of a PC or equivalent. To achieve the two-way serial communication required, Senseca recommends the use of a PC running the Sensor Interface Software. If this software is not available, use a terminal program - for example Windows® HyperTerminal™.

2.1   STEP 1 - Unpacking the sensor

Calibration Kit
(Option)

Documentation

Top Layer

VPF-730 shown
Other sensors will
be packed similarly

Spaces for VPF-750
accessories

Cables, Mounting kit,
Temp sensor

Bottom Layer
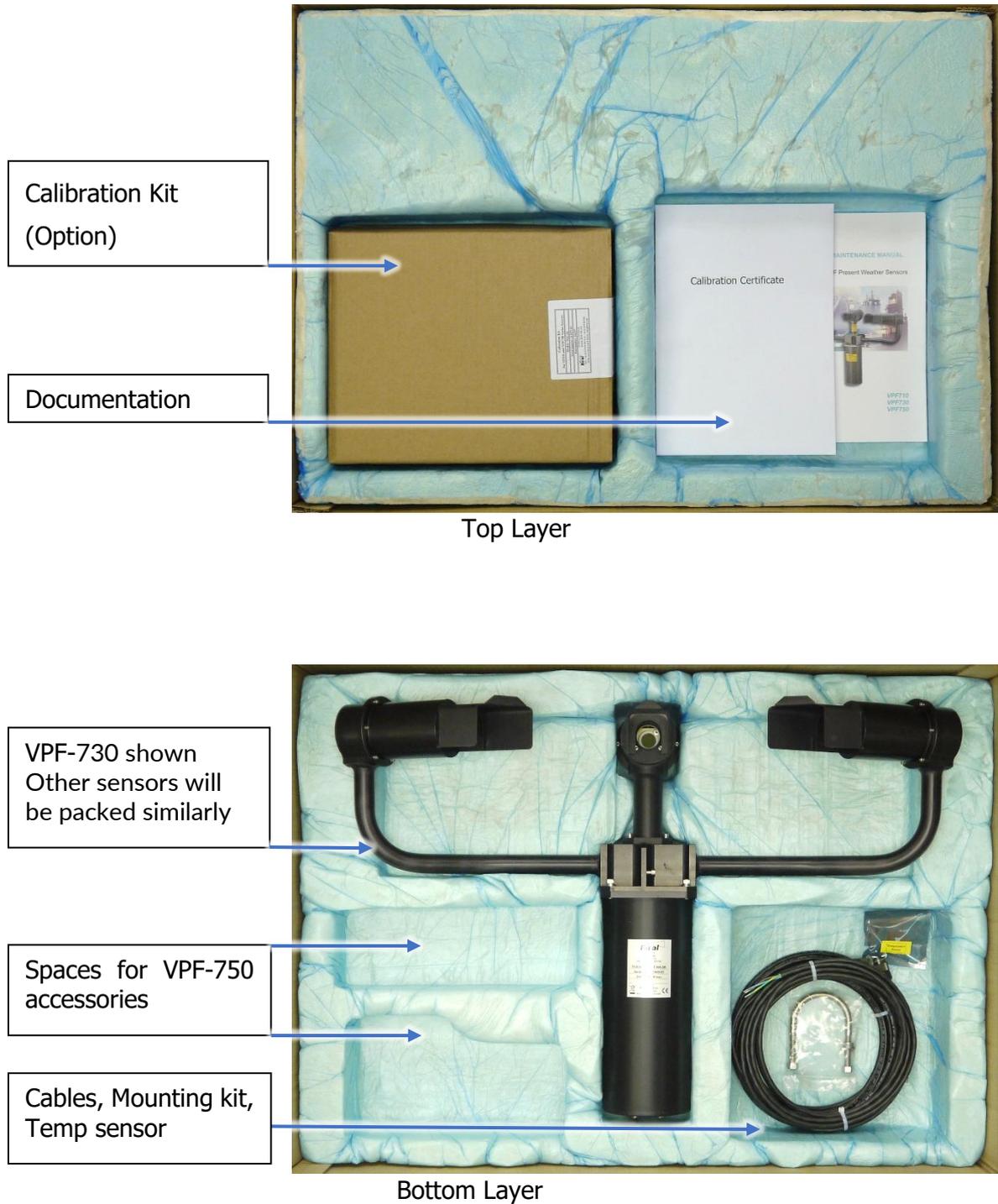
Figure 2-1 VPF-730 in its packaging

2.1.1   Other optional components you may have ordered:

Calibration Kit

The calibration kit is supplied in a protective carrying case, containing: a calibration screen, mounting arm and connector (referred to as the calibration reference plaque when assembled) and 3 x grey foam plugs.

Mains Adapter

A mains adapter to operate a 12V or 24V sensor using mains power.

Ambient Light Sensor

A very wide range background light meter that measures from 2 to 40,000 cd.m^{-2}. This sensor connects via a 1m cable to the factory installed input on any of the VPF-700 series of sensors. Light levels are appended to the sensor data string as a 5 digit ASCII character string giving the luminance value in cd.m^{-2}, see Sections 3.3.2 and 3.4.

External High Accuracy Temperature and Humidity Sensor

Supplied as standard on the VPF-750. Not applicable to the VPF-710. When fitted to the VPF-730 it enables Dust, Smoke and Mist to be identified, distinguishing these from Haze and Fog.

2.2 STEP 2 - Electrical Connections

All electrical connections should be completed before applying power to the sensor.

2.2.1 Cables

The VPF-700 series of sensors are supplied with all necessary cables. Generally, two cables are required, one for power and one for data. These two cables are supplied in a standard length of 6m. Any other length up to 25m can be supplied as an option if specified at time of order. A single power and data cable can be supplied as an option if specified at time of order. This single cable version can only be supplied configured for RS232 data communication option, and only in the 12V DC or 24V DC models.

🛈 NOTE:

> The RS232 configuration is suited to low to moderate electrical noise environments with moderate cable lengths and baud rates. For higher electrical noise environments with higher baud rates and longer cable lengths RS422 is recommended.

All the cables are supplied terminated at one end with the applicable connectors. Contacts in the plugs and receptacles are gold over nickel-plated copper for maximum corrosion resistance. Internal gaskets assure watertight performance. The cables are terminated with tinned tails at the other end for user connections. Each connector configuration is specific to its sensor function so that each can only be mated to the correct cable. An option for the cables to be permanently connected to the sensor via cable glands is available, see Section 2.2.7.

Temperature Sensor
3 Pin Socket

Power Input
3 Pin Plug

Data Cable
6 Pin Plug
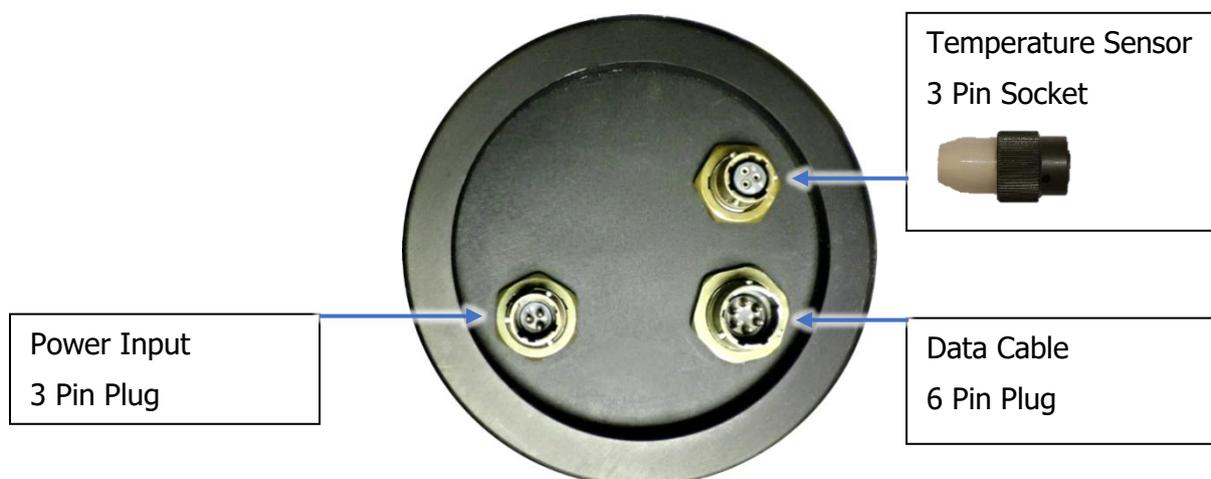
2.2.2 Sensor Connections VPF-710 and VPF-730

Figure 2-2 Example of VPF-710 and VPF-730 Connectors

Figure 2-2 Example of VPF-710 and VPF-730 Connectors, shows the base of a typical sensor.

The sensor will only be fitted with the required connectors, so the actual number and position of the connectors may not be as shown. The cables supplied will be correct for the specific sensor and can only be mated with the correct sensor socket for each function.

2.2.3   Sensor Connections VPF-750

| Power Input |
| Temperature/Humidity |
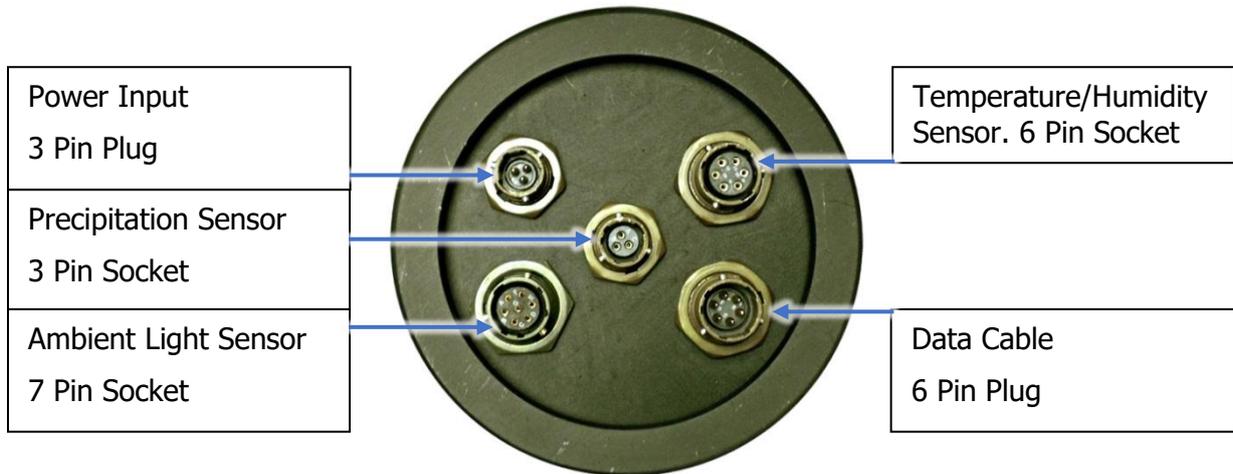
Figure 2-3 VPF-750 Connectors

Figure 2-3 VPF-750 Connectors, shows the base of a typical VPF-750 sensor. It shows the option of separate power and data connection, the connection for the temperature and humidity sensor, the precipitation sensor connection and the ambient light sensor connection.

2.2.4   Power Input Connections – Twin Cable Sensors

The power cable furnished with the sensor has the following pin and conductor assignments.

110 and 230VAC Models

Pin Number	Conductor Colour	Function
A	Brown	AC Live
B	Blue	AC Neutral
C	Yellow/Green	Sensor Ground

Table 2-1 AC Power Connections

⚠️ WARNING

For Mains Powered Sensors

A switch or circuit breaker must be included in the installation

It must be suitably located and easily reached

It must be marked as the disconnecting device for the VPF sensor

Ensure the installation complies with all local regulations

12 and 24VDC Models

Pin Number	Conductor Colour	Function
A	Brown	12V DC or 24V DC
B	Blue	0V
C	Yellow/Green	Sensor Ground

Table 2-2 DC Power Connections

2.2.5   Data Connections – Twin Cable Sensors

RS232 Signal Connections

When operating in the RS232 interface mode, the output signal cable furnished with the sensor has the following pin and conductor assignments. The cable consists of 3 sets of twisted pairs. The Function data refers to the SENSOR function.

Pin Number	Pair Number	Conductor Colour	Function
A	1	Red	Tx Data
B	1	White	Not Used
C	2	Brown	Rx Data
D	2	White	Not Used
E	3	Grey	Signal Ground
F	3	White	Sensor Chassis Ground

Table 2-3 RS232 Signal Connections

RS422/485 Signal Connections

When operating with the RS422 or RS485 interface protocols, the output signal cable furnished with the sensor has the following pin and conductor assignments. The cable consists of 3 sets of twisted pairs. The Function data refers to the SENSOR function.

Pin Number	Pair Number	Conductor Colour	Function
A	1	Red	Tx Data +
B	1	White	Tx Data –
C	2	Brown	Rx Data +
D	2	White	Rx Data -
E	3	Grey	Signal Ground
F	3	White	Sensor Chassis Ground

Table 2-4 RS422/485 Signal Connections

2.2.6   Option – Single Combined Power and Data Cable.

When configured for a single combined power and data cable, the cable furnished with the sensor has the following pin and conductor assignments. The cable consists of 3 sets of twisted pairs. The Function data refers to the SENSOR function.

ⓘ NOTE:

This configuration is only available with the RS232 communication protocol used on a DC power supply sensor.

Pin Number	Pair Number	Conductor Colour	Function
A	1	Red	+ve DC
B	1	White	-ve DC
D	2	Brown	Rx Data
E	2	White	Tx Data
C	3	Grey	Signal Ground
G	3	White	Sensor Chassis Ground
F			Not Used

Table 2-5 Combined Power and Data Connections

2.2.7   Option – Glanded cable outlets

This option is not available for the VPF-750.

For extreme environments, in particular continual salt spray, even the military specification passivated aluminium connectors can suffer serious corrosion over a few years. Senseca can provide a sensor with cables passing through plastic environmentally secure glands as a replacement for the standard connectors. The cables in this option of the sensor are permanently connected to the sensor during manufacture.

The cables fitted will be as specified above. See Table 2-1 AC Power Connections to Table 2-5 Combined Power and Data Connections, for the connection details for the free end of the glanded cables.

2.3   STEP 3 - Equipment Test

Senseca recommends that the equipment is powered and checked on the bench before site installation. This is to ensure that you are comfortable with the functionality of the sensor and to pre-empt any queries that arise before attempting site installation.

❗ NOTE

> This procedure assumes a default configuration for the sensor - please check the Calibration Certificate supplied with your sensor for specific configuration details.

❗ NOTE

> In this test, and in all subsequent sections of this manual, the following convention MUST be observed:
>
> ALL COMMANDS MUST BE TERMINATED WITH <CARRIAGE RETURN> AND <LINE FEED> (ASCII CHARACTERS 13 AND 10). In this manual this is abbreviated to <CRLF>.

Equipment Test Procedure

1. Connect the power-input cable to a local power source. Do not turn power source on. Connect sensor earth lug to earth, this may not be necessary but can help prevent communication errors with certain PCs.

2. Connect the signal cable to a PC running the Sensor Interface Software. If this is not available, use a terminal program - for example Windows® HyperTerminal™. (For RS422/485 sensors a RS422 to RS232 converter must be used). *Note: Senseca recommends testing to be done with RS232 or RS422 as applicable. When you are confident that the sensor is working it can then be set up for RS485 if required.*

3. Configure the terminal program, either Sensor Interface Software or HyperTerminal™ as follows:

   Default Interface Parameters

   Baud Rate..1200 (9600 on VPF-750)

   Data Bits...8

   Stop Bits 1

   Parity..None

   Flow Control..None

   (If using HyperTerminal™ the options 'Send line ends with line feeds' and 'Echo typed characters locally' in ASCII set up should be checked.)

4. Turn the local power source "ON".
   If communications are working the sensor will respond with "Biral Sensor Startup".

5. Check Data Transmission To Sensor:
   Send the command   R?   from the PC terminal to the sensor:
   The sensor will respond with its Remote Self-Test & Monitoring Message.
   For example:
   100,2.509,24.1,12.3,5.01,12.5,00.00,00.00,100,105,107,00,00,00,+021.0,4063

6. Check Data Transmission From Sensor:
    If the sensor is NOT in polled mode:
    Wait for the sensor to transmit a Data Message (approx. 80 seconds from power up

    If the sensor is in polled mode:
    Send the command   D?   from the PC terminal to the sensor:
    A Data Message will be transmitted immediately.

7. EXCO Calibration check:

**THIS PROCEDURE CAN ONLY BE COMPLETED IF A SUITABLE
VPF-700 SERIES CALIBRATION KIT AND PC ARE AVAILABLE**

Carry out the calibration check procedure in Section 6.2, to ensure that the EXCO value changes i.e. the sensor responds to changes in visibility.

 NOTE

As this calibration check is being carried out indoors the EXCO value may NOT agree with that marked on your calibration reference plaque.

The sensor is fully calibrated before it leaves Senseca.

2.4   STEP 4 - Configuration Options

There are several configuration options available for the user to select. These options are set directly using commands. The configuration commands are detailed below in sections 2.4.1 to 2.4.10.

An alternative method of configuring the sensor is to use the Sensor Interface Software. The "Sensor Settings" tab provides an easy method of viewing or changing the settings.

2.4.1   Message Checksum

A checksum byte can be included with messages sent by the sensor to verify that noise in the communications link has not changed the message. Generally, noise is not a problem and checksum verification is not required.

Note: if RS485 communications are selected then this checksum is not used.

By default, the sensor is configured at the factory with checksum DISABLED.

To check the setting of the checksum option, send the command: OPCS?

The sensor will respond as follows:

<div align="center">

00   = Checksum disabled

01   = Checksum enabled

</div>

To enable the checksum, send the commands: CO followed by OPCS1

To Disable the checksum, send the commands: CO followed by OPCS0

The checksum character is positioned after the message and before the end characters (<crlf>). The checksum value is between 0 and 127, and is the sum modulo 128 (the remainder after the sum is divided by 128) of all the ASCII values of the characters in the message except the end characters.

The checksum value is replaced by its bit wise complement if it happens to be any of the following: ASCII 8 (backspace), ASCII 10 (linefeed), ASCII 13 (carriage return), ASCII 17 through ASCII 20 (DC1 through DC4), or ASCII 33 (exclamation point '!').

For any message:

C1 ... Cm <cksum><crlf>

The calculation is as follows:

$$< cksum >= \left(\sum_{n-1}^{m} c_n \right) MOD\, 128$$

IF <cksum> = 8 THEN <cksum> = 119

IF <cksum> = 10 THEN <cksum> = 117

IF <cksum> = 13 THEN <cksum> = 114

IF <cksum> = 17 THEN <cksum> = 110

IF <cksum> = 18 THEN <cksum> = 109

IF <cksum> = 19 THEN <cksum> = 108

IF <cksum> = 20 THEN <cksum> = 107

IF <cksum> = 33 THEN <cksum> = 94

2.4.2   RS485 Communications Configuration

The VPF sensors can use either RS232C or RS422/RS485 signal voltage levels. The configuration of the sensor is selected at time of manufacture.

If the signal voltage levels for RS422/RS485 are set either RS422 or addressable RS485 communication protocols may be used. By default, the sensor is configured at the factory for RS422 protocol unless specifically requested when ordering.

To determine the RS485 communications setting

To query the RS485 setting, send the following command: OP485?

The sensor will respond with:

>00   = Disabled
>
>01   = Enabled

Enabling the addressable RS485 Communications

To enable RS485 communications, send the commands: CO followed by OP4851

To disable RS485 Communications

To disable the RS485 communications, send the commands: CO followed by OP4850

RS485 Protocol Format

The RS485 communication protocol is based on the Modbus ASCII Frame Format.

Each data request and transfer is configured as follows:

Start: ':' (3A Hex).

Sensor Address: 2 Character address field.

Data: As standard VPF message format, see Section 3.

LRC Checksum: 2 Characters - Longitudinal Redundancy Check.

End: 2 Characters - Carriage return, Line Feed.

Start

The ':' (colon) symbol is used as a start flag which is 3A Hex.

Sensor Address

The 2 character sensor address is defined by the operator for the unit and programmed as specified in Section 2.4.3. It can be any numeric value between 00 and 99. It is used by the sensor to identify the recipient of the message.

Data

This is a variable length ASCII character string as defined in Section 3. The master has a defined range of commands available for the SWS sensor. The SWS sensor has a range of defined data messages. These messages can either be sent as a response to a request for data by the master unit, or sent without any request on a timed basis, according to the sensor's configuration. It is recommended that a polled system is used in a multi-sensor application as this can avoid most data contention issues through the design of a suitable system operating schedule.

