Preface 3rd edition

Optimum control quality can only be achieved where accurate measurement is possible.

This was the guiding principle behind the first edition of this sensor installation handbook. The principle is still valid today, and questions of instrumentation & control and sensor installation are more topical than ever.

Legislation increasingly calls for economic use of energy. At the same time, there are stringent requirements relating to the indoor environment. If we are to satisfy both sets of requirements in the best way possible, we must have all the necessary measured data at our disposal, and sensors that function reliably for many years.

To meet this objective, we not only need professional, top quality products, but also some basic rules of good practice.

This sensor installation handbook was written by practitioners for practitioners, and over the years it has become a popular and indispensable reference guide.

In response to the considerable demand, Siemens has decided to re-issue the guide without amendment. It has been re-printed with the kind consent of suissetec (formerly CLIMA-SUISSE).

Siemens Switzerland Ltd
Building Technologies Group
International Headquarters

Christoph Bleiker
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To the reader

We have participated with enthusiasm in the work on the second edition of this "Sensor Installation" guide. The subject matter is of particular relevance to our association because, with the help of our members, we are in a position to set the right course and define good practice.
We are sending you the revised and extended guide in the current format, which consists, as before, of a printed version for installers on site. This now also includes a CD-ROM for reference at home or in the office. Diagrams or whole sections can be printed from this CD and used as a mounting guide.
The same team of writers once again gave their time unstintingly to update this guide for practitioners and by practitioners, to reflect the state of the art. Here, we would like to express our sincere thanks to all those who have contributed in one way or another to the drafting and production of the handbook.
We have no doubt that the Sensor Installation Handbook meets the real needs of our corporate members and of the building services industry in general.

CLIMA-SUISSE
Verband Schweizerischer und Liechtensteinischer Heizungs- und Lüftungsfirmen
(Association of heating & ventilation companies in Switzerland and Liechtenstein)

Lucius Dürr
Director

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Technology, Energy, Environment

To the reader

A control system is only as good as the sensor used to measure the controlled variable (temperature, humidity, pressure etc.) and transmit it as a measured value to the controller. It is crucial that the sensor should provide an accurate measurement of the controlled variable at the reference point in the control loop. However, it is often found in practice that too little attention has been paid both to the way in which the sensor is mounted, and to its location. This generally results in a failure to meet the desired conditions satisfactorily, and this, in turn, can lead to customer complaints.

The Swiss controls companies Landis & Gyr Building Control (Schweiz) AG, Steinhausen, Fr. Sauter AG, Basle, and Staefa Control System AG, Stäfa, decided some time ago to contribute towards better control engineering by producing a "Sensor Installation" handbook. Thanks to the active involvement of Sulzer Infra (Schweiz) AG, Zurich, the handbook incorporates practical expertise from experienced system contractors.

While "Sensor Installation" is written for the benefit of engineers and installers on site, it will also provide the project engineer with useful information at the design stage. It is written by practitioners for practitioners, but also makes a contribution to energy optimisation.

The writers hope that this booklet fulfils the aims described.

Best regards,

Landis & Gyr
Building Control (Schweiz) AG

Fr. Sauter AG, Basle

Staefa Control System AG

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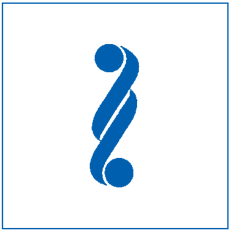
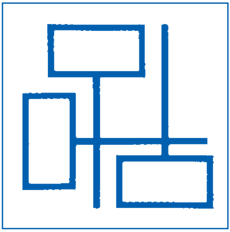
General notes for all sensors

Always observe local installation and safety regulations.



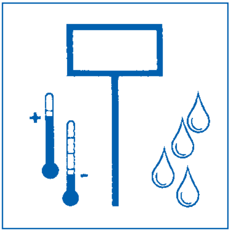
Do not install sensors so that they protrude in any direction, and do not suspend them below the horizontal.
Ensure that they are protected against damage and vandalism and will not cause injury.

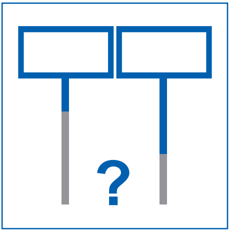
Be aware of the effects of orientation on the functioning of the sensor.



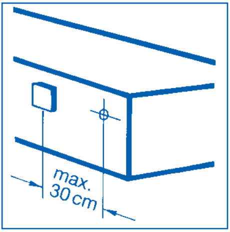
Always determine the following before mounting:

- Min./max. ambient temperature
- Ambient humidity and exposure to spray water
- Exposure to vibration
- Explosion protection
- External influences





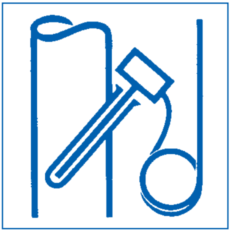
Take account of the active and inactive sections of a sensor probe.



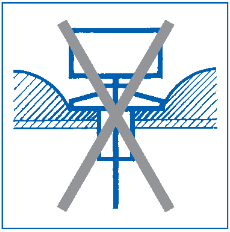
A tight-sealing test-hole must be provided adjacent to every sensor.

The cable should be installed with a "drip loop" to prevent water from entering the sensor housing.

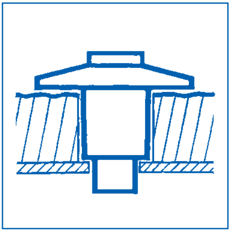
Always allow a sufficient length of spare cable so that the sensor can be removed at any time without disconnecting the wiring.



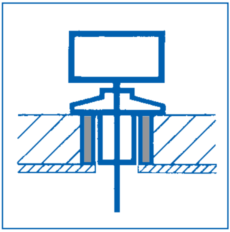
When installing a sensor, avoid compressing the lagging.

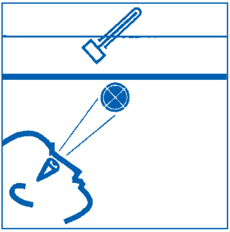


Use a graduated-diameter mounting flange to avoid compressing the lagging.

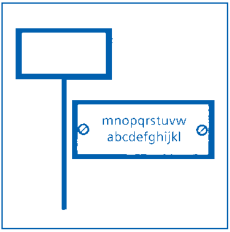


If the mounting flange supplied does not have the appropriate graduations, use spacing bushes to avoid compressing the lagging.

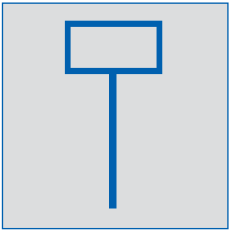




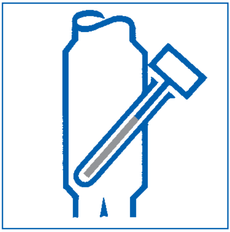
If the sensors are to be concealed (e.g. in false ceilings, shafts etc.), mark their locations visibly and record them in the site documentation.



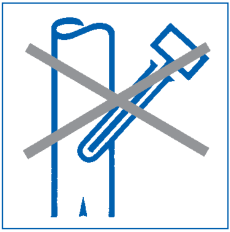
Fix a labelling plate in the direct vicinity of the sensor. This must include a plain text description and the reference number, which appears in the plant schematic. Do not attach the label to the device itself.

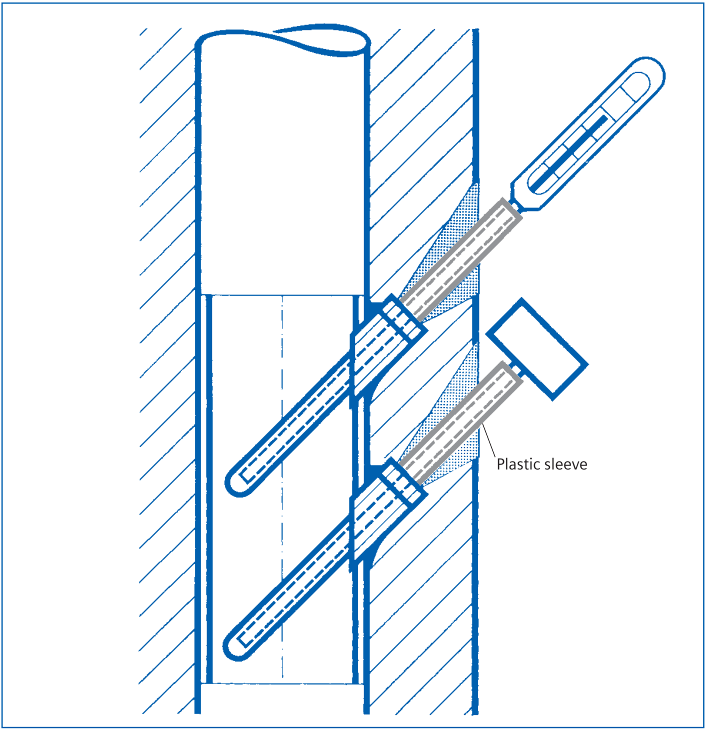


Ensure that the full active length of the sensor is immersed in the medium.



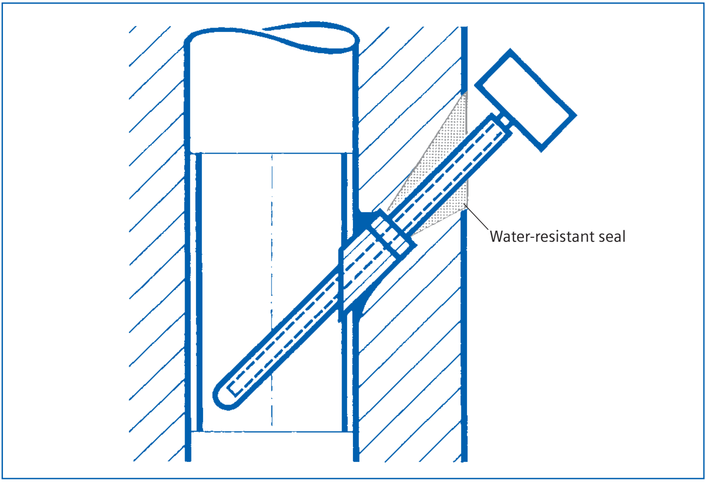
Incorrect installation





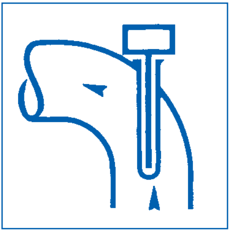
Chilled water and refrigeration pipes

To prevent condensation, extend the immersion pocket inside the lagging by use of a plastic sleeve.



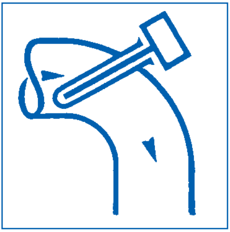
Chilled water and refrigeration pipes

The hole in the lagging must be sealed, to prevent the ingress of moisture (water-resistant seal).



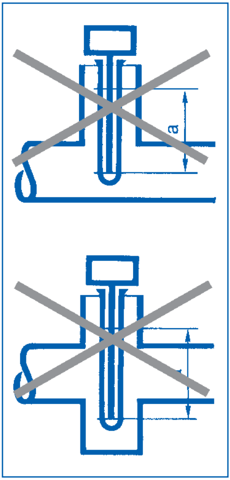
Install sensors against the direction of flow.

Incorrect installation

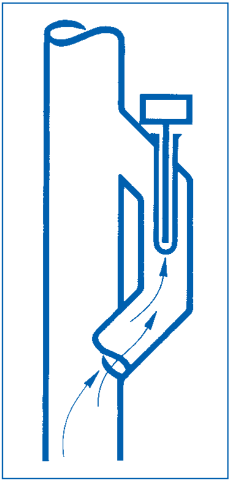


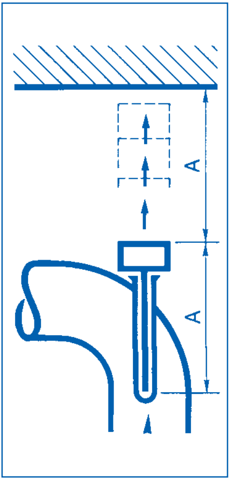
Install at the correct angle.

If the active length (a) of the sensor probe is longer than the diameter of the pipe, the sensor should be installed diagonally, or in a bypass pipe or bend.

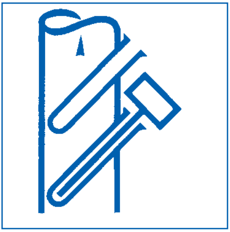


The inlet side of the bypass pipe should project into the main pipe.

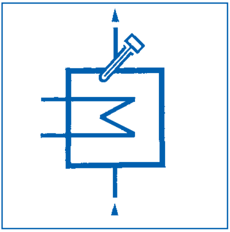




Maintain a clearance (distance A) between the sensor and any obstruction, so that there is room to remove the sensor from the immersion pocket.

