DEWPOINT MIRROR

MEASURING SYSTEM

OPERATING MANUAL

Software Version 1.00

1.334 / 01.95
1. Edition: January 1995

Heinz Walz GmbH • Eichenring 6 • 91090 Effeltrich • Germany
Phone +49-(0)9133/7765-0 • Telefax +49-(0)9133/5395
Email info@walz.com • Internet www.walz.com

Printed in Germany

The Dewpoint Mirror TS-2 Software

With a Windows Computer System the TS-2 software can be used to collect data measured with the TS-2 Dewpoint Mirror.

1.1 Installation of the TS-2 Software

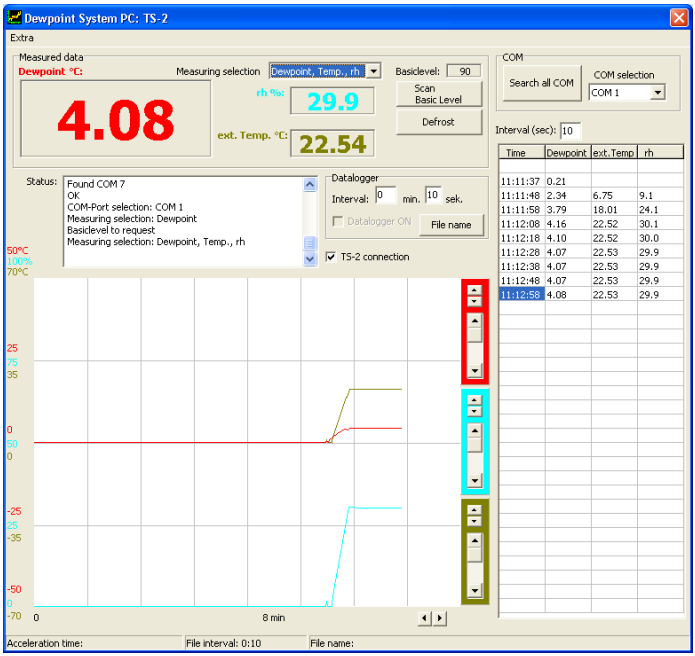
The TS-2 software is delivered as an application file on a CD together with the TS-2 instrument or can be found as actual version on the Walz homepage (www.walz.com) for download.

Please copy the executable file to the designated folder on your PC and connect the computer with the TS-2 control unit using the provided RS232 cable and switch on the instrument.

Start the application by double-clicking on the programm ikon. If the TS-2 is already connected with the computer the COM port for the communication will automatically be found. Otherwise click on the button “Search all COM” for a new connection or select the COM port manually by clicking on the arrow beneath the Com selection menue (see picture below).

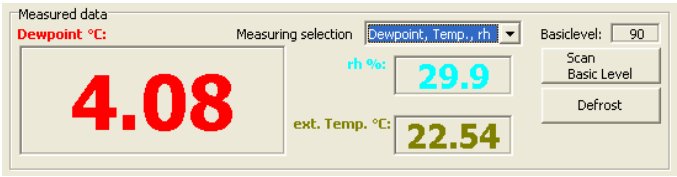
1.2 The TS-2 software user surface

The user surface contains all the informations concerning the measured values and the actual status of the instrument and is divided in five different areas.



1.2.1 Measured Data Screen

The measured data field shows the actual dewpoint [°C], optional the relative humidity [%] and also optional the external temperature depending on a connected temperature sensor or the “Measuring selection”. The values shown represent an average over 20 s, which means that the displayed values in the Measured Data Screen may show are slowly increasing after starting the software and show a difference to the values displayed on the TS-2 instrument.



In the case a menue button on the TS-2 control unit is pressed by mistake the communication will be interrupted and values are frozen on the screen. Press “Search all COM” (1.1) and the communication is started from new.

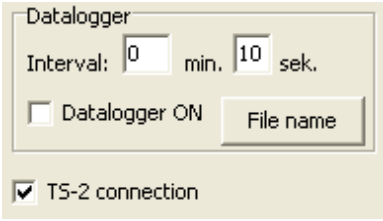
The Basic Level is a measure for the reflectivity of the mirror. It is corellated with ice or dirt settled on the mirror. The measurement is done once the instrument is started and manually when the button “Scan Basic Level” is pressed. If this level exceeds 260, a warning message “Please Clean Mirror” will appear in the status window. High Basic levels due to ice on the mirror can be removed by pressing “Defrost” once. In this case the peltier element that controls the temperature of the mirror will be switched off and can heat up to vaporise the ice. The defrost procedure will take a minute. During the defrost cycle, the basic level is measured and the operating level is recalculated. As it is not possible to measure the dewpoint during the defrost cycle, the display for the measured data shows no values.

1.2.2 Status Screen

Provides informations about the current status of the connection to the TS-2. Error messages and software version numbers will be shown here.

1.2.3 Datalogger Screen

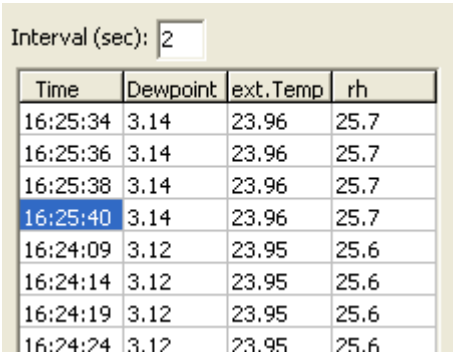
This Screen shows clock controls for storing measured data to a file. After definition of a storage interval (10 s in the example picture) and a file name the Datalogger can be switched on by checking the field “Datalogger ON”



The checked field “TS-2 connection” denotes that the software is ready to receive data and enables the user to switch off the communication between computer and TS-2 while both instruments are connected. The Control unit will keep its status and sends measured data which will not be stored by the computer.

1.2.4 The Interval Screen

A data sampling interval can be set in the Interval Screen.



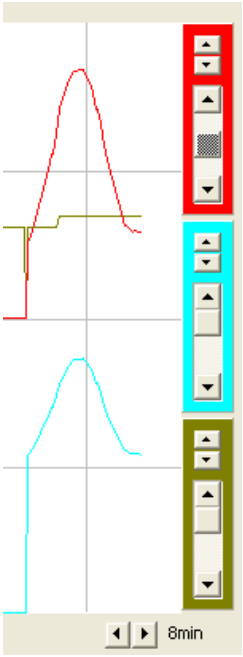
These values will not automatically be stored. This can be done via the Datalogger Screen (1.2.3). The data shown here are just listed in the table.

When the last line in the screen is reached the actual data will be filled in from the beginning and the old lines will be

overwritten. The actual line in the table will be shown inverted.

The number of columns shown depends on the options selected in the Measured Data Screen (1.2.1).

1.2.5 The Graphic Screen



With the Graphics Screen the measured Values (1.2.1 and 1.2.4) can easily be followed. The colors used for the values correspond to the colors used in the “Measured Data” window. With the little Arrow buttons the spreading of the Y-axis can be influenced and with the scroll-bar the position of the curve in the graphic can be determined. The Arrows on the button determin the spreading of the X-axis.

1. Introduction

The dewpoint mirror measuring system is one of the most accurate and reliable methods of measuring the absolute humidity of a gas. The model described belongs to the third generation of dewpoint mirror measuring systems developed by the Walz company. Building on earlier experience, the new generation includes digital technology for the first time. This has opened up a number of additional characteristics and features to make the device suitable for a wider range of applications. At the same time, however, the device remains simple to operate. The dewpoint mirror measuring system is designed for use as a stand-alone unit or it can be integrated in a very wide variety of equipment. It can be operated via the keyboard or via the serial interface. The system is ideally suited for control or alarm monitoring applications.

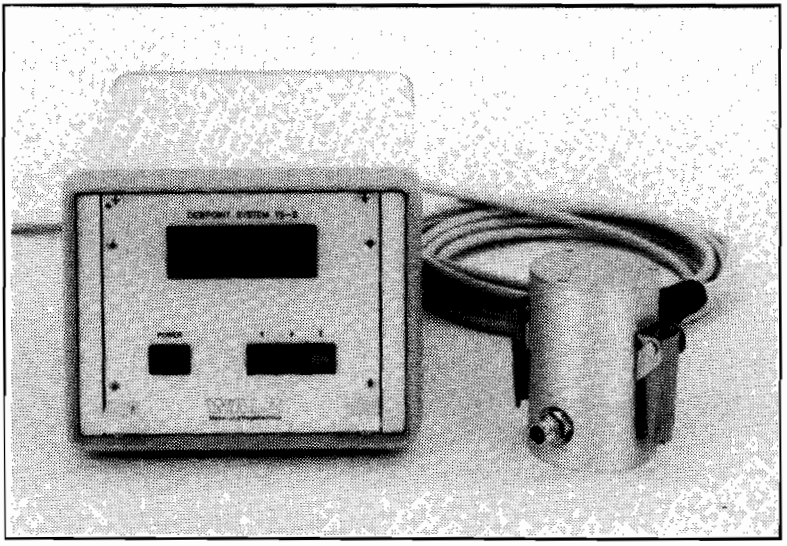


Fig. 1: Control and Display Unit TS-2 and
Dewpoint Mirror Measuring Head TS-2M

2. System components

The basic configuration of the dewpoint mirror measuring system consists of the Control and Display Unit TS-2 and the Dewpoint Mirror Measuring Head TS-2M. This basic configuration enables the dewpoint of a measuring gas to be measured. The dewpoint mirror measuring head is connected to the control and display unit via a cable. This enables the dewpoint mirror measuring head to be installed directly at site, whereas it is possible to stand the control and display unit further away or integrate it into other systems (no problem thanks to use of the 19" technology). In order to record the dewpoint it is necessary for the measuring gas to flow continuously through the dewpoint mirror measuring head. If information on the relative humidity of the measuring gas is required in addition to the dewpoint temperature, use of the Measuring Gas Temperature Sensor TS-2T is recommended. The latter is also connected to the control and display unit via a cable. In this configuration the relative humidity is calculated automatically per software from the measuring gas and dewpoint temperature.

The control and display unit includes a data acquisition system. The data memory is backed up by a lithium battery, i.e. the data are retained even after the device is switched off. The life of the battery is approx. 10 years. The frontplate of the control and display unit (see Fig. 2) features the On/Off switch (1), the LC display (2) and the three pushbuttons (3). The rear panel of the control and display unit (see Fig. 3) contains the mains connection (4) with fuse holder (5), the connectors for the measuring gas sensor (6) and the dewpoint mirror measuring head (7), the analog and alarm outputs for dewpoint and measuring gas temperature (8) and the RS 232 interface (9). The application possibilities offered by the hardware and software are described in Chapter 5. (Functions).

The housing of the dewpoint mirror measuring head includes a removable lid, which incorporates two gas connections. The optics located underneath this lid are well protected against contamination by

a sintered metal filter.