LRC Checksum

This enables error checking, allowing the master to request a re-send if errors are detected. For RS485 a Longitudinal Redundancy Check (LRC) Checksum is generated on the data.

NOTE

This checksum is different from the optional RS232/RS422 Checksum.

The LRC is one byte, containing an 8–bit binary value. The LRC value is calculated by the transmitting device, which appends the LRC to the message. The receiving device calculates an LRC during receipt of the message, and compares the calculated value to the actual value it received in the LRC field. If the two values are not equal, an error is implied, and the message is discarded.

The LRC is calculated by adding together successive 8–bit bytes of the message, discarding any carries, and then two's complementing the result. It is performed on the ASCII message field contents excluding the 'colon' character that begins the message, and excluding the

<crlf> pair at the end of the message. The LRC byte is converted to 2 ASCII characters and appended to the message.

For example, the message:

:42D?

Checksum is calculated as :

ASCII string 42D?

BYTE Values (in Hex) 34+32+44+3F

Sum is E9

One's compliment (0xFF – 0xE9) = 0x16

Two's compliment 0x16 + 1 = 0x17

Checksum is 0x17 (Hex)

Checksum ASCII characters are "17"

Transmitted string will therefore be:

:42D?17<CRLF>

End

All communications will end with the standard 2 characters, carriage return line feed <CRLF> pair (ASCII values of 0D & 0A Hex).

Checksum Override

When using addressable RS485 communications, the sensor will disregard any commands that do not have the sensor address or have an incorrect checksum. For a command to be valid, it must be prefixed by :XX (where XX is the address) and have the 2 character checksum on the end. If the checksum character is set to FF then the sensor will accept the message without checking the checksum. This is useful when using programs such as HyperTerminal™ for diagnostics.

For example.

A sensor with address 00 to request a data message:

Send command:

:00D?FF

Recommendations

When using the sensor on an RS485 network it is recommended that the sensor be set up in polled mode (Automatic message transmission disabled) rather than transmitting a data message automatically. See Section 2.4.4 for full instructions for setting this configuration.

🛈 NOTE

When RS485 communications are enabled the sensor will not output the "Biral Sensor Startup" message on power up and reset.

2.4.3   Sensor Addressing – RS485 sensors only

To use addressable RS485 communication each sensor must have a unique address in the range 0-99. By default, the sensor address is set to 0.

Querying the sensor address

To query the sensor address, send the command: ADR?

The sensor should respond with the address: e.g. 00.

Changing the sensor address

To change the sensor address, send the command: ADRxx

where xx is a number between 00 and 99.

e,g, ADR02 sets the sensor address to 02.

The sensor should respond with: OK.

2.4.4   Automatic message setting

The sensor can be set to send a data message automatically after each data collection period, or to send a data message only when requested (polled mode). The default setting is for automatic data transmission. To check which method is programmed send the command:

OSAM?

The sensor will send the reply:

00 = Automatic message transmission disabled

01 = Automatic message transmission enabled

To set the sensor to the required automatic message setting, send the message:

OSAMx

Where x is:

0 = Automatic message transmission disabled

1 = Automatic message transmission enabled

The sensor will respond with "OK".

2.4.5   Data message type setting

The sensor can be set to send a compressed data message or an expanded data message, as detailed in Section 3. The default setting is for expanded data message. To check which message is programmed send the message:

OSCM?

The sensor will send the reply:

00 = Expanded data message enabled

01 = Compressed data message enabled

To set the sensor to the required data message setting, send the message:

OSCMx

Where x is:

0 = Expanded data message enabled

1 = Compressed data message enabled

The sensor will respond with "OK".

2.4.6   Optional hood heater operating setting

The sensor can be set to have the hood heaters disabled, or for them to work automatically. The default setting, for sensors with fitted hood heaters, is for automatic hood heater operation. To check which configuration is programmed send the message:

   OSHH?

The sensor will send the reply:

00 = Hood heaters disabled

01 = Hood heaters on automatic

To set the sensor to the required hood heater configuration, send the message:

   OSHHx

Where x is:

0 = Hood heaters disabled

1 = Hood heaters on automatic

The sensor will respond with "OK".

2.4.7   Window heater operation setting

The sensor can be set to have the window heaters disabled, permanently enabled, or for them to be controlled according to contamination levels. The default setting is for window heaters enabled and on. To check which configuration is programmed send the message:

OSWH?

The sensor will send the reply:

00 = Window heaters disabled

01 = Window heaters enabled and on

02 = Window heaters enabled and controlled according to contamination levels

To set the sensor to the required window heater configuration, send the message:

OSWHx

Where x is:

0 = Window heaters disabled

1 = Window heaters enabled and on

2 = Window heaters enabled and controlled according to contamination levels

The sensor will respond with "OK".

2.4.8   Baud Rate Configuration

Default communication parameters are 1200 Baud (9600 for VPF-750), 8 data bit, 1 stop bit, no parity, and no flow control. The baud rate may be changed if required as follows:

Send   %Bn

Where n is a number from 1 to 7.

Just typing %B will bring up the different baud rate options:

SELECT REQUIRED BAUDRATE BY TYPING %B(NUMBER)

1....1200 BAUD

2....2400 BAUD

3....4800 BAUD

4....9600 BAUD

5....19K2 BAUD

6....38K4 BAUD

7....57K6 BAUD

Select the baud rate to use, for example to select 9600 baud the user would type

%B4<CRLF>

The user then receives a prompt to send an "OK" to the sensor at the new baud rate setting. The new setting will only be accepted if the user manages to communicate with the sensor at the new baud rate within 60 seconds. Otherwise the sensor will reset and continue operation with the original baud rate settings. If an "OK" command is received at the new baud rate the sensor will update its settings and restart.

2.4.9   Configuring **the MOR Output**

In the factory default setting the Meteorological Optical Range (MOR) values output in the data messages are expressed in kilometres to a resolution of 10m. The output can also be expressed in metres to a resolution of 1m or kilometres to a resolution of 1m.

Changing the output format of the MOR value does not affect the EXCO output field in the sensor data message.

Querying the MOR Output Resolution

To query the MOR output resolution, send the KM? command. The sensor will respond with five characters as shown below:

00000 Default Setting, MOR expressed in km to 10m (xx.xx KM)

00001 Metre output, MOR expressed in m to 1m (xxxxx M)

00002 Kilometre output, MOR expressed in km to 1m (xx.xxx KM)

Setting the MOR Output Resolution

To set the MOR resolution send the KMn command, with n set as follows:

KM0   Default Setting, MOR expressed in km to 10m (xx.xx KM)

KM1   Metre output, MOR expressed in m to 1m (xxxxx M)

KM2   Kilometre output, MOR expressed in km to 1m (xx.xxx KM)

NOTE

The sensor will undergo a soft reset when the command is processed.

2.4.10 Configuring the EXCO Output

The way in which sensors report EXCO can be configured using the PEn command to allow the reporting of either EXCO or TEXCO. TEXCO is Transmissometer equivalent EXCO. This is the forward scatter total EXCO adjusted to compensate for the difference in reporting between transmissometers and forward scatter sensors during liquid precipitation events. TEXCO is reported as xxx.xx in units of km^{-1}. The VPF-710 can additionally be configured to report MOR in place of EXCO.

The configuration options vary significantly between sensor types and whether compressed or standard data messages are configured. Details of the configuration options for each sensor model are given in Section 3.

Querying the EXCO output Setting

To query the EXCO output setting, send the PE? Command. The sensor will respond with five characters as shown below:

    00000 Default Setting, forward scatter EXCO or no EXCO value

    00001 TEXCO output

    00002 MOR Output (VPF-710 Only)

Setting the EXCO Output

To set the EXCO output send the PEn command, with n set as follows:

    PE0   Default Setting, EXCO field is total forward scatter

    PE1   TEXCO reported in EXCO field

    PE2   MOR reported (VPF-710 Only)

The effect of the PEn command on the data message of each sensor is described in Section 3.

2.5   STEP 5 - Installation

Please consider the following factors when installing the sensor:

    (1) Siting considerations.

    (2) Height of the sensor above ground.

    (3) Orientation of the sensor.

    (4) Mounting the sensor.

    (5) Electrical grounding.

Each of these factors is covered in more detail below:

2.5.1   Siting Considerations

Pollutants – Care should be taken to ensure that the sensor is situated away from any possible sources of pollutants (for example car exhausts, air-conditioning outlets etc.). Particulates entering the sensor's sample volume will cause errors in the reported visibility measurements and precipitation reports.

Reflected Light – Care should be taken to ensure that the sensor is situated away from any causes of reflected light (for example walls, trees and people etc.). Reflected light entering the sensor's optics will cause errors in the reported visibility measurements.

Air-flow – Care should be taken to ensure that the sensor is situated away from objects that disrupt the 'normal' flow of air to and through the sensor sampling volume (for example walls, trees and other equipment etc.).

RFI Interference – In addition to the above mentioned natural effects that may influence the performance of the sensor, due regard should also be given to radiated electrical interference. Sources of potential interference include radio antennas and radiated transients from high-voltage plant located near to the sensor installation.

2.5.2   Height Above Ground:

The optimum height at which to mount the sensor depends on the application. The table below shows some recommended heights.

Application	Typical height	Comment
Highway fog-warning systems.	1.5 to 2 metres (4.9 to 6.6 feet).	Recommended height for the sensor sample volume is the average distance of a vehicle driver's eyes above the roadway.
Airport applications.	4.3 metres (14 feet) above the runway.	This is the standard height for visibility sensors in the U.S. This height may differ in other countries.
General meteorological.	1.8 metres (6 feet).	This is a suitable height unless the particular application dictates otherwise.

Table 2-6 Recommended Sensor Height Above Ground

2.5.3   Orientation of Sensor Head

The orientation of the sensor head should be such that the rising or setting sun does not appear in the field-of-view of the receiver lens.

🛈 NOTE

It is desirable to avoid sunlight from flooding the receiver optics and to avoid sunlight induced noise spikes from creating false precipitation counts, although false-alarm algorithms in the sensors invariably eliminate such false counts.

VPF-710 Orientation

The VPF-710 receiver optics should be aligned with true North (true South in the Southern Hemisphere) as shown in Figure 2-4 VPF-710 Orientation.
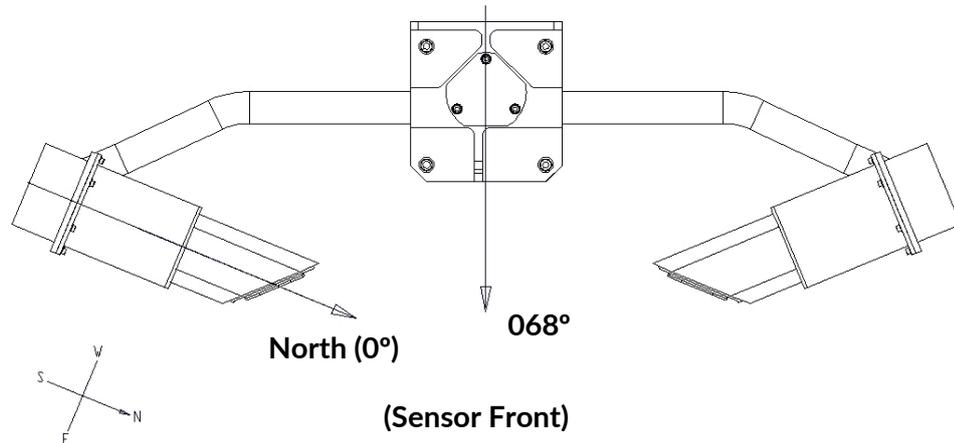
Figure 2-4 VPF-710 Orientation

VPF-730 and VPF-750 Orientation

The VPF-730 and VPF-750 alignment should be such that neither the forward nor the backscatter receiver optics is aligned with the rising or setting sun.

For the Northern Hemisphere the best mounting orientation is shown in Figure 2-5 VPF-730 and VPF-750 Orientation (for the Southern Hemisphere the bearings should be increased by 180°).
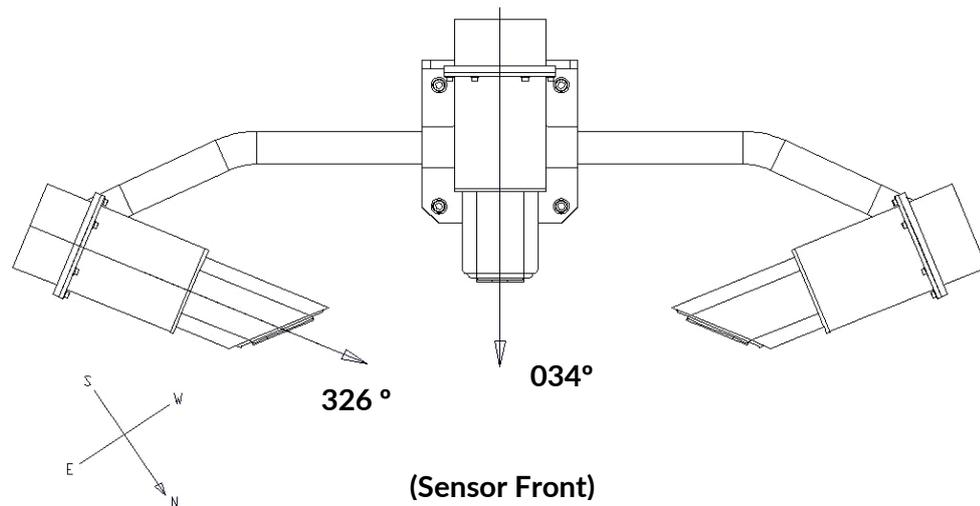
Figure 2-5 VPF-730 and VPF-750 Orientation

2.5.4   Mounting the Sensor – All Models

The sensor head should be attached at the very top of the mounting pedestal with a U-bolt. The mast should be made from galvanised steel pipe or heavy walled aluminium tube whose outer diameter is in the range from 40 to 64 mm. *(Note: The maximum diameter for the VPF-750 temperature and humidity radiation shield is 50mm).* Pipe or tubing with an outer diameter greater than 66 mm will not permit use of the U-bolt provided with the sensor. Pipe diameters less than 40 mm may not provide the U-bolt with adequate bearing surface.

A stainless steel U-bolt with hardware is provided for securing the sensor to the top of the mast. A V-block saddle is attached to the sensor head mounting plate to oppose the U-bolt, thus providing a secure grip on the mast. The sensor head should be mounted near the very top so that the mast will not interfere with the free flow of fog or precipitation through the sample volume. The flat stainless steel washers should be placed next to the anodised surface of the mounting plate to prevent gouging by the lock washers as the nuts are tightened.
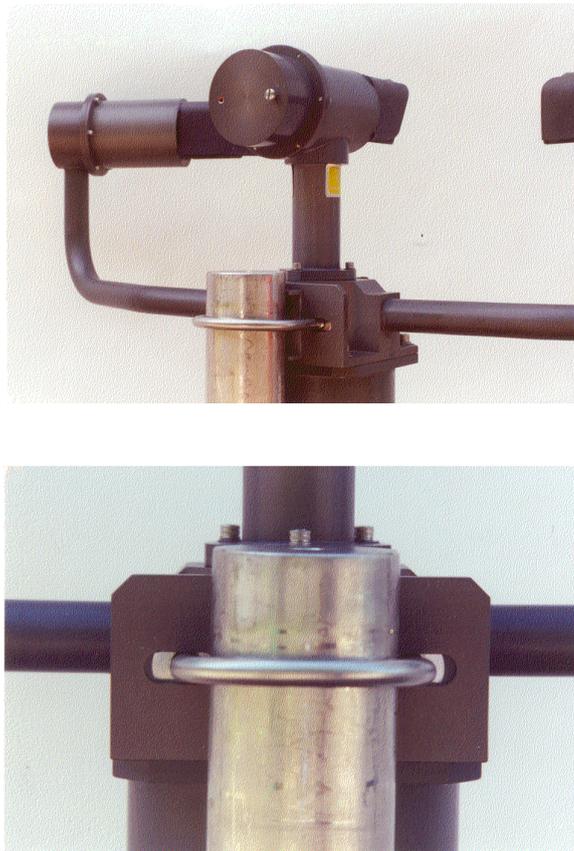
Figure 2-6 U-bolt Mounting Method

2.5.5   Mounting the Sensor – VPF-750 Specific

The VPF-750 consists of a VPF-700 Present Weather Sensor, combined with a Precipitation Sensor, a Precision Temperature and Humidity sensor with radiation shield and an optional Ambient Light Sensor. The complete system is assembled as shown in Figure 2-7 VPF-750 System:
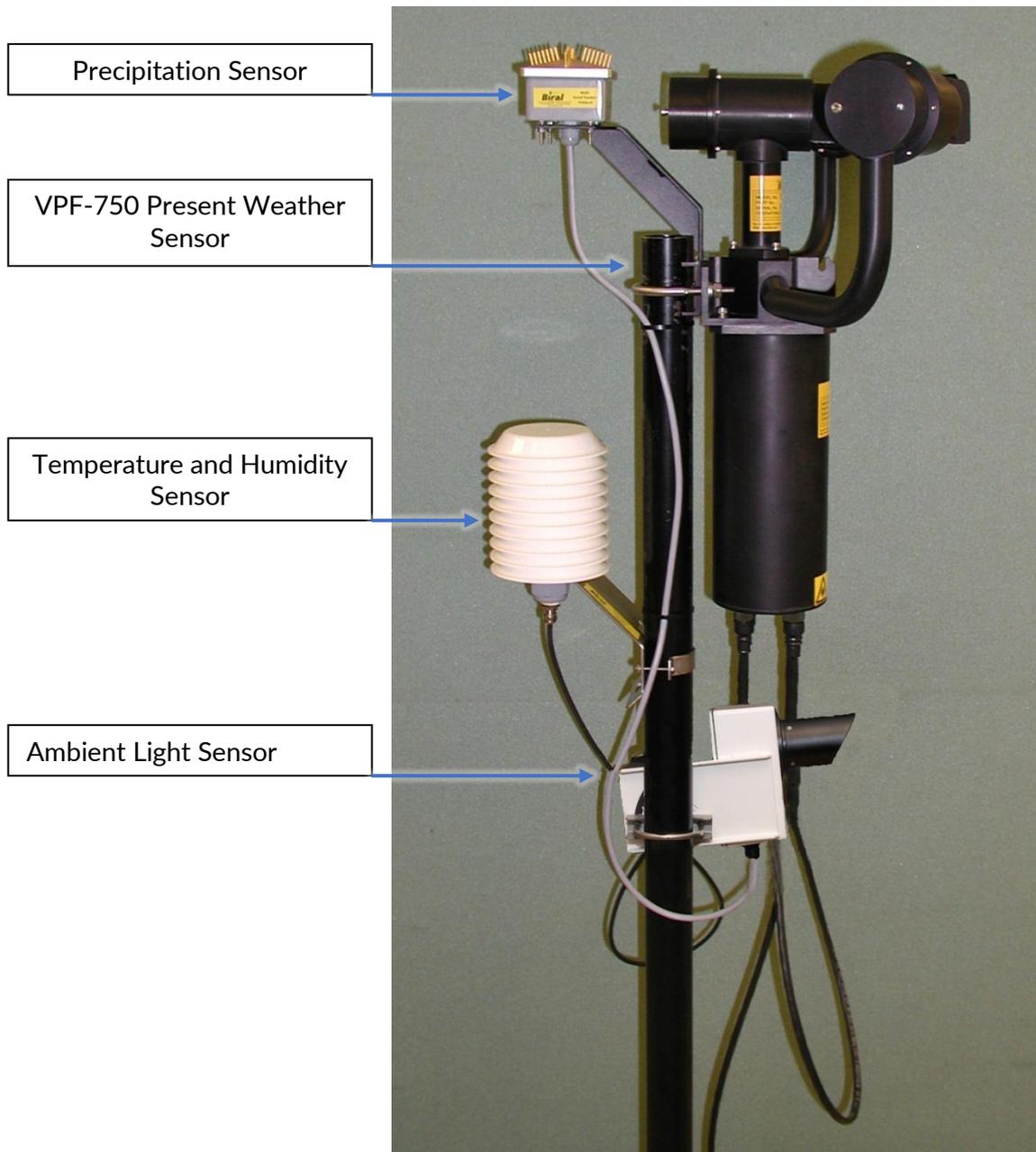
Figure 2-7 VPF-750 System

2.5.6   Assembly Instructions VPF-750

On the rear of the present weather sensor, unscrew the small saddle which locates the system onto the mounting pole. Place the appropriate end of the Precipitation Sensor mounting bracket under this saddle and replace. This will locate the Precipitation Sensor immediately behind the back-scatter head as shown in Figure 2-8 Precipitation Sensor Mounting Details.