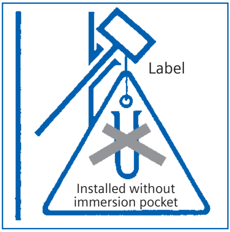


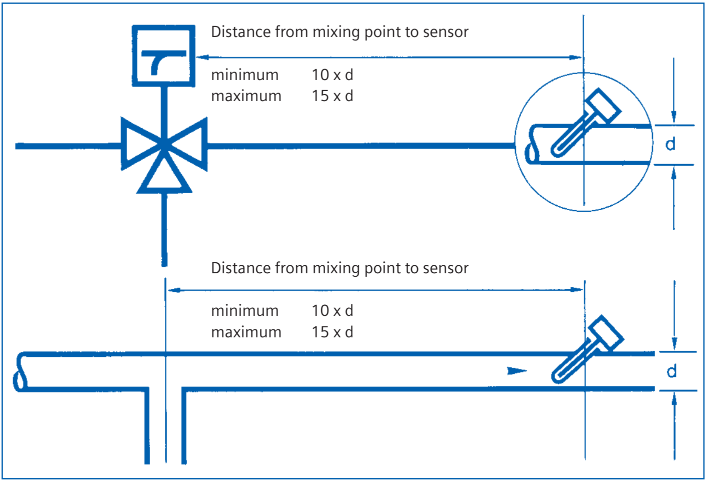
For each sensing point, an additional immersion pocket, adjacent to the sensor, must be provided for test purposes.



Install outlet-temperature sensors directly at the heat exchanger outlet.

Sensors mounted without immersion pockets or with slotted or perforated immersion pockets must be identified accordingly.
Attach a label marked:
Installed without immersion pocket.

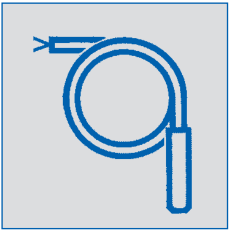


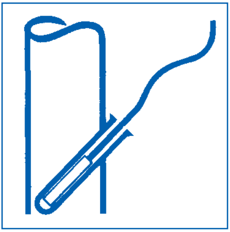


When mixing water at different temperatures, always maintain an adequate distance between the mixing point and the sensor (to take account of stratification).

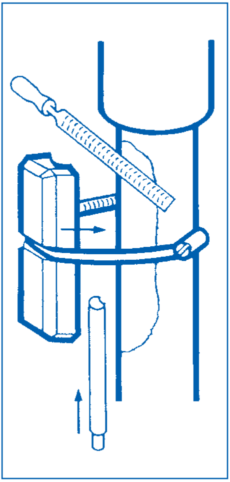
Temperature

Cable sensors · Water

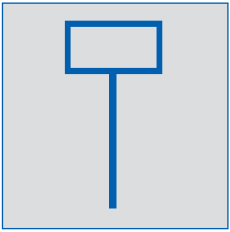




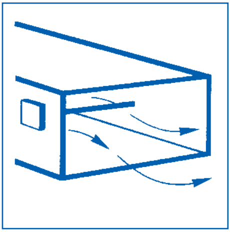
The sensor element is not affected by orientation, but must be fully immersed in the medium to be measured (air or water).



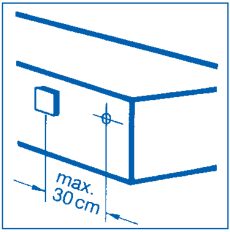
Use a file to ensure a smooth, clean contact surface, and fill the space between the sensor and the pipe with heat-conductive compound to improve thermal conductivity.



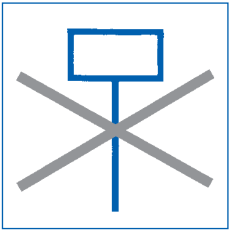
Ensure that the full length of the sensor probe is exposed to the air flow.



A test hole must be provided adjacent to every sensor.

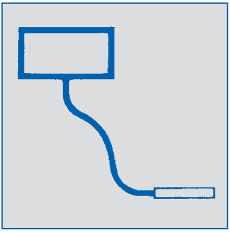


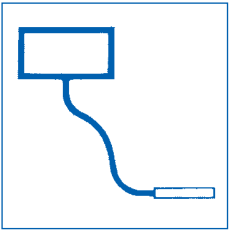
Do not use probe-type sensors in areas where stratification can occur (e.g. downstream of mixing dampers, heating coils, cooling coils or heat recovery units). Averaging sensors should be considered.



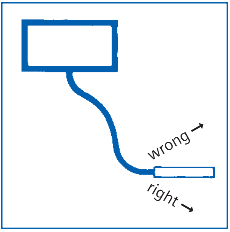
Temperature

Capillary sensors with probes



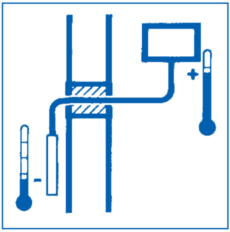


Install so that the device head is higher than the sensor probe.

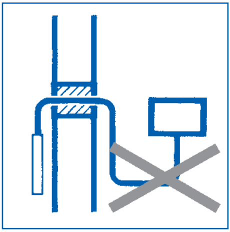


The sensor probe should be tilted downwards.

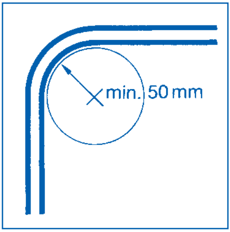
The ambient temperature at the device head must always be higher than the temperature to which the sensor probe is exposed.



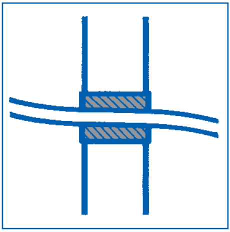
The sensor element must always point downwards.
Do not allow the capillary to form a U-shape.

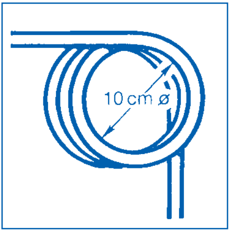


Do not bend the capillary too tightly (radius of bend must not be less than 50 mm).

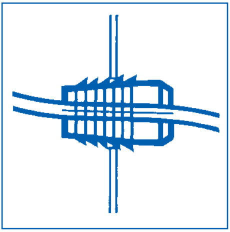


When routing the capillary through internal or external walls, for example, always use a lined and insulated conduit.

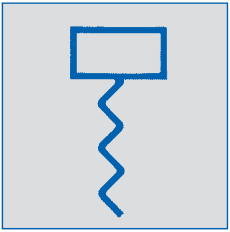




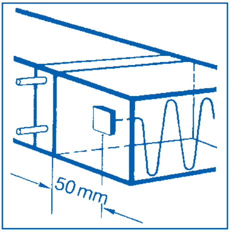
Any unused length of capillary should be neatly rolled.



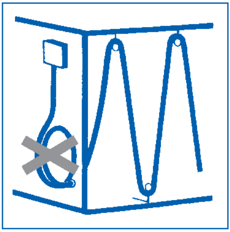
Where the capillary passes through sheet metal, protect it with a rubber grommet
(to prevent shearing).



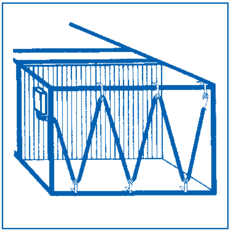
Allow a distance of at least 50 mm between the heat exchanger and the sensor.

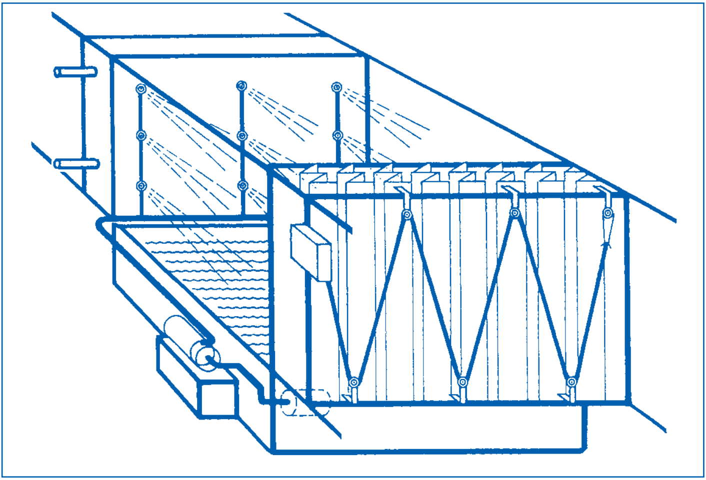


The entire length of an averaging sensor must be installed fully inside the air duct.



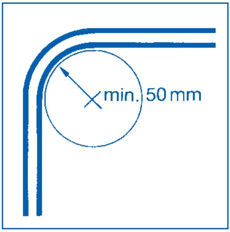
The sensor element must be distributed evenly over the full cross-section.



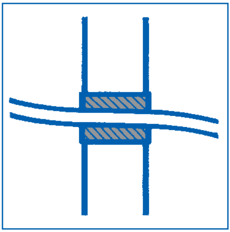


If air washers are used for humidification, install the sensor element downstream of the eliminator plate, in the direction of air flow.

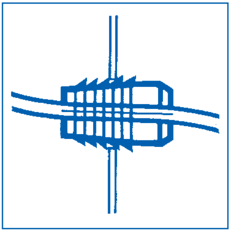
Do not bend the capillary too tightly
(radius of bend must not be less than 50 mm).



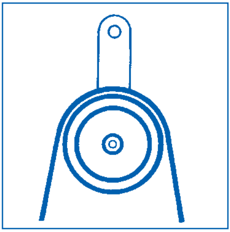
When routing the capillary through internal or external walls, for example, always use a lined and insulated conduit.



Where the capillary passes through sheet metal, protect it with a rubber grommet
(to prevent shearing).

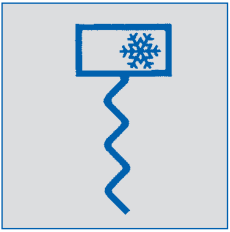


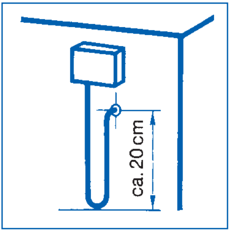
Install the sensor element using capillary supports.



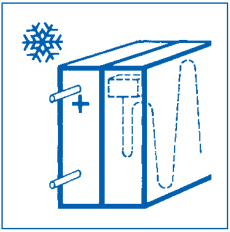
Temperature

Frost protection · Air

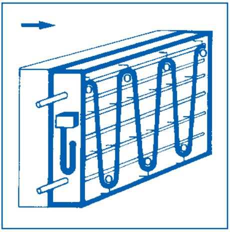




Leave a spare capillary loop of 20 cm so that functioning can be tested outside the unit.

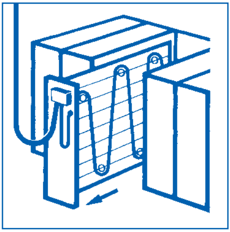


If the supply ductwork is outdoors or in an unheated space, then both the measuring head **and** the test loop of the thermostat must be located inside the duct and downstream of the heat exchanger.

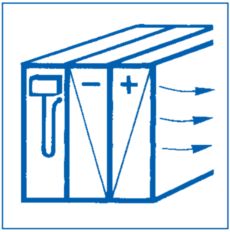


Install the capillary in the direction of air flow, downstream of the first water-filled heating coil exposed to frost.
The capillary must be installed diagonal to the heat-exchanger pipes.

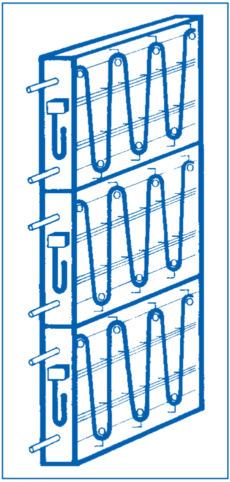
When installing on "drawer"-type units, ensure that the electrical connections are long enough to enable the units to be pulled out.

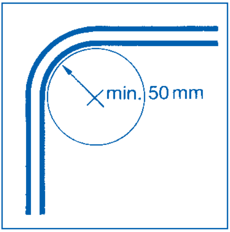


If a water-filled cooling coil is installed upstream of the first heat exchanger, then the frost protection thermostat must be installed upstream of the cooling coil, in the direction of the air flow.

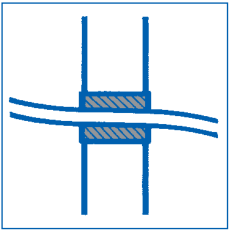


With large heat exchangers, or with heat exchangers comprising several units, more than one frost thermostat must be installed (minimum 1 per unit).