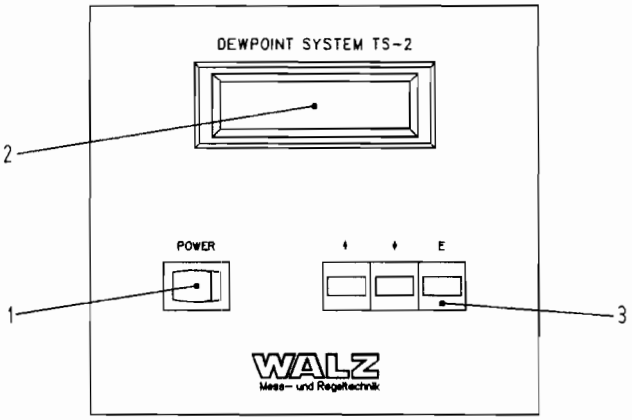


Fig. 2: Frontplate of the Control and Display Unit TS-2

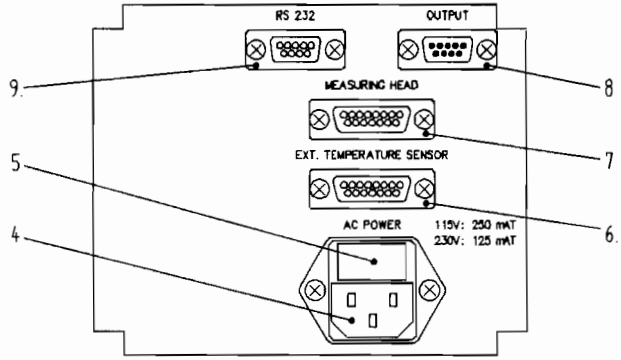


Fig. 3: Rear panel of the Control and Display Unit TS-2

3. Measuring principle

Dewpoint measurement using a temperature controlled mirror is based on the physical relationship between the dewpoint temperature and the water vapor partial pressure. The temperature of the mirror in the dewpoint mirror measuring head is cooled and controlled until a defined layer of condensate forms on the mirror. The condensate on the mirror is analyzed optically using the beam of an infrared LED directed at the mirror at a set angle of incidence. Located vertically above the point where the beam strikes the mirror is a phototransistor. If there is no layer of condensate on the mirror, the beam is reflected according to the angle of incidence and the phototransistor receives no or hardly any infrared radiation (basic level). If condensate has formed, the radiated infrared light is partially dispersed. The degree of dispersion depends on the thickness of the condensate layer and can be recorded using a phototransistor (operating level). Through optical scanning of the mirror it is possible to adjust the temperature of the latter exactly to the dewpoint temperature of the measuring gas. A Pt 100 temperature sensor embedded in the mirror provides the mirror temperature, which in the controlled state corresponds to the dewpoint temperature of the measuring gas. Since the dewpoint of a gas can only be equal or less than the gas temperature, it is adequate if it is only possible to cool the mirror. Cooling takes place using a Peltier element thermally coupled to the mirror. In order to achieve a high cooling capacity and thus be able to measure extremely low dewpoints in comparison with the ambient temperature, the Peltier element has a two-stage structure. If dewpoints below 0 °C are measured over longer periods or if very low dewpoints are measured, it is possible that the mirror might frost over. A further effect is that the mirror might become slightly contaminated or a change in ambient temperature might influence the basic level. In such cases measurement of the dewpoint is automatically interrupted at intervals for a short time to enable the film on the mirror to recede. At the same time the basic level is measured.

4. Preparing for operation

The control and display unit has a switch for 115/230 V. Before switching the unit on, please make sure that it is set to the correct mains voltage and that the correct fuse is in the fuse holder. The same applies following a change of installation location and thus mains voltage. If necessary, the fuse holder can be withdrawn by pressing the two side fasteners together. The small insert with the mains voltage data printed on it is then removed from the fuse holder and reinserted so that the required mains voltage data can be seen in the window. The correct fuse must then be placed in the holder and the holder returned to its original position.

Please make sure that the control and display unit is always switched off when the cable connections for the dewpoint mirror measuring head or the measuring gas temperature sensor are pulled or reconnected. The dewpoint mirror measuring head is connected to the control and display unit by means of a cable. The mains unit circuit board of the control and display unit features a jumper, which is set according to the length of the cable. At the factory the jumper is set correctly for the cable supplied. If your unit is supplied with several cables or if you make up cables yourself, make sure that the jumper setting is correct (see Chapter 10.). Whereas the housing and the cable connections of the dewpoint mirror measuring head are insensitive to splash water and largely resistant to corrosion, the control and display unit must be accommodated in a weather-protected housing.

The following points should be noted when installing the dewpoint mirror measuring head. The side marked "THIS SIDE UP!" should face upwards during operation since it is calibrated in this position. On the other hand the direction of the gas flow through the dewpoint mirror measuring head is unimportant.

The dewpoint mirror measuring head can be installed directly in a measuring gas flow provided the flow rate remains within the specified

limits (see Fig. 4). If the flow rate exceeds the specified quantities, the required amount can be diverted from the measuring gas flow or suctioned off using a pump (see Fig. 5). If a loss of measuring gas is to be avoided, the diverted amount can then be returned to the flow as shown in the diagram. Depending on the level of contamination of the measuring gas it is advisable to install a dust filter upstream of the dewpoint mirror measuring head. The filter should have minimum water absorption/desorption characteristics. This should also apply to the connecting hoses used upstream of the dewpoint mirror measuring head, e.g. Teflon hoses are especially suitable for this purpose. The shorter the hose lengths chosen, the lower the absorption/desorption effects are and the faster the changes in dewpoint can be recorded. If a gas pump is used, it must be positioned downstream of the dewpoint mirror measuring head because abrasion in the case of diaphragm pumps can lead to contamination of the mirror and it is also possible for water absorption/desorption effects to occur in the case of pumps. It is especially important to make sure that the pressure conditions in the measuring gas do not change as the result of design characteristics, since otherwise this will impair measurement of the dewpoint. This is another reason why short hose lengths are preferred upstream of the dewpoint mirror measuring head. The flow through the head can be monitored using a simple flow monitor. If the dewpoint mirror measuring head is installed at the end of a measuring setup, another hose at least 50 cm in length should be attached to the gas outlet orifice to prevent water vapor from the ambient air entering the dewpoint mirror measuring head counter to the flow direction and corrupting the measurement result.

If the measuring gas temperature sensor is used, it should also be connected to the control and display unit. The measuring gas temperature sensor should be positioned as close as possible to the point in the system at which the relative humidity is to be recorded. Otherwise, errors will occur when recording the measuring gas temperature and consequently when calculating the relative humidity.

If all components are installed in accordance with the above instructions, the control and display unit can be switched on. It is ready to operate in less than one minute. The messages that appear when the unit is switched on are described below. The analog and alarm outputs can be picked off at any time and the connection established via the serial interface without having to switch off the control and display unit.

All of the functions that the hardware and software offer are described in Chapter 5. See also Chapter 6. which contains practical notes.

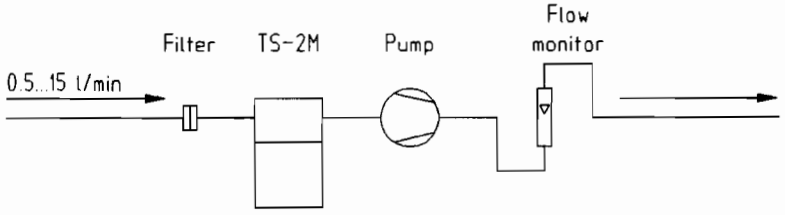


Fig. 4: Integration of the Dewpoint Mirror Measuring Head TS-2M in a pneumatic system with a measuring gas flow of 0.5 - 15 l/min

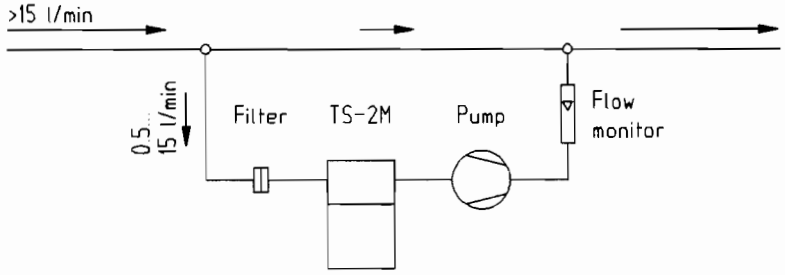
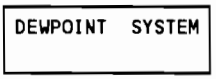


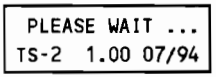
Fig. 5: Integration of the Dewpoint Mirror Measuring Head TS-2M in a pneumatic system with a measuring gas flow greater than 15 l/min

Start-up messages

When the unit is switched on, the following messages appear in the order given provided that no faults occur:



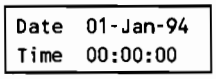
Type of unit
A short message appears stating the type of unit.



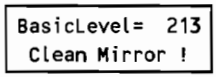
Wait time
The unit uses this time to measure basic level and to determine operating level. The second line contains the device designation, software version number and release date.

Display mode
The device is now ready for operation and displays measured values. The display layout can be varied.

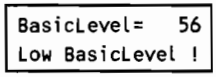
If the system contains faults when the unit is switched on, the following messages may occur:



The internal lithium battery has been exchanged or is empty. Date and time are entered as described under menu number 41 in Section 5.6.



The basic level is too high (> 160, see error messages in Chap. 8.).



The basic level is too low (< 60, see error messages in Chap. 8.).

5. Functions

5.1. Menu structure, menu selection and parameter input

Menu structure

The software of the dewpoint mirror measuring system has a menu structure and requires only the three pushbuttons for operation [↑], [↓] and [E]. The menu is subdivided into four main menus, which in turn contain submenus. The menu structure is described in Fig. 6.

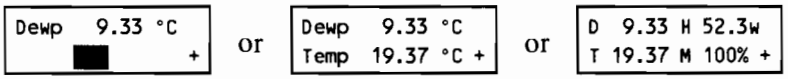
1. DISPLAY MODE	2. DATA LOGGER	3. ALARM CONFIG	4. SETUP
10 DISPLAY MODE E x i t	20 DATA LOGGER E x i t	30 ALARM CONFIG E x i t	40 SETUP E x i t
11 DISPLAY MODE Dewp Bargraph	21 DATA LOGGER Logger On/Off	31 ALARM CONFIG Alarms On/Off	41 SETUP Date and Time
12 DISPLAY MODE Dewp and Temp	22 DATA LOGGER Output	32 ALARM CONFIG Alarm Ranges	42 SETUP Defrost-Interv
13 DISPLAY MODE Dewp, Temp, relH	23 DATA LOGGER Setup Mem		43 SETUP Analog Output
	24 DATA LOGGER Free Mem		44 SETUP Remote On/Off

Fig. 6: Summary of the menu structure for the dewpoint mirror measuring system

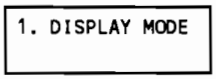
The main menus are numbered from "1." to "4.", the number is followed by the main menu text. In the submenus the "." is replaced by the number of the submenu to form a two-digit menu number. In addition, the associated submenu text appears in the second line.