Precipitation Sensor Mounting Bracket

Grounding Screw

Saddle Mounting Screws
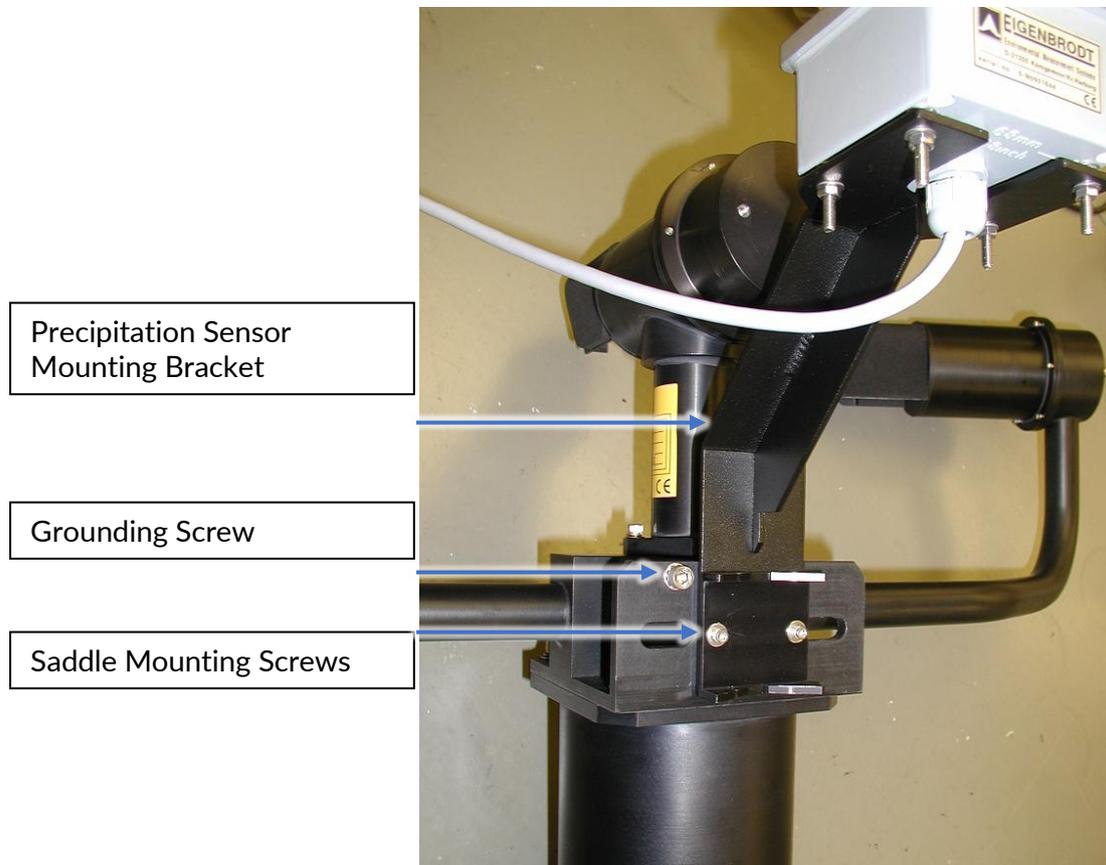
Figure 2-8 Precipitation Sensor Mounting Details

Mount the Precipitation Sensor to the mounting bracket as shown.

Mount the Present Weather Sensor to the mast keeping the Present Weather Sensor orientation as shown in Section 2.5.3.

Mount both the Temperature and Humidity Sensor and the optional Ambient Light Sensor to the mast as shown in Figure 2-7 VPF-750 System. Align the Ambient Light Sensor (if fitted) at a suitable angle above horizontal as defined by local requirements.

The Present Weather Sensor has between three to five connectors on its lower face. A typical configuration is specified in Section 2.2.3, but the number and position of the connectors may vary depending on the exact configuration purchased. The cables provided will only fit the appropriate connectors on the sensor.

2.5.7   Electrical Grounding

⚠ WARNING

This product **MUST BE EARTHED.** Failure to install a suitable earth may result in inaccurate readings and damage to the product and attached equipment.

Failure to install an earth will make the unit potentially unsafe when mains power is applied.

Possible sensor failure can result from the damaging effects of over-voltage transients induced on the power line and the signal distribution lines.

Destruction of sensitive components can result from unprotected lines, or sensor failure may occur over a long period of time due to slow device degradation. Destructive over volt transients can occur in many ways; e.g., lightning induced transients, AC power line transients and EMI/RFI electromagnetic noise. The power/control subsystem of the sensor contains transient surge-arrestors on all power and signal lines as a standard feature. EMI filters are present on the power and signal lines entering the power/control subsystem.

It is essential to connect the sensor to earth ground for maximum protection of the sensor. The following notes are intended to provide some guidance in the design and construction of an electrical grounding system.

(1) Ground Rod: A 2.5m ground rod should be used to make contact with moist soil during even the driest periods.

(2) Lead Lengths: No. 6 AWG solid copper wire should be used to connect the sensor and thus the transient voltage suppressers to the ground rod. Use the shortest and most direct paths to the ground. Simply connect the ground lead to the grounding screw provided on the front of the lower mounting flange of the sensor (Figure 2-8 Precipitation Sensor Mounting Details).

(3) System Interconnections: Eliminate all isolated ground loops. The shield of the signal output cable, for example, should be attached only at one end of the cable and left floating at the other end. Preferably, it should be attached to ground at the sensor end of the signal cable.

(4) Connections: Use tight, corrosion-proof bare metal connections throughout the grounding system.

2.6   STEP 6 - Test and Commissioning

The following steps contain a few basic checks to provide confidence that the unit is functioning correctly after installation.

These checks are recommendations only and are neither essential nor exhaustive.

2.6.1   Checking Power Supply

Before connecting the power cable to the sensor, the supply voltage being provided should be measured to ensure that the voltage present is compatible with the sensor power requirement. Use a multimeter to measure AC/DC voltage (dependent on sensor voltage according to order). For AC supplies, check conformity with local and National installation requirements (see CE Certification – Safety, page x).

⚠ DANGER of electric shock!

Exercise caution when performing this measurement.

⚠ WARNING

Only connect the power cable if it matches the voltage requirements of the sensor. Damage caused by improper voltage connection is not covered under warranty.

2.6.2   Checking Data link

1.   Connect the power-input cable to a local power source, do not turn power source on.

2.   Connect the signal cable to a PC running the Sensor Interface Software. If this is not available, use a terminal program - for example Windows® HyperTerminal™. (For RS422/485 sensors a RS422 to RS232 converter must be used).
     Note: Senseca recommends testing to be done with RS232 or RS422 as applicable. When you are confident that the sensor is working it can then be set up for RS485 if required.

3.   Configure the terminal program as follows:

> **Default Interface Parameters**
>
> Baud Rate..1200 (9600 on VPF-750)
>
> Data Bits...8
>
> Stop Bits...1
>
> Parity...None
>
> Flow Control.......................................None

4.   Turn the local power source "ON".

    If communications are working the sensor will respond with "Biral Sensor Startup".

5. Check Data Transmission To Sensor.

Send the command R? from the PC terminal to the sensor.

The sensor will respond with its remote Self-Test & Monitoring message.

For example (see Section 2.6.3 for explanation):
100,2.509,24.1,12.3,5.01,12.5,00.00,00.00,100,105,107,00,00,00,+021.0,4063

6. Check Data Transmission From Sensor.

If the sensor is NOT in polled mode:

Wait for the sensor to transmit a Data Message (approx. 80 seconds from power up).

If the sensor is in polled mode, send the command: D? from the PC terminal to the sensor.

A Data Message will be transmitted immediately.

2.6.3   Remote Self-Test Check

Check that the values in the remote Self-Test & Monitoring message from the previous Data Transmission To Sensor Check are within the ranges indicated in Table 2-7 below.

Field 1:	Space	Message starts with a space.
Field 2:	100 or 108	Heater state and error flags.
Field 3:	2.450 - 2.550	Internal reference voltage.
Field 4:	9.00 - 36.00	Supply voltage.
Field 5:	11.2 -17.5	Internal operating voltage.
Field 6:	4.5 - 5.5	Internal operating voltage.
Field 7:	11.2 -17.5	Internal operating voltage.
Field 8:	00.00 - 06.00	Forward scatter background brightness.
Field 9:	00.00 - 06.00	Backscatter background brightness (VPF-730 and VPF-750 only).
Field 10:	85 - 105	Transmitter power monitor.
Field 11:	80 - 120	Forward receiver monitor (Option for VPF-710 and VPF-730).
Field 12:	80 - 120	Back receiver monitor (Not VPF-710, Option for VPF-730).

Table 2-7 Remote Self-Test and Monitoring Message Fields

2.6.4   Calibration Check

The sensor is fully calibrated before it leaves Senseca. However, if you would like to carry out a user confidence calibration check please follow the calibration check procedure in Section 6.2 to ensure that the MOR value changes i.e. the sensor responds to changes in visibility.

THIS PROCEDURE CAN ONLY BE COMPLETED IF A SUITABLE

VPF-700 SERIES CALIBRATION KIT IS AVAILABLE

2.6.5   Test Command

If you wish to test the connections to the serial outputs of the sensor, use the TEST command. This command allows the sensor to be set to a known condition for a set period of time allowing the unit to temporarily simulate foggy and clear conditions, which will allow checking of the sensor and overall system performance.

Command Syntax

To ensure the TEST command is not used inadvertently it must be proceeded by the Calibration Enable command, CO.

The TEST command takes the following form:

TEST,tt,vv.vv,f,c,pw<CRLF>

Where:

- tt   Duration of test in minutes – range 00 to 60,

  (00 will stop the test).

- vv.vv   Visibility in km
  Range 0.01 to maximum range of sensor.

- f   State of the Other Selftest digit in the Selftest & Monitoring field of the data message.
  0 = No Fault,
  1 = Other selftest fault exists.

- c   Window Contamination Indicator digit in the Selftest & Monitoring field of the data message.
  0= Windows not contaminated
  1= Window Contamination Warning
  2= Window Contamination Alert.

- pw   Present weather code – See below for available codes.

Available PW Codes:

> VPF-710: Not Applicable.

> VPF-730 & VPF-750:

>> 00,04,10,27,30,40,50,51,52,53,60,61,62,63,70,71,72,73,89

> An invalid code will return code 00 in the sensor message string.

(!) NOTE

The available codes may not be valid for the sensor in question and not all possible codes are available.

Example:

> TEST,02,07.50,0,0,00 – Outputs a visibility of 7.5 km for 2 min (Clear conditions)

> TEST,06,00.10,0,0,30 – Outputs a visibility of 0.1 km for 6 min (Foggy conditions)

Command Operation

Where trailing fields of the TEST command are omitted they will be automatically substituted by the value zero.

Example:

> TEST,5,2.34<CRLF>   (Sets the visibility to 2.34km for 5 minutes)
> has the same meaning as,

> TEST,5,2.34,0,0,0

Where a present weather code is supplied in the TEST command sent to a visibility only sensor such as a VPF-710, the present weather code is ignored.

Where a parameter is outside of the allowable range for the configuration of the sensor, the sensor will respond with BAD CMD. For example, if a VPF-710 has been configured to have a maximum reporting range of 20km and the TEST command states 50km the sensor will respond with BAD CMD.

At the end of the test period, or when the test period is terminated using TEST,0, the sensor will undergo an automatic soft reset.

For the duration of the test output the first character of the Selftest & Monitoring field of the data message will be set to T. This allows the system to which the sensor is connected to be aware that the data message contains test values and should not be used operationally.

Example:

> VPF-710 Sensor

>> VS01,000.55,TOO,100000,2.510,00.82,100,00,100,00,4040,+002.5,0000

CONGRATULATIONS

YOUR SENSOR SHOULD NOW BE FULLY CONFIGURED, TESTED
AND INSTALLED READY FOR USE

THE REMAINDER OF THIS MANUAL COVERS:
- **STANDARD DATA MESSAGES**
- **COMMANDS AND RESPONSES**
- **OPERATIONAL AND MAINTENANCE PROCEDURES**
- **CALIBRATION CHECK AND RE-CALIBRATION**
  PROCEDURE
- **MEASUREMENT PRINCIPLES**
- **SENSOR DETAILS AND SPECIFICATIONS**

3   STANDARD OPERATING DATA

When in standard mode a data message will be output from the sensor every measurement period (default 60 seconds). When in polled mode the same message is output only in response to the D? command. The operating mode is checked by sending command "OSAM?". The standard mode (default) is selected if the response is "01". If the response is "00", the polled mode is selected. Instructions for setting this configuration are provided in Section 2.4.4.

For each model in the VPF-700 series of sensors, either a compressed data message or an expanded data message can be selected. The type of message is checked by sending command "OSCM?". The expanded data message (default) is selected if the response is "00". If the response is "01", the compressed data message is selected. Instructions for setting this configuration are provided in Section 2.4.5.

🛈 NOTE

All responses from the sensor are appended with carriage return and line feed characters (<crlf>, see Section 2.3).

The following sections provide full details of the compressed and the expanded data messages for each sensor in the series.

3.1   Data Output Message VPF-710

3.1.1   VPF-710 Compressed Data Message

The data message format is:

CPaa,bbb.bb,ccc<cs>crlf

Note: < > denotes an optional field.

Message	Meaning
CP	Compressed message header.
aa	Sensor identification number set by the user.
bbb.bb	Total EXCO in km^{-1}.
c c c	Self-test and Monitoring (see Section 5.2): c c c O = Other self-test values OK. X = Other self-test faults exist. O = Windows not contaminated. X = Window contamination warning – cleaning recommended. F = Window contamination alert – cleaning required. T = Sensor in Test Mode. O = Sensor not reset since last "R?" command. X = Sensor reset since last "R?" command.
<cs>	If selected this will be the checksum character. The checksum is off by default.

Table 3-1 VPF-710 Compressed Data Massage

Typical compressed data messages from a VPF-710 are as follows:

Default Configuration or EXCO field set to TEXCO. PEn set to 0 or 1, see Section 2.4.10.

CP01,000.12,OOO

EXCO field replaced with MOR expressed in kilometres to two decimal places. PEn set to 2, see Section 2.4.10.

CP01, 25.00 KM,OOO

EXCO field replaced with MOR expressed in metres. PEn set to 2, see Section 2.4.10. See Section 2.4.9 for configuration of the MOR output format.

CP01, 25000 M,OOO

3.1.2   VPF-710 Expanded Data Message

The data message format is:

VSaa,bbb.bb,ccc,dddddd,e.eee,ff.ff,ggg,hh,iii,jj,kkkk,±lll.l,mmmm<cs>crlf

Note: < > denotes an optional field.

Message	Meaning
VS	Expanded visibility sensor message header.
aa	Sensor identification number set by the user.
bbb.bb	Total EXCO in km^{-1}.

Message	Meaning
c c c	Self-Test and Monitoring (see Section 5.2). c c c O = Other self-test values OK. X = Other self-test faults exist. O = Windows not contaminated. X = Window contamination warning – cleaning recommended. F = Window contamination alert – cleaning required. T = Sensor in Test Mode. O = Sensor not reset since last "R?" command. X = Sensor reset since last "R?" command.
dddddd	Error Status: Bit 1: Transmitter Sync Signal Missing Bit 2: A/D control signal error Bit 3: RAM Error Detected Bit 4: EPROM check sum error Bit 5: Non-volatile memory check sum error Bit 6: Sensor reset has occurred
e.eee	A/D reference channel measured voltage (2.450 to 2.550).
ff.ff	Forward scatter receiver background illumination (00.00 to 10.00).
ggg	Ired optical power (85 to 110).
hh	Transmitter window contamination (00 to 99).
iii	Forward scatter receiver gain (80 to 120).
jj	Receiver window contamination (00 to 99).
kkkk	AC interrupts per second.
±lll.l	Temperature (°C).
mmmm	Not used.
<cs>	If selected this will be the checksum character. The checksum is off by default.

Table 3-2 VPF-710 Expanded Data Message

Typical expanded data messages from a VPF-710 are as follows:

Default Configuration or EXCO field set to TEXCO. PEn set to 0 or 1, see Section 2.4.10.

VS01,000.55,XOO,100000,2.510,00.82,100,00,100,00,4040,+002.5,0000

EXCO field replaced with MOR expressed in kilometres to two decimal places. PEn set to 2, see Section 2.4.10.

VS01,05.45 KM,XOO,100000,2.510,00.82,100,00,100,00,4040,+002.5,0000

EXCO field replaced with MOR expressed in metres. PEn set to 2, see Section 2.4.10. See Section 2.4.9 for configuration of the MOR output format.

VS01,05452 M,XOO,100000,2.510,00.82,100,00,100,00,4040,+002.5,0000

3.2   Data Output Message VPF-730

3.2.1   VPF-730 Compressed Data Message

The data message format is:

CPaa,bb,ccc.cc,dd.dddd,±eee.e,fff<cs>crlf

Note: < > denotes an optional field.

Message	Meaning
CP	Compressed message header.
aa	Sensor identification number set by the user.
bb	Present weather codes. From WMO Table 4680 (Automatic Weather Station). 00 No significant weather observed, or sensor starting 04 Haze or Smoke or Dust 10 Mist (Special Configuration. Only available with external humidity probe.) 30 Fog 40 Indeterminate precipitation type 51 Slight Drizzle 52 Moderate Drizzle 53 Heavy Drizzle 61 Slight Rain 62 Moderate Rain 63 Heavy Rain 71 Slight Snow 72 Moderate Snow 73 Heavy Snow 89 Hail
ccc.cc	Transmissometer equivalent EXCO (km^{-1}).
dd.dddd	Amount of water in precipitation in last measurement period (mm).
±eee.e	Temperature (°C).

Message	Meaning
f f f	Self-Test and Monitoring (see Section 5.2). f f f 　　　O = Other self-test values OK. 　　　X = Other self-test faults exist. 　　　O = Windows not contaminated. 　　　X = Window contamination warning – cleaning recommended. 　　　F = Window contamination alert – cleaning required. 　　　T = Sensor in Test Mode. 　　　O = Sensor not reset since last "R?" command. 　　　X = Sensor reset since last "R?" command.
<cs>	If selected this will be the checksum character. The checksum is off by default.

Table 3-3 VPF-730 Compressed Data Message

Typical compressed data message from a VPF-730 is as follows:

Default Configuration or EXCO field set to TEXCO. PEn set to 0 or 1, see Section 2.4.10.

CP01,71,000.96,00.0048,-005.4,OOO

MOR output is not possible for the VPF-730 in compressed message configuration.

3.2.2   VPF-730 Expanded Data Message

The data message format is:

PWaa,bbbb,cccc,ddd.dd   KM,eee,ff,gg.gg,hh.hhhh,±iii.i   C,jjjj,kkk.kk,lll.ll,±mmm.mm, nnnn,ooo,ppp,qqq.qq<cs>crlf

Note: < > denotes an optional field.

Message	Meaning
PW	Present Weather message header.
aa	Sensor identification number set by the user.
bbbb	Last measurement period (seconds).
cccc	Time since this report was generated (seconds).
ddd.dd KM	Meteorological optical range (km).
eee	Precipitation type message: NP No precipitation DZ- Slight drizzle DZ Moderate drizzle DZ+ Heavy drizzle RA- Slight rain RA Moderate rain RA+ Heavy rain SN- Slight snow SN Moderate snow SN+ Heavy snow UP Indeterminate precipitation type GS Small Hail GR Hail X Initial value or error
ff	Obstruction to vision message: (blank) No obstruction HZ Haze FG Fog DU Dust ⌉ Only available in Special Configuration with FU Smoke ⊢ factory fitted external temperature/humidity sensor BR Mist ⌋
gg.gg	Receiver background illumination.