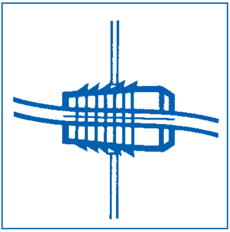




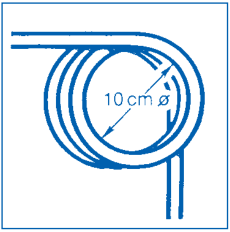
Do not bend the capillary too tightly
(radius of bend must not be less than 50 mm).



When routing the capillary through internal or external walls, for example, always use a lined and insulated conduit.

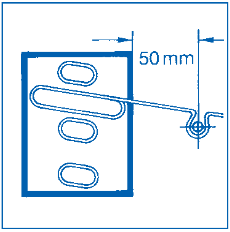


Where the capillary passes through sheet metal, protect it with a rubber grommet
(to prevent shearing).

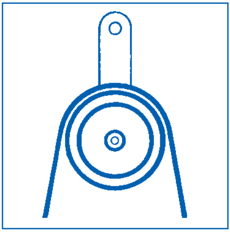


Any unused length of capillary should be neatly rolled.

Use spacing clips to maintain a 50 mm clearance.

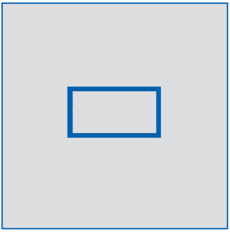


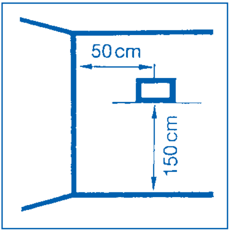
Install the sensor element using capillary supports.



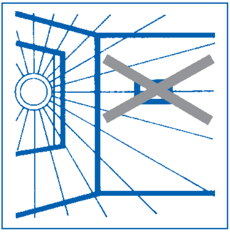
Temperature

Room sensors

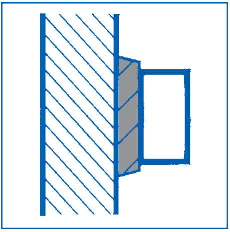




Install sensors at a height of 1.5 m in occupied spaces, and at least 50 cm from the adjacent wall.

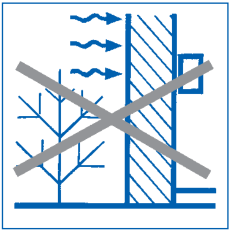


Do not install where sensor will be exposed to direct solar radiation.

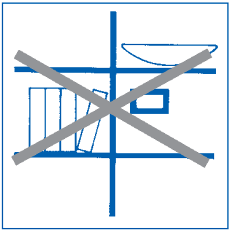


Always use a thermally-insulated backing when fitting to solid walls (steel, concrete etc.)

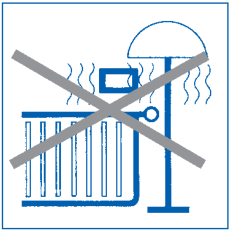
Do not install on external walls.



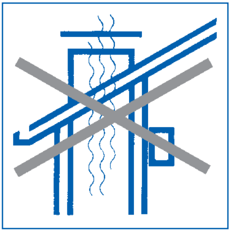
Avoid recesses (e.g. shelving) and alcoves.

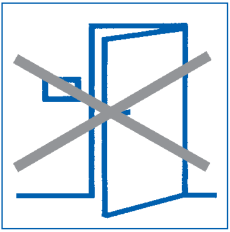


Do not install near lamps or above radiators.

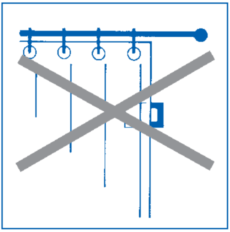


Avoid chimney walls.

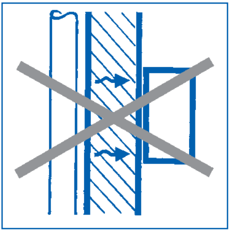




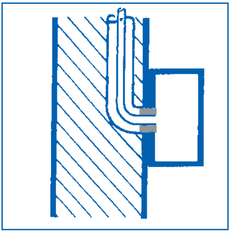
Do not install directly adjacent to doors.



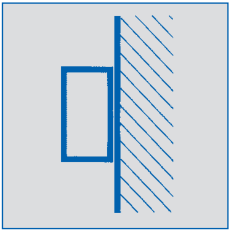
Do not install behind curtains.



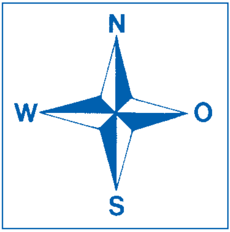
Do not fit to walls concealing hot-water pipes.



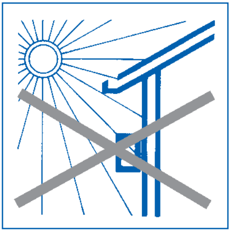
Seal gaps between cable/plastic tubing and conduit. Otherwise measurements will be falsified by incorrect circulation of the air.



The system design determines the façades (N,S,E,W) on which the sensor should be located.

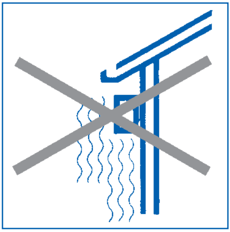


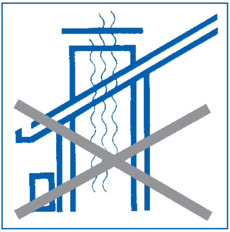
Do not expose to direct solar radiation.



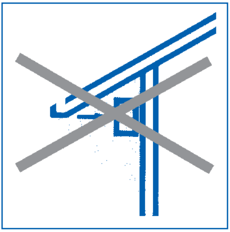
Do not install on façades affected by significant rising heat.

Do not install on façades warmed by solar radiation.

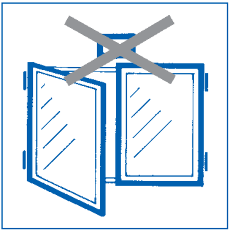




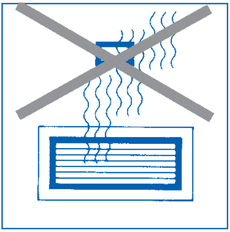
Avoid chimney walls.



Do not install under eaves.



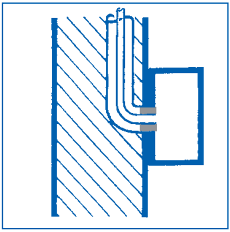
Do not install above windows.



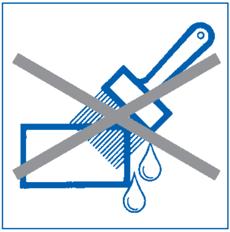
Do not install above ventilation shafts.

Seal gaps between cable/plastic tubing and conduit.

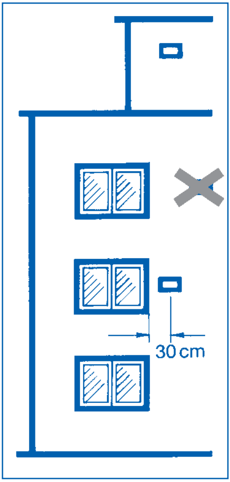
Otherwise measurements will be falsified by incorrect circulation of the air.



Do not paint the sensor.

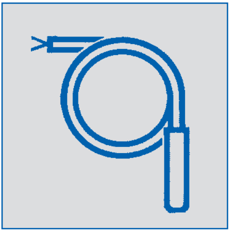


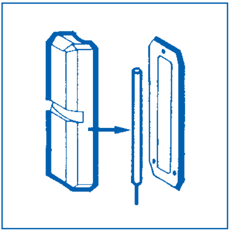
Ensure accessibility (for inspection/testing)



Temperature

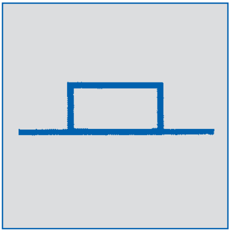
Outdoor sensors · Cable sensors





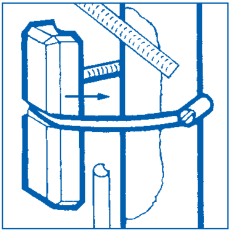
The same rules apply to outdoor cable sensors as to any other outdoor sensors. The cable should be connected from below (to protect it from dripping water).

Surface-mounted strap-on sensors

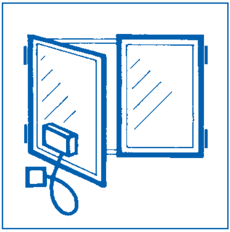


The surface must be clean and smooth (remove paint). The sensor must be fixed firmly to the surface. Use heat-conductive compound.

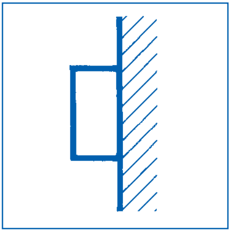
Important:
Avoid exposure to external heat gains.

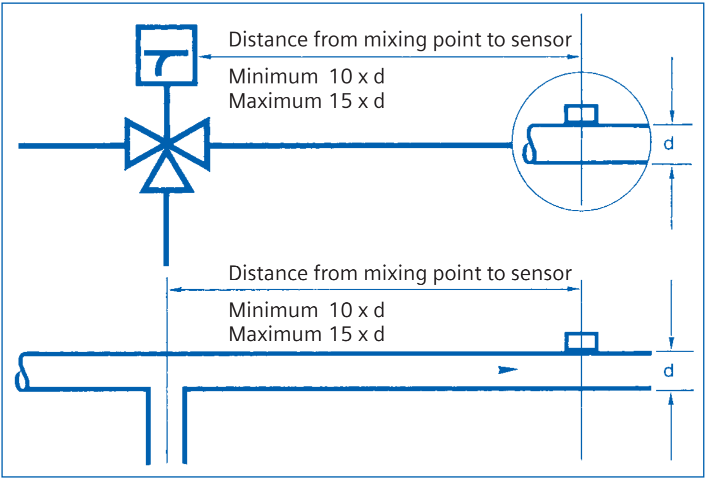


Consider cable length when fitting to windows which can be opened!
The sensor must be fixed directly to the window surface.



The sensor must be fixed directly to the surface.
Use heat-conductive compound.

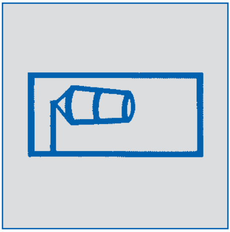




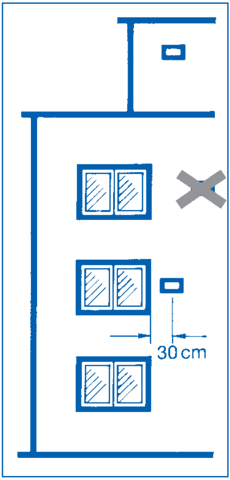
When mixing water at different temperatures, always maintain an adequate distance between the mixing point and the sensor (to take account of stratification).

Temperature

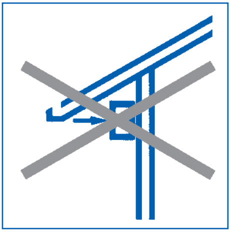
Wind sensors



Install on the façades exposed to the main wind direction.
Make sure the sensor is accessible
(for inspection/testing).

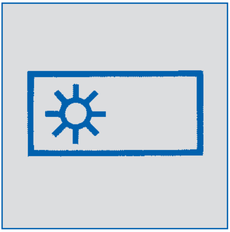


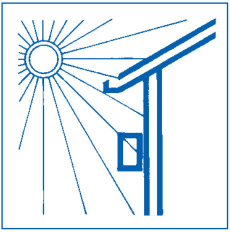
Do not install under eaves.
Do not install in recesses.



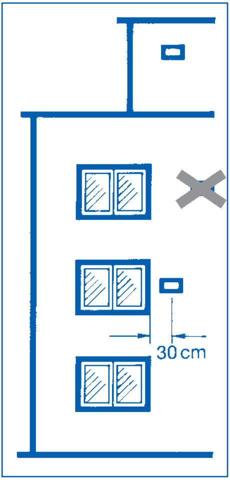
Temperature

Solar sensors



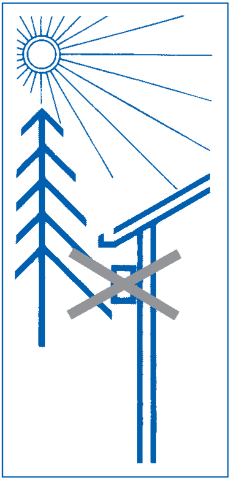


Install solar sensors on the façades behind which the associated control system is operative.



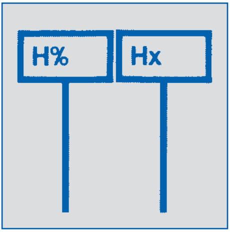
Install the sensor where it is easily accessible (for inspection/testing).