Menu selection

The software is normally in display mode, i.e. measured values are displayed in one of three modes according to menu number 11, 12 or 13:



Starting with this as a basis, you can move to the main menu by pressing pushbutton [↑], [↓] or [E] whereupon the following message appears:



Using the pushbuttons [↑] or [↓] you can select one of the four main menus. From here you can press pushbutton [E] to move to the submenu level, where you can move again using buttons [↑] and [↓]. If you now press pushbutton [E], you will execute the selected menu item. The submenus with the number "0" are intended for returning to display mode without causing a function to be executed.

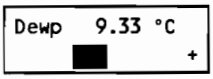
Parameter input

Logical values (Yes/No, On/Off) or integer values can be entered during execution of functions. In each case the required settings are made by pressing pushbuttons [↑] and [↓], which must then be acknowledged using [E]. Confirmation with [E] is always required even if the values have not (been) changed. When setting integer values, the input value can be rapidly increased/decreased by continuously pressing pushbuttons [↑] or [↓].

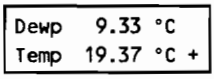
Example describing selection of a particular menu number with parameter input

If, for example, you wish to select alarm monitoring (menu number 31), proceed as follows.

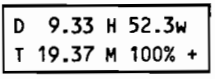
You start with one of the following three display modes:



or

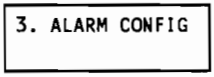


or



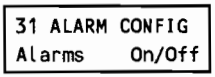
By pressing pushbutton [↑], [↓] or [E], you enter the main menu:

By pressing [↑] or [↓] you move on the main menu level until the following message appears:



By pressing [E] you enter the submenu level of the main menu "3. ALARM CONFIG" and the following message appears:

Using pushbuttons [↑] or [↓] you move in the submenu level until the following message appears:



By pressing pushbutton [E] this submenu item is executed. In the example described it was assumed that the alarms were switched off in advance. The logical request for enabling/disabling the alarm for the dewpoint appears:

```
31 ALARM CONFIG
AlarmDewp  = Off
```

The alarm for the dewpoint is activated using [↑] or [↓]:

```
31 ALARM CONFIG
AlarmDewp  = On
```

Confirmation of the setting using pushbutton [E] leads to the next request:

```
31 ALARM CONFIG
AlarmTemp  = Off
```

The alarm for the measuring gas temperature is activated using [↑] or [↓]:

```
31 ALARM CONFIG
AlarmTemp  = On
```

The setting is confirmed using pushbutton [E]. Since the submenu item is now terminated, current measured values are displayed again in one of the three display modes:

```
Dewp   9.33 °C
       ■       +
```

or

```
Dewp   9.33 °C
Temp  19.37 °C +
```

or

```
D  9.33 H 52.3w
T 19.37 M 100% +
```

5.2. Main menu

The following four main menus are available:

1. DISPLAY MODE

This main menu contains the various display modes which are at the user's disposal. The display modes vary according to which parameters are to be displayed.

2. DATA LOGGER

This main menu contains all functions for setting and monitoring the data logger and for sending the contents of its memory.

3. ALARM CONFIG

The functions of this main memory are used to activate/deactivate the alarm outputs and to set the alarm thresholds.

4. SETUP

This main menu includes the functions for setting the date and time, the defrosting interval, the range limits for the analog outputs and the remote control.

5.3. Submenus of "1. DISPLAY MODE"

The user can choose between three different display modes. The mode selected will depend on whether a measuring gas temperature sensor is connected and which parameters are to be displayed. In all three display modes, the last position of each display line indicates the status of the device (the symbols used are explained below).

Device status symbols:

The following flashing symbols appear at the end of the first line:

"I" A flashing "I" only appears if the data logger is activated and the data have been stored correctly.

"L" If the "Stack memory" mode (see menu number 23 in section 5.4.) was selected and the data logger is activated, the flashing "I" is replaced by a flashing "L" as soon as the memory is full.

"h" This character appears when the device is in hold mode (see menu number 42 in section 5.6.). In a defrosting phase it is not possible to measure the dewpoint and all measured values measured before the defrosting period are therefore retained and displayed until defrosting is terminated. The "h" then disappears and current measured values are displayed again.

The following flashing symbols can appear at the end of the second line:

"-" The device has not yet adjusted to the dewpoint, i.e. the control deviation is still outside the fixed limits. The values displayed for dewpoint and relative humidity can therefore deviate strongly from the real values.

"+" The control deviation fluctuates within the fixed limits and is therefore considered to be adjusted.

```
10 DISPLAY MODE
   E x i t
```

Return to display mode

If this message is acknowledged with pushbutton [E], the software returns to the preselected display mode corresponding to menu number 11 in the above example.

Pressing [E] is followed by:

```
Dewp  8.31 °C
      ■      +
```

```
11 DISPLAY MODE
 Dewp Bargraph
```

Dewpoint temperature display with graphic representation of the dewpoint temperature change

The dewpoint ("Dewp") is displayed in °C. Changes in dewpoint temperature are represented by a trend bar. A black box represents a constant dewpoint. If the dewpoint rises, the box extends to the right and if the dewpoint falls it extends to the left. The length of the bar is proportional to the change in dewpoint.

Pressing [E] is followed by:

```
Dewp  8.31 °C
      ■      +
```

```
12 DISPLAY MODE
 Dewp and Temp
```

Display of dewpoint and measuring gas temperature

In this display mode the measuring gas temperature ("Temp" in °C) is displayed in addition to the dewpoint temperature ("Dewp" in °C). Selection of this mode is only practical if a measuring gas temperature sensor is connected.

Pressing [E] is followed by:

```
Dewp  9.33 °C
Temp 19.37 °C +
```

```
13 DISPLAY MODE
Dewp, Temp, relH
```

Display of dewpoint temperature, measuring gas temperature, calculated relative humidity and free memory space

Pressing [E] is followed by:

```
D  9.33 H 51.9w
T 19.36 M 100% +
```

Selection of this display mode is also only practical if a measuring gas temperature sensor is connected. In addition to the dewpoint temperature ("D" in °C) and the measuring gas temperature ("T" in °C), the resulting relative humidity ("H" in %) is also displayed. If the dewpoint temperature falls below -10 °C, the water vapor partial pressure above ice is used for the dewpoint temperature to calculate the relative humidity. The two states are distinguished using the symbol "w" (water) and "i" (ice) appearing after the humidity value. The user can choose between the option Stack memory or Ring memory (see menu number 23 in section 5.4.). If the Stack memory option is selected, the free memory capacity is specified for the memory ("M") in %. If the Ring memory is selected, the name "Ring" appears for the memory ("M"), because in this case there is no need to specify the free memory space.

5.4. Submenus of "2. DATA LOGGER"

```
20 DATA LOGGER
   E x i t
```

Return to display mode

If this message is acknowledged with pushbutton [E], the software returns to the preselected display mode corresponding to menu number 11 in the above example.

Pressing [E] is followed by:

```
Dewp   8.31 °C
       ■       +
```

```
21 DATA LOGGER
 Logger   On/Off
```

Switching the data logger on or off

If this function is selected, a message appears indicating the current status of the data logger ("Logger = Off" or "Logger = On"). This can be changed if required. If the data logger is switched on, a request for a time interval follows for which a value can be selected in the minute (1, 2, 5, 10, 15, 30) or hour range (1, 2, 4, 6). After each time interval, a data record containing current measured values is stored in the data memory and is also output via the serial interface to a printer or connected terminal in ASCII format (for output format, see Appendix C). The memory capacity holds 1310 records. Please note that data storage is only active in display mode. The time interval for data storage is independent of the defrosting interval (see menu number 42 in section 5.6.). If storage of a data record happens to coincide with a defrosting cycle, it is executed after defrosting has ended.

Pressing [E] is followed by:

```
21 DATA LOGGER
 Logger    = Off
```

or

```
21 DATA LOGGER
 Logger    = On
```

Requesting a time interval:

```
21 DATA LOGGER
Interv  = 30 min
```

```
22 DATA LOGGER
 Output
```

Pressing [E] is followed by:

```
22 DATA LOGGER
 Output     = No
```

Activation of data transmission by pressing [↑] or [↓]:

```
22 DATA LOGGER
 Output     = Yes
```

The following message appears after data transmission, if the memory is empty, if data transmission is aborted or not executed:

```
End of Data
```

Output of the whole data memory via the serial interface

An introductory precautionary message appears ("Output = No"), which must be changed if the user wishes to transmit data ("Output = Yes"). In the case of transmission, the data from the most current data record are output via the serial interface in ASCII format (for output format, see Appendix C). During transmission, the display contains the following information relating to the data record being transmitted: serial number, time, date, dewpoint temperature, measuring gas temperature and relative humidity. Data transmission can be interrupted by pressing pushbutton [E]. If all data records are transmitted, if no data are stored, if data transmission is aborted or not executed, the display "End of Data" appears. By pressing [E], you can return again to display mode.

```
23 DATA LOGGER
 Setup Mem
```

Pressing [E] is followed by:

```
23 DATA LOGGER
RingMem    = No
```

or

```
23 DATA LOGGER
RingMem    = Yes
```

This is followed by a request for deletion of the data memory:

```
23 DATA LOGGER
Clear Mem  = No
```

If the previous request is answered positively (Yes), the precautionary question is asked:

```
23 DATA LOGGER
Erase Data = No
```

Setting the memory mode and erasing the data memory

The user has a choice of two memory modes: Stack memory and Ring memory. In the case of Stack memory mode and assuming that the memory is free, the data records are stored in sequence. If the memory is full, data recording is stopped (indicated in display mode by symbol "L" with reference to the device status). In Ring memory mode, the oldest data record is overwritten as soon as the data memory is full. If pushbutton [E] is pressed, a message appears which specifies the current memory mode ("RingMem = No" or "RingMem = Yes"). If the data memory is to be erased without changing the memory mode, the message is simply acknowledged with [E]. If the memory mode is to be changed, it should be noted that part of the data memory can be lost and it is therefore advisable to carry out any data transmission beforehand. Selection of the memory type is followed by the question, whether the memory is to be erased or not ("Clear Mem = No"). If the answer to this question is Yes, a precautionary question is asked ("Erase Data = No"), which must also be answered positively if the data memory is to be erased.

```
24 DATA LOGGER
 Free Mem
```

Pressing [E] is followed by:

```
24 DATA LOGGER
Free Mem = 100 %
```

Display of free memory capacity

The free memory capacity is displayed in %. It is only relevant for the Stack memory since, in this case, data recording is halted if the memory is full.