Message	Meaning
hh.hhhh	Amount of water in precipitation in last measurement period (mm).
±iii.i C	Temperature (°C).
jjjj	Number of precipitation particles detected in last measurement period.
kkk.kk	Transmissometer equivalent EXCO (km^{-1}).
lll.ll	EXCO less precipitation particle component (km^{-1}).
±mmm.mm	Backscatter EXCO (km^{-1}).
	Two spaces – delimiter.
nnnn	Reserved field.
ooo	Reserved field.

p p p	Self-Test and Monitoring (see Section 5.2).
	
	p p p
	  O = Other self-test values OK.
	  X = Other self-test faults exist.
	
	  O = Windows not contaminated.
	  X = Window contamination warning – cleaning recommended.
	  F = Window contamination alert – cleaning required.
	
	  T = Sensor in Test Mode.
	  O = Sensor not reset since last "R?" command.
	  X = Sensor reset since last "R?" command.

qqq.qq	Total EXCO (km^{-1}).
<cs>	If selected this will be the checksum character. The checksum is off by default.

Table 3-4 VPF-730 Expanded Data Message

Typical expanded data messages from a VPF-730 are as follows:

EXCO output configuration: PEn command not applicable to the VPF-730 expanded output message as both EXCO and TEXCO provided. MOR in default configuration, see Section 2.4.9.

PW01,0060,0000,000.42 KM,NP ,FG,00.41,00.0000,+013.0 C,0000,007.12, 007.12,+026.17, 0001,000,OOO,007.12

MOR output in metres, see Section 2.4.9 .

PW01,0060,0000,00424 M,NP ,FG,00.41,00.0000,+013.0 C,0000,007.12, 007.12,+026.17, 0001,000,OOO,007.12

3.3   Data Message Variations For ALS or WSM (VPF-710 and VPF-730)

For sensors fitted with an Ambient Light Sensor or Weather Station Module, data output strings are identical to the standard message with the following appended to the message prior to the optional check sum<cs> and the carriage return and line feed <crlf>.

3.3.1   Weather Station Module

, EXT:aaaa,bbbb,cccc,dddd

Message	Maning
EXT:	Optional external inputs.
aaaa	WSM Channel 1 (0000=0.00V, 1000=10.00V).
bbbb	WSM Channel 2 (0000=0.00V, 1000=10.00V).
cccc	WSM Channel 3 (0000=0.00V, 1000=10.00V).
dddd	Not used.

Table 3-5 Message Extension for WSM

3.3.2   Ambient Light Sensor

, ALS,±aaaaa,bbb

Message	Meaning
ALS	ALS data message prefix.
±aaaaa	ALS Signal, 1 minute averaged value (cd/m^2).
b b b	ALS Self-Test and Monitoring (see Section 5.2). FFF if ALS-2 not connected O = Other self-test values OK X = Other self-test fault exists O = Window not contaminated X = Window contaminated – cleaning recommended/required F = Window contaminated – alert S = Sensor input saturated O = Sensor not reset since last "R?" command X = Sensor reset since last "R?" command

Table 3-6 Message Extension for ALS

3.4 Data Output Message VPF-750

3.4.1 VPF-750 Compressed Data Message

The data message format is:

CP,nnn,ww,aa.aa KM,bb.bbbb,±ccc.c,ddd,+eeeee,fff<cs>crlf

Note: < > denotes an optional field.

Message	Meaning
CP	Compressed message header.
nnn	Sensor identification number set by the user.
ww	Present weather codes. From WMO Table 4680 (Automatic Weather Station). XX Not Ready (first 5 minutes from restart) 00 No significant weather observed 04 Haze or Smoke or Dust 10 Mist 11 Diamond Dust 20 Fog in last hour but not at time of observation 21 Precipitation in last hour but not at time of observation 22 Drizzle in last hour but not at time of observation 23 Rain in last hour but not at time of observation 24 Snow in last hour but not at time of observation 25 Freezing Drizzle or Freezing Rain in last hour but not at time of observation 28 Blowing or drifting snow, visibility ≥ 1 km 29 Blowing or drifting snow, visibility < 1 km 30 Fog 31 Fog in patches 32 Fog becoming thinner in last hour 33 Fog no appreciable change in last hour 34 Fog begun or becoming thicker in last hour 35 Freezing Fog 40 Indeterminate precipitation type 51 Slight Drizzle 52 Moderate Drizzle 53 Heavy Drizzle

Message	Meaning
	54 Freezing Slight Drizzle
	55 Freezing Moderate Drizzle
	56 Freezing Heavy Drizzle
	57 Slight Drizzle and Rain
	58 Moderate or Heavy Drizzle and Rain
	61 Slight Rain
	62 Moderate Rain
	63 Heavy Rain
	64 Freezing Slight Rain
	65 Freezing Moderate Rain
	66 Freezing Heavy Rain
	67 Slight Rain and Snow
	68 Moderate or Heavy Rain and Snow
	71 Slight Snow
	72 Moderate Snow
	73 Heavy Snow
	74 Slight Ice Pellets
	75 Moderate Ice Pellets
	76 Heavy Ice Pellets
	77 Snow Grains
	78 Ice Crystals
	81 Slight Rain Showers
	82 Moderate Rain Showers
	83 Heavy Rain Showers
	85 Slight Snow Showers
	86 Moderate Snow Showers
	87 Heavy Snow Showers
	89 Hail
aa.aa KM	Meteorological Optical Range (KM).
bb.bbbb	Amount of water in precipitation in last minute (mm).
±ccc.c	Temperature (°C)

Message	Meaning
d d d	Self-Test and Monitoring (see Section 5.2). O = Other self-test values OK X = Other self-test fault exists F = Forward Scatter Receiver Flooded with Light B = Backscatter Receiver Flooded with Light T = Temperature / Humidity sensor Fault O = Windows not contaminated X = Windows contaminated – cleaning recommended/required F = Windows contaminated – alert T = Sensor in TEST Mode O = Sensor not reset since last "R?" command X = Sensor reset since last "R?" command
±eeeee	ALS signal, 1 minute average value (cd/m^2).
f f f	ALS Self-Test and Monitoring (see Section 5.2). FFF if ALS-2 not connected O = Other self-test values OK X = Other self-test fault exists O = Window not contaminated X = Window contaminated – cleaning recommended/required F = Window contaminated – alert S = Sensor input saturated O = Sensor not reset since last "R?" command X = Sensor reset since last "R?" command
<cs>	If selected this will be the checksum character. The checksum is off by default.

Table 3-7 VPF-750 Compressed Data Message

Typical compressed data messages from a VPF-750 are as follows:

EXCO output configuration: PEn command not applicable to the VPF-750 compressed output message as no EXCO field provided. MOR in default configuration, see Section 2.4.9.

CP,001,52,09.30 KM,00.0426,+008.6,OOO,+00071,OOO

MOR output in metres, see Section 2.4.9 .

CP,001,62,09871 M,00.0612,+008.6,OOO,+00102,OOO

3.4.2   VPF-750 Expanded Data Message

The data message format is:

VPF750,nnn,xxxx,aa.aa KM,cc, w$_1$, w$_2$,dd,eeeee,fff.fff,gg.gg KM, hhh.hh,±iii.ii,±jjj.j C,kkk %,lll,±mmmmm,nnn,oo.oooo,ppp<cs>crlf

Note: < > denotes an optional field.

Message	Meaning
VPF750	Model number.
nnn	Sensor identification number set by the user.
xxxx	Averaging time period in seconds.
aa.aa KM	Meteorological Optical Range (KM). This is the averaged value.
cc	Present weather codes. From WMO Table 4680 (Automatic Weather Station). XX　　Not Ready (first 5 minute from restart) 00　　No significant weather observed 04　　Haze or Smoke or Dust 10　　Mist 11　　Diamond Dust 20　　Fog in last hour but not at time of observation 21　　Precipitation in last hour but not at time of observation 22　　Drizzle in last hour but not at time of observation 23　　Rain in last hour but not at time of observation 24　　Snow in last hour but not at time of observation 25　　Freezing Drizzle or Freezing Rain in last hour but not at time of observation 28　　Blowing or drifting snow, visibility ≥ 1 km 29　　Blowing or drifting snow, visibility < 1 km 30　　Fog 31　　Fog in patches 32　　Fog becoming thinner in last hour 33　　Fog no appreciable change in last hour 34　　Fog begun or becoming thicker in last hour 35　　Freezing Fog 40　　Indeterminate precipitation type 51　　Slight Drizzle 52　　Moderate Drizzle

Message	Meaning
	53 Heavy Drizzle
	54 Freezing Slight Drizzle
	55 Freezing Moderate Drizzle
	56 Freezing Heavy Drizzle
	57 Slight Drizzle and Rain
	58 Moderate or Heavy Drizzle and Rain
	61 Slight Rain
	62 Moderate Rain
	63 Heavy Rain
	64 Freezing Slight Rain
	65 Freezing Moderate Rain
	66 Freezing Heavy Rain
	67 Slight Rain and Snow
	68 Moderate or Heavy Rain and Snow
	71 Slight Snow
	72 Moderate Snow
	73 Heavy Snow
	74 Slight Ice Pellets
	75 Moderate Ice Pellets
	76 Heavy Ice Pellets
	77 Snow Grains
	78 Ice Crystals
	81 Slight Rain Showers
	82 Moderate Rain Showers
	83 Heavy Rain Showers
	85 Slight Snow Showers
	86 Moderate Snow Showers
	87 Heavy Snow Showers
	89 Hail
W_1	Past Weather Type1 SYNOP Code:
	/ No past weather code
	4 Fog or Thick Haze
	5 Drizzle
	6 Rain
	7 Snow or Mixed rain & snow
	8 Showers

Message	Meaning
w₂	Past Weather Type2 SYNOP Code: / No past weather code 4 Fog or Thick Haze 5 Drizzle 6 Rain 7 Snow or Mixed rain & snow 8 Showers
dd	Obstruction to Vision Message: (Blank) No obstruction HZ Haze FG Fog DU Dust FU Smoke BR Mist
eeeee	METAR Reporting Code. See Table 3-9 METAR Codes.
fff.fff	Precipitation Rate (mm/hr).
gg.gg KM	Meteorological Optical Range (KM). This is the instantaneous value.
hhh.hh	Total Exco (/KM). This is the averaged value.
±iii.ii	Backscatter Channel Exco (/KM). This is the averaged value.
±jjj.j C	Temperature (°C).
kkk %	Relative Humidity (%).
lll	Precipitation Indication
±mmmmm	ALS signal, 1 minute average value (cd/m²).
n n n	Self-Test and Monitoring (see Section 5.2). O = Other self-test values OK X = Other self-test fault exists F = Forward Scatter Receiver Flooded with Light B = Backscatter Receiver Flooded with Light T = Temperature / Humidity sensor Fault O = Windows not contaminated X = Windows contaminated – cleaning recommended/required F = Windows contaminated – alert T = Sensor in TEST Mode O = Sensor not reset since last "R?" command X = Sensor reset since last "R?" command

Message	Meaning
oo.oooo	Amount of water in precipitation in last minute (mm).
p p p	ALS Self-Test and Monitoring (see Section 5.2). FFF if ALS-2 not connected O = Other self-test values OK X = Other self-test fault exists O = Window not contaminated X = Window contaminated – cleaning recommended/required F = Window contaminated – alert S = Sensor input saturated O = Sensor not reset since last "R?" command X = Sensor reset since last "R?" command
<cs>	If selected this will be the checksum character. The checksum is off by default.

Table 3-8 VPF-750 Expanded Data Message

Typical expanded data messages from a VPF-750 are as follows:

Default Configuration or EXCO field set to TEXCO. PEn set to 0 or 1, see Section 2.4.10. MOR configured to report in km to two decimal places.

VPF750,001,0060,09.30 KM,52,/,/,   ,DZ   ,000.426,08.76 KM,000.32,
+000.14,+008.6 C,086 %,099,+00125,OOO,00.0071,OOO

EXCO field set to EXCO or TEXCO, PEn set to 0 or 1, see Section 2.4.10. MOR configured to report in km to three decimal places.

VPF750,001,0060,09.303 KM,52,/,/,   ,DZ   ,000.426,08.764 KM,000.32,
+000.14,+008.6 C,086 %,099,+00125,OOO,00.0071,OOO

3.4.3   METAR Codes

Code Number	METAR Code	Description
XX		Not Ready (first 5 minutes from restart)
00		No significant weather observed, or sensor starting
04	HZ	Haze, visibility greater than or equal to 1KM
04	FU	smoke, visibility greater than or equal to 1KM
04	DU	Dust, visibility greater than or equal to 1KM
10	BR	Mist
11	IC	Diamond Dust
20		Fog in last hour but not at time of observation
21		Precipitation in last hour but not at time of observation
22		Drizzle in last hour but not at time of observation
23		Rain in last hour but not at time of observation
24		Snow in last hour but not at time of observation
25		Freezing Drizzle or Freezing Rain in last hour but not at time of observation
28	BLSN	Blowing or drifting snow, visibility ≥ 1 km
29	+BLSN	Blowing or drifting snow, visibility < 1 km
30	FG	Fog
31	BCFG	Fog in patches
32	FG	Fog becoming thinner in last hour
33	FG	Fog no appreciable change in last hour
34	FG	Fog begun or becoming thicker in last hour
35	FZFG	Freezing Fog
40	UP	Indeterminate precipitation type
51	-DZ	Drizzle, not freezing, slight
52	DZ	Drizzle, not freezing, moderate
53	+DZ	Drizzle, not freezing, heavy
54	-FZDZ	Drizzle, freezing, slight
55	FZDZ	Drizzle, freezing, moderate
56	+FZDZ	Drizzle, freezing, heavy
57	-RADZ	Drizzle and Rain, slight
58	RADZ	Drizzle and Rain, moderate
58	+RADZ	Drizzle and Rain, heavy

Code Number	METAR Code	Description
61	-RA	Rain, not freezing, slight
62	RA	Rain, not freezing, moderate
63	+RA	Rain, not freezing, heavy
64	-FZRA	Rain, freezing, slight
65	FZRA	Rain, freezing, moderate
66	+FZRA	Rain, freezing, heavy
67	-RASN	Rain (or Drizzle) and Snow, slight
68	RASN	Rain (or Drizzle) and Snow, moderate
68	+RASN	Rain (or Drizzle) and Snow, heavy
71	-SN	Snow, slight
72	SN	Snow, moderate
73	+SN	Snow, heavy
74	-PL	Ice Pellets, slight
75	PL	Ice Pellets, moderate
76	+PL	Ice Pellets, heavy
77	SG	Snow Grains
78	IC	Ice Crystals
81	-SHRA	Rain Showers, slight
82	SHRA	Rain Showers, moderate
83	+SHRA	Rain Showers, heavy
85	-SHSN	Snow Showers, slight
86	SHSN	Snow Showers, moderate
87	+SHSN	Snow Showers, heavy
89	GS	Small Hail
89	GR	Hail

Table 3-9 METAR Codes

3.4.4 VPF-750 WMO 4680 and METAR Codes

The VPF-750 reports weather phenomena using both WMO Table 4680 and METAR codes (WMO Table 4678). As there is not always a METAR code associated with the WMO Table 4680 code the following logic is used to determine what codes to report.

Field cc Present Weather Code Table 4680	The sensor reports the highest Table 4680 number associated with the current conditions.
Field dd Obstruction to Vision METAR	The sensor examines the Table 4680 codes associated with the current conditions that are classed as obstruction to vision codes and converts the highest Table 4680 numeric code to the associated METAR code. If the Table 4680 code has no direct METAR equivalent the next lower Table 4680 obstruction to vision code with a METAR equivalent that is currently valid is reported.
Field eeeee METAR Reporting Code	The sensor takes the Table 4680 code numeric code as used in field cc and converts it to the associated METAR code. If the Table 4680 code has no direct METAR equivalent the next lower Table 4680 code with a METAR equivalent that is currently valid is reported.

Code IC is used in field eeeee to represent the METAR equivalent code for WMO Table 4680 codes 11 and 78, respectively Diamond Dust and Ice Crystals. Code IC is not referenced in WMO Table 4678 but is recognised by the WMO as a code used in METAR reports produced in the United States of America.

4   COMMANDS AND RESPONSES

4.1   Sensor Commands

All commands should be terminated with <Carriage Return> and <Line Feed> <crlf>, (see Section 2.3).

*Commands marked with * cause the sensor to reset.*

Commands marked with # must be preceded by the calibration enable command CO.

Command	Function	Response	710	730	750
A?	Query precipitation accumulation amount.	See Section 4.1.1		√	√
AC	Clear accumulated precipitation. **See Section 4.1.1**	OK		√	√
ADR?	Query RS485 address. **See Section 2.4.3.**	xx	√	√	√
ADRxx	Set RS485 address. Range 00-99. See **Section 2.4.3.**	OK	√	√	√
BB?	Send instantaneous value of backscatter EXCO.	±xxx.xx		√	√
BL?	Send instantaneous value of Total EXCO less precipitation particle component.	±xxx.xx		√	√
BT?	Send instantaneous value of Total EXCO.	±xxx.xx	√	√	√
CA#	Perform precipitation amount calibration (Calibration must be enabled).	See Section 6.5		√	√
CE#	Perform EXCO calibration. (Calibration must be enabled).	See Section 6.3	√	√	√
CO	Enable calibration.	OK	√	√	√
CT#	Temperature sensor calibration.	See Section 6.4	√	√	
CX*	Disable calibration.	OK	√	√	√
D?	Send latest data message.	See Section 3	√	√	√
DHO	Turn hood heaters on temporarily. If off at time of command, the heaters will turn off after 2 minutes (for maintenance only).	OK	√	√	√

Command	Function	Response	710	730	750
DHX	Turn hood heaters off temporarily. If on at time of command, the heaters will turn on after 2 minutes (for maintenance only).	**OK**	√	√	√
IDx*	Set sensor identification number displayed in data message. 710/730 Range x = 0 to 99. (Default = 1). 750 Range x = 0 to 999. (Default = 1).	**OK**	√	√	√
KM?	Query current MOR output resolution.	**See Section 2.4.9**	√	√	√
KMn*	Set MOR output resolution.	**See Section 2.4.9**	√	√	√
M?	Send precipitation matrix accumulated over last five measurement periods. This is a matrix of 16 rows with up to 21 readings. Zeros to right not displayed.	**See Section 4.1.3**		√	√
OPCS?	Query checksum option setting. **Section 2.4.1.**	**See Section 2.4.1**	√	√	√
OPCSx*#	Set checksum option. **Section 2.4.1.**	**OK**	√	√	√
OP485?	Query Addressable 485 communications setting. **Section 2.4.2.**	**See Section 2.4.2**	√	√	√
OP485x*#	Set Addressable RS485 communications. **Section 2.4.2.**	**OK**	√	√	√
OSAM?	Query automatic message setting	**See Section 2.4.4**	√	√	√
OSAMx*	Set automatic message setting, **Section 2.4.4**	**OK**	√	√	√
OSCM?	Query message type setting	**See Section 2.4.5**	√	√	√
OSCMx*	Set message type setting. See **Section 2.4.5**	**OK**	√	√	√
OSHH?	Query hood heater setting	**See Section 2.4.6**	√	√	√
OSHHx*	Set hood heater setting. See **Section 2.4.6**	**OK**	√	√	√
OSWH?	Query window heater setting	**See Section 2.4.7**	√	√	√
OSWHx*	Set window heater setting. See **Section 2.4.7**	**OK**	√	√	√
PE?	Check current EXCO output configuration.	**See Section 2.4.10**	√	√	√

Command	Function	Response	710	730	750
PEn	Set EXCO output configuration.	**See Section 2.4.10**	√	√	√
PV?	Query program version message.	**SIxxxxxx.yyy**	√	√	√
R?	Send remote self-test and monitoring message.	**See Section 4.1.2**	√	√	√
RST*	Restart sensor.	**OK**	√	√	√
T?	Query sensor times message.	**See Section 4.1.4**	√	√	√
SN?	Query sensor serial number.	**xxxxxx.xxx**	√	√	√
TAx*	Set auxiliary measurement sample period. **See Section 4.1.4**	**OK**	√	√	√
TEST,tt,vv.v v,f,c,pw*#	Set the sensor into a test mode. **Section 2.6.5**	**See Section 2.6.5**	√	√	√
TMx*	Set measurement interval. Range x = 10-300 (seconds). (Default 60). **See Section 4.1.4**	**OK**	√	√	√
WF?	Query Window Contamination Alert Threshold Percentage.	**See Section 5.2.2**	√	√	√
WFn *#	Set Window Contamination Alert Threshold Percentage. Range n= WT to 50%. Calibration must be enabled. Default 30%.	**See Section 5.2.2**	√	√	√
WT?	Query current window contamination threshold for warning indication.	**See Section 5.2.2**	√	√	√
WTx*#	Set window contamination threshold for a warning indication, % transmission. Range: 0 to **WF** (%). Calibration must be enabled. Default = 10.	**See Section 5.2.2**	√	√	√
%Bx	Set communication baud rate. Range 1-7.	**See Section 2.4.8**	√	√	√

Table 4-1 Commands for VPF-700 Series of Sensors

4.1.1   Commands A? and AC – Precipitation Accumulation

These commands apply only to the VPF-730 and VPF-750.