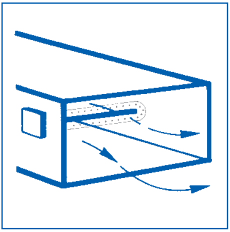
Avoid shade (from trees or neighbouring houses etc.)



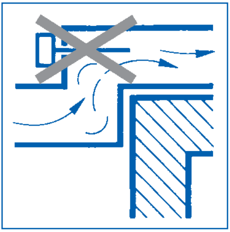
Humidity

Duct sensors

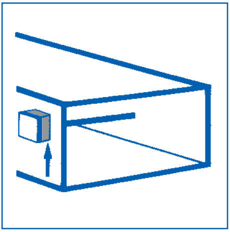




Note that humidity sensors are affected by air velocity. The air velocity in the vicinity of the sensor must not exceed 10 m/sec.
Precaution: Fit the sensor with a perforated shield or cover (e.g. perforated steel)

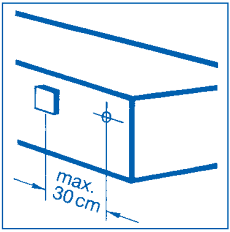


Avoid dead-legs. (Supersaturation can occur in areas where there is no air flow.)

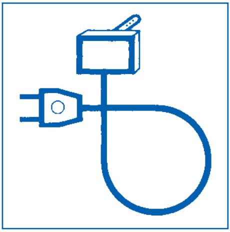


Important:
When installing sensors in ducts with negative pressure, it is possible for air from an external source to be drawn into the device and the installation hole.
(Seal tightly to prevent false readings.)

A test hole must be provided for every humidity sensor (downstream of the sensor).
Recommended diameter: 40 mm.



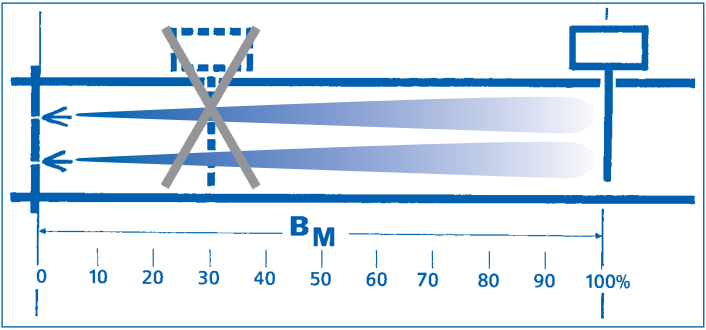
For maintenance purposes, the electrical connections should be of the plug-in type (e.g. TT45...).



Distance for humidification measurements for B_M

B_M is the distance between the humidifier and the humidity sensor necessary to allow the air to absorb 100% of the water supplied. The required distance depends on the amount of water supplied, the velocity of the air and the type of humidifier system.

If the humidity sensor is not mounted at the required distance, it will produce a false reading.



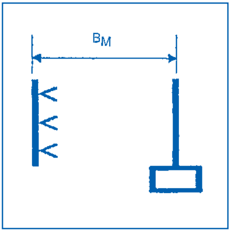
Example: Because it is in the wrong position, the sensor here measures only 30% of the water or steam introduced into the system, as only this amount has been fully absorbed in gaseous form into the air. The sensor element will get wet, produce an incorrect reading, and may be damaged.

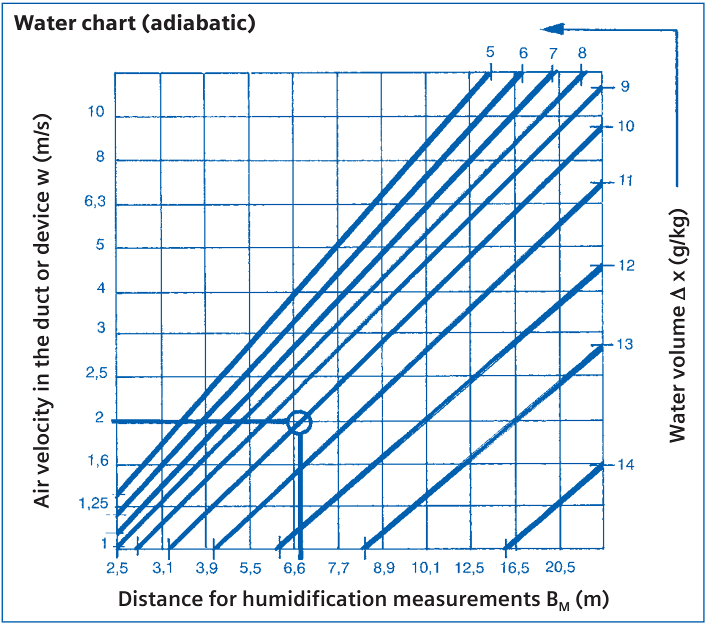
Humidification systems:

Air washers	B_M downstream of eliminator plate	
Tray-type humidifier	B_M 3.5 m	
Spray rehumidifiers	B_M 5.5 m	
Spray humidifiers	See water volume diagram (adiabatic)	page 39
Ultrasound humidifiers		
Centrifugal humidifiers		
Atomizer humidifiers		
	see diagram for steam	page 40
Pressurized steam	B_M = Isotherm	
"Pressure-free" steam	B_M = Isotherm · 1.3	

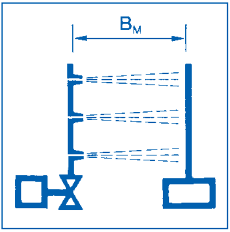
Distance for adiabatic humidification measurements

This diagram is designed for use in winter, with an absolute humidity content of 1.5 g/kg on the intake side, and a supply air temperature of 18 °C.





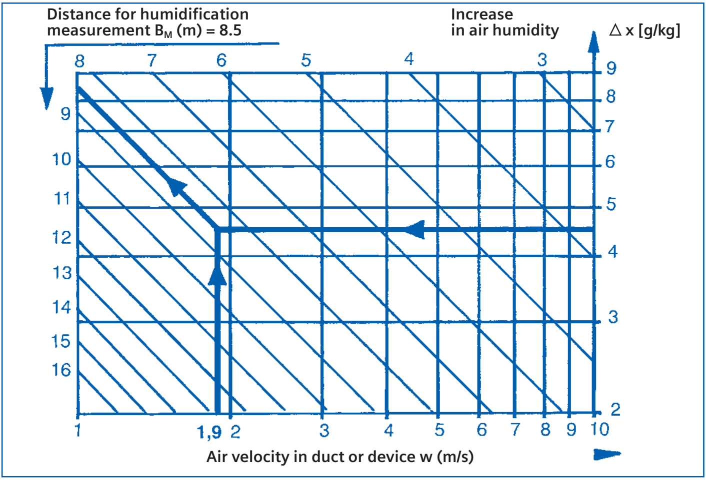
Method: Enter the air velocity (in m/s) on the left edge of the diagram (e.g. 2.0 m/s). From this point, draw a line to the right, along the line indicating the increase in humidity (example: $\triangle x = 10$ g/kg).
Starting where the two lines intersect, draw a vertical line and read the required distance B_M for humidification measurements on the horizontal line at the bottom of the diagram (6.7 m).



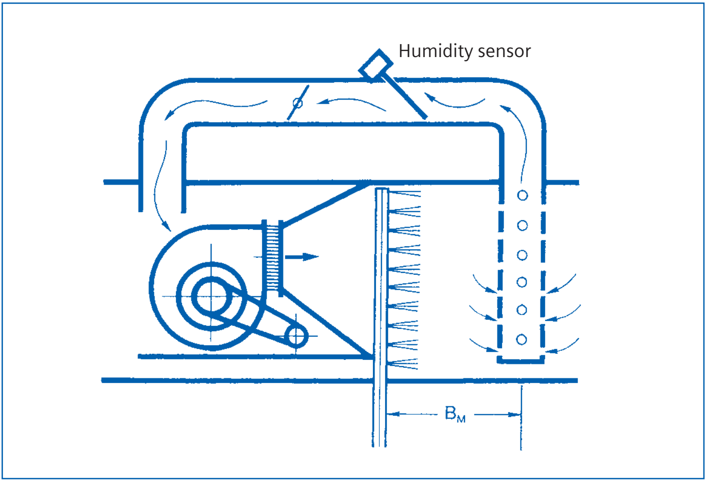
Distance B_M for humidification measurements with steam humidifiers

A certain distance is required between humidifier and sensor, so that the air has time to absorb the water (vapour) supplied by the humidifier before the sensor measures the humidity. This distance is marked on the diagram as B_M. The minimum distance between the humidifier and the humidity sensor must be equivalent to at least B_M.

Determining B_M



Method: Enter the increase in humidity in g water/kg air (e.g. 4.5 g/kg) on the right edge of the diagram.
Draw a horizontal line extending from this point towards the left.
Enter the minimum duct air velocity (in m/s) on the bottom edge of the diagram (e.g. 1.9 m/s) and draw a vertical line extending upwards from this point.
From the point of intersection of these two lines, draw a diagonal line extending upwards and parallel to the existing diagonals. Read the distance, B_M, in metres, from the scale on the edge of the diagram (example 8.5 m).



Average humidity measurement

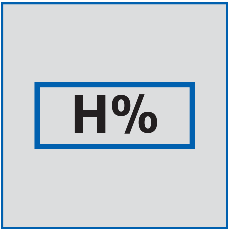
Locating the humidity sensor in a bypass duct improves the measurement of average, relative or absolute humidity, and should be used:

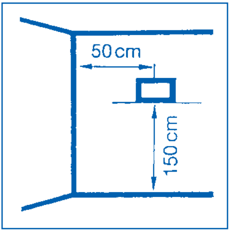
In cases of temperature or humidity stratification.

Here too, the appropriate distance for humidity measurements, B_M, must be maintained.

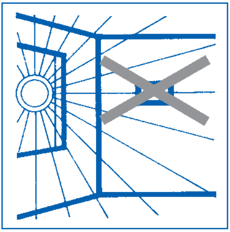
Humidity

Room sensors

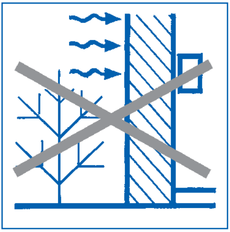




Install sensors at a height of 1.5 m in occupied spaces, and at least 50 cm from the adjacent wall.



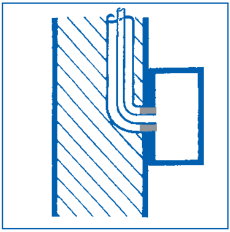
Do not install where sensor will be exposed to direct sunlight.



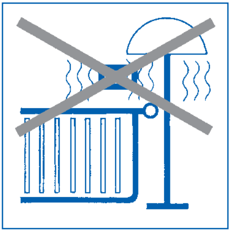
Do not install on external walls.

Seal gaps between cable/plastic tubing and conduit.

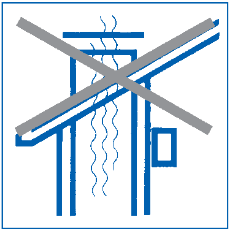
Otherwise measurements will be falsified by incorrect circulation of the air.



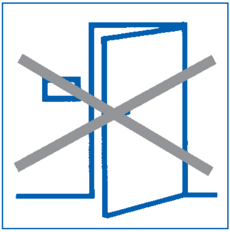
Do not install near lamps or above radiators.



Avoid chimney walls.

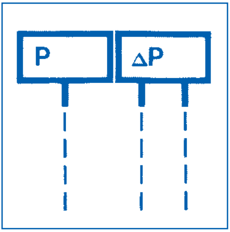


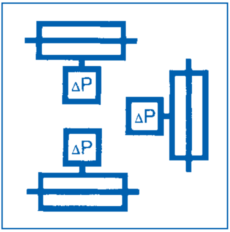
Do not install directly adjacent to doors.



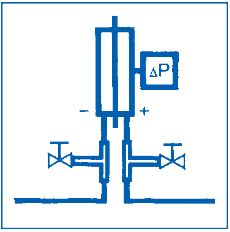
Pressure

General

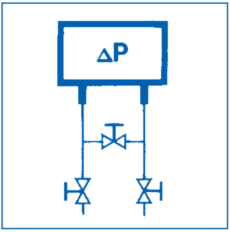




Pressure sensors are affected by orientation (see manufacturer's installation instructions).

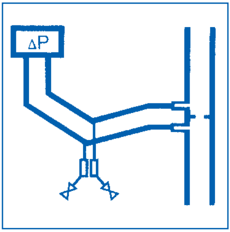


Pressure tubes must be provided with an isolatable T-fitting near the device head for test purposes.