5.5. Submenus of "3. ALARM CONFIG"

```
30 ALARM CONFIG
   E x i t
```

Pressing [E] is followed by:

```
Dewp   8.31 °C
       ■       +
```

Return to display mode

If this message is acknowledged with pushbutton [E], the software returns to the preselected display mode corresponding to menu number 11 in the above example.

```
31 ALARM CONFIG
Alarms      On/Off
```

Pressing [E] is followed by:

```
31 ALARM CONFIG
AlarmDewp  = Off
```

or

```
31 ALARM CONFIG
AlarmDewp  = On
```

The following message appears after entry of the required setting and confirmation with [E]:

```
31 ALARM CONFIG
AlarmTemp  = Off
```

or

```
31 ALARM CONFIG
AlarmTemp  = On
```

Switching the alarm monitoring on and off for the dewpoint and measuring gas temperature

If the alarm monitoring function is switched on, a TTL signal is activated if the upper or lower alarm limits are violated (see Chapter 10.). In addition, the display line containing the corresponding measured value starts to flash in display mode. In display mode 11, violation of the upper or lower alarm limits for the measuring gas temperature is not visible through flashing of the display line, since the measuring gas temperature is not displayed. The alarm limits are fixed under menu number 32. Alarm monitoring is possible for dewpoint and measuring gas temperature and can be activated separately for each function. The first request is for alarm monitoring of the dewpoint temperature ("AlarmDewp"), then for the measuring gas temperature ("AlarmTemp"). Each request is accompanied by the current status, which can be changed if required.

```
32 ALARM CONFIG
Alarms Ranges
```

Pressing pushbutton [E] is followed by a request for the upper and lower alarm threshold for the dewpoint:

```
Alarm  Hi= 50 °C
Dewp   Lo=-50 °C
```

This is followed by a request for the upper and lower alarm threshold for the measuring gas temperature:

```
Alarm  Hi= 70 °C
Temp   Lo=-70 °C
```

Setting the alarm limits

The upper and lower alarm limit is first set for the dewpoint ("Alarm Dewp") and then for the measuring gas temperature ("Alarm Temp"). The alarm limits last set are displayed in each case. The first limit to be set is the upper alarm threshold ("Hi"); after confirmation, the lower limit is set ("Lo"). It is necessary to ensure at this point that the upper value is above the lower one, since otherwise it is not possible to exit the input function and the question will appear again.

5.6. Submenus of "4. SETUP"

```
40 SETUP
   E x i t
```

Pressing [E] is followed by:

```
Dewp   8.31 °C
       ■       +
```

Return to display mode

If this message is acknowledged with pushbutton [E], the software returns to the preselected display mode corresponding to menu number 11 in the above example.

```
41 SETUP
Date and Time
```

Pressing [E] is followed by:

```
Date 16-Jun-94
Time 12:28:45
```

If you wish to set the date or time, press pushbutton [↑] or [↓], respectively, for the appropriate request:

```
Date 16-__-__
Time 12:28:45
```

Setting the date and time

When this menu number is called, the current date and current time appear on the display. If pushbutton [E] is pressed, the date and time are retained unchanged. If a change is to be made, pushbutton [↑] or [↓] must be pressed. The cursor then jumps to the first digit of the date. The date and/or time are then entered in the normal way. To begin with, changes are executed using the [↑] or [↓] pushbuttons and then acknowledged with [E]. After each confirmation, the cursor jumps to the next digit of the date and/or time. When the seconds have been entered, the time is stored and the clock begins counting again as can be seen on the display. If the entry is correct, you can press pushbutton [E] to switch to display mode. Otherwise press [↑] or [↓] to repeat the procedure.

```
42 SETUP
Defrost-Interv
```

Pressing [E] is followed by:

```
42 SETUP
Defrost = 24 h
```

Setting the defrosting interval

This menu number enables you to enter a time interval (30 min or 1, 2, 4, 6, 12 or 24 h). At these intervals the mirror is automatically defrosted by interrupting the cooling of the mirror for a certain period. During the defrosting cycle, the basic level is measured and the operating level is recalculated. As it is not possible to measure the dewpoint during the defrosting cycle, the display continues to show the last measured dewpoint temperature, measuring gas temperature and relative humidity for this time. The analog value for the dewpoint and measuring gas temperature is also retained. This device status is indicated in display mode by a flashing "h" (hold). The defrosting interval is preset to 24 h. This value is to be retained for the majority of applications. However, if very low dewpoints are measured or the measuring gas is strongly contaminated, it might be advisable to set shorter intervals (see section 6.3.).

```
43 SETUP
Analog Output
```

Pressing pushbutton [E] is followed by a request for the upper and lower range limit for the dewpoint:

```
Outp   Hi= 50 °C
Dewp   Lo=-50 °C
```

This is followed by a request for the upper and lower range limit for the measuring gas temperature:

```
Outp   Hi= 70 °C
Temp   Lo=-70 °C
```

Setting the output ranges for the analog outputs

The device has analog outputs in the form of a voltage and a current output for the dewpoint and for the measuring gas temperature. The analog outputs have ratings of 0 - 10 V, 4 - 20 mA and normally correspond to the entire measuring range for dewpoint and measuring gas temperature. However, the output ranges for the analog outputs can be spread randomly using this function. An upper limit ("Hi") corresponding to 10 V or 20 mA can be entered together with a lower limit ("Lo") for 0 V or 4 mA. The limits are set first for the dewpoint ("Outp Dewp") and then for the measuring gas temperature ("Outp Temp"). In each case, the upper limit is set first and then the lower limit. When making the settings, please make sure that the upper limit is above the lower one since otherwise the input function cannot be exited and the request reappears on the display.

```
44 SETUP
Remote     On/Off
```

Pressing [E] is followed by:

```
44 SETUP
Remote     = Off
```

Switching the remote control on and off

The device can be controlled via the RS 232 interface, provided a terminal with VT52 emulation is connected to the serial interface. When the dewpoint system is switched on, it is always in the "Remote = Off" setting. This means that the device can be controlled from an external source and that the messages appearing on the display are not output via the serial interface. For user information, the dewpoint system only outputs the message "MENU ENTRY" when the software jumps to the menu. In order to select a particular menu number it is possible to follow up the "MENU ENTRY" message by directly entering the corresponding number using keys 1-9. The following key assignment applies for the terminal: [E] = Enter key; [↑] = Tab key; [↓] = Backspace key. These keys can be used to make all the required settings. Although it is not possible to accelerate up/down counting of the input value by continuously pressing the Tab or Backspace keys, values can be entered directly using the keys 0-9. If the "Remote = On" option is set using menu number 44, all messages appearing on the display are output via the serial interface and can be processed using a terminal program. Operation is as described above using the Enter, Tab and Backspace keys as well as keys 0-9. Selection of the "Remote = On" option stops continuous output of the stored measured values via the RS 232 interface (see menu number 21) when the data logger is switched on. It is only then possible to transfer the complete contents

of the memory (see menu number 22). The terminal program must be able to process the following VT52 commands: ESC G (deletes the screen starting at the cursor position) and ESC Yyx (moves cursor to position (x,y) of the screen).

6. Practical notes

6.1. Using the sintered filter

The sintered filter protects the dewpoint mirror against contamination and reduces any negative effects of the air flow. Use of the sintered filter means that the dewpoint mirror does not have to be cleaned so frequently even if the gas used is contaminated and, in addition, a more stable measuring signal is obtained. A large part of the measuring gas flows to the side of and past the sintered filter, whereas a smaller part of the gas flows through it. If the dewpoint changes, the water vapor partial pressure in the entire pore space of the sinter filter must be balanced to match the new water vapor partial pressure of the measuring gas. This influences the dynamics of the dewpoint measurement process, i.e. water vapor molecules are absorbed/released by the sintered filter over a long period. In the case of high dewpoints a high water vapor partial pressure is present in the measuring gas and the absorption/release of water vapor molecules by the sintered filter is relatively low in comparison with the water vapor partial pressure of the measuring gas. Dewpoints can still be recorded with sufficient speed and accuracy, thus giving preference to the sintered filter in the case of high dewpoints. At low dewpoints the water vapor partial pressure of the measuring gas is very low and the effects caused by absorption/release of water vapor molecules of the sintered filter can be relatively high in comparison with the water vapor partial pressure of the measuring gas. These effects can be particularly serious if there is a change from a high to a low dewpoint and show an extended hysteresis. Over a longer period this leads to corruption of the dewpoint measurement even though the dewpoint mirror has adjusted - as indicated by the "+" status. At dewpoints below 0 °C, for example, it can therefore be of more advantage to remove the sintered filter.

6.2. Influence of the hose length on the measuring result

Hoses are the normal type of gas conduit used for the dewpoint mirror measuring head. Absorption/desorption of water molecules is a characteristic of hoses too. This means that they show the same effects as the sintered filter as already described in section 6.1. In general, it is advisable to use hoses with the lowest possible adsorption/desorption characteristics, e.g. Teflon. Shorter hoses result in fewer undesired effects. At high dewpoint temperatures, adsorption/desorption plays a less important role if considered relative to the water vapor partial pressure of the measuring gas. Where the dewpoints being measured tend to fluctuate fairly heavily and, in particular, if changes from high to very low dewpoints are likely to occur, the hose material should be given special attention and the hose lengths used should be as short as possible.

6.3. Selection of the defrosting interval

If the mirror becomes contaminated, its optical characteristics change and this directly influences the basic level. In addition, the basic level changes slightly with the ambient temperature of the dewpoint mirror measuring head. The dewpoint mirror is automatically defrosted at regular intervals. The interval is set as described in Chapter 5. under menu number 42. During the defrosting phase, the layer of condensate on the mirror disappears completely and the basic level is measured and the operating level is recalculated. This compensates to a large extent for the effects on dewpoint measurement caused by a change in the basic level (slight contamination or change in ambient temperature). If the mirror is greatly contaminated, it must of course be cleaned. In rare cases it can happen that a fairly thick layer of ice forms on the mirror when measuring very low dewpoints with the result that the dewpoint can no longer be recorded correctly. Regular defrosting is also advisable even for these rare cases. The defrosting interval is preset to 24 h which is sufficient and recommended for most applications. It is only necessary

to shorten the defrosting interval if the measuring gas is strongly contaminated or if the mirror repeatedly ices over.

7. Calculation of the relative humidity

The dewpoint mirror measuring system supplies the dewpoint and the measuring gas temperature. The water vapor pressure of the measuring gas e'(TDP) is calculated from the dewpoint temperature TDP and the possible saturation vapor pressure of the measuring gas e(T) from the measuring gas temperature T. The relative humidity rH is obtained in % as follows:

$$rH = 100 * \frac{e'(TDP)}{e(T)}$$

Appendix A contains the saturation vapor pressures above water e_w and Appendix B the saturation vapor pressures above ice e_i as a function of temperature. In all cases the saturation vapor pressure above water $e_w(T)$ was calculated for the measuring gas temperature T, even if the measuring gas temperature was below 0 °C, since the water vapor pressures above water e_w are normally used to calculate the relative humidity. At dewpoint temperatures below 0 °C a layer of water or ice can form on the mirror. During operation it is not possible to distinguish between the two states. Exactly which layer has formed on the mirror depends on a number of factors. Experience shows that the deposit forming on the mirror at dewpoint temperatures between -10 and 0 °C quite probably consists of water, whereas it is highly probable that ice forms at dewpoint temperatures below -10 °C. Since the layer on the mirror is in equilibrium with the water vapor partial pressure of the measuring gas, allowance must be made for the fact that a deposit of water or ice might have formed on the surface of the mirror.