The sensor records the total amount of precipitation detected in a 24-hour period. The 24-hour period starts when the sensor is powered or when the accumulated precipitation value is reset. The value can be queried at any time, with the total recorded at that time being reported. The precipitation amount is reported in mm.

The following commands are used:

A?	Reports the accumulation amount in mm and the accumulation time in minutes. For accumulation amounts less than 600mm the value is reported as xxx.xx, for accumulation amounts greater than 600mm the amount is reported as xxxx.x.
Example:	Sensor responds **105.65,1224** This equates to 105.65mm of accumulated precipitation in the last 1224 minutes.
Example:	Sensor responds **1022.8,1392** This equates to 1022.8mm of accumulated precipitation in the last 1392 minutes.
AC	Clears the accumulated precipitation amount and resets the accumulation period. The sensor responds with OK.

4.1.2   Command R? - Send Remote Self-Test and Monitoring Message

Example response:

100,2.509,24.1,12.3,5.01,12.5,00.00,00.00,100,105,107,00,00,00,+021.0,4063

Field	Range / Value	Description
Field 1:	**Space**	The message starts with a space.
Field 2:	**ABC**	Heater state and error flags.
		A = 1 - Window heaters ON.
		A = 2 - Hood Heaters ON.
		A = 4 - A/D control signal error.
		B = 1 - EPROM checksum error.
		B = 2 - Non-volatile memory checksum error.
		B = 4 - RAM error.
		C = 2 - Ired commanded OFF.
		C = 4 - Receiver test in progress (Ired OFF).
		C = 8 - Sensor power reset since last R? Command.
		or any combination of these.
Field 3:	2.450 - 2.550	Internal reference voltage.
Field 4:	9.00 - 36.00	Supply voltage. DC powered sensors only.
Field 5:	11.2 - 17.5	Internal operating voltage.
Field 6:	4.5 - 5.5	Internal operating voltage.
Field 7:	11.2 – 17.5	Internal operating voltage.
Field 8:	0.00 - 6.00	Forward scatter background brightness.
Field 9:	0.00 - 6.00	Backscatter background brightness (Not VPF-710).
Field 10:	85 - 105	Transmitter power monitor.
Field 11:	80 - 120	Forward receiver monitor (Option for VPF-710 and VPF-730).
Field 12:	80 - 120	Backscatter receiver monitor (Not VPF-710, Option for VPF-730).
Field 13:	00 - 99	Transmitter window contamination.
Field 14:	00 - 99	Forward receiver window contamination (Option for VPF-710 and VPF-730).
Field 15:	00 - 99	Backscatter receiver window contamination (Not VPF-710, Option for VPF-730).
Field 16:		Temperature °C.
Field 17:	3300-4200	ADC interrupts per second.

Table 4-2 Command R? Response

4.1.3   Command M? – Send Precipitation message

This command is only available for the VPF-730 and VPF-750.

The sensor responds by sending a precipitation matrix accumulated over the last five measurement periods. This is a matrix of 16 rows with up to 21 readings, each being the number of precipitation particles of that specific size and velocity. Zeros to right are not displayed. The meaning of the matrix is graphically presented in Section 7, Figure 7-3 Precipitation Matrix.

An example response, which was during a period of heavy rain, is provided below:

```
M001
M001,001,002,001,001,000,000,000,001
M009,002,006,002,001,001
M009,019,020,020,010,002,000,000,001,001
M011,033,068,078,056,042,020,005,001,000,001
M003,031,048,041,047,033,038,027,014,009,008,003
M004,007,027,020,013,016,011,007,002,008,006,007,004
M000,005,006,005,007,003,000,002,003,001,000,000,000,001
M000,000,006,004,005,000,001,002,001,000,000,001
M000,001,007,000,005,002,001,000,001
M000,000,001,000,001
M000,000,000,001
M000,000,000,000,001
M000
M000
M000
```

This shows the greatest precipitation amount in rows 5 and 6, relatively slow hydrometeor velocity (~3.3m/sec) and in columns 2 to 8, relatively small hydrometeor size (~0.5mm).

4.1.4   Command T? - Send Sensor Times Message

Response: **aaaa,bbbb,ccccc,dddd**

aaaa:	Measurement interval for each operational data message (10 to 300 seconds)
	(default = 60).
bbbb:	Auxiliary measurement sample period - time between measurement of peripheral signals during measurement interval. (2 to 20 seconds) (default = 5).
ccccc:	Not used.
dddd:	Not used.

The auxiliary measurement period should always be set such that the measurement interval is an integer multiple of the auxiliary period. For example, if the measurement period is set to 15 seconds, set the auxiliary period to 3 seconds. Recommended values are shown below:

TM ≥ 60	TA = 5
TM = 30	TA = 5
TM = 15	TA = 3
TM = 10	TA = 2

To set the auxiliary measurement period use the following command: Tax

Where x is the time in seconds. Range 2 to 20 seconds. Default 5 seconds.

4.1.5   VPF-750 Present Weather Measurement Timing

For the VPF-750 only, the present weather coding and the precipitation type and intensity are always calculated at one minute intervals. The measurement timing command TMx will set the timing interval for all visibility related measurements, but not the present weather coding or precipitation details. It is recommended that this visibility timing is set to one minute intervals (command TM60), the default value, for consistency with the precipitation measurements and coding.

4.2 Sensor Responses

Response	Meaning
BAD CMD	Your command was not understood by the sensor. Check the text of the command and re-send.
COMM ERR	An error was detected in a character in the command. Re-send the command.
OK	Command with no quantitative response was understood and executed.
TIMEOUT	Command was sent with more than 10 seconds between characters. Re-send the command.
TOO LONG	Command message was longer than 24 characters including end characters. Re-send the command.

Table 4-3 Responses from Sensor

5   MAINTENANCE PROCEDURES

The VPF-700 series of sensors require very little maintenance. The following sections detail the checks that are advisable to ensure continued good operation of the sensor. The frequency of these checks depends upon the location and environmental conditions under which the sensor operates.

It is suggested that a general check, plus window cleaning should take place typically at three monthly intervals. This period may be increased or decreased dependent on the contamination determined during these inspections. It is also recommended that a calibration check (see Section 6.3) is carried out at six monthly intervals to verify that the sensor is still continuing to perform within the specification.

Section 5.2, Self-Test Codes, describes the meaning of the self-test codes provided in all the standard data messages. It specifies what actions, if any, are required to restore the sensor to full operational capability.

5.1   General Checks

A general check of the physical condition of the sensor should be carried out at regular intervals. Particular attention should be paid to the condition of the cables from the base of the unit.

5.1.1   De-mister Heaters (fitted as standard to all sensors)

The window de-misters are low powered heaters designed primarily to prevent condensation. They maintain the temperature of the windows at a few degrees above ambient temperature.

The default setting is ON. See Section 2.4.7 for details.

The warmth may be detected with the finger on the window but is easier to detect using a thermometer with surface temperature probe. The windows should be between 2 and 10°C above ambient temperature after at least 10 minutes operation. Ensure that windows are cleaned after coming into contact with the skin or other sources of contamination.

5.1.2   Hood Heaters (optional)

Hood heaters, if ordered, are fitted to the inside of each of the hoods (2 on the VPF-710 and 3 on the VPF-730 and VPF-750).

The hood heaters are high-power heaters to help prevent the build-up of frozen precipitation in the hoods. The operation of these heaters is dependent on the ambient temperature (by default); they are only switched on when the temperature is below 2°C. They will then switch off when the temperature rises above 4°C. When switched on, it is easy to detect the heat from these heaters by placing a finger on the end of the hood. When the temperature is above the switching temperature the heaters will be switched off but may be controlled using a PC running a terminal program such as the Sensor Interface Software, or HyperTerminal™. The heaters may be switched on temporarily using the command DHO and off again using the command DHX. The default setting is ON with automatic control. These can be switched OFF permanently to save power if required. See Section2.4.6 for details.

5.1.3   Window Cleaning

A VPF-700 series sensor is an optical sensor and is therefore susceptible to accumulation of contaminants on the windows in the hoods. The windows should be cleaned by gently wiping the windows using a dilute detergent solution or pure alcohol (propanol) and a soft cloth *(appropriate safety precautions must be taken when using pure alcohol)*.

All VPF-700 series of sensors are fitted with a Transmitter Window monitoring system. An equivalent Receiver Window monitoring system is fitted to the VPF-750 and is available as an option for the VPF-710 and VPF-730 sensors. This monitoring system measures the optical contamination of the window and corrects the measured EXCO or MOR to compensate for this contamination. A warning is generated when the contamination reduces the signal by more than the amount set by the WT warning threshold, default 10%. When this warning occurs, the windows should be cleaned at the earliest possible opportunity. If the contamination continues to increase up to a limit set by the WF threshold, default 30%, the appropriate part of the remote maintenance and self-test message in the sensor Data Output Message changes from X (Warning) to F (Alert), see Sections 3 and 5.2.2. The accuracy of the sensor, if operated at greater contamination levels, may begin to deteriorate. The windows require cleaning as a matter of urgency.

5.2   Self-Test Codes

Self-Test and Monitoring information is provided in all standard Operating Data Messages, both of compressed and expanded formats. This information consists of three alpha-numeric characters which have the following meanings.

🛈 NOTE:

> The command "R?" provides a response with full diagnostic information. The extent of this information depends on the sensor configuration specified at time of purchase. This response is detailed in Section 4.1.2.

5.2.1   Most Significant Character (Sensor Reset Flag)

This will be set to "X" on start-up. It will only be set to "O" following receipt of an "R?" command. If it subsequently is set to "X", this is an indication that a fault, such as a power interruption, has caused the processor to reset. This is generally of no importance, but may assist in the diagnosis of installation problems.

The value "T" will be reported when the sensor is in test mode.

5.2.2   Central Character (Window Contamination)

All VPF-700 series sensors have monitoring of contamination on the transmitter window. Monitoring of the receiver windows is fitted as standard on the VPF-750 and is an option available at time of purchase for the VPF-710 and VPF-730. The processor compensates the visibility reading to allow for this contamination and checks each of the contamination figures against warning (WT) and alert (WF) thresholds with default values of 10% and 30% respectively. This Self-test code can be one of three characters, O, X or F dependent on the contamination reading(s) received. These have the following meaning:

"O":	Window contamination is less than WT. WT can be adjusted by the user, see command WTx, Section4.1. No action required.
"X":	Window contamination warning. The window contamination is between WT and WF. The visibility reading provided is corrected utilising this contamination figure, but it is recommended that the windows are cleaned at the earliest possible opportunity.
"F":	Window contamination alert. The window contamination is above WF. Although the visibility reading is still corrected using this contamination figure, the accuracy may deteriorate as the contamination increases. The windows require cleaning.

The values of WT and WF can be queried and set using the WT and WF commands as described in Section4.1.

🛈 NOTE:

> The ALS has an additional code of "S". This indicates that the sensor is saturated with a VERY bright light source (such as direct view of the sun). Although the reported light level will be in error, it can be implied that the true ambient light level is high. Refer to the ALS-2 manual for full details of ALS-2 error codes.

5.2.3   Least Significant Character (Other Self-Test errors)

A variety of operating parameters are regularly checked against normal operational figures as an early warning of possible sensor faults. This character indicates whether all parameters other than window contamination are normal. This Self-test code can be one of two characters, O, or X. The VPF-750 has an additional three codes, F, B and T. These have the following meaning:

"O":	No Fault. No action required.
"X":	Internal error. Send command "R?" to list all internally monitored parameters. Check against Section 2.6.3 to determine the cause of this error. Send command "RST" to restart the sensor. If the fault persists, arrange for the sensor to be serviced at the earliest possible opportunity.
"F" (750 only):	This indicates that the Forward scatter receiver is saturated with a bright light source (such as direct view of the sun). This will affect the visibility reading and any precipitation readings. If possible, the sensor should be repositioned (see Section 2.5.3) to prevent this occurrence.
"B" (750 only):	This indicates that the Backscatter receiver is saturated with a bright light source (such as direct view of the sun). This will affect the visibility reading and any precipitation readings. If possible, the sensor should be repositioned (see Section 2.5.3) to prevent this occurrence.
"T" (750 only):	This indicates a fault in the external temperature and humidity sensor. Arrange for the temperature and humidity sensor to be serviced at the earliest possible opportunity. The VPF-750 will continue to work correctly as a visibility sensor with either this fault present or the temperature and humidity sensor disconnected. It will also detect the presence of precipitation correctly, but may provide incorrect precipitation type indications.

5.3   User Confidence Checks

> **The following user confidence checks require bi-directional communications with a PC running the Sensor Interface Software. If this is not available, use a terminal program - for example Windows HyperTerminal™.**

5.3.1   EXCO Calibration Check

If you wish to carry out a user confidence calibration check please follow the calibration check procedure in Section 6.2 to ensure that the Exco value changes i.e. the sensor responds to changes in visibility.

THIS PROCEDURE CAN ONLY BE COMPLETED IF A SUITABLE

VPF-700 SERIES CALIBRATION KIT AND PC ARE AVAILABLE

5.3.2   Temperature Calibration Check

🛈 NOTE:

Temperature is not shown for model VPF-710 with compressed data message.

The temperature sensor has a long thermal lag. The temperature reading can be incorrect for at least 30 minutes if the sensor is moved from one location to another of different temperature just prior to testing. In operation, at a fixed site, this is not a problem because ambient temperature changes are slow. If a very accurate check of the temperature reading is required, the sensor should be operated for at least 60 minutes at a fairly constant temperature before making the check. A verification of correct operation of the temperature sensor can be made without this "warm up" period. The check is made as follows:

Step 1.   Use as a reference standard a thermometer accurate to ± 1 degree C. Ensure the standard thermometer has had time to stabilise to the ambient temperature environment.

Step 2.   Verify that the value in the temperature field in the sensor data message matches the reference thermometer reading to within ±3°C (±5°C for VPF-710).

5.3.3   Window Monitor Checks

The VPF-700 series of sensors all monitor the contamination of the transmitter window. Monitoring of the receiver windows is standard for the VPF-750 and a factory fitted option for the VPF-710 and VPF-730. The values measured are used to adjust the EXCO value, and are also used to determine when the windows should be cleaned.

The performance of the monitoring circuits can be checked by the following procedures:

Transmitter Window Monitor

Step 1.   Clean the transmitter window.

Step 2.   Send the command: R?

Step 3.   Verify that the 'Transmitter Window Contamination' field value (see Section 4.1.2) in the sensor response is 00 to 02.

Step 4.   Insert a piece of white card or paper in the transmitter hood that blocks and almost touches the window.

Step 5.   Send the command: R?

Step 6.   Verify that the 'Transmitter Window Contamination' field value in the sensor response is much greater than 10 (e.g. 99).

Step 7.   Remove the white card.

Receiver Window Monitor(s) (advanced self-test configured sensors only).

This procedure is used for the forward scatter receivers on all sensors and the additional backscatter receiver on the VPF-730 and VPF-750 sensors.

Step 1   Clean the forward scatter receiver window.

Step 2.   Wait for operational data in message from the sensor.

Step 3.   Send the command: R?

Step 4.   Verify that the 'Forward Scatter Receiver Window Contamination' field value (see Section 4.1.2) in the sensor response is 00 to 02.

Step 5.   Insert a piece of white card or paper in the forward scatter receiver hood so that it blocks the window, and almost touches it.

Step 6.   Wait for operational data message from the sensor.

Step 7.   Send the command: R?

Step 8.   Verify that the 'Forward Scatter Receiver Window Contamination' field value in the sensor response is much greater than 10 (i.e. 99).

Step 9.   Remove the white card.

Step 10.   For the VPF-730 and VPF-750, repeat steps 1 to 9, but applying to the backscatter head and the 'Backscatter Receiver Window Contamination' field value in the sensor response.

🛈 NOTE:

A delay of 5 minutes is introduced between a window contamination threshold being exceeded and the appropriate flag being set in the data message. This delay is introduced to remove repeated warnings caused by transient events such small water droplets deposited on the windows. Small droplets evaporate quickly due to the heated windows.

5.3.4   Receiver Background Brightness Measurement Checks

The receiver background brightness value measures the optical signal detected by the receiver caused by the intensity of the ambient background. This value is used to set the threshold values for precipitation particle detection and interpretation. The following procedure will check this function (this procedure is used for both the forward scatter and backscatter receivers). For the VPF-710 sensor only carry out the forward scatter test:

Step 1.   Insert a zero plug (part of the VPF-700 sensor calibration kit) in the receiver hoods, blocking all light from the window.

Step 2.   Send the command: R?

Step 3.   Verify that the value in the 'Forward Scatter Receiver Background Brightness' field in the sensor response (see Section 4.1.2) is less than 00.06.

Step 4.   Remove the zero plugs from the Sensor Head receiver hood.

Step 5.   While shining a flashlight directly into the receiver window send the command: R?

🛈 NOTE:

This test requires the use of a filament bulb flashlight.
There is insufficient IR radiation from a visible LED source.

Step 6.   Verify that the value in the 'Forward Scatter Receiver Background Brightness' field in the sensor response is much greater than 00.06.

Step 7.   For the VPF-730 and VPF-750, repeat steps 1 to 6, but applying to the backscatter head and the 'Backscatter Receiver Background Brightness' field value in the sensor response.

6   CALIBRATION PROCEDURES

This Section explains how to CHECK the calibration of the sensor and ONLY IF NECESSARY how to recalibrate it.

ALL THE PROCEDURES IN THIS SECTION REQUIRE A

VPF-700 SERIES CALIBRATION KIT

⚠️ WARNING

ENSURE THE CORRECT MODEL AND REVISION OF CALIBRATION KIT IS AVAILABLE.

Use of the wrong calibration kit will result in incorrect calibration of the sensor. See Section 5.1 for details.

The Extinction Coefficient (EXCO) calibration of the forward scatter channel and the backscatter channel are checked by the procedure outlined below.

The Calibration Reference Plaque used for the calibration check has been assigned a forward scatter value which is a simulation of an EXCO expressed in (kilometres)$^{-1}$. This value is shown on the label which is attached to the arm of the calibration plaque. This label also states the serial number of the calibration plaque to ensure that the correct plaque is used with that arm.

Each calibration plaque also has a backscatter value which although it also is expressed in (kilometres)$^{-1}$, is an artificial value assigned only for the purpose of checking that the sensitivity of the backscatter channel is within its proper limits. This is not used for the VPF-710 sensors.

Please see Figure 6-1 Assembly of Calibration Reference Plaque for a diagram of the Calibration Reference Plaque attached to a sensor.

6.1   Calibration Plaque Identification

Only the Calibration Kit designed for use with the VPF-700 sensor family should be used. Use of a Calibration Kit intended for use with another sensor family is not possible due to the unique mounting arrangements. Any attempt to use an incompatible Calibration Kit may result in damage to the sensor and Calibration Kit. The carry case of the VPF Calibration Kit is fitted with a label stating, "VPF Calibration Plaque" or "VPF.CAL".

In January of 2014 the main IRED light source of the VPF-700 sensor family was changed from a device operating at 880nm to one operating at 850nm; this change was necessary due to component obsolescence. A consequence of the change of wavelength is that calibration plaques intended for use at 880nm are not compatible with sensors operating at 850nm and vice versa.

To ensure that it is not possible to use an incompatible calibration plaque the alignment features that control the fitting of the plaque to the sensor and the fitting of the plaque disk to the plaque arm are different on plaques intended for 880nm use compared to those intended for 850nm use.

IF THE PLAQUE DOES NOT FIT EASILY ON TO THE SENSOR IN THE CORRECT POSITION IT IS NOT COMPATIBLE WITH THE SENSOR.

UNDER NO CIRCUMSTANCE MUST THE PLAQUE BE FORCED INTO POSITION OR THE ALIGNMENT FEATURES BE TAMPERED WITH.