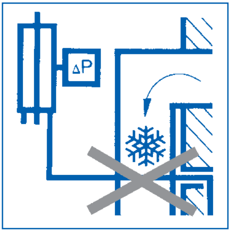


To prevent overload on one side when making adjustments, the connection must always be fitted with an isolating bypass.

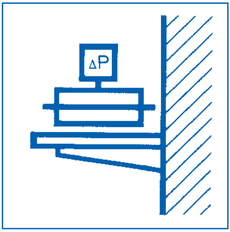
Where there is a risk of condensation, the differential pressure tube must be installed at a gradient of 1:30 and fitted with a drain mechanism. The drainage point must be lower than the device head and sensing point. Protect from frost and avoid U-shapes.



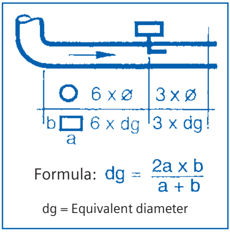
Pressure tubes containing circulating air must not be introduced into the open air or routed through cold rooms or ducts.
This prevents the risk of condensate freezing in the tubes (e.g. with pneumatic venting sensors).



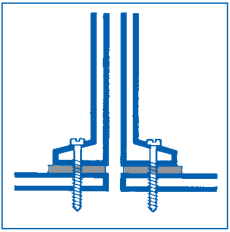
Mount on a vibration-free surface.



The pressure-tapping point must not be located in turbulent air. Ensure sufficiently long settling-zones upstream and downstream of the tapping point.
A settling-zone consists of a straight section of pipe or duct, with no obstructions.



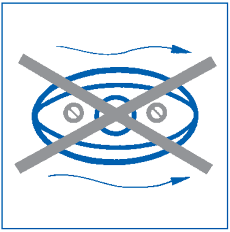
Pressure



Air

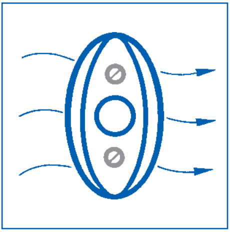
The measuring tip is screwed or glued to the duct wall.

Seal to protect from external air. Remove any swarf from the inside of the duct.



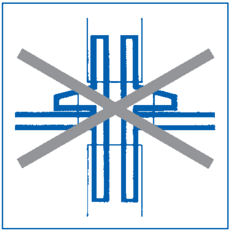
Important

Protruding fixing screws will impair correct measurement.

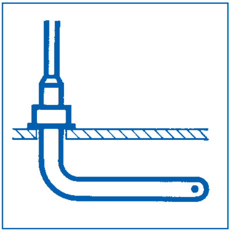


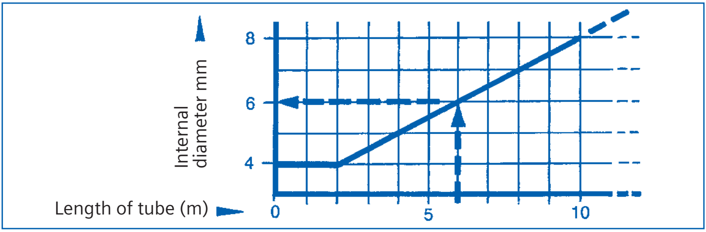
Correct installation.

Avoid using tips which protrude into the duct for static pressure measurements.

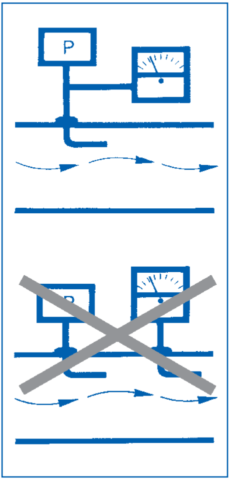


Probes are used to measure static pressure in the duct. Must be installed parallel to the flow and either with the flow or against it.

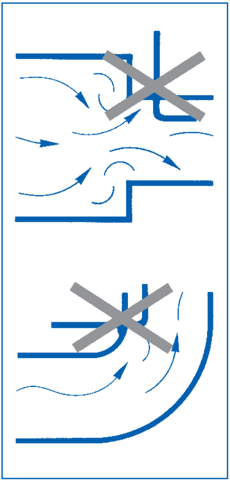




Sizing the pressure tubes ("measuring tubes") for air and gases: Keep the tube as short as possible.
An internal diameter of 4 mm is sufficient for pressure tubes of up to two metres in length. For longer pressure tubes, the internal diameter should be as indicated in the diagram.
(Example: A pressure tube of 6 m requires an internal diameter of 6 mm.)

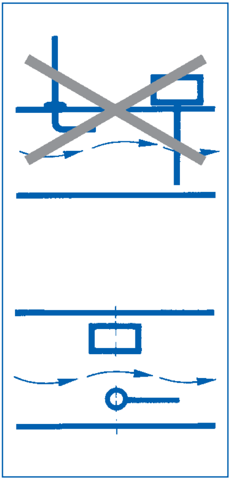


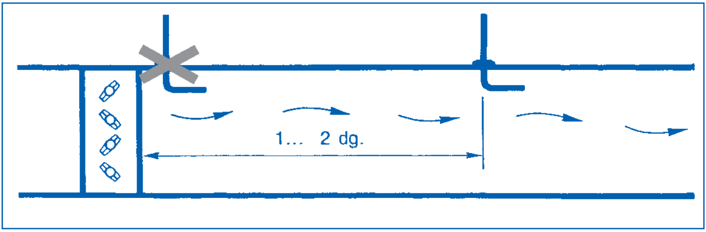
Connect the sensor and measuring instrument to the same point.



The tapping point must not be located where it will be affected by obstructions to the flow.

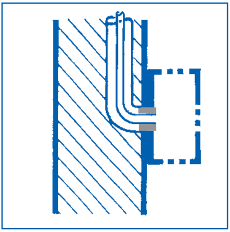
Where more than one sensor is used, the sensors should be installed on the same plane in the flow, and not in a position where one device will obstruct the air flow to the other.





dg = Equivalent diameter, page 45
Leave sufficient clearance downstream of any obstacles.

Pressure

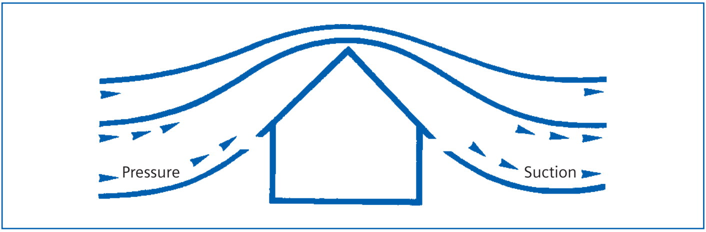


Room

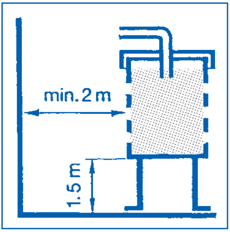
The end of the pressure tube leading into the room should be protected by an air-permeable cover.
Seal gaps between cable/plastic tubing and conduit. Otherwise measurements will be falsified by incorrect circulation of the air.

Pressure

Outside air



Measure the outdoor pressure in an area sheltered from wind. Individual façades are not suitable measurement locations, as the pressure varies according to the wind direction.
The correct location for measurement is a place where the air can circulate freely, such as a flat roof. Note, however, that the sensing point must be fitted with a wind shield.



Options:

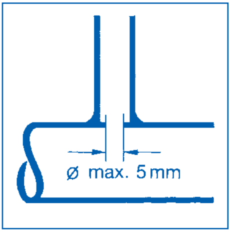
Calculate average based on pressure measurements taken on several façades.
Measure pressure in an open space
(min 1.5 m above ground level).
Multiple sensing point on flat roof.

Pressure

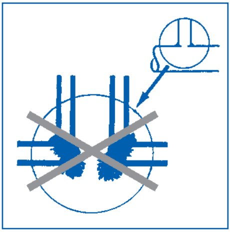
Liquids

Pressure tapping point:

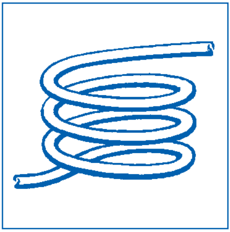
Sensing hole: diameter 5 mm, drilled and deburred.



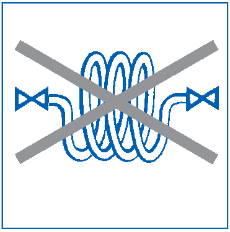
Smooth interior (no burrs).

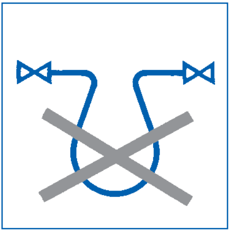


Use a damping coil to avoid transferring vibrations. Bend a 1 m long copper pipe, 4...6 mm in diameter, into a spiral with loops with a diameter of 15 cm.

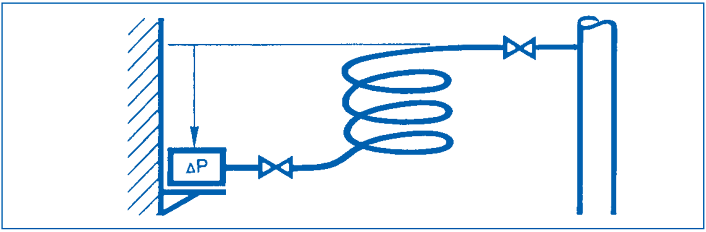


Wrong:
Air bubbles and condensate remain trapped.

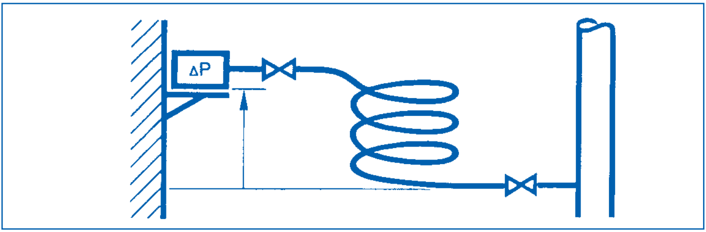




Wrong:
Condensate cannot be drained.



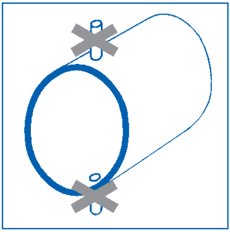
Installation in conjunction with liquids:
Always install the pressure sensor in a location which is lower than the sensing point.



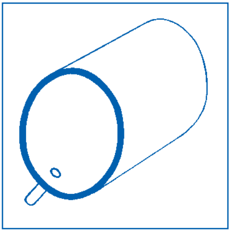
Installation in conjunction with vapours/gases
Always install the pressure sensor in a location which is higher than the sensing point.

Pressure measurement in conjunction with liquids

Do not measure at the top of the pipe (trapped air or air bubbles) or at the bottom (dirt).

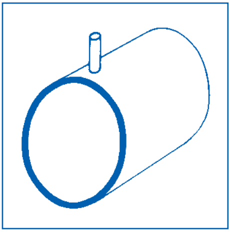


The correct location for a sensing point is at the side.

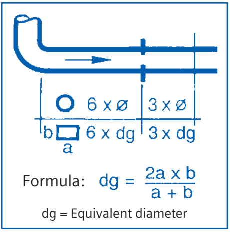


Condensing gases

Measure at the top to prevent condensate from entering the pressure tube.

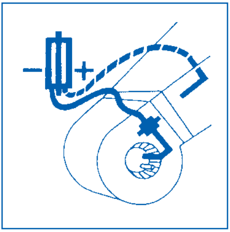


Flow velocity



Air

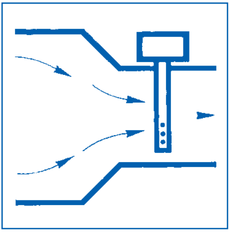
The pressure-tapping point must not be located in turbulent air. Ensure sufficiently long settling-zones upstream and downstream of the tapping point.
A settling-zone consists of a straight section of pipe or duct, with no obstructions.



Fan-belt monitoring

The differential pressure across the fan is only suitable for fan-belt monitoring.

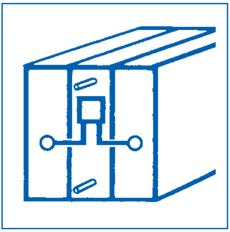
- Negative connection (–) on suction side use copper tube
- Positive connection (+) on discharge side: use Pitot tube



Flow monitoring

Flow detectors (electrothermal)

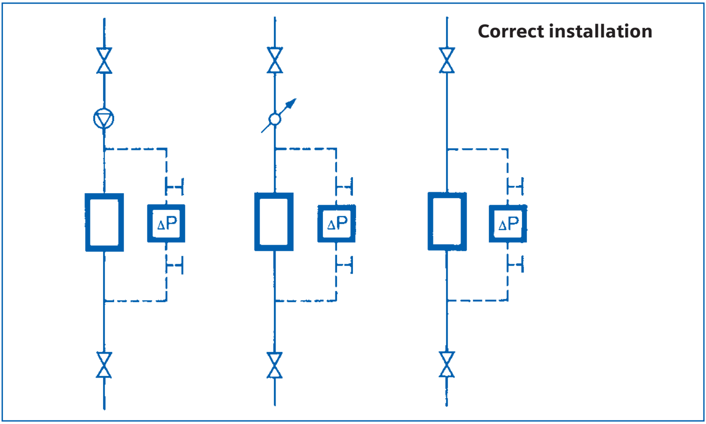
Electrothermal flow detectors must be installed in a zone with a high flow velocity, e.g. where pipes narrow.