Based on experience, the water vapor pressure of the measuring gas above water e'_w(TDP) was therefore used to calculate the relative humidity for dewpoint temperatures TDP above -10 °C, i.e. as calculated from the table in Appendix A:

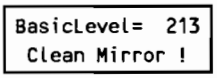
$$rH = 100 * \frac{e'_w(TDP)}{e_w(T)} \qquad for\ TDP > -10\ °C$$

To calculate the relative humidity for dewpoint temperatures TDP below -10 °C the water vapor pressure of the measuring gas above ice e'_i(TDP) was used, i.e. as calculated from the table in Appendix B:

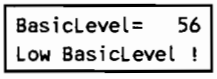
$$rH = 100 * \frac{e'_i(TDP)}{e_w(T)} \qquad for\ TDP < -10\ °C$$

8. Error messages and warning notes

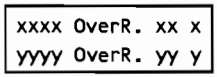
If an error message or a warning note appears it is not possible to switch to the menu using pushbutton [E] (see section 5.1. Menu selection). This can only be executed using [↑] or [↓]. Some error messages or warning notes can be eliminated by pressing [E]. In the case of an alarm limit being exceeded, for example, it may suffice to acknowledge this. Following messages such as "Clean Mirror" it is also necessary of course to eliminate the cause of the message. If measuring ranges or alarm limits continue to be violated, the error message or warning note cannot be made to disappear.



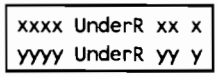
This message appears when the basic level is too high (> 160). The reason for this is that the dewpoint mirror is too highly contaminated. It must be cleaned as described in Chapter 9.



The basic level is too low (< 60). The reason for this is that the measuring head is not connected or is defective.



The measured value for dewpoint temperature ("Dewp") or measuring gas temperature ("Temp") exceeds the measuring range limit value of +50.00 °C or +70.00 °C, resp.



The measured value for dewpoint temperature ("Dewp") or measuring gas temperature ("Temp") undershoots the measuring range limit value of -50.00 or -70.00 °C, resp.

Flashing display line The upper display line flashes when the alarm monitoring function for the dewpoint temperature is switched on ("AlarmDewp = On", see menu number 31) and alarm limits entered for the dewpoint temperature (see menu number 32) are violated. The lower display line flashes when the alarm monitoring function for the measuring gas temperature is switched on ("AlarmTemp = On", see menu number 31) and the alarm limits entered for the measuring gas temperature (see menu number 32) are violated. The display lines continue to flash even when the measured values are inside the limits again so that it is possible to see that a violation has occurred. When the measured values move within the limit range again, flashing of the display can be halted by pressing [E]. If the measured values move outside of the limit range, it is not possible to stop the display flashing. Since the measuring gas temperature cannot be displayed in display mode 11, a violation of the alarm limits cannot be indicated on the display.

9. Maintenance

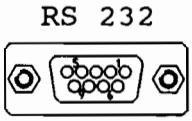
The mirror must be cleaned at certain intervals depending on the degree of contamination of the measuring gas. At the latest, cleaning should be carried out when the message "Clean Mirror!" appears or when the dewpoint displayed begins to oscillate. For this purpose, the control and display unit is switched off and the measuring head cover is removed. It is important to ensure that the sintered filter and the O ring fit properly when reassembling the cover.

A thin object with soft paper wrapped around it (e.g. a toothpick with paper tissue) should be used to clean the mirror. Plastic objects are not suitable, because they are dissolved by the cleaning fluid. Trichloroethane is used as cleaning fluid. Alcohol solutions are not recommended. Apply a drop of trichloroethane to the surface of the mirror. Lightly rub the toothpick with tissue paper uniformly over the mirror surface until you hear a squeaking noise. Then breathe on the mirror and the surface should mist over evenly - otherwise repeat cleaning. **The mirror surface should never be scratched or treated with abrasive cleaning agents.**

10. Connector pin assignments

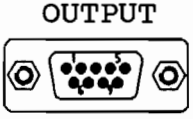
Described below are the pin assignments of all connectors/sockets located on the rear of the control and display unit:

Interface RS 232



1: not used
2: TxD
3: RxD
4: not used
5: GND
6: not used
7: not used
8: not used
9: not used

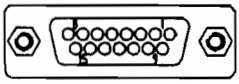
Analog and alarm outputs



1: Analog output dewpoint 4...20 mA
2: Analog output dewpoint 0...10 V
3: Analog output temperature 4...20 mA
4: Analog output temperature 0...10 V
5: GND for analog outputs
6: Alarm output dewpoint
7: Alarm output temperature
8: DIGGND for alarm outputs
9: not used

Measuring Head TS-2M

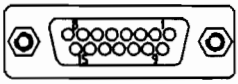
MEASURING HEAD



1: not used
2: Supply voltage +15 V
3: Supply voltage -15 V
4: GND
5: not used
6: Peltier +
7: Peltier +
8: Peltier -
9: Peltier -
10: U_A
11: Signal input -5...+5 mA
12: not used
13: PE
14: not used
15: not used

Measuring Gas Temperature Sensor TS-2T

EXT. TEMPERATURE SENSOR

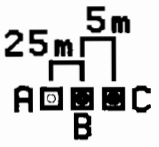


1: not used
2: Supply voltage +15 V
3: Supply voltage -15 V
4: GND
5: not used
6: not used
7: not used
8: not used
9: not used
10: not used
11: Signal input -7...+7 mA
12: not used
13: not used
14: not used
15: not used

Jumper position on the mains unit circuit board

The mains unit circuit board of the control and display unit contains a jumper, which is set according to the length of the cable. The jumper is set correctly at the works for the cable supplied with the unit. If your unit is supplied with several cables or if you make up cables yourself, make sure that the jumper setting is correct.

To do this, first pull the mains plug from the control and display unit and disconnect all cables. If the control and display unit is installed in a housing or similar, it must be removed from this. It is normally fastened using four screws on the frontplate. The rear panel, also fastened by four screws, must also be removed. The base of the control and display unit can now be withdrawn. The jumper for the various cable lengths is located on the mains unit circuit board directly in front of the transformer. See Fig. 7 for the correct position of the jumper. Then reassemble the housing in reverse order and reconnect the cables.



Jumper position 5 m (jumper between B and C) for cables of length < 10 m, e.g. for cable TS-K5

Jumper position 25 m (jumper between A and B) for cables of length ≥ 10 m, e.g. for cable TS-K10 and TS-K20

Fig. 7: Jumper position as a function of cable length

11. Technical data

Dewpoint Mirror Measuring Head TS-2M

Measuring range:	-50 ... +50 °C dewpoint
Measuring accuracy:	±0.15 °C at dewpoint temperatures above 0 °C ±1 °C at dewpoint temperatures below 0 °C
Reproducibility:	±0.05 °C
Measuring principle:	Optically scanned dewpoint mirror
Cooling:	2-stage Peltier element
Temperature difference:	Max. 60 °C to the environment
Measuring element:	Pt 100, class A
Measuring volume:	Approx. 35 ml
Measuring gas requirement:	0.5 ... 15 l/min
Pneumat. connection:	Internal thread R 1/4" with hose connections 6/8 mm
Ambient temperature:	-20 ... +60 °C
Dimensions:	68 mm dia., 98 mm height
Weight:	0.8 kg

Connecting Cable TS-K5

Cable length:	5 m
Weight:	0.4 kg

Connecting Cable TS-K10

Cable length:	10 m
Weight:	0.8 kg

Connecting Cable TS-K20

Cable length:	20 m
Weight:	1.4 kg

Gas Temperature Sensor TS-2T

Measuring range:	-30 ... +70 °C
Measuring accuracy:	±0.15 °C
Measuring element:	Pt 100, class A
Pneumat. connection:	Internal thread R 1/4" with hose connections 6/8 mm
Cable length:	5 m
Ambient temperature:	-20 ... +60 °C

Control and Display Unit TS-2

Display:	2-line (16 positions each) alphanumeric LC display with backlighting, character height 5.5 mm
Display ranges:	-50.00 ... +50.00 for dewpoint -70.00 ... +70.00 for temperature
Keyboard:	3 keys for parameter input
Microcontroller:	16-bit CMOS, 16 MHz
A/D converter:	CMOS, 13-bit resolution
D/A converter:	CMOS, 12-bit resolution
Program memory:	CMOS EPROM 64 kB
Data memory:	CMOS RAM 64 or 256 kB, battery-backed
Real-time clock:	CMOS, accuracy 15 seconds per month
Analog outputs:	0 ... 10 V (load ≥ 2 kΩ) and 4 ... 20 mA (burden ≤ 450 Ω) for dewpoint and temperature, output ranges software-selectable
Alarm outputs:	TTL signal (5 V = active, 0 V = inactive, max. 5 mA) for dewpoint and temperature,

	alarm ranges software-selectable
Interface:	RS 232, 9600 Baud
Voltage supply:	Selectable 115/230 V, 50/60 Hz
Fuse:	250 mAT at 115 V 125 mAT at 230 V
Power consumption:	Max. 11 VA
Ambient temperature:	0 ... 50 °C
Dimensions:	Slide-in module 28 pitch, 3 HU, 262 mm deep
Weight:	2.1 kg

19" Housing TS-G1

Design:	Desktop housing 28 pitch, 3 HU, 262 mm deep for accommodating a control and display unit TS-2
Dimensions:	26.5 cm x 18.5 cm x 14.5 cm (LxWxH)
Weight:	2.6 kg

19" Housing TS-G2

Design:	Desktop housing 63 pitch, 3 HU, 262 mm deep for accommodating two control and display units TS-2
Dimensions:	26.5 cm x 36.5 cm x 14.5 cm (LxWxH)
Weight:	3.8 kg

19" Housing TS-G3

Design:	Desktop housing 84 pitch, 3 HU, 262 mm deep for accommodating three control and display units TS-2
Dimensions:	26.5 cm x 47.0 cm x 14.5 cm (LxWxH)
Weight:	5 kg

Appendix A: Saturation vapor pressure over water (Robert List, 1984: Smithonian Meteorological Tables)