To provide a quick and simple method of checking the compatibility of a plaque with a sensor the colour of the sensor label, Calibration Kit case and plaque metalwork are used. See the table below for details.

Feature	880nm	850nm
Sensor Label	Yellow	Silver
Calibration Kit box colour	Black	Blue
Calibration plaque frame colour	Black	Silver

6.2   Calibration Check

The following instructions show you how to check the calibration of a VPF-700 series sensor. This procedure can only be completed with:

1.   A VPF-700 Series Calibration Kit.

2.   Connection to a PC running the Sensor Interface Software, or, if this is not available, terminal emulation software (such as Windows ® HyperTerminal™). This will use the signal data cable as provided. *If you need help with this, please do not hesitate to contact us (contact details on page vi).*

CALIBRATION CHECK NOTES

PLEASE READ THESE NOTES BEFORE CONTINUING

The EXCO (Extinction Coefficient) values depend heavily on the location and prevailing weather conditions and should only be carried out with the sensor:

1. **MOUNTED OUTSIDE AND ON A CLEAR DRY DAY (VISIBILITY>10KM)**

2. **POWERED FOR AT LEAST 1 HOUR**

3. **NOT LOCATED NEAR A WALL OR OTHER OBSTRUCTION**

4. **NOT RECEIVING OPTICAL REFLECTIONS (FROM SURFACES OR CLOTHING)**

Assembly of the calibration plaque to the sensor

The calibration reference plaque should first be attached to the arm. Confirm that the serial number marked on the calibration reference plaque matches that on the label on the calibration arm. If not, do NOT use this assembly as it may not give a true calibration. This assembly should then be attached to the sensor as shown in Figure 6-1 Assembly of Calibration Reference Plaque.

🛈 NOTE:

All commands should be terminated with <Carriage Return> and <Line Feed> <crlf>, (see Section 2.3).

The figure shows the calibration plaque assembly fixed to a VPF-730, but the same configuration is used for the VPF-710 and VPF-750.
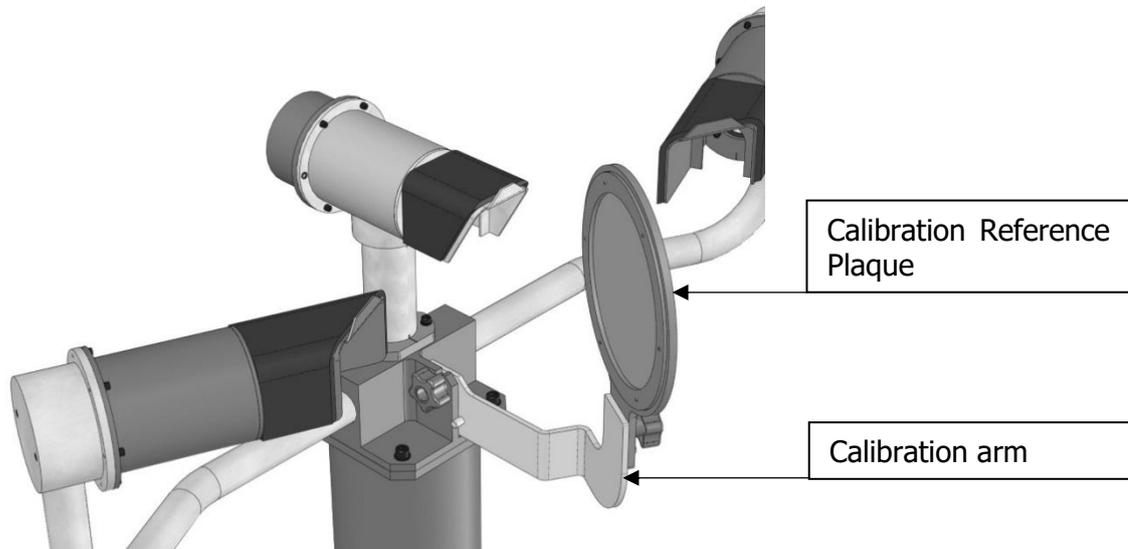

Figure 6-1 Assembly of Calibration Reference Plaque

(Example of calibration plaque in-situ on VPF-730)

Step 1:   Clean all windows on the sensor using a dilute detergent solution or pure alcohol (propanol) and soft cloth or tissue, preferably lens tissue. Check the cleanliness using a portable light if possible.

(Step 1 may not be necessary if checking or commissioning a new sensor).

Step 2:   Attach the calibration reference plaque to the sensor as shown in Figure 6-1 Assembly of Calibration Reference Plaque (power to the sensor need not be removed). Do not stand close to the sensor during calibration as reflections may cause errors in the reported values.

EXCO Zero Check:

Step 3:   Insert GREY FOAM PLUGS in the front of each window blocking out all light. (There are 3 foam plugs in the calibration case - you will only use 2 of these for the VPF-710).

Step 4:   Send the command "RST". Verify the response "OK".

Step 5:   If the sensor is operating in the polled mode, send the "D?" command at 60 seconds intervals. (If the sensor is set to automatically output data then the sensor will output data every 60 seconds).

Step 6: Wait for the fifth (5th) data message from the sensor. Send the command "BT?" Check that the response is between 0.00 and 0.05.

Step 7: **NOT for VPF-710**: Send the command "BB? ". Verify that the response is between -0.10 and 0.10.

Step 8: Remove the foam plugs.

EXCO gain Check:

Step 9: Send the command "RST" to restart the sensor. Verify the response is "OK".

Step 10: If the sensor is operating in the polled mode, send "D?" command at 60 seconds intervals. (If the sensor is set to automatically output data then the sensor will output data every 60 seconds).

Step 11: Wait for the fifth (5th) data message from the sensor. Send the command "BT?" Check that the response is within ± 5% of the Forward EXCO value assigned to the calibration reference plaque (the value on the label attached to the plaque).

Step 12: **NOT for VPF-710**: Send the command "BB? ". Check that the response is within ± 10% of the Back EXCO value assigned to the calibration reference plaque (the value on the label attached to the plaque).

Step 13: Remove the calibration reference plaque from the sensor, dismantle it and return it to its protective case for storage.

If the results of the calibration check have agreed with the value on the label attached to the calibration reference plaque within the above limits, re-calibration is NOT required.

A re-calibration is required ONLY if the EXCO values are outside those on the calibration reference plaque AND the calibration check has been carried out ACCORDING TO THE CALIBRATION CHECK NOTES on page 83.

6.3   Sensor Re-Calibration

RE-CALIBRATING THE EXTINCTION COEFFICIENT

SHOULD <u>ONLY</u> BE CARRIED OUT IF THE SENSOR HAS FAILED A CORRECTLY PERFORMED USER CONFIDENCE CHECK

<u>WARNING</u>

ERRORS DURING THIS RE- CALIBRATION PROCEDURE WILL CAUSE THE SENSOR TO GIVE INCORRECT DATA

BEFORE CONTINUING ENSURE THAT:

1. **THE VISIBILITY IS GREATER THAN 10KM**
2. **THERE IS NO PRECIPITATION**
3. **SENSOR IN CONTINUOUS OPERATION FOR AT LEAST 1 HOUR**
4. **WINDOWS ARE CLEAN**
5. **SENSOR NOT LOCATED NEAR A WALL OR OTHER OBSTRUCTION**
6. **SENSOR IS NOT RECEIVING OPTICAL REFLECTIONS (from surfaces or clothing)**

🛈 NOTE:

All commands should be terminated with <Carriage Return> and <Line Feed> <crlf>, (see Section 2.3).

Step 1.   Set up the sensor with the calibration reference plaque in place - see previous section, Section6.2 (power to the sensor need not be removed).

Step 2.   Send command "CO". Sensor replies: OK.

Step 3.   Send command: "CE".   Sensor replies:

        CLEAN WINDOWS,

        BLOCK FWD SCAT RCVR OPTICS,

        BLOCK TRANSMITTER OPTICS,

        BLOCK BK SCAT RCVR OPTICS, *(not for VPF-710)*,

        INSTALL REF STD,

ENTER FWD SCAT EXCO (/KM)

FORM: XXX.XX

Step 4. Ensure that the windows are clean. Fit the three foam plugs (supplied with the calibration kit) against the windows (only 2 used for the VPF-710).

Step 5. Enter Forward scatter EXCO value as written on the calibration plaque.

Step 6. **VPF-730 and VPF-750 only:**

Sensor replies:

ENTER BACK SCAT EXCO (/KM)

FORM: XXX.XX.

Enter backscatter EXCO value as written on the calibration plaque.

Step 7. Sensor Replies: CAL IN PROGRESS

Wait for approximately 2 minutes.

Sensor replies:

REMOVE OPTICS BLOCKS,

ENTER "OK".

Step 8. Remove foam plugs from all windows and send text:" OK".

Sensor replies: CAL CONTINUES.

Step 9. Wait for approximately 2 minutes.

Sensor replies:

CAL COMPLETE

REMOVE REF STD.

🛈 NOTE:

Do not remove the calibration reference plaque at this point.

Step 10. Wait for the third data message to be received at the PC.

Step 11. Note the 'Total EXCO' and the backscatter EXCO (NOT VPF-710) value(s) reported by the sensor.

Step 12.   If the Total EXCO reported is within 3% of the Forward EXCO value of the calibration plaque and (Not for VPF-710) the backscatter EXCO reported is within 5% of the Back EXCO value of the calibration plaque then the sensor is within its calibration limits. The sensor can be returned to its operational configuration with confidence. If the values are outside these limits carefully repeat the calibration procedure. If the limits are again exceeded contact Senseca.

Step 13.   Remove the calibration reference plaque assembly from the sensor, dismantle it and return it to its protective case for storage.

6.4   Temperature Calibration (Not VPF-750)

ⓘ NOTE:

All commands should be terminated with <Carriage Return> and <Line Feed> <crlf>, (see Section 2.3).

Step 1.   Send the command: "CO". Sensor replies: OK.

Step 2.   Send the temperature calibration command: "CT". Sensor replies:
                ENTER TEMP DEG C
                FORM: (-)XX.X

Step 3.   Enter the ambient temperature in °C (e.g.19.3). Sensor replies:
                CAL IN PROGRESS

Step 4.   Almost immediately, the sensor will send the message:
                CAL COMPLETE

Step 5.   The calibration process is complete.

6.5   Precipitation Amount Calibration

ⓘ NOTE:

All commands should be terminated with <Carriage Return> and <Line Feed> <crlf>, (see Section 2.3).

This process is not applicable to the VPF-710.

This process provides for adjusting the calibration factor of the sensor precipitation measurement. The amount of adjustment to this factor is determined by making an independent measurement of the liquid accumulation over several rain episodes and

comparing the accumulation reported by the sensor to this independently measured accumulation.

The value to be entered to adjust the precipitation amount factor is calculated as follows:

$$\text{Value entered} = \frac{\text{Desired precipitation accumulation}}{\text{Sensor's reported precipitation accumulation}} \times 100$$

EXAMPLE: Over several rainstorms, a reference sensor measures an accumulation of 225 millimetres. The sensor reported an accumulation of 244 millimetres. To adjust the sensor's precipitation accumulation factor, the value to be entered is:

$$\frac{225}{244} \times 100 = 92.2$$

The procedure to be used for precipitation amount calibration is as follows:

Step 1.   Send the parameter command: "CO". The sensor replies: OK.

Step 2.   Send the precipitation amount calibration command: "CA". Sensor replies:
ENTER PRECIP AMT ADJ FACTOR
IN PERCENT (30.0 TO 300.0)
FORM: XXX.X

Step 3.   Send the required adjustment factor: (e.g. 92.2). Sensor replies:
CAL COMPLETE

Step 4.   The precipitation amount calibration process is complete.

7   MEASUREMENT PRINCIPLES

7.1   Visibility Measurement Terminology

The VPF-700 Sensor of Series has all the capabilities of a forward scatter meter (FSM); i.e. it belongs to the class of nephelometers which measure the amount of light scattered at angles less than 90 degrees by small particulates suspended in, or large particles passing through its sample volume. In the case of the VPF-700 series of sensors, the sample volume is defined by the intersection of the transmitted beam of light and the ray-cone which defines the field of view of the forward scatter receiver as shown in Figure 7-1 Sensor Sample Volume.
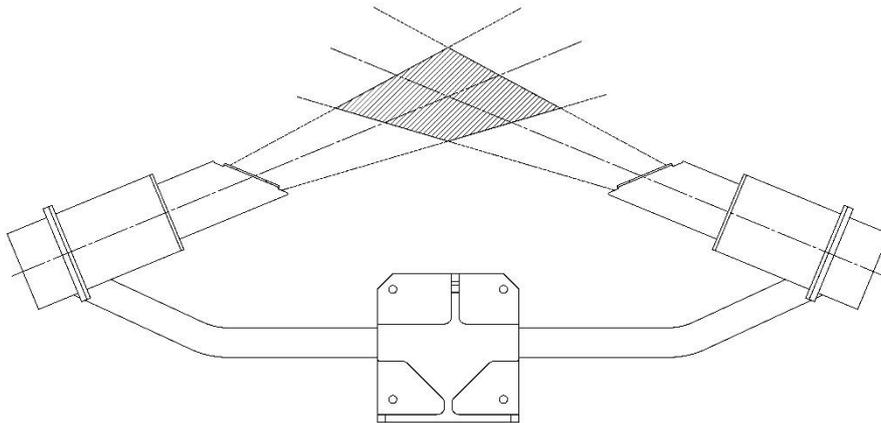
Figure 7-1 Sensor Sample Volume

Suspended particles such as fog, haze and smoke aerosols and precipitating particles such as rain, snow, ice pellets, drizzle and mist account for essentially all of the atmospheric extinction of visible and near-visible optical radiation for horizontal visual ranges up to approximately 100 kilometres. Beyond that range scattering by the molecular constituents of the atmosphere begin to play a role. In the visible and near visible spectral regions the dominant aerosol attenuation process is Mie-scattering. Aerosol absorption plays a negligible role in most natural environments; thus, the atmosphere scattering coefficient and extinction coefficient are synonymous.

7.2   Visual Range Determination

Nearly all instrumental methods of determining visual range start with a quantitative measurement of the atmospheric extinction coefficient β. Because β is measured in the vicinity of the sensor an assumption must be made that the prevailing environmental conditions are uniform over the scale of visual ranges of interest. The extinction coefficient is converted to visual range by application of:

(1) Koschmieder's Law (for daytime visual range),

(2) Allard's Law (for night-time visual range), or

(3) Variations on Koschmieder and Allard's Laws.

When an observer looks at a distant target the light from the target that reaches the observer is diminished by absorption and scattering (the two components of extinction). In addition to the light that originates at the target and ultimately reaches the observer, extraneous light scattered into the line-of-sight by the intervening atmosphere is also seen by the observer. It is this air light which we recognise as haze or fog.

The effect of extinction and added air light on the perceived brightness of visual targets is shown graphically below in Figure 7-2 Effects of Atmosphere on Perceived Brightness of Target Objects. From this illustration we note that the apparent contrast between object and horizon sky decreases with increasing distance from the target. This is true for both bright and dark objects.
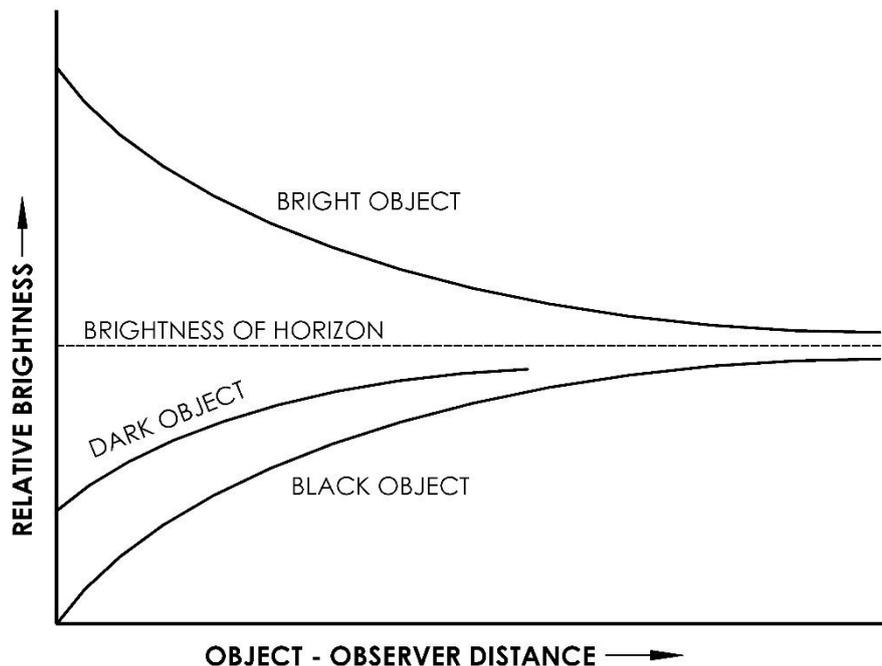
Figure 7-2 Effects of Atmosphere on Perceived Brightness of Target Objects

7.2.1   Daytime Visual Range

The original formula for calculating daytime visual range VR that was formulated by Koschmieder in 1924 is:

$$V_R = \frac{3.912}{\beta}$$

Where β is the atmospheric extinction coefficient.

Subsequent investigations concluded that Koschmieder used too optimistic a value (0.02) for the liminal contrast threshold value of the human eye. A liminal value of 0.05 is believed to be more realistic. For the latter contrast threshold Koschmieder's Law is modified to become:

$$V_R = \frac{3.00}{\beta}$$

This simple law accounts for both the extinction of light by the atmosphere and the addition of air light by the same atmosphere - for a black target viewed against the horizon sky. Thus,

the strict definition of daytime visual range implies the limiting distance at which a black target can be discerned against the horizon sky.

7.2.2 Night-time Visual Range

Night-time visual range refers to the distance at which an observer can see lights through the atmosphere at night. Allard gave the formula for the distance at which lights of intensity I can be seen at night in 1876.

Allard's Law is expressed as:

$$E_t = \frac{Ie^{-\beta V}}{V^2}$$

Where Et is the observer's illuminance threshold, β is the atmospheric extinction coefficient and V is visual range.

In addition to the extinction of light by the atmosphere, this formula accounts for the decrease of light from the point sources of light as the inverse square of the distance.

This formula for calculating night-time visual range has a significant mathematical difference from the formula derived from Koschmieder's law. Where the latter has a single algebraic relation between visibility and extinction coefficient, the former has a transcendental relation between the two quantities. Thus, the solution can only be found by an iterative numerical procedure or from a prepared table of values.

7.2.3 Meteorological Optical Range

Meteorological Optical Range (MOR) is the length of the path in the atmosphere required to reduce the luminous flux in a collimated beam from an incandescent lamp at a colour temperature of 2700°K to 0.05 of its original value. That is, the length of the path in the atmosphere for which the regular transmittance is 0.05.

For practical purposes one may calculate MOR in the same manner as Daytime Visual Range; i.e. MOR is given by the relation:

$$MOR = \frac{3.00}{\beta}$$

The use of MOR satisfies the requirements of a meteorologist since it yields a one-to-one correlation with atmospheric transmittance. A change from day to night does not produce, by itself, a change in the visibility.

7.3 Extinction Coefficient Calibration

The calibration of all VPF-700 sensor is traceable to a dual baseline transmissometer owned and operated by the Royal Netherlands Meteorological Institute (KNMI) at the De Bilt facility in The Netherlands. The calibration exercise was conducted over a period of approximately one year using the process described in International Civil Aviation Organisation document 9328 – Manual of Runway Visual Range Observing and Reporting Practices.

A Primary Scatter Meter Calibration Unit (SCU) or calibration plaque was produced as part of the calibration exercise. Secondary calibration plaques are used to calibrate all Senseca visibility and present weather sensors.

7.4   Theory of Forward Scatter Meters

7.4.1   Optical Sensor Configuration

The visibility measurement capability of the VPF-700 series of sensors derives from its forward scatter meter (FSM) configuration. Unlike a transmissometer, which measures the total atmospheric extinction coefficient, a FSM measures only an angular portion of the atmospheric scattering coefficient, that is, the scattering in a narrow range of angles around a central forward scatter angle.