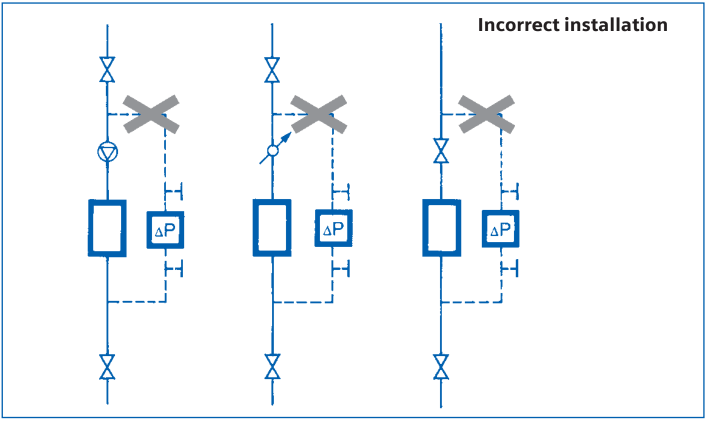
Differential pressure

Do not monitor flow or differential pressure where flow resistance is variable, e.g. at filters, cooling coils, fans etc. Suitable locations: heating coils, silencers, baffles, attenuators.

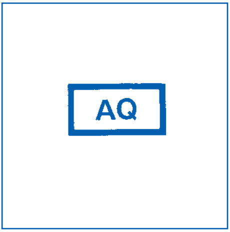
Flow monitoring Water

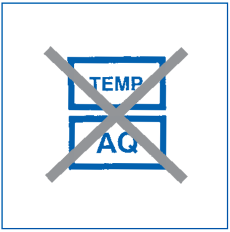


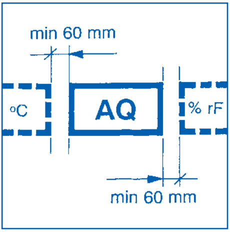
If differential pressure is used to monitor the flow, it is important to ensure that there are no stop valves or balancing valves between the sensing points.

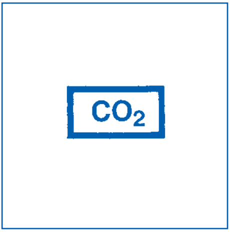


Air quality sensors









Room sensors

There are two types of air quality sensors:

Mixed gas (or VOC) sensors
The accumulation of up to 24 different gases is measured in the ambient air (total concentration measured)

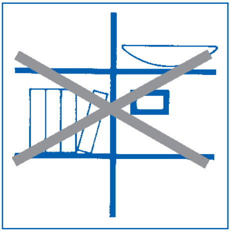
Selective gas sensors
These measure only one gas (e.g. CO_2) in the ambient air (selective measurement).

Do not locate temperature or humidity sensors above or below the AQ sensor.

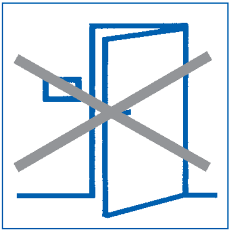
The heated sensor element produces significant intrinsic heat in the device. Owing to this characteristic, the room temperature or room humidity must not be measured in the immediate vicinity.
Maintain a clearance of minimum 60 mm on each side of the AQ sensor.

CO_2 sensors
Selective gas sensors may require maintenance at regular intervals. Please consult the manufacturer's instructions. The sensor must be installed in an accessible location.

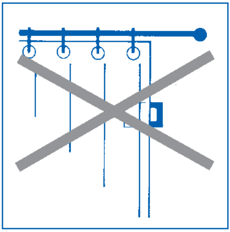
Avoid recesses (e.g. shelving) and alcoves.



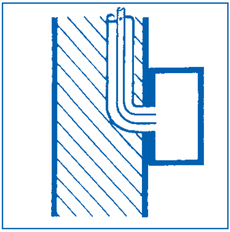
Do not install directly adjacent to doors.



Do not install behind curtains.



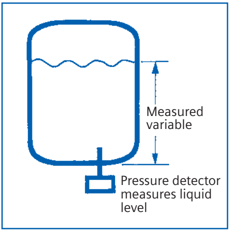
Seal gaps between cable/plastic tubing and conduit. Otherwise measurements will be falsified by incorrect circulation of the air.



Liquid level sensing

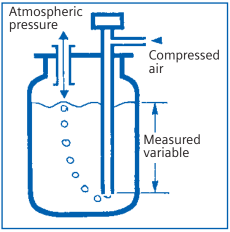
A distinction is made between the following methods:

- Capacitive measuring probes
- Pressure/differential pressure (hydrostatic)
- Ultrasound
- Tank weighing systems
- Electromechanical sensing



Pressure measurement:

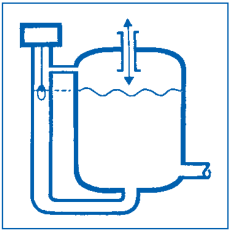
The pressure is defined by the height of the liquid medium, measured from the sensor to the surface of the liquid. There are no critical factors to consider when installing the pressure sensor. The sensor material must be suitable for use with the liquid medium.



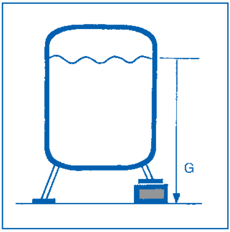
Bubble technique:

The pressure measurement is determined by the height of the liquid above the bubble-tube outlet.

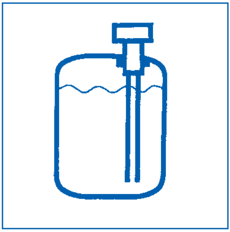
Floats:
These are used in open and sealed systems.
The device head must be installed above the maximum expected liquid level.



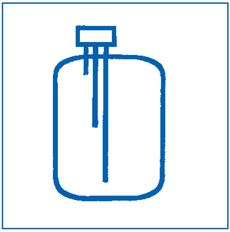
Tank weighing system
The measured result is determined by the tank content (mass weight).
The sensor should be mounted in accordance with the manufacturer's instructions.

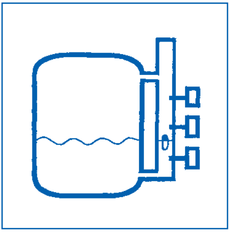


Capacitive measuring probes:
These are used in open and sealed tanks.
Mounting: The distance from the next electrically conductive component must be as specified by the manufacturer.



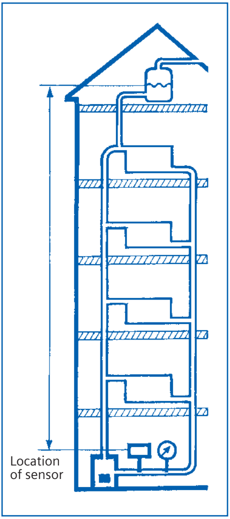
Conductance systems:
These are used in open and sealed tanks.
The measured result is determined by the length of the immersed electrodes.
Mounting: The distance from the next electrically conductive component must be as specified by the manufacturer.





Magnetic level switches:
These are used in open and sealed tanks.

Mounting:
The liquid-level tube and the location of the level switch are determined by the manufacturer. Level switches are installed at the same height as the required liquid level.



Hydrostatic level sensing:
The measurement is based on the maximum liquid level and the location of the sensor.

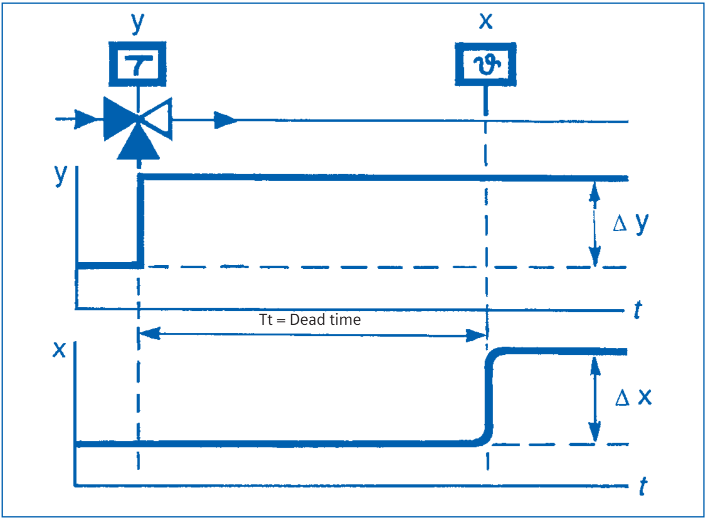
Principles of operation

General

All measuring systems transmit physical variables such as temperature, humidity, pressure etc. with a particular response characteristic.
The "response characteristic" (e.g. Tt = dead time / T = time constant or "lag") refers to the reactions of the measuring systems.

Transfer with dead time, Tt, e.g. mixed-water temperature

As the valve is adjusted by a given stroke, the temperature of the mixed water in the valve changes without any time delay.
However, the valve and the temperature sensor are some distance apart. This is the distance the mixed water has to travel before the sensor can detect the change.
This "transportation time" is referred to as "dead time".

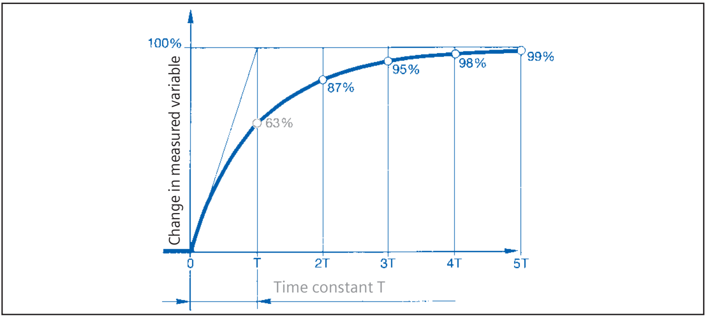


Time constant of measuring sensors in liquids

For measuring or acquiring medium temperatures in piping systems, sensors are usually installed with protection pockets. These pockets represent the first delay element in the measuring process, the air gap between pocket and sensing element the second. The third delay element is the sensor's time constant. Of these three delays in series, that of the air gap between pocket and sensing element is the greatest since the heat conductivity of air is poor. This poor transmission of heat from the medium to the sensing element can be considerably improved by filling the air gap with oil or glycerin.
If glycerin is used, the welded protection pocket must be inclined.

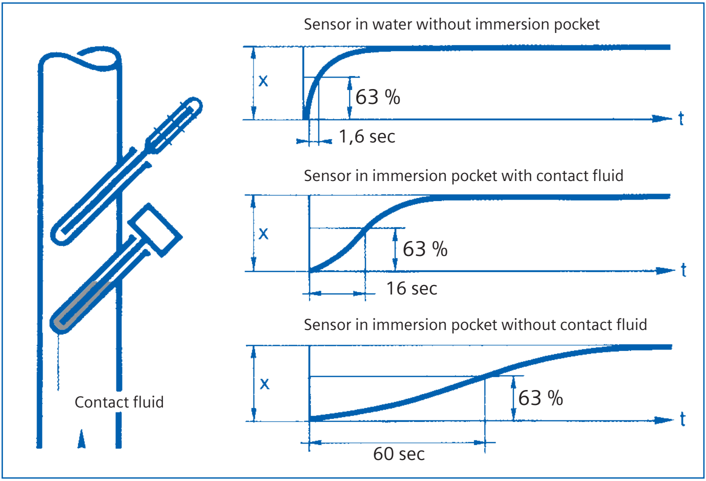
Transfer with time constant = T

No sensors transmit the change in a measured variable instantaneously. The delay in transmission time (the time constant, or "lag", T) can be shown in diagrammatic form.



The time taken to transmit 63% of the total change in the measured variable is referred to as the time constant, T.
It takes a period equivalent to five times the time constant to transmit approximately 99% of the change in measured variable.