Temperature	Metric units									
	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
°C.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	mb.
−50	0.06356									
−49	0.07124	0.07044	0.06964	0.06885	0.06807	0.06730	0.06654	0.06578	0.06503	0.06429
−48	0.07975	0.07886	0.07797	0.07710	0.07624	0.07538	0.07453	0.07370	0.07287	0.07205
−47	0.08918	0.08819	0.08722	0.08625	0.08530	0.08435	0.08341	0.08248	0.08156	0.08065
−46	0.09961	0.09852	0.09744	0.09637	0.09531	0.09426	0.09322	0.09220	0.09118	0.09017
−45	0.1111	0.1099	0.1087	0.1075	0.1063	0.1052	0.1041	0.1030	0.1018	0.1007
−44	0.1239	0.1226	0.1213	0.1200	0.1187	0.1174	0.1161	0.1149	0.1136	0.1123
−43	0.1379	0.1364	0.1350	0.1335	0.1321	0.1307	0.1293	0.1279	0.1266	0.1252
−42	0.1534	0.1518	0.1502	0.1486	0.1470	0.1455	0.1440	0.1424	0.1409	0.1394
−41	0.1704	0.1686	0.1669	0.1651	0.1634	0.1617	0.1600	0.1583	0.1567	0.1550
−40	0.1891	0.1872	0.1852	0.1833	0.1815	0.1796	0.1777	0.1759	0.1740	0.1722
−39	0.2097	0.2076	0.2054	0.2033	0.2013	0.1992	0.1971	0.1951	0.1931	0.1911
−38	0.2323	0.2299	0.2276	0.2253	0.2230	0.2207	0.2185	0.2162	0.2140	0.2119
−37	0.2571	0.2545	0.2520	0.2494	0.2469	0.2444	0.2419	0.2395	0.2371	0.2347
−36	0.2842	0.2814	0.2786	0.2758	0.2730	0.2703	0.2676	0.2649	0.2623	0.2597
−35	0.3139	0.3108	0.3077	0.3047	0.3017	0.2987	0.2957	0.2928	0.2899	0.2870
−34	0.3463	0.3429	0.3396	0.3362	0.3330	0.3297	0.3265	0.3233	0.3201	0.3170
−33	0.3818	0.3781	0.3745	0.3708	0.3673	0.3637	0.3602	0.3567	0.3532	0.3497
−32	0.4205	0.4165	0.4125	0.4085	0.4046	0.4007	0.3968	0.3930	0.3893	0.3855
−31	0.4628	0.4584	0.4541	0.4497	0.4454	0.4412	0.4370	0.4328	0.4287	0.4246
−30	0.5088	0.5040	0.4993	0.4946	0.4899	0.4853	0.4807	0.4762	0.4717	0.4672
−29	0.5589	0.5537	0.5485	0.5434	0.5383	0.5333	0.5283	0.5234	0.5185	0.5136
−28	0.6134	0.6077	0.6021	0.5966	0.5911	0.5856	0.5802	0.5748	0.5694	0.5642
−27	0.6727	0.6666	0.6605	0.6544	0.6484	0.6425	0.6366	0.6307	0.6249	0.6191
−26	0.7371	0.7304	0.7238	0.7172	0.7107	0.7042	0.6978	0.6914	0.6851	0.6789
−25	0.8070	0.7997	0.7926	0.7854	0.7783	0.7713	0.7643	0.7574	0.7506	0.7438
−24	0.8827	0.8748	0.8671	0.8593	0.8517	0.8441	0.8366	0.8291	0.8217	0.8143
−23	0.9649	0.9564	0.9479	0.9396	0.9313	0.9230	0.9148	0.9067	0.8986	0.8906
−22	1.0538	1.0446	1.0354	1.0264	1.0173	1.0084	0.9995	0.9908	0.9821	0.9734
−21	1.1500	1.1400	1.1301	1.1203	1.1106	1.1009	1.0913	1.0818	1.0724	1.0631
−20	1.2540	1.2432	1.2325	1.2219	1.2114	1.2010	1.1906	1.1804	1.1702	1.1600
−19	1.3664	1.3548	1.3432	1.3318	1.3204	1.3091	1.2979	1.2868	1.2758	1.2648
−18	1.4877	1.4751	1.4627	1.4503	1.4381	1.4259	1.4138	1.4018	1.3899	1.3781
−17	1.6186	1.6051	1.5916	1.5783	1.5650	1.5519	1.5389	1.5259	1.5131	1.5003
−16	1.7597	1.7451	1.7306	1.7163	1.7020	1.6879	1.6738	1.6599	1.6460	1.6323
−15	1.9118	1.8961	1.8805	1.8650	1.8496	1.8343	1.8191	1.8041	1.7892	1.7744
−14	2.0755	2.0586	2.0418	2.0251	2.0085	1.9921	1.9758	1.9596	1.9435	1.9276
−13	2.2515	2.2333	2.2153	2.1973	2.1795	2.1619	2.1444	2.1270	2.1097	2.0925
−12	2.4409	2.4213	2.4019	2.3826	2.3635	2.3445	2.3256	2.3069	2.2883	2.2698
−11	2.6443	2.6233	2.6024	2.5817	2.5612	2.5408	2.5205	2.5004	2.4804	2.4606
−10	2.8627	2.8402	2.8178	2.7956	2.7735	2.7516	2.7298	2.7082	2.6868	2.6655
− 9	3.0971	3.0729	3.0489	3.0250	3.0013	2.9778	2.9544	2.9313	2.9082	2.8854
− 8	3.3484	3.3225	3.2967	3.2711	3.2457	3.2205	3.1955	3.1706	3.1459	3.1214
− 7	3.6177	3.5899	3.5623	3.5349	3.5077	3.4807	3.4539	3.4272	3.4008	3.3745
− 6	3.9061	3.8764	3.8468	3.8175	3.7883	3.7594	3.7307	3.7021	3.6738	3.6456
− 5	4.2148	4.1830	4.1514	4.1200	4.0888	4.0579	4.0271	3.9966	3.9662	3.9361
− 4	4.5451	4.5111	4.4773	4.4437	4.4103	4.3772	4.3443	4.3116	4.2791	4.2468
− 3	4.8981	4.8617	4.8256	4.7897	4.7541	4.7187	4.6835	4.6486	4.6138	4.5794
− 2	5.2753	5.2364	5.1979	5.1595	5.1214	5.0836	5.0460	5.0087	4.9716	4.9347
− 1	5.6780	5.6365	5.5953	5.5544	5.5138	5.4734	5.4333	5.3934	5.3538	5.3144
− 0	6.1078	6.0636	6.0196	5.9759	5.9325	5.8894	5.8466	5.8040	5.7617	5.7197

Appendix A: Saturation vapor pressure over water (Robert List, 1984: Smithonian Meteorological Tables)

Metric units

Temperature	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
°C.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	mb.
0	6.1078	6.1523	6.1971	6.2422	6.2876	6.3333	6.3793	6.4256	6.4721	6.5190
1	6.5662	6.6137	6.6614	6.7095	6.7579	6.8066	6.8556	6.9049	6.9545	7.0044
2	7.0547	7.1053	7.1562	7.2074	7.2590	7.3109	7.3631	7.4157	7.4685	7.5218
3	7.5753	7.6291	7.6833	7.7379	7.7928	7.8480	7.9036	7.9595	8.0158	8.0724
4	8.1294	8.1868	8.2445	8.3026	8.3610	8.4198	8.4789	8.5384	8.5983	8.6586
5	8.7192	8.7802	8.8416	8.9033	8.9655	9.0280	9.0909	9.1542	9.2179	9.2820
6	9.3465	9.4114	9.4766	9.5423	9.6083	9.6748	9.7416	9.8089	9.8765	9.9446
7	10.013	10.082	10.151	10.221	10.291	10.362	10.433	10.505	10.577	10.649
8	10.722	10.795	10.869	10.943	11.017	11.092	11.168	11.243	11.320	11.397
9	11.474	11.552	11.630	11.708	11.787	11.867	11.947	12.027	12.108	12.190
10	12.272	12.355	12.438	12.521	12.606	12.690	12.775	12.860	12.946	13.032
11	13.119	13.207	13.295	13.383	13.472	13.562	13.652	13.742	13.833	13.925
12	14.017	14.110	14.203	14.297	14.391	14.486	14.581	14.678	14.774	14.871
13	14.969	15.067	15.166	15.266	15.365	15.466	15.567	15.669	15.771	15.874
14	15.977	16.081	16.186	16.291	16.397	16.503	16.610	16.718	16.826	16.935
15	17.044	17.154	17.264	17.376	17.487	17.600	17.713	17.827	17.942	18.057
16	18.173	18.290	18.407	18.524	18.643	18.762	18.882	19.002	19.123	19.245
17	19.367	19.490	19.614	19.739	19.864	19.990	20.117	20.244	20.372	20.501
18	20.630	20.760	20.891	21.023	21.155	21.288	21.422	21.556	21.691	21.827
19	21.964	22.101	22.240	22.379	22.518	22.659	22.800	22.942	23.085	23.229
20	23.373	23.518	23.664	23.811	23.959	24.107	24.256	24.406	24.557	24.709
21	24.861	25.014	25.168	25.323	25.479	25.635	25.792	25.950	26.109	26.269
22	26.430	26.592	26.754	26.918	27.082	27.247	27.413	27.580	27.748	27.916
23	28.086	28.256	28.428	28.600	28.773	28.947	29.122	29.298	29.475	29.652
24	29.831	30.011	30.191	30.373	30.555	30.739	30.923	31.109	31.295	31.483
25	31.671	31.860	32.050	32.242	32.434	32.627	32.821	33.016	33.212	33.410
26	33.608	33.807	34.008	34.209	34.411	34.615	34.820	35.025	35.232	35.440
27	35.649	35.859	36.070	36.282	36.495	36.709	36.924	37.140	37.358	37.576
28	37.796	38.017	38.239	38.462	38.686	38.911	39.137	39.365	39.594	39.824
29	40.055	40.287	40.521	40.755	40.991	41.228	41.466	41.705	41.945	42.187
30	42.430	42.674	42.919	43.166	43.414	43.663	43.913	44.165	44.418	44.672
31	44.927	45.184	45.442	45.701	45.961	46.223	46.486	46.750	47.016	47.283
32	47.551	47.820	48.091	48.364	48.637	48.912	49.188	49.466	49.745	50.025
33	50.307	50.590	50.874	51.160	51.447	51.736	52.026	52.317	52.610	52.904
34	53.200	53.497	53.796	54.096	54.397	54.700	55.004	55.310	55.617	55.926
35	56.236	56.548	56.861	57.176	57.492	57.810	58.129	58.450	58.773	59.097
36	59.422	59.749	60.077	60.407	60.739	61.072	61.407	61.743	62.081	62.421
37	62.762	63.105	63.450	63.796	64.144	64.493	64.844	65.196	65.550	65.906
38	66.264	66.623	66.985	67.347	67.712	68.078	68.446	68.815	69.186	69.559
39	69.934	70.310	70.688	71.068	71.450	71.833	72.218	72.605	72.994	73.385
40	73.777	74.171	74.568	74.966	75.365	75.767	76.170	76.575	76.982	77.391
41	77.802	78.215	78.630	79.046	79.465	79.885	80.307	80.731	81.157	81.585
42	82.015	82.447	82.881	83.316	83.754	84.194	84.636	85.079	85.525	85.973
43	86.423	86.875	87.329	87.785	88.243	88.703	89.165	89.629	90.095	90.564
44	91.034	91.507	91.981	92.458	92.937	93.418	93.901	94.386	94.874	95.363
45	95.855	96.349	96.845	97.343	97.844	98.347	98.852	99.359	99.869	100.38
46	100.89	101.41	101.93	102.45	102.97	103.50	104.03	104.56	105.09	105.62
47	106.16	106.70	107.24	107.78	108.33	108.88	109.43	109.98	110.54	111.10
48	111.66	112.22	112.79	113.36	113.93	114.50	115.07	115.65	116.23	116.81
49	117.40	117.99	118.58	119.17	119.77	120.37	120.97	121.57	122.18	122.79
50	123.40	124.01	124.63	125.25	125.87	126.49	127.12	127.75	128.38	129.01

Appendix A: Saturation vapor pressure over water (Robert List, 1984: Smithonian Meteorological Tables)