The application of the standard universally accepted formulae for the calculation of daytime and night-time visibility requires that the total atmospheric extinction coefficient be measured, not the angular scattering coefficient. Thus, it is necessary to show that a measurement of the angular scattering coefficient, under certain strict conditions, can be related to the total atmospheric extinction coefficient (EXCO). Where EXCO includes both scattering and absorption of radiation at all angles from 0 to 180 degrees and by all atmospheric constituents be they suspended aerosols, precipitation or molecules of air.

The first step in that conversion process is to demonstrate that the total atmospheric scattering coefficient and total atmospheric extinction coefficient are synonymous for all practical purposes.

Assumption (1): The visibility measurements are restricted to less than 100 kilometres. (Rayleigh scattering by air molecules does not contribute significantly to atmospheric attenuation of visible light for visibility less than 100 kilometres).

Assumption (2): Absorption by fog, natural aerosols and precipitation contributes a negligible amount of attenuation compared to their scattering for visible and near visible radiation.

Given the above reasonable assumptions, the total scattering coefficient can be equated to the total extinction coefficient.

The next step in the process requires equating the angular scattering coefficient as measured by a FSM with the total scattering coefficient. That transition requires restrictions to be placed on the physical configuration of a FSM and on the wavelengths of radiation employed.

7.4.2   Visibility in Fog & Haze

The angular scattering coefficient can be separated into two components, a phase function $\Phi(\theta)$ and the total scattering coefficient σ as follows:

$$\sigma(\theta) = \Phi(\theta)\sigma$$

To replace the total scattering coefficient by the angular scattering coefficient, as required for valid measurements with a FSM, it is obvious that the phase function must be a constant for all environmental conditions in which visibility measurements are of interest (usually all weather conditions).

During WWII, British scientists discovered a natural phenomenon that allowed substitution of the angular scattering coefficient for the total scattering coefficient. In the scattering angle region between 35 to 55 degrees, they found very little change in the phase function for all classes of fogs and hazes. It was given the code name "Loofah". (See: W.E.K. Middleton, Vision through Atmosphere, University of Toronto Press). Much post-WWII work has substantiated the existence of this phenomenon.

Many FSMs employ a 35-degree scattering angle configuration since this angle provides more scattered light, hence more signal, than do greater "Loofah" angles. (The phase function has an inverse dependence with increasing scattering angle, its value being largest at smaller angles).

Whatever central angle is chosen for the FSM configuration, there is no simple way of providing an absolute calibration for the FSM. Calibration of a FSM must be accomplished by a comparison of measurements with an instrument that measures the atmospheric extinction coefficient directly. A transmissometer is such an instrument. Only one FSM of a given type, usually the prototype, need be calibrated against a well-maintained visible light transmissometer. The calibration of the prototype sensor is transferred to a calibration reference standard, which then serves as the primary reference standard for calibration of all other FSMs of an identical configuration. The primary standard for a given FSM is not a reliable reference standard for FSMS with any other size, central angle, types of optics or light source.

Well-maintained transmissometers that are available for calibration purposes are airport type transmissometers, dedicated to the measurement of visual range in heavy haze and fog. Such transmissometers prove to be accurate calibration references only over a limited range of visibilities, namely 1/2B to 20B, where B is the baseline of the transmissometer. A typical airport transmissometer has a baseline in the neighbourhood of 100 meters. Thus, its range of valid measurements extends from 50 meters to 2000 meters. This range encompasses only two environmental conditions, fog and very heavy haze.

To assure that the fog calibration of VPF sensors remains valid for lighter haze conditions and clear air, extensive use has been made of visual observations and televisiometer measurements. Proper targets for such observations must satisfy the conditions required by daytime visual range formulae; i.e., large, dark objects silhouetted against the horizon sky with no cloud cover present. A minor wavelength dependence effect is present for haze measurements, which is discussed later.

7.4.3   Visibility During Precipitation

It is highly desirous that the fog/haze calibration of a FSM carries over to various forms of precipitation. For this condition to be satisfied requires that the measurements of a fog/haze calibrated FSM give identical results to a transmissometer in snow and rain.

Forward scatter meters configured for a central scattering angle of 35 degrees and calibrated against transmissometers in fog/haze environments will overestimate the visibility in snow and underestimate the visibility in rain. To find out if there is a common "Loofah" angle for fog, haze, snow and rain VPF FSMs with central scattering angles other than 35 degrees have been operated for several years comparing their measurements with those of transmissometers in all types of weather. The results indicate that with a scattering angle near 45 degrees, a fog/haze calibration will remain valid for snow.

There is no common "Loofah" angle that allows transmissometer measurements in rain to agree with those of a FSM. The best result that can be achieved is a minimisation of the difference between the readings of a FSM in rain verses those of transmissometer. Since FSMs give higher EXCOs in rain than transmissometers (i.e. the corresponding visibilities are lower) the difference is a fail-safe error if one accepts the transmissometer readings as the "true" value.

Disagreement between FSMs and transmissometers in rain has two root causes:

(1) The phase function for scattering by rain is dramatically different from that of fog, haze and snow: (the phase function has a highly forward-directed diffraction component that accounts for one-half of the light energy scattered by a raindrop) and,

(2) The receiver of a transmissometer is unable to distinguish between un-scattered light and diffracted light and treats both as un-scattered radiation. As a result, transmissometer measurements underestimate the total extinction coefficient.

(3) There are two schools of thought regarding which sensor type gives the more valid visibility measurement in rain, FSMs or transmissometers. One school believes the eye performs the same function as the transmissometer receiver, hence the transmissometer readings give the correct extinction coefficient. The second school counters with the opinion that while the first argument may be valid for point light sources, it is certainly not valid for non-self-luminous objects, especially for the theoretical black target used in the definition of daytime visual range. In the second case, the target contrast is reduced by the air light that results from light scattered by the raindrop at all angles. There is no light emanating from a black target to be diffracted toward the eye.

7.4.4 Transmissometer Equivalent EXCO

A Senseca present weather sensor can satisfy either school of opinion using its unique measurement techniques. For those that believe that the FSM measurements characterise the true extinction coefficient in rain, the total EXCO value normally provided by the sensors is always available. For the other school who believe that the true extinction coefficient in rain is that measured by transmissometers, the Senseca present weather sensors can provide the Transmissometer Equivalent EXCO, (TEXCO).

(1) The Transmissometer Equivalent EXCO is arrived at by the following steps:

(2) The sensor must first determine that the precipitation is rain not snow or other form of frozen precipitation.

(3) Separate the total EXCO into its components: EVENTS EXCO and EXCO MINUS EVENTS. (This step is essential to remove the fog or haze component from EXCO).

(4) Using an empirically determined relationship, convert the FSM EVENTS EXCO to TRANSMISSOMETER EVENTS EXCO.

(5) Restore the EXCO-EVENTS component (i.e. non-rain component of EXCO) to arrive at TEXCO.

(6) Output EXCO, EXCO-EVENTS and TEXCO.

(7)

7.4.5   Wavelength Dependence of FSM Measurements

Measurements by forward scatter meters and transmissometers in fog have no wavelength dependence on the radiation employed by their light sources. This fact is easily confirmed by the observation that fog is white in appearance.

Such is not the case with haze that has a decidedly blue cast in appearance. The transition to fog from haze is not a gradual affair. Middleton points to an abrupt transition in wavelength dependence at an extinction coefficient of 4 km^{-1}. This he takes to be the transition point from haze to fog. Above 4 km^{-1}, there is no variation of the extinction coefficient with wavelength. Below 4 km^{-1}, there is a distinct variation. Angstrom demonstrated that this wavelength variation of extinction in haze is due to aerosol scattering and has a wavelength dependence of:

$$\sigma(\lambda) = const\frac{1}{\lambda^{1.3}}$$

Others have shown this variation to be generally applicable for the spectral range from visible to near-infrared wavelengths of 1.0 micron and for visibilities extending to 100 kilometres.

Senseca FSMs operate at a wavelength of 0.85 microns because of the high powered IREDs available at that wavelength compared with LED's operating in the visible spectral region at the peak of the eye response (0.55 microns). The variation with wavelength in haze implies that if two FSMS, one operating at 0.85 micron and one at 0.55 micron are calibrated against a visible light transmissometer in fog then their measurement in haze will differ by the amount:

$$\sigma(0.85) = \left(\frac{0.55}{0.85}\right)^{1.3} \sigma(0.55)$$

$$= 0.57\sigma(0.55)$$

In fog and haze, the visible light transmissometer will measure the total scattering coefficient σ (.55). A visible light FSM might also give σ (.55) in haze, but it does not because it measures the angular scattering coefficient not the total scattering coefficient.

Atmospheric aerosol models show, in addition to the wavelength dependence, a slight wavelength dependence of the phase functions as well. For the two wavelengths of interest in the above example, the phase functions in fog and haze are as follows:

$$\Phi_{FOG}(0.55) = \Phi_{FOG}(0.85) = 0.13$$

$$\Phi_{HAZE}(0.55) = \Phi_{HAZE}(0.85) = 0.22$$

Thus, a FSM operating at 0.85 micron and calibrated in fog will show a phase function difference in haze by the amount:

$$\Phi_{HAZE}(0.85) = \frac{0.22}{0.13}\Phi_{FOG}(0.85)$$

$$= 1.7\Phi_{FOG}(0.85)$$

For a FSM operating at 0.85 microns, the two wavelength dependent components of the angular scattering coefficient are in the opposite direction and nearly offset one another, resulting in a difference between 0.55 and 0.85 microns of only 3%. The net result is that a calibration made in fog will be applicable to haze situations.

Such is not the case for a FSM operating at 0.55 microns. At that wavelength there is no spectral difference between FSM and a visible light transmissometer. The total scattering coefficient portion of the angular scattering function will remain unchanged, but the phase function will jump in the transition from fog to haze. Larger than "true" extinction coefficients will result with the subsequent underestimation of the true visual range in haze.

7.5   Precipitation Measurements

An automated present weather sensor must be capable of determining the type, intensity and quantity of precipitation in addition to the visibility. In the case of the VPF-700 series of sensors these precipitation parameters are established by a combination of several methods.

7.5.1   Identification:

The type of precipitation is established by one of two independent techniques. In one of the techniques, the ratio of the backscatter atmospheric extinction coefficient (BACK SCATTER EXCO) to the forward scatter atmospheric extinction coefficient (FORWARD SCATTER EXCO) is determined. A ratio greater than a specific value indicates snow while a ratio lower than a specific value indicates rain. In the second the size and velocity distributions of the precipitation particle are used to determine the type of precipitation. These two techniques are intended to complement one another. However, under some circumstances one of the techniques is programmed to override the other. The particular circumstance under which the one is programmed to veto the other has been established by several years of empirical observations.

7.5.2   Precipitation Recognition Matrix

The VPF-700 series of sensors measure the amplitude and duration of the light pulse created by each precipitation particle as it falls through the sample volume. From the amplitude and duration it then determines the particle size and velocity. The size and velocity information is collected in a data matrix by the microcomputer and is stored for a time interval (the measurement time period, usually one minute) adequate to provide a statistically significant and representative sample of particle sizes and velocities. The size and velocity distributions of particles in the matrix are available to determine the type of precipitation. Small numbers of particles with distributions not indicative of rain or snow are considered not to be precipitation and are rejected by false alarm algorithms.

Once precipitation occurrence has been determined, the particle size distribution is used to measure the intensity. To measure the intensity, the number of particles in each size bin of the matrix are summed, and then multiplied by the equivalent volume of water and a calibration constant. If the precipitation is identified as snow, a density factor is applied to determine the equivalent water content.

Because the size/velocity matrix is a convenient presentation for identifying various forms of precipitation we have termed it the "Precipitation Recognition Matrix". Types of precipitation are identified from their "Signature" in the Precipitation Recognition Matrix. The "Signature" is the particle size/velocity distribution that is characteristic of each type of precipitation phenomena.

An example of a precipitation recognition matrix is shown in Figure 7-3 Precipitation Matrix. This figure portrays a 16 x 21-matrix array of particle sizes and velocities. Sizes are arranged in columns and velocities in rows.

The Marshall-Palmer model for raindrop size-distribution and the Gunn-Kinzer measured velocities for raindrops in stagnant air were used to construct the matrix scales. If rainfall behaved in the exact manner of the Marshall-Palmer and Gunn-Kinzer models all raindrop measurements would fall in the data bins along the diagonal of the Precipitation Recognition Matrix. In practice, several factors tend to disperse the size/velocity relationship from the idealised characterisations.

(1) The Marshall-Palmer size distribution for raindrops is only a best-fit approximation,

(2) Winds and wind gusts can perturb the velocity/size relationship,

(3) The shape of the sample volume can significantly influence the velocity/size characteristics of particles. (i.e. Particles falling through a portion of the sample volume other than the centre, or falling in other than a vertical direction because of wind, will exhibit slightly different velocity/size characteristics depending upon the shape of the sample volume and the direction of the wind).

For the foregoing reasons, one expects raindrop counts to show up in some off-diagonal bins of the Precipitation Recognition Matrix as shown in the schematic illustration given in Figure 7-3 Precipitation Matrix. Indeed, this conjecture is substantiated in practice. This diagram shows a schematic portrayal of the use of the Precipitation Matrix to identify different kinds of precipitation. The locations of various forms of precipitation, which are schematically illustrated in the matrix, are also borne out in practice.

7.5.3   Signal Processing

A functional block diagram of the VPF-700 series of sensors is shown in Figure 7-4 VPF-700 Sensor Functional Block Diagram. Those components of the sensor housed in the transmitter and receivers are shown enclosed in one dashed line. Those components housed in the power/control system are shown enclosed in the other dashed line.

When a particle of precipitation passes through the sample volume, light from the LED source, which is housed in the transmitter section of the sensor head, is scattered into the receiver section where it is sensed by the photo detector. Because the LED source is modulated at 2kHz, the detector and amplifier chain generates an AC signal whose amplitude is proportionally to the size of the particle and whose duration is inversely proportional to its velocity.

7.5.4   Quantity and Intensity

Typically, a sampling time interval of one minute is employed in automated present weather sensors. When rain is identified the quantity of water falling in the one-minute sampling time interval is determined from the number and size of the raindrops passing through the sample volume. The intensity is established by a comparison of the quantity of rainfall in one minute with the intensity scale of the country or organisation for which the sensor is configured. When snow is identified the intensity is established on the basis of the visual range or liquid water equivalent depending on the country configuration. For other forms of frozen precipitation, the intensity is established on the basis of the equivalent water content rate of fall.

Figure 7-3 Precipitation Matrix.

COLUMNS	NO.	Equivalent Particle Radius (mm)		ROWS	NO.	Particle Velocity (m/sec.)
	1	<0.200			1	.40-.70
	2	.200-.250			2	.70-1.20
	3	.250-.300			3	1.20-1.62
	4	.300-.350			4	1.62-2.06
	5	.350-.400			5	2.06-2.87
	6	.400-.450			6	2.87-3.67
	7	.450-.500			7	3.67-4.35
	8	.500-.550			8	4.35-4.90
	9	.550-.600			9	4.90-5.65
	10	.600-.650			10	5.65-7.00
	11	.650-.700			11	7.00-8.26
	12	.700-.800			12	8.26-10.76
	13	.800-.950			13	10.76-12.73
	14	.950-1.130			14	12.73-15.55
	15	1.130-1.345			15	15.55-20.00
	16	1.345-1.600			16	>20.00
	17	1.600-1.900				
	18	1.900-2.260				
	19	2.260-2.690				
	20	2.690-3.200				
	21	>3.200				

Figure 7-4 VPF-700 Sensor Functional Block Diagram.

8   PRODUCT OVERVIEW

8.1   VPF-700 Series of Present Weather Sensors

8.1.1   Available Sensor Models

There are three models in the VPF-700 series of present weather sensors, the VPF-710, the VPF-730 and the VPF-750. They use the same basic opto-mechanical and electronic components and have an optical transmitter and forward scatter receiver. The VPF-730 and VPF-750 also have a backscatter receiver to aid in precipitation identification.

All models have the same time-proven software for measuring visibility and precipitation type and performing remote self-test diagnostics.

The measurement capabilities of these models are as follows:

Sensor Model	Capability

VPF-710   Visibility

VPF-730   Visibility

This model has an extra backscatter receiver for:

>   Precipitation type identification
>
>   Rain rate
>
>   Snowfall rate
>
>   Precipitation accumulation

VPF-750   Visibility

                         Precipitation type identification

This model has an extra precipitation sensor and

an extra high accuracy temperature and humidity sensor for:

                         50 weather codes (from WMO

                         Code Table 4680), including:

                         Past Weather

                         Freezing Rain

                         Ice Pellets

8.1.2   Sensor Components

Each sensor has been engineered and manufactured with high-reliability components to provide accurate measurements under all weather conditions. Its rugged anodised, aluminium construction is intended to serve you in the severest of environmental conditions throughout the long life of the sensor.

A VPF-700 series sensor system consists of the major components listed below:

Item	QUANTITY
Basic Sensor assembly incorporating: transmitter, receiver and electronics housing	1
Stainless steel mounting U-bolt kit for fixing to a pole	1
Temperature Sensor	As required
Cable Assemblies	As Required
Operation and Maintenance Manual	1

The VPF-750 has, in addition:

Item	QUANTITY
Precipitation Sensor	1
High quality temperature and humidity sensors within a radiation shield	1

8.1.3   Optional Items

Hood Heaters

Heaters for the transmitter and receiver hoods. These are to minimise any build-up of ice within the optical paths. They consist of 15W heaters per hood on all versions.

Advanced Self-Test and Monitoring

In addition to the standard self-test transmitter window monitoring the sensors can have the optional receiver window monitoring to provide warning of additional contamination build-up. This option includes monitoring of the receiver sensitivities. This option is supplied as standard on the VPF-750.

Single Cable for both Power and Data

The sensor can be supplied with a single cable connector to carry both the power and data. This can only be supplied for DC sensors with RS232 data configuration.

Customer Specified Cable Lengths

The data and power cables can be supplied at any length (up to 25m), as specified by the customer.

🛈 NOTE:

> The RS232 configuration is suited to low to moderate electrical noise environments with moderate cable lengths and baud rates. For higher electrical noise environments with higher baud rates and longer cable lengths RS422 is recommended.

8.1.4   Accessories

Calibration Kit

The calibration kit, containing a reference standard calibration plaque in a protective carrying case, is employed only at those times that the sensor calibration is being checked.

Mains Adapter

A mains adapter is available if required.

Ambient Light Sensor

An ambient light sensor can be supplied as part of the VPF-700 system. This provides measurements of the ambient light intensity up to 40,000 Cd/m^2, with its output integrated into the standard VPF-700 data output string. See Section3.3.2, Ambient Light Sensor for models VPF-710 and VPF-730, and Section3.4, Data Output Message VPF-750.

External High Accuracy Temperature and Humidity Sensor

Supplied as standard on the VPF-750. Not applicable to the VPF-710. When fitted to the VPF-730 as a Special Configuration it enables Dust, Smoke and Mist to be identified, distinguishing these from Haze and Fog.

8.2   Sensor Features

The VPF-710 is a visibility sensor, the VPF-730 and VPF-750 are both visibility and present weather sensors. All these sensors have the necessary optimum configuration for accurate measurement of visibility in the densest of fogs to very clear air conditions. They can detect the onset of precipitation (not VPF-710) as readily as a human observer and can measure the size and velocity of precipitation particles. Unique patented techniques utilising precipitation size/velocity distributions and backscatter/forward scatter ratios provide high reliability identification of the type of precipitation. False alarms and false identifications are kept to a minimum by the application of empirically derived algorithms sensitive to the characteristic of electronic noise and insects. Also unique is the sensor's capability of separating the contribution of extinction due to precipitation from the total atmospheric extinction coefficient, thus giving the sensor the capability to identify fog whenever it is simultaneously present during a precipitation episode.

In addition to its optimal and unique measurement capabilities, the VPF-700 sensors have a number of distinctive physical features:

Compactness:

Each sensor is a single package, small in size and weight. It can be readily installed by one person and can be used in portable or fixed installations.

Proven Software:

The basic software incorporated into the sensor has evolved over a long period of time and has been tested and proven in hundreds of sensors.

Ease of Maintenance and Calibration:

Routine maintenance, including a check on calibrations, is performed in a matter of a few minutes. A re-calibration if required takes only slightly longer and is easily performed by one person.

8.2.1   Real Time Data Output

The output of the sensor is a serial-digital message that is provided at the signal interface with a sample time interval selected by the operator (a typical sample time interval is one minute). The message is provided automatically, or if the sensor is in the polled mode the data message is transmitted after the polling command is sent to the sensor.