Example of response characteristic



Sensor in pipe

Output signals

The sensor converts the measured variable into an output signal. Sensors (measuring devices) are divided on the basis of their output signals into two main categories:

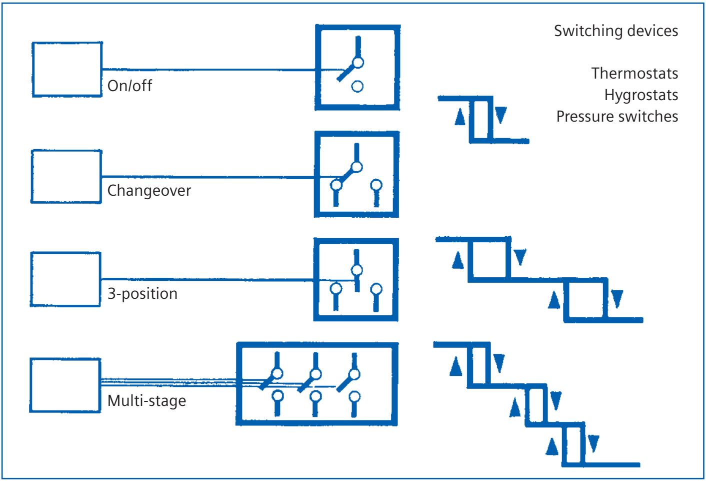
Switching devices, examples:

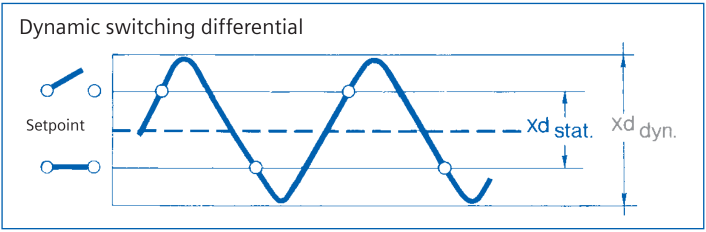
Thermostats, hygrostats, pressure switches

Stepless (continuously variable) signals, examples:

Temperature sensors, humidity sensors, pressure sensors

Switching devices



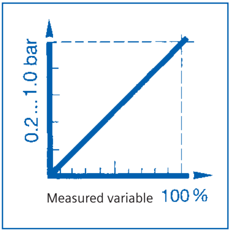


Where a switching device such as a thermostat is installed in a system, it should be noted that the temperature swing will be wider than the switching differential of the thermostat. The thermostat operates at the switching points specified in the data sheet (static switching differential), but the inertia of the system (residual heat, dead time etc.) causes the controlled variable to overshoot or undershoot. The finally measurable temperature swing (the dynamic switching differential) will therefore always be wider than the static switching differential of the thermostat.

Stepless devices

Stepless devices (sensors) produce a continuously variable, or “stepless” output signal. A given output value is assigned to each measured variable (temperature, humidity, pressure etc.) and the output signals are standardized.
Normally, pressure, current, voltage or resistance signals are used for this purpose.

Pneumatic control system
Pressure output signal: 0.2 ... 1.0 bar

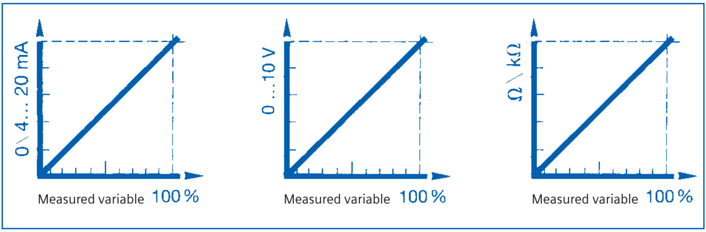


Sensors used in electronic control systems operate with various output signals.

Output signal
Current :
0 ... 20 mA / 4 ... 20 mA

Output signal
Voltage:
0 ... 10 V / 0 ... 1 V

Output signal
Resistance:
Various resistance values [ohms]



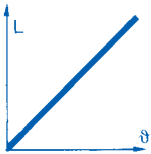
Temperature

Deflection of metals

Metals respond to a change in temperature by a corresponding expansion (deflection). Sensors can be constructed in various ways to transfer this response.

Bimetal strips:

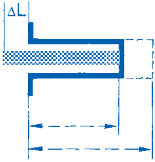
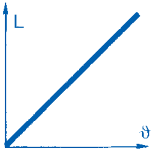
A bimetal strip is composed of two strips of metal with different coefficients of expansion, bonded together. As the temperature changes, one material (A) expands more than the other, causing the strip to bend.
The curvature can be converted into an output signal.

Material	Construction	Function	System
Bimetal rod Steel/brass Invar/brass			– Deflection

Metal A = Large expansion

Metal B = Smaller expansion

Bimetal rod and tube

Material	Construction	Function	System
Tube Steel/brass Invar/brass			– Deflection

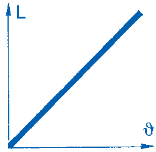
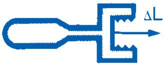
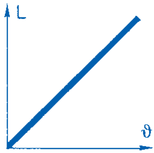
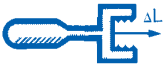
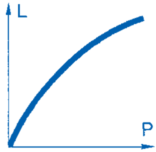
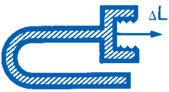
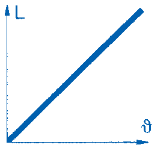
The tube (metal A) increases in length as the temperature rises. The Invar rod (metal B) does not change in length, with the result that the linear expansion of the tube is transmitted as a change in position. This, in turn, can be converted into an output signal.

Metal A

Metal B (Invar)

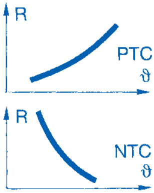
Force/deflection response of liquids and gases

Liquids and gases also expand in response to a change in temperature. Various types of construction can be used to convert this expansion into a change in position. The output signal is derived from the change in position (potentiometer, inductive deflection, baffle plates etc.).

Material	Construction	Function	System
Liquid e.g. mercury, alcohol			Force/deflection
Gas e.g. helium			Force/deflection
Vapour For small measuring ranges			Force/deflection Non-linear due to to latent heat involved in a change change of state (phase transformation)
Liquid “averaging” type sensors The total length of the capillary is active.			Force/deflection

Electrical resistance sensors

Metals change their resistance (measure in ohms) with a change in temperature.
The change in resistance per Kelvin (K) is different for every metal, and is used directly as an output signal.

Material	Construction	Function	System
Platinum Nickel			Electrical resistance, R, in ohms Ω

There are two types of change in resistance:

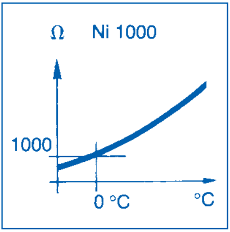
PTC: Positive temperature coefficient

Rising temperature = increased resistance
Falling temperature = reduced resistance

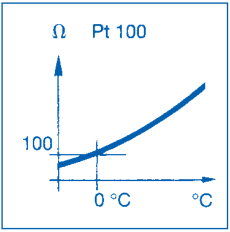
NTC: Negative temperature coefficient

Rising temperature = reduced resistance
Falling temperature = increased resistance

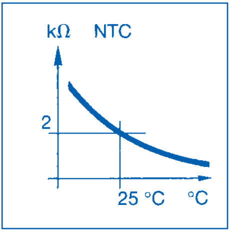
The relationship between the measured variable (temperature) and the resistance value is shown on a graph.
The designation of the various PTC sensor elements is standardized and comprises:
a) the material of the sensor element
b) its resistance at 0 °C



e.g. Ni 1000
Nickel sensor element
1000 Ω resistance at 0 °C.



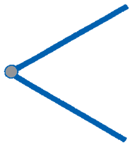
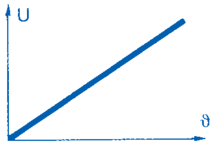
e.g. Pt 100
Platinum sensor element
100 Ω resistance at 0 °C.



NTC sensors
The characteristic curve of the NTC sensor is not linear.
The measuring ranges are defined by the manufacturer.

Thermocouples

These consist of two wires of dissimilar metals, welded together at one end.

Construction	Function	System
		Voltage U in mV

Examples:

Copper (Cu)/Constantan, Iron (Fe)/Constantan, Chromium (Cr)/Constantan, Nickel (Ni)/Constantan etc.

A voltage (mV) is generated as a function of temperature at the welding point or “junction”.

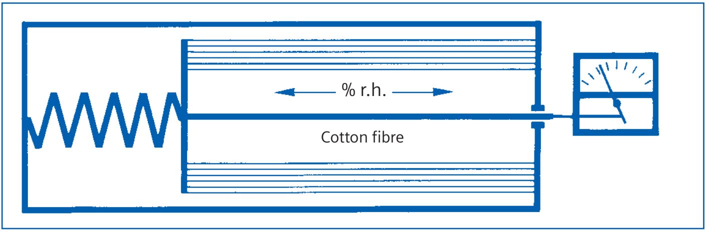
Measuring humidity

Humidity is generally measured by use of hygroscopic materials. i.e. materials which respond to changes in humidity.

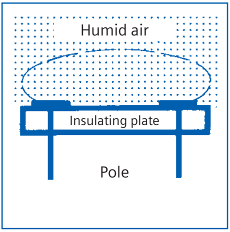
Relative humidity (% r.h. = φ)

Principle: physical change in length

Textile fibres (cotton, nylon etc.) expand as a function of relative humidity (producing a deflection).



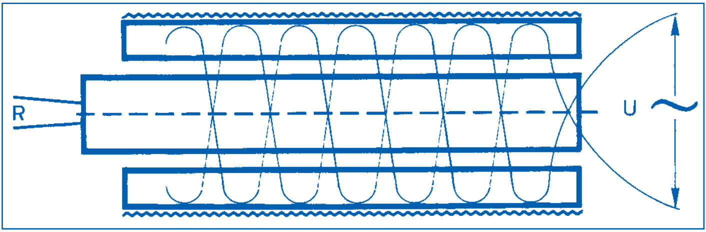
The deflection can be used as follows:
To move a pointer (hygrometer), to operate a switch (hygrostat), to adjust a potentiometer, to adjust nozzles/baffles etc. (pneumatics), and to change inductivity (electrical variable).



Principle: change in electrical capacitance

Capacitive elements respond to relative humidity by changing their electrical charge-storing capacity. Two electrical poles are connected to an insulating plate. In conjunction with the moist air, these poles store the electrical charge. The charge-storing capacity between the two poles depends on the ambient humidity.

Absolute humidity x g H_2O per kg of dry air



Salts (such as lithium chloride, LiCl) have hygroscopic properties. Their electrical conductivity changes according to the amount of moisture absorbed by the salt. A temperature sensor is wrapped with in a woven fabric which holds the salt. The fabric is wound with two non-touching electrical wires connected to an alternating current. As the air humidity rises, the moisture content in the salt increases, so reducing the electrical resistance between the wires. The smaller the resistance, the higher the electrical current, so that the two wires act as an electric heating element. The heat produced causes the water to evaporate. As the moisture content is reduced, so the resistance increases again, and the heat output is reduced. This alternating process is repeated until the amount of water evaporated is equal to the amount of water absorbed. At this point, a state of equilibrium (constant temperature) is reached. This temperature (the transformation temperature) is a measure of absolute humidity.

Combined humidity sensors

There are also combined humidity sensors on the market, which operate simultaneously with the temperature and humidity measurement principles described above. By measuring the temperature and relative humidity, these sensors can be used to calculate the dew point (°Tp) or the moisture content (g H_2O). Alternatively, the relative humidity (φ) can be calculated on the basis of the temperature and the moisture content (g H_2O) or dew point (°Tp).

Measuring pressure

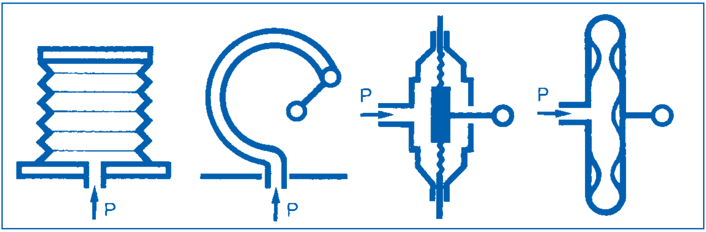
Force/deflection systems

With pressure sensors of this type the pressure is converted into a change in position or force. This can be used to:

- Move a pointer
- Operate a switch
- Adjust a potentiometer, etc.

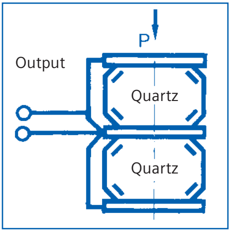
There are various ways of converting the pressure into a deflection. The main methods are:

- Bellows: Pressure switches or manostats for higher pressures
- Bourdon tube: Manometers
- Diaphragm: Fine-pressure measuring instruments
- Aneroid barometer: Fine-pressure measuring instruments

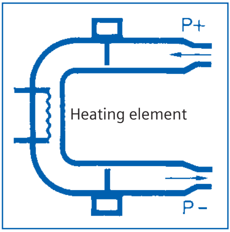


Bellows Bourdon tube Diaphragm Barometer

Electronic systems



Piezoelectric elements:
The force acting on the quartz crystals generates an electrical charge. This charge is converted into an output signal corresponding to the pressure.