Metric units

Temperature	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
°C.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	mb.
50	123.40	124.01	124.63	125.25	125.87	126.49	127.12	127.75	128.38	129.01
51	129.65	130.29	130.93	131.58	132.23	132.88	133.53	134.19	134.84	135.51
52	136.17	136.84	137.51	138.18	138.86	139.54	140.22	140.91	141.60	142.29
53	142.98	143.68	144.38	145.08	145.78	146.49	147.20	147.91	148.63	149.35
54	150.07	150.80	151.53	152.26	152.99	153.73	154.47	155.21	155.96	156.71
55	157.46	158.22	158.97	159.74	160.50	161.27	162.04	162.82	163.59	164.38
56	165.16	165.95	166.74	167.53	168.33	169.13	169.93	170.74	171.55	172.36
57	173.18	174.00	174.82	175.65	176.48	177.31	178.15	178.99	179.83	180.68
58	181.53	182.38	183.24	184.10	184.96	185.83	186.70	187.58	188.45	189.34
59	190.22	191.11	192.00	192.89	193.79	194.69	195.60	196.51	197.42	198.34
60	199.26	200.18	201.11	202.05	202.98	203.92	204.86	205.81	206.76	207.71
61	208.67	209.63	210.59	211.56	212.53	213.51	214.49	215.48	216.46	217.45
62	218.45	219.45	220.45	221.46	222.47	223.48	224.50	225.52	226.54	227.58
63	228.61	229.65	230.70	231.74	232.79	233.85	234.91	235.97	237.03	238.11
64	239.18	240.26	241.34	242.43	243.52	244.62	245.72	246.82	247.93	249.04
65	250.16	251.28	252.41	253.54	254.67	255.81	256.95	258.10	259.25	260.40
66	261.56	262.73	263.90	265.07	266.25	267.43	268.61	269.80	271.00	272.20
67	273.40	274.61	275.82	277.04	278.26	279.49	280.72	281.96	283.20	284.45
68	285.70	286.96	288.21	289.48	290.75	292.02	293.30	294.58	295.86	297.15
69	298.45	299.75	301.06	302.37	303.69	305.01	306.34	307.67	309.00	310.34
70	311.69	313.04	314.39	315.75	317.12	318.49	319.87	321.25	322.63	324.02
71	325.42	326.82	328.22	329.63	331.05	332.47	333.89	335.33	336.76	338.20
72	339.65	341.10	342.56	344.03	345.50	346.97	348.45	349.93	351.42	352.91
73	354.41	355.91	357.43	358.94	360.46	361.99	363.52	365.06	366.61	368.15
74	369.71	371.27	372.84	374.41	375.99	377.57	379.16	380.75	382.35	383.95
75	385.56	387.18	388.80	390.43	392.06	393.70	395.34	396.99	398.65	400.31
76	401.98	403.65	405.34	407.02	408.71	410.41	412.11	413.82	415.53	417.25
77	418.98	420.71	422.45	424.20	425.95	427.71	429.47	431.24	433.02	434.80
78	436.59	438.38	440.18	441.99	443.80	445.62	447.45	449.28	451.11	452.96
79	454.81	456.67	458.53	460.40	462.28	464.16	466.05	467.94	469.85	471.76
80	473.67	475.59	477.52	479.45	481.39	483.34	485.29	487.25	489.22	491.19
81	493.17	495.16	497.15	499.16	501.17	503.18	505.20	507.23	509.26	511.30
82	513.35	515.41	517.47	519.54	521.62	523.70	525.79	527.89	529.99	532.10
83	534.22	536.35	538.48	540.62	542.77	544.92	547.08	549.25	551.43	553.61
84	555.80	557.99	560.20	562.41	564.62	566.85	569.08	571.32	573.57	575.83
85	578.09	580.36	582.64	584.93	587.22	589.52	591.83	594.14	596.46	598.79
86	601.13	603.48	605.83	608.19	610.56	612.94	615.32	617.72	620.12	622.52
87	624.94	627.36	629.79	632.23	634.68	637.13	639.59	642.07	644.55	647.03
88	649.53	652.03	654.54	657.06	659.59	662.12	664.66	667.22	669.78	672.34
89	674.92	677.50	680.09	682.69	685.30	687.92	690.55	693.18	695.82	698.47
90	701.13	703.80	706.47	709.16	711.85	714.55	717.26	719.98	722.71	725.45
91	728.19	730.94	733.70	736.47	739.25	742.04	744.84	747.64	750.46	753.28
92	756.11	758.95	761.80	764.66	767.52	770.40	773.29	776.18	779.09	782.00
93	784.92	787.85	790.79	793.74	796.69	799.66	802.63	805.62	808.61	811.62
94	814.63	817.65	820.69	823.73	826.78	829.84	832.91	835.99	839.08	842.17
95	845.28	848.40	851.52	854.66	857.80	860.96	864.12	867.30	870.48	873.68
96	876.88	880.09	883.31	886.55	889.79	893.04	896.30	899.57	902.86	906.15
97	909.45	912.76	916.08	919.42	922.76	926.11	929.47	932.84	936.23	939.62
98	943.02	946.43	949.85	953.28	956.73	960.18	963.65	967.12	970.61	974.10
99	977.61	981.13	984.65	988.19	991.74	995.30	998.87	1002.45	1006.04	1009.64
100	1013.25	1016.87	1020.50	1024.14	1027.80	1031.46	1035.13	1038.82	1042.51	1046.22
101	1049.94	1053.67	1057.41	1061.16	1064.93	1068.70	1072.49	1076.28	1080.09	1083.91
102	1087.74									

Appendix B: Saturation vapor pressure over ice (Robert List, 1984: Smithonian Meteorological Tables)

Temperature °C.	Metric units .0	.1	.2	.3	.4	.5	.6	.7	.8	.9
Unit:	10^{-3} mb.	10^{-3} mb.	10^{-3} mb.	10^{-3} mb.	10^{-3} mb.	10^{-3} mb.	10^{-3} mb.	10^{-3} mb.	10^{-3} mb.	10^{-3} mb.
−100	1.403									
− 99	1.719	1.685	1.651	1.617	1.585	1.553	1.522	1.491	1.461	1.432
− 98	2.101	2.059	2.019	1.979	1.939	1.901	1.863	1.826	1.790	1.754
− 97	2.561	2.511	2.462	2.414	2.366	2.320	2.274	2.230	2.186	2.143
− 96	3.117	3.057	2.997	2.939	2.882	2.826	2.771	2.717	2.664	2.612
− 95	3.784	3.712	3.640	3.571	3.502	3.435	3.369	3.304	3.240	3.178
− 94	4.584	4.497	4.412	4.329	4.246	4.166	4.087	4.009	3.932	3.858
− 93	5.542	5.438	5.336	5.236	5.138	5.041	4.946	4.853	4.762	4.672
− 92	6.685	6.561	6.439	6.320	6.203	6.088	5.975	5.863	5.754	5.647
− 91	8.049	7.902	7.757	7.615	7.475	7.338	7.203	7.070	6.939	6.811
− 90	9.672	9.497	9.324	9.155	8.988	8.825	8.664	8.506	8.351	8.199
− 89	11.60	11.39	11.19	10.98	10.79	10.59	10.40	10.22	10.03	9.850
− 88	13.88	13.63	13.39	13.15	12.92	12.69	12.46	12.24	12.02	11.81
− 87	16.58	16.29	16.00	15.72	15.45	15.18	14.91	14.65	14.39	14.13
− 86	19.77	19.43	19.09	18.76	18.43	18.11	17.79	17.48	17.18	16.88
− 85	23.53	23.13	22.73	22.34	21.96	21.58	21.21	20.84	20.48	20.12
− 84	27.96	27.48	27.02	26.56	26.10	25.66	25.22	24.79	24.36	23.94
− 83	33.16	32.60	32.05	31.51	30.98	30.45	29.93	29.43	28.93	28.44
− 82	39.25	38.60	37.95	37.32	36.69	36.08	35.48	34.88	34.30	33.72
− 81	46.38	45.62	44.86	44.12	43.40	42.68	41.97	41.28	40.59	39.91
− 80	54.72	53.83	52.95	52.08	51.23	50.39	49.56	48.75	47.95	47.16
− 79	64.44	63.40	62.37	61.36	60.37	59.39	58.43	57.48	56.54	55.62
− 78	75.77	74.56	73.36	72.19	71.03	69.89	68.77	67.66	66.57	65.50
− 77	88.94	87.53	86.14	84.78	83.43	82.11	80.80	79.52	78.25	77.00
− 76	104.2	102.6	101.0	99.41	97.85	96.31	94.79	93.29	91.82	90.37
Unit:	10^{-3} mb.	10^{-3} mb.	10^{-3} mb.	10^{-3} mb.	10^{-3} mb.	10^{-3} mb.	10^{-3} mb.	10^{-3} mb.	10^{-3} mb.	10^{-3} mb.
− 75	1.220	1.201	1.182	1.164	1.146	1.128	1.110	1.093	1.076	1.059
− 74	1.425	1.403	1.382	1.360	1.340	1.319	1.299	1.279	1.259	1.239
− 73	1.662	1.637	1.612	1.587	1.563	1.539	1.515	1.492	1.470	1.447
− 72	1.936	1.907	1.878	1.850	1.822	1.794	1.767	1.740	1.714	1.688
− 71	2.252	2.218	2.185	2.152	2.120	2.088	2.057	2.026	1.995	1.965
− 70	2.615	2.576	2.538	2.501	2.464	2.427	2.391	2.355	2.320	2.286
− 69	3.032	2.988	2.944	2.901	2.858	2.816	2.775	2.734	2.694	2.654
− 68	3.511	3.460	3.410	3.360	3.311	3.263	3.215	3.169	3.122	3.077
− 67	4.060	4.002	3.944	3.887	3.831	3.776	3.721	3.668	3.615	3.562
− 66	4.688	4.621	4.555	4.490	4.426	4.363	4.301	4.239	4.179	4.119
− 65	5.406	5.330	5.255	5.180	5.107	5.035	4.964	4.893	4.824	4.755
− 64	6.225	6.138	6.052	5.968	5.884	5.802	5.721	5.640	5.561	5.483
− 63	7.159	7.060	6.962	6.866	6.771	6.677	6.584	6.493	6.402	6.313
− 62	8.223	8.110	7.999	7.889	7.781	7.674	7.568	7.464	7.361	7.259
− 61	9.432	9.304	9.177	9.053	8.930	8.808	8.688	8.569	8.452	8.337
− 60	10.80	10.66	10.51	10.37	10.24	10.10	9.961	9.826	9.693	9.562
− 59	12.36	12.20	12.03	11.87	11.72	11.56	11.40	11.25	11.10	10.95
− 58	14.13	13.94	13.76	13.58	13.40	13.22	13.04	12.87	12.70	12.53
− 57	16.12	15.91	15.70	15.49	15.29	15.09	14.89	14.70	14.51	14.32
− 56	18.38	18.14	17.91	17.68	17.45	17.22	17.00	16.77	16.55	16.34
− 55	20.92	20.65	20.39	20.12	19.86	19.61	19.36	19.11	18.86	18.62
− 54	23.80	23.50	23.20	22.90	22.61	22.32	22.03	21.75	21.47	21.19
− 53	27.03	26.69	26.35	26.02	25.69	25.37	25.05	24.73	24.42	24.11
− 52	30.67	30.29	29.91	29.53	29.17	28.80	28.44	28.08	27.73	27.38
− 51	34.76	34.33	33.90	33.48	33.06	32.65	32.24	31.84	31.45	31.06
− 50	39.35	38.87	38.39	37.92	37.45	36.99	36.53	36.08	35.64	35.20