The ASCII text data message is easy to interface to a wide range of hardware and software. The message can also be directly interpreted using the Sensor Interface Software or a terminal emulation program for test and debugging purposes:

(1) Data processing can occur, such as the application of Allard's Law for visibility of point light sources.

(2) Precipitation accumulation for selected intervals of time (e.g., every hour, every six hours, every 24 hours, etc.) can be obtained (not VPF-710).

(3) All or selected parts of the data message can be archived.

8.3   Present Weather Measurements

8.3.1   Present Weather Definition

The term "Present Weather" is generally employed to define a large class of atmospheric phenomena that includes tornado activity, thunderstorm activity, precipitation, obstructions to vision, and "other atmospheric phenomena" such as aurora. For purposes of Automated Present Weather Sensors, the term "present weather" is restricted to those atmospheric phenomena that are local to the sensor. These phenomena include:

All forms of liquid and frozen precipitation; e.g., rain, drizzle, snow, snow pellets, snow grains, ice pellets (formerly sleet) and hail.

Those suspended particles that are classed as obstructions to vision; namely, mist, fog, haze, dust and smoke.

8.3.2   Overview

These sensors utilise microprocessor technology to perform automatic visibility, precipitation (not VPF-710) and temperature measurements. Both DC versions and mains driven versions of each sensor are available. Patented techniques are employed to identify precipitation and to determine the presence of fog during episodes of precipitation.

8.3.3   Visibility Related Measurements

The measurement capabilities of the sensor are summarised in the table below. Determination of visual range is based on measurements of the atmospheric extinction coefficient (EXCO). Note that EXCO includes the attenuating effects of both suspended particles and precipitating particles. Meteorological optical range (MOR) is determined by application of the standard relation:

$$MOR = 3.00/EXCO$$

Haze and fog are the two most common forms of obstructions to vision. In the absence of precipitation, the sensor determines the presence of haze or fog based on the MOR. If the MOR is less than 1 km, then fog (FG) is indicated in the output message. If the MOR is between 1 and 10 km, then haze (HZ) is indicated in the output message. If MOR is greater than 10 km, no obstruction to vision is indicated.

In the presence of precipitation, the sensor software measures the fraction of the atmospheric extinction coefficient due to precipitation and subtracts it from the total extinction coefficient to obtain a quantity we have named EXCO-EVENTS. If the value of EXCO-EVENTS is greater than 3.00, then fog is declared to be present in addition to the precipitation as an obstruction to vision.

Visibility Measurements

Function	Details
Meteorological Optical Range	10 metres to 75km (30 feet to 46 miles) Other ranges between 10m and 99.99km by special request
Atmospheric Extinction Coefficient (EXCO)	$300km^{-1}$ to $0.04km^{-1}$
Accuracy	± 2% at 2 km ± 10% at 16 km ± 20% 16 to 30 km
Obstruction to vision	Identifies Fog or Haze (precipitation absent) Identifies Fog in presence of precipitation

Table 8-1 Visibility Measurement Specification

Function	Details
Liquid Precipitation:	0.00025 mm/min (0.00001 in/min) 0.015 mm/hr (0.00060 in/hr).
Snow (H_2O Equivalent):	0.000025 mm/min (0.000001 in/min) 0.0015 mm/hr (0.000060 in/hr).
Identification/Intensity	Drizzle: Slight/Moderate/Heavy Rain: Slight/Moderate/Heavy Snow: Slight/Moderate/Heavy Hail
Precipitation rate	Rain – Up to 1000 mm/hr (40 in/hr) Snow – Rain Equivalent up to 1000 mm/hr (40 in/hr)
Obstruction to vision	Haze Fog

Table 8-2 Additional Measurement Capabilities VPF-730

Additional Precipitation/Obstruction to Vision Measurements (VPF-750)

Function	Details
Identification/Intensity Non-Freezing	Drizzle and Rain: Slight/Moderate/Heavy
Identification/Intensity Freezing	Freezing Fog Freezing Drizzle Slight/Moderate/Heavy Freezing Rain Slight/Moderate/Heavy Rain (Drizzle) and Snow Slight/Moderate/Heavy Ice Pellets Slight/Moderate/Heavy Diamond Dust Blowing or Drifting Snow Snow Grains Ice Crystals Hail / Small Hail
Obstruction to Vision	Smoke (HZ) Dust (DU Mist (BR)

Table 8-3 Additional Measurement Capabilities VPF-750

Past Weather Determination (VPF-750)

Function	Time Constraints
Fog	In last hour but not at time of observation
Precipitation	In last hour but not at time of observation
Drizzle	In last hour but not at time of observation
Rain	In last hour but not at time of observation
Snow	In last hour but not at time of observation
Freezing Drizzle or Rain	In last hour but not at time of observation
Fog	In patches Becomming thinner in last hour No appreciable change in last hour Begun or becomming thicker in last hour
Rain showers	Slight/Moderate/Heavy

Function	Time Constraints
Snow Showers	Slight/Moderate/Heavy

Table 8-4 Past Weather Determination VPF-750

8.3.4   Precipitation Measurements

The VPF-730 and VPF-750 sensors identify three forms of precipitation, namely drizzle, rain and snow together with a wide variety of frozen forms of these (VPF-750 only). Detection of the onset of precipitation is extremely sensitive, being 0.00025 mm per minute for rain and approximately 0.000025 water equivalent mm per minute for snow.

Intensity of precipitation may be defined differently from one country to another. In some countries, the intensity of precipitation is defined differently for drizzle and rain than for snow. For drizzle and rain, the intensity (slight, moderate and heavy) is based on the rate of fall of precipitation. For snow the intensity is based on visual range unless fog is present. In classifying precipitation intensity, the sensor uses country specific definitions specified at time of order. As an example, the definitions used in the United Kingdom for aviation are shown in the in the tables below.

Drizzle

Slight	Less than 0.26 mm/hr
Moderate	Equal to or more than 0.26 mm/hr to less than 1.01 mm/hr
Heavy	Equal to or more than 1.01 mm/hr.

Rain

Slight	Less than 0.50 mm/hr
Moderate	Equal to or more than 0.50 mm/hr to less than 3.99 mm/hr
Heavy	Equal to or more than 3.99 mm/hr

Snow

Slight	Visibility greater than 800m
Moderate	Visibility greater than or equal to 400m but less than or equal to 800m.
Heavy	Visibility less than 400m

8.3.5 Reported Precipitation Codes

The following present weather codes, from WMO Table 4680 are used on the VPF-700 series of sensors:

VPF-710 – Visibility only, no weather codes

VPF-730 – Compressed message only:

00 No significant weather observed, or not ready

04 Haze or Smoke or Dust

10 Mist (If optional high accuracy temperature / humidity sensor fitted)

30 Fog

40 Indeterminate precipitation type

51 Slight Drizzle

52 Moderate Drizzle

53 Heavy Drizzle

61 Slight Rain

62 Moderate Rain

63 Heavy Rain

71 Slight Snow

72 Moderate Snow

73 Heavy Snow

89 Hail

VPF-750:

XX Sensor not ready

00 No significant weather observed

04 Haze or Smoke or Dust

10 Mist

11 Diamond Dust

20 Fog in last hour but not at time of observation

21 Precipitation in last hour but not at time of observation

22 Drizzle in last hour but not at time of observation

23 Rain in last hour but not at time of observation

24 Snow in last hour but not at time of observation

25 Freezing Drizzle or Freezing Rain in last hour but not at time of observation

28 Blowing or drifting snow, visibility ≥ 1km

29 Blowing or drifting snow, visibility < 1km

30 Fog

31	Fog in patches
32	Fog becoming thinner in last hour
33	Fog no appreciable change in last hour
34	Fog begun or becoming thicker in last hour
35	Freezing Fog
40	Indeterminate precipitation type
51	Slight Drizzle
52	Moderate Drizzle
53	Heavy Drizzle
54	Freezing Slight Drizzle
55	Freezing Moderate Drizzle
56	Freezing Heavy Drizzle
57	Drizzle and Rain, Slight
58	Drizzle and Rain, Moderate or Heavy
61	Slight Rain
62	Moderate Rain
63	Heavy Rain
64	Freezing Slight Rain
65	Freezing Moderate Rain
66	Freezing Heavy Rain
67	Rain and Snow, Slight
68	Rain and Snow, Moderate or Heavy
71	Slight Snow
72	Moderate Snow
73	Heavy Snow
74	Ice Pellets, Slight
75	Ice Pellets, Moderate
76	Ice Pellets, Heavy
77	Snow Grains
78	Ice Crystals
81	Rain Showers, Slight
82	Rain Showers, Moderate
83	Rain Showers, Heavy
85	Snow Showers, Slight
86	Snow Showers, Moderate
87	Snow Showers, Heavy
89	Hail

8.4   Sensor Specifications

The specifications for all versions of the VPF-700 series of sensors are summarised in the following pages. To adapt the table to a particular sensor model, disregard non-pertinent information. For example, in the case of the Model VPF-710 visibility sensor, disregard those portions of the specification pertaining to precipitation measurements.

Atmospheric Extinction Coefficient (EXCO) and Precipitation Measurements

Function	Details
Meteorological Optical Range (MOR)	10m to 75km Other ranges between 10m and 99.99km by special request.
Measures:	Atmospheric Extinction Coefficient (EXCO), reductions in visibility caused by: fog, haze, smoke, sand, drizzle, rain, snow and general precipitation
Measurement Accuracy at 16 km	± 10%
Measurement Accuracy at 2 km	± 2%
Measurement Time Constant	30 seconds

Stability of EXCO Zero Setting

Function	Details
Ambient Temperature Effects	<= 0.02/km
Long Term Drift	<= 0.02/km

Precipitation Measurements (Not VPF-710)

Function	Details
Detection Threshold: Rain	0.015mm/hr (0.0006 in/hr)
Detection Threshold: Snow (H20 Equiv.)	0.0015mm/hr (0.00006 in/hr)
Rain Rate (Maximum)	~ 500mm/hr (20 in/hr)
Rain Rate Accuracy	± 10%

Maintenance

Function	Details
MTBF (Calculated)	52,500 hrs (6 years)
Calibration Check	6 months recommended
Clean Windows	3 months recommended, dependent on environment
Remote Self-Test Monitoring	Included

VPF-750 Specific Temperature and Humidity Measurements

Function		Details
Humidity:	Type	Capacitive
	Range	0 to 100% Relative Humidity
	Accuracy	± 2 % Relative Humidity
	Response Time	< 20 seconds
Temperature:	Type	PT 100 Class B
	Range	-30°C to 70°C
	Accuracy 10°C to 40°C	± 0.2 °C
	Accuracy <10°C, >40°C	± 0.2 °C ±0.0073°C/°C
	Response Time	< 20 seconds

Table 8-5 Sensor Specifications

8.4.1   Sensor Characteristics

Physical

Function	Details
Scattering Angle Coverage	39° to 51°
Sample Volume	400 cm^3

Weight
 	
VPF-710   DC Sensors
 	
           Mains Powered Sensors
 	
VPF-730   DC Sensors
 	
           Mains Powered Sensors
 	
VPF-750   DC Only
	
	4.9kg
	
	6.1kg
	
	5.6kg
	
	6.8kg
	
	7.4kg

Length	0.75 m

Light Source

Function	Details
Type	IRED
Central Wavelength	0.85μm
Bandwidth	0.04μm
Lifetime	>10 years
Modulation Frequency	2,000 Hz

Detector

Function	Details
Type (Photovoltaic)	Silicon
Response	Silicon
Filter Bandwidth	0.08μm at 0.85μm

Power Requirements

Function	Details
Basic Sensor	3.5 W
De-Icing Heaters (Optional)	**VPF-710:** 30W (17W for 12V DC Version) **VPF-730:** 45W (25W for 12V DC Version) **VPF-750:** 45W
No-Dew Window Heaters	**VPF-710:** 1.7 W **VPF-730 and VPF-750:** 2.5 W

VPF-750 Additional Sensors:
  Precipitation Sensor
  Temperature and Humidity Sensor
  Ambient Light Sensor
	
	21W
	0.2W
	2.0W (17W with optional hood heater)

Environmental

Function	Details
Operating Temperature Range	-50°C to +60°C
Altitude	0 to 6,000 km
Precipitation	All weather
Humidity	0 to 100%
Protection Rating	IP66
CE Certified	√
EMC Compliant	EN61326-1 2013
RoHS and WEE Compliance	EN50581 2012

Table 8-6 Sensor Characteristics

8.4.2 Digital Communication Interface

Communication Protocols

Function	Details
Interface Type	RS232C, (Full Duplex)
Optional	RS422 or RS485

Parameters

Function	Details
Baud Rates	1200 Baud to 57K6 Baud, selectable
Data Bits	8
Parity	None
Stop Bits	1
Flow Control	None
Message Termination	CR-LF
Message Check Sum:	Selectable
Reporting Interval	Programmable (Response to poll, or Automatic at programmable intervals: 10 to 300 seconds)
Message Content:	• Sensor Identification Number (Programmable) • Reporting Interval (seconds) • Meteorological Optical Range • Precipitation Type • Obstruction to Vision (Fog, Haze, None) • Precipitation Amount (One Minute Interval) • Temperature • Remote Self-Test & Monitoring Flags

Table 8-7 Digital Communication Interface Specifications

8.4.3   Sensor Remote Self-Test Capabilities

Standard Self-Test and Monitoring

- Optical Source Power
- Transmitter Window Contamination
- Power Supply Voltages
- Non-Volatile Memory Check Sum Test
- EPROM Check-Sum Test
- Restart Occurrence
- Sensor Sample Interrupt Verification
- RAM Read/Write Verification
- Register Read/Write Verification
- A/D Control Signal Test
- A/D Conversion Accuracy Check
- Input Voltage Check (Battery Check on DC Powered Sensors Only)
- Forward-Scatter Background Illumination Level
- Back-Scatter Background Illumination Level

Advanced Self-Test and Monitoring

- Optical Source Power
- Forward-Scatter Receiver Sensitivity
- Back-Scatter Receiver Sensitivity
- Transmitter Window Contamination
- Forward-Scatter Receiver Window Contamination
- Back-Scatter Receiver Window Contamination
- Power Supply Voltages
- Non-Volatile Memory Check Sum Test
- EPROM Check-Sum Test
- Restart Occurrence
- Sensor Sample Interrupt Verification
- RAM Read/Write Verification
- Register Read/Write Verification
- A/D Control Signal Test
- A/D Conversion Accuracy Check
- Input Voltage Check (Battery Check on DC Powered Sensors Only)
- Forward-Scatter Background Illumination Level
- Back-Scatter Background Illumination Level

Standard Self-Test and Monitoring is a Standard Feature on the VPF-710 and VPF-730 sensors.

Advanced Self-Test and Monitoring is an Optional Accessory on the VPF-710 and VPF-730 sensors. Advanced selftest is a standard feature of the VPF-750

8.5   VPF-700 Series of Sensors - Dimensions

The model shown is the VPF-730 (and VPF-750). The VPF-710 is identical except that the Backscatter Head is not fitted.

Backscatter Head
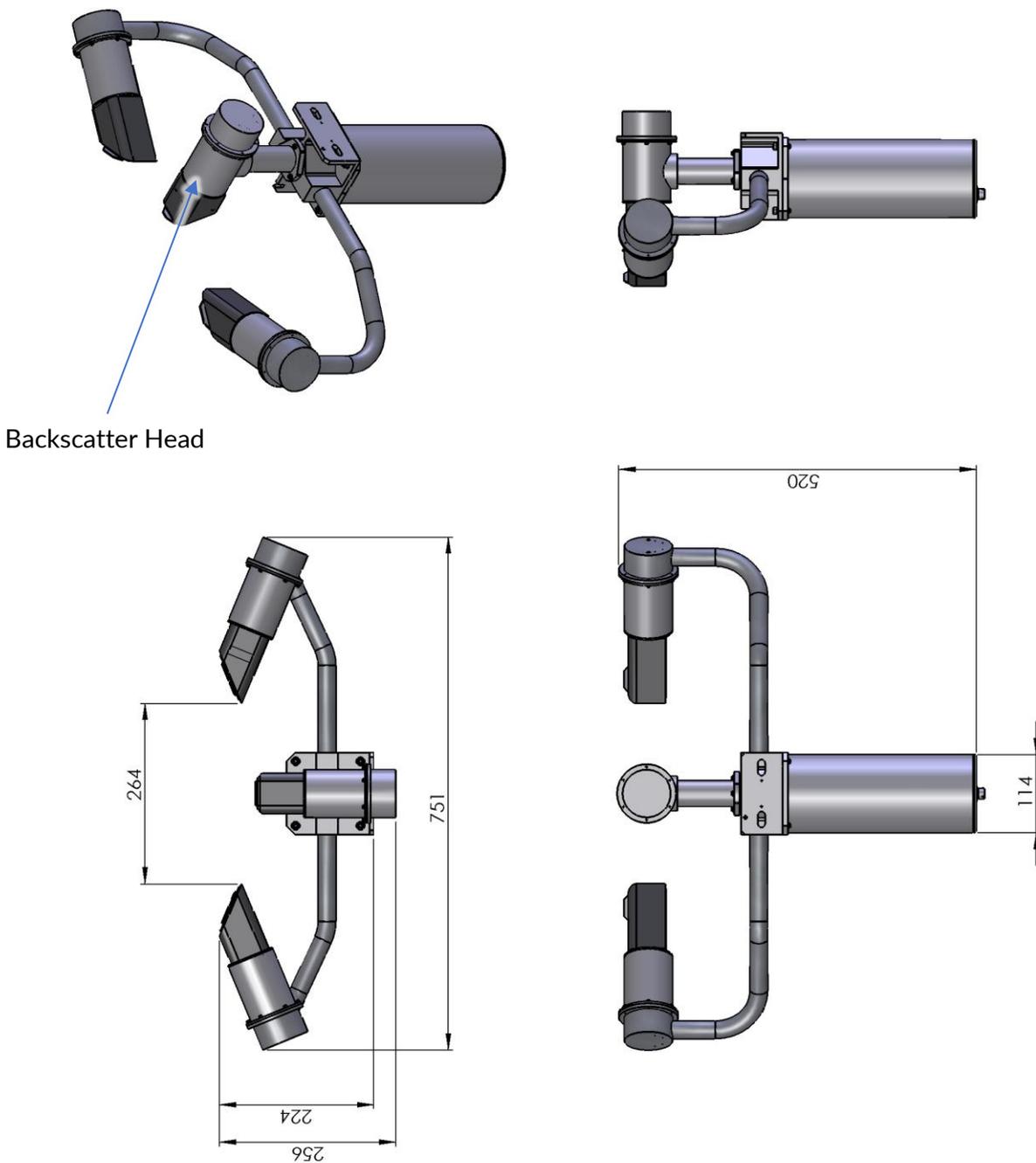
Figure 8-1 VPF-730 Model Dimensions (mm). (VPF-750) is identical)

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NOTES

NOTES

WARRANTY

The manufacturer is required to respond to the "factory warranty" only in those cases provided by the Consumer Rights Act 2015. Each instrument is sold after rigorous inspections; if any manufacturing defect is found, it is necessary to contact the distributor where the instrument was purchased from. During the warranty period (12 months from the date of invoice) any manufacturing defects found will be repaired free of charge. Misuse, wear, neglect, lack or inefficient maintenance as well as theft and damage during transport are excluded. Warranty does not apply if changes, tampering or unauthorized repairs are made on the product.
The manufacturer repairs the products that show defects of construction in accordance with the terms and conditions of warranty included in the manual of the product.

TECHNICAL INFORMATION

The quality level of our instruments is the result of the continuous product development. This may lead to differences between the information reported in the manual and the instrument you have purchased. We reserve the right to change technical specifications and dimensions to fit the product requirements without prior notice.

DISPOSAL INFORMATION
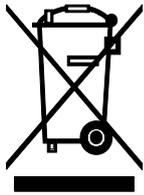
Electrical and electronic equipment marked with specific symbol in compliance with 2012/19/EU Directive must be disposed of separately from household waste. European users can hand them over to the dealer or to the manufacturer when purchasing a new electrical and electronic equipment, or to a WEEE collection point designated by local authorities. Illegal disposal is punished by law.

Disposing of electrical and electronic equipment separately from normal waste helps to preserve natural resources and allows materials to be recycled in an environmentally friendly way without risks to human health.

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