Appendix B: Saturation vapor pressure over ice (Robert List, 1984: Smithonian Meteorological Tables)

Temperature °C.	Metric units .0	.1	.2	.3	.4	.5	.6	.7	.8	.9
Unit:	mb.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	mb.	mb.
−50	0.03935	0.03887	0.03839	0.03792	0.03745	0.03699	0.03653	0.03608	0.03564	0.03520
−49	0.04449	0.04395	0.04341	0.04289	0.04236	0.04185	0.04134	0.04083	0.04033	0.03984
−48	0.05026	0.04965	0.04905	0.04846	0.04788	0.04730	0.04673	0.04616	0.04560	0.04504
−47	0.05671	0.05603	0.05536	0.05470	0.05405	0.05340	0.05276	0.05212	0.05150	0.05087
−46	0.06393	0.06317	0.06242	0.06168	0.06095	0.06022	0.05950	0.05879	0.05809	0.05740
−45	0.07198	0.07113	0.07030	0.06947	0.06865	0.06784	0.06704	0.06625	0.06547	0.06469
−44	0.08097	0.08003	0.07909	0.07817	0.07725	0.07635	0.07546	0.07457	0.07370	0.07283
−43	0.09098	0.08993	0.08889	0.08786	0.08684	0.08584	0.08484	0.08386	0.08289	0.08192
−42	0.1021	0.1010	0.09981	0.09866	0.09753	0.09641	0.09530	0.09420	0.09312	0.09204
−41	0.1145	0.1132	0.1119	0.1107	0.1094	0.1082	0.1070	0.1057	0.1045	0.1033
−40	0.1283	0.1268	0.1254	0.1240	0.1226	0.1212	0.1198	0.1185	0.1171	0.1158
−39	0.1436	0.1420	0.1404	0.1389	0.1373	0.1358	0.1343	0.1328	0.1313	0.1298
−38	0.1606	0.1588	0.1571	0.1553	0.1536	0.1519	0.1502	0.1485	0.1469	0.1452
−37	0.1794	0.1774	0.1755	0.1736	0.1717	0.1698	0.1679	0.1661	0.1642	0.1624
−36	0.2002	0.1980	0.1959	0.1938	0.1917	0.1896	0.1875	0.1855	0.1834	0.1814
−35	0.2233	0.2209	0.2185	0.2161	0.2138	0.2115	0.2092	0.2069	0.2047	0.2024
−34	0.2488	0.2461	0.2435	0.2409	0.2383	0.2357	0.2332	0.2307	0.2282	0.2257
−33	0.2769	0.2740	0.2711	0.2682	0.2653	0.2625	0.2597	0.2569	0.2542	0.2515
−32	0.3079	0.3047	0.3014	0.2983	0.2951	0.2920	0.2889	0.2859	0.2828	0.2799
−31	0.3421	0.3385	0.3350	0.3315	0.3280	0.3246	0.3212	0.3178	0.3145	0.3112
−30	0.3798	0.3759	0.3720	0.3681	0.3643	0.3605	0.3567	0.3530	0.3494	0.3457
−29	0.4213	0.4170	0.4127	0.4084	0.4042	0.4000	0.3959	0.3918	0.3877	0.3838
−28	0.4669	0.4621	0.4574	0.4527	0.4481	0.4435	0.4390	0.4345	0.4300	0.4256
−27	0.5170	0.5118	0.5066	0.5014	0.4964	0.4913	0.4863	0.4814	0.4765	0.4717
−26	0.5720	0.5663	0.5606	0.5549	0.5493	0.5438	0.5383	0.5329	0.5276	0.5222
−25	0.6323	0.6260	0.6198	0.6136	0.6075	0.6015	0.5955	0.5895	0.5836	0.5778
−24	0.6985	0.6916	0.6848	0.6780	0.6713	0.6646	0.6580	0.6515	0.6450	0.6386
−23	0.7709	0.7634	0.7559	0.7485	0.7412	0.7339	0.7267	0.7195	0.7125	0.7055
−22	0.8502	0.8419	0.8338	0.8257	0.8176	0.8097	0.8018	0.7940	0.7862	0.7785
−21	0.9370	0.9280	0.9190	0.9101	0.9013	0.8926	0.8840	0.8754	0.8669	0.8585
−20	1.032	1.022	1.012	1.002	0.9928	0.9833	0.9739	0.9645	0.9553	0.9461
−19	1.135	1.124	1.114	1.103	1.092	1.082	1.072	1.062	1.052	1.042
−18	1.248	1.236	1.225	1.213	1.201	1.190	1.179	1.168	1.157	1.146
−17	1.371	1.358	1.345	1.333	1.320	1.308	1.296	1.284	1.272	1.260
−16	1.506	1.492	1.478	1.464	1.451	1.437	1.424	1.410	1.397	1.384
−15	1.652	1.637	1.622	1.607	1.592	1.577	1.562	1.548	1.534	1.520
−14	1.811	1.795	1.778	1.762	1.746	1.730	1.714	1.698	1.683	1.667
−13	1.984	1.966	1.948	1.930	1.913	1.895	1.878	1.861	1.844	1.827
−12	2.172	2.153	2.133	2.114	2.095	2.076	2.057	2.039	2.020	2.002
−11	2.376	2.355	2.334	2.313	2.292	2.271	2.251	2.231	2.211	2.191
−10	2.597	2.574	2.551	2.529	2.506	2.484	2.462	2.440	2.419	2.397
− 9	2.837	2.812	2.787	2.763	2.739	2.715	2.691	2.667	2.644	2.620
− 8	3.097	3.070	3.043	3.017	2.991	2.965	2.939	2.913	2.888	2.862
− 7	3.379	3.350	3.321	3.292	3.264	3.236	3.208	3.180	3.152	3.124
− 6	3.685	3.653	3.622	3.591	3.560	3.529	3.499	3.468	3.438	3.409
− 5	4.015	3.981	3.947	3.913	3.879	3.846	3.813	3.781	3.748	3.717
− 4	4.372	4.335	4.298	4.262	4.226	4.190	4.154	4.119	4.084	4.049
− 3	4.757	4.717	4.678	4.638	4.600	4.561	4.523	4.485	4.447	4.409
− 2	5.173	5.130	5.087	5.045	5.003	4.961	4.920	4.878	4.838	4.797
− 1	5.623	5.577	5.530	5.485	5.439	5.394	5.349	5.305	5.260	5.217
− 0	6.107	6.057	6.007	5.958	5.909	5.860	5.812	5.764	5.717	5.670

Appendix C: Data format of measured values output via the serial interface

When the data logger is switched on, data records are continuously sent in abbreviated form to a printer or terminal connected. The time and date are followed by the dewpoint temperature, measuring gas temperature and the value for the calculated relative humidity. The listing has the following form:

```
10:43 29-Nov-94   7.11  17.27  51.1
10:44 29-Nov-94   7.15  17.24  51.4
10:45 29-Nov-94   7.05  17.24  51.0
10:46 29-Nov-94   7.19  17.26  51.5
10:47 29-Nov-94   7.16  17.25  51.4
10:48 29-Nov-94   7.09  17.26  51.1
10:49 29-Nov-94   7.23  17.26  51.6
10:50 29-Nov-94   7.28  17.25  51.9
10:51 29-Nov-94   7.28  17.26  51.8
10:52 29-Nov-94   7.37  17.26  52.1
10:53 29-Nov-94   7.30  17.25  51.9
10:54 29-Nov-94   7.30  17.26  51.9
10:55 29-Nov-94   7.42  17.26  52.3
10:56 29-Nov-94   7.50  17.26  52.6
```

List of data records as output to a printer or terminal following transmission of the contents of memory (output begins with the data record last measured):

```
14  10:56  29-Nov-94  Dewp  7.50 °C  Temp  17.26 °C  relH  52.6 %
13  10:55  29-Nov-94  Dewp  7.42 °C  Temp  17.26 °C  relH  52.3 %
12  10:54  29-Nov-94  Dewp  7.30 °C  Temp  17.26 °C  relH  51.9 %
11  10:53  29-Nov-94  Dewp  7.30 °C  Temp  17.25 °C  relH  51.9 %
10  10:52  29-Nov-94  Dewp  7.37 °C  Temp  17.26 °C  relH  52.1 %
 9  10:51  29-Nov-94  Dewp  7.28 °C  Temp  17.26 °C  relH  51.8 %
 8  10:50  29-Nov-94  Dewp  7.28 °C  Temp  17.25 °C  relH  51.9 %
 7  10:49  29-Nov-94  Dewp  7.23 °C  Temp  17.26 °C  relH  51.6 %
 6  10:48  29-Nov-94  Dewp  7.09 °C  Temp  17.26 °C  relH  51.1 %
 5  10:47  29-Nov-94  Dewp  7.16 °C  Temp  17.25 °C  relH  51.4 %
 4  10:46  29-Nov-94  Dewp  7.19 °C  Temp  17.26 °C  relH  51.5 %
 3  10:45  29-Nov-94  Dewp  7.05 °C  Temp  17.24 °C  relH  51.0 %
 2  10:44  29-Nov-94  Dewp  7.15 °C  Temp  17.24 °C  relH  51.4 %
 1  10:43  29-Nov-94  Dewp  7.11 °C  Temp  17.27 °C  relH  51.1 %
```

Warranty Conditions

All products supplied by the Heinz Walz GmbH, Germany, are warranted by Heinz Walz GmbH, Germany to be free from defects in material and workmanship for one (1) year from the shipping date (date on invoice).

The warranty is subject to the following conditions:

1. This warranty applies if the defects are called to the attention of Heinz Walz GmbH, Germany, in writing within one year (1) of the shipping date of the product.
2. This warranty shall not apply to any defects or damage directly or indirectly caused by or resulting from the use of unauthorized replacement parts and/or service performed by unauthorized personnel.
3. This warranty shall not apply to any product supplied by the Heinz Walz GmbH, Germany which has been subjected to misuse, abuse, abnormal use, negligence, alteration or accident.
4. This warranty does not apply to damage caused from improper packaging during shipment or any natural acts of God.
5. This warranty does not apply to underwater cables, batteries, fiberoptic cables, lamps, gas filters, thermocouples, fuses or calibrations.

To obtain warranty service, please follow the instructions below:

1. The Warranty Registration form must be completed and returned to Heinz Walz GmbH, Germany.
2. The product must be returned to Heinz Walz GmbH, Germany, within 30 days after Heinz Walz GmbH, Germany has received written notice of the defect. Postage, insurance, custom duties,

and/or shipping costs incurred in returning equipment for warranty service are at customer expense.

3. All products being returned for warranty service must be carefully packed and sent freight prepaid.

4. Heinz Walz GmbH, Germany is not responsible or liable, for missing components or damage to the unit caused by handling during shipping. All claims or damage should be directed to the shipping carrier.