Thermodynamic pressure sensors:
The amount of air flowing through the pressure tube varies according to the differential pressure. The air is heated by a heating element with a constant heat output. The higher the differential pressure, the more air will flow through the tube, thereby reducing the heating effect. The change in temperature is measured by two sensor elements, and provides a measure of the differential pressure.

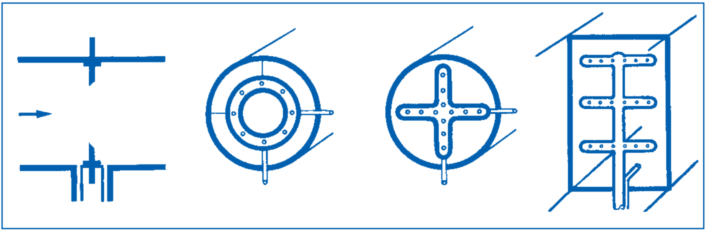
Important:
Take care to size the differential pressure tube correctly (see page 47).

Measuring air velocity and air flow

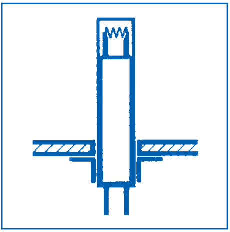
(Measured variable w = m/s)

Velocity measurements based on effective differential pressure

A fixed obstacle (orifice plate, flow nozzle etc.) placed in the air flow creates a pressure differential which varies according to flow velocity.
The flow velocity can be determined by measuring this differential pressure and converting it appropriately.
Special flow detectors are available for this purpose:



Orifice plate | Flow nozzle | Flow cross | Flow grid

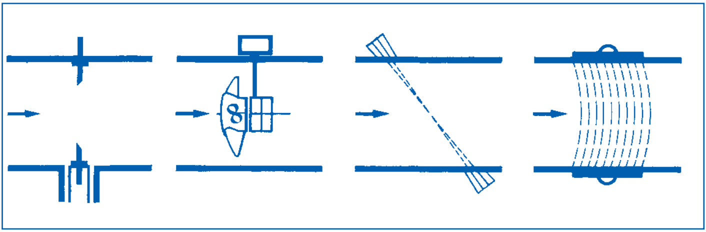


Hot-wire anemometer (thermoelectric)
A heating element is heated to a given temperature. The heat output required to maintain this temperature varies according to the flow velocity. The required heat output is measured and converted into a flow velocity.
Important: The hot-wire anemometer is only suitable for **spot** measurements.

Measuring water velocity and flow

Like air velocity, water velocity can be measured with orifice plates. Velocity measurements, however, are primarily required in order to determine heat volume.
There are various commercially available heat meters, based on different mechanisms for measuring flow velocity.

Example:



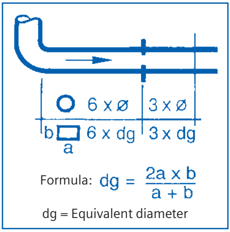
Orifice | Impeller | Ultrasound | Magnetic flux Inductiv

Important:
The required steadying zones must be allowed for, upstream and downstream of the sensor.

Flow velocity

To determine the flow velocity, the differential pressure at the flow detector (orifice plate, flow grid etc.) is measured. The same general mounting instructions apply as for differential pressure sensors.

Important:
The required steadying zones must be allowed for, upstream and downstream of the sensor.



Selecting the right sensor

Temperature measurements in pipework

Immersion sensors: In most cases, the immersion sensor offers the greatest advantages.
The entire active length of the sensor must be fully immersed in the pipe.

Strap-on sensors Used in cases where installation conditions make the immersion sensor unsuitable.
For retrofit installation (renovation projects).
For heating systems in residential buildings.

Cable sensors: The cable sensor has significant advantages (e.g. sealing) in refrigerant pipes.

Temperature measurement in tanks

Important: Avoid measurements at outer extremities of tank (20 cm).

Capillary sensors with probes/cable sensors These sensors are particularly suitable where a clearance is required between the sensor and the device head due to vibration, space problems or temperature conditions.

Probe sensors: Generally suitable for this application.

Temperature measurement in ducts

Probe sensors: These produce spot measurements and should be used only in ducts where there is no stratification.

Averaging sensors: Recommended for all applications. The length of the rod or capillary tube must be suitable for the duct cross-section (approximately 4 m per m^2).
Never install sensors with plastic-coated sensor elements downstream of electric heating coils.
Where this is unavoidable, fit a radiant-heat shield.

Room temperature measurement

Room sensors:	In large spaces, it is advisable to use more than one sensor (for an average value). With high internal loads and where extractors are used above lamps, sensors must not be sited in the exhaust air flow. **Important:** Remember to take account of reheating in the duct
Air quality sensors:	Do not install near heat sources.

Outdoor temperature measurement

Outdoor sensors:	Suitable for heating systems. In ventilation systems, the temperature must be measured directly after the weather shield in the outside air intake.

Measuring humidity

The time constant (lag coefficient, or response time) of the humidity sensor can vary from 10 s...5 mins, depending on the type of sensor.
As a general rule, sensors with a short response time (less than 1 minute) should be used for measurements in the supply air.
Table of lag coefficients for various sensor elements:

Sensor element:	Approx. lag coefficient
Man-made fibres	1...3 min
Cotton	3 mins
Lithium chloride	110 s
Capacitance	10...20 s

Fast humidification systems: supply air, steam humidifiers, spray humidifiers.

Important:
Solvents in laboratories, chlorine in swimming pools, disinfectants in hospitals etc. will impair the service life and operation of humidity sensors.
Air velocity: The maximum admissible air velocity at the sensing point of a humidity sensor must not be exceeded.

Measuring pressure and differential pressure of gases (air) and liquids

The nominal pressure PN of the pressure sensor must correspond to the safety pressure of the system.

The maximum permissible load on one side must not be exceeded. The pressure sensor must be approved for use with the medium to be measured (water, vapour, refrigerant, foods, gases etc.). The measuring range must be selected so that the set value is not at the start or end of the scale.

Measuring velocity and volumetric flow rate

Various measuring systems are available for measuring velocity or volumetric flow rate. The key factor here is whether a spot measurement or an average is required.

Measuring systems:

Spot measurements:	Suitable for:
Pressure tube	Gases, liquids
Hot-wire anemometer	Gases
Vane anemometer	Gases, liquids

Averaged measurements:	Suitable for:
Orifice plates	Gases, liquids
Flow nozzles (cross)	Gases
Flow nozzles (ring)	Gases
Ultrasound	Liquids
Magnetic flux	Liquids
Helical flow	Liquids
Ring piston	Liquids

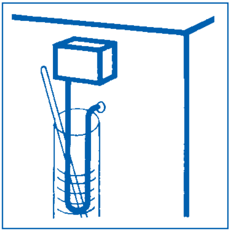
With spot measurements, the measured result is closely dependent on the flow profile. This is why it is strongly advisable when measuring velocity and volumetric flow rates, to use measuring systems of the “averaging” type.

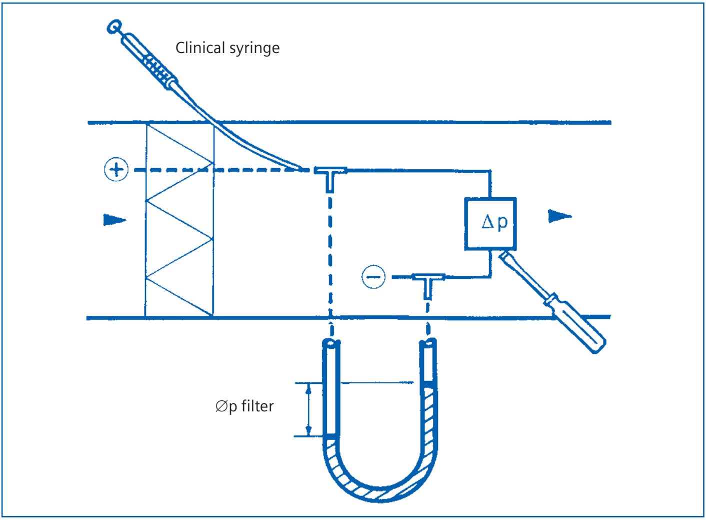
Calibration of measuring sensors

The process is always based on a comparison.
In order to calibrate sensors, a high-quality measuring instrument must be used.
This type of check is only useful if the measured variable remains constant throughout the calibration process.
Important:
Avoid external influences (e.g. heat gain from the tester's own body etc.)
The calibration process must be carried out directly on the sensor.
The verification of sensors in conjunction with the electrical installation must be carried out only by qualified personnel (see regulations).

Calibrating a frost thermostat

The loop on the capillary tube (20 cm) is immersed in a vessel filled with water and ice cubes. This “iced water” is measured with the thermometer.
Set the frost protection thermostat to the measured temperature. The frost protection thermostat should now trip at this temperature (recalibrate if necessary).
Now set the frost protection thermostat to +2 °C above the frost protection setpoint.





Calibrating a filter monitor

Use a clinical syringe to check the filter monitor as follows:

Method:

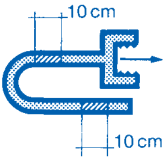
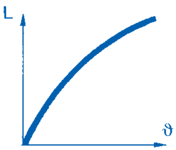
- Switch off the system.
- Disconnect the differential pressure tubes (+ and –) from the pressure-tapping points.
  Connect the syringe and a manometer (U-tube) to the "+" side.
- Switch on the system.
- Gradually increase the pressure with the syringe until the manometer shows that the switching point has been reached.
- The alarm device should trip at this point. (Recalibrate if necessary.)
- Switch off the system.
- Re-connect the differential pressure tubes.
- Switch on the plant again.

Practical tips

Frost protection thermostats

Purpose:
Frost protection thermostats are designed to prevent water-filled heat exchangers from freezing.

Method:
The air-side frost temperature must be monitored with a capillary sensor.

Construction	Function	System
		Force/deflection

The capillary frost-protection sensor operates on the principle of vapour pressure condensation. If the temperature falls below the preset switching point of 2 °C at any point along any 10 cm length, the vapour pressure in the sensor system drops, causing the frost alarm to trip.

Basic circuit:
If the air temperature downstream of the heat exchanger falls below the preset temperature, then:
- the supply/extract fans switch off
- the outside air/exhaust air dampers close
- the heating coil valve opens
- the internal pump switches on
- the frost alarm trips.

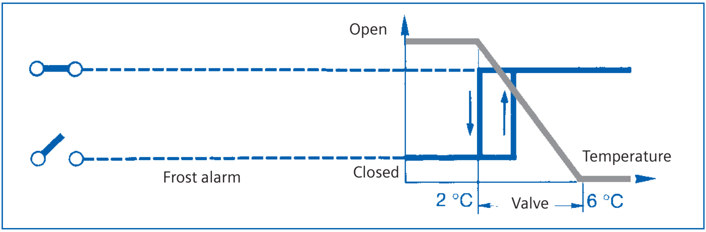
The frost alarm is self-locking, to prevent the system from being switched on again automatically by the frost thermostat. The alarm must be acknowledged locally (remote acknowledgement is prohibited).
To prevent overheating inside the unit, the heating coil valve is regulated by the frost protection thermostat while the frost alarm is active.

Tips for avoiding nuisance frost alarms:
The main cause of a frost alarm is a drop in temperature. It is possible, however, for a frost thermostat to trip even when the heat supply is adequate. This may be due to one of the following circumstances:
a) Changes in load, such as a change from one fan-stage to another, or a heat recovery system coming on/off load
b) Temperature stratification
c) System start-up after a shutdown

To prevent the frost thermostat from tripping in situations where the temperature is adequate, the following basic circuits have proven effective:
- Preventive frost protection thermostat
- Stabilised start function
- Setpoint-regulated start-up control

Preventive frost protection thermostat:

The preventive frost protection thermostat operates in two phases.



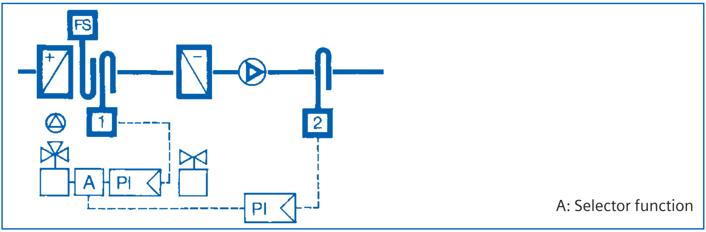
Example:

1. If the air temperature around the frost thermostat drops below 6 °C, the thermostat takes over control of the heat exchanger valve to maintain the air temperature at a value between 2 °C and 6 °C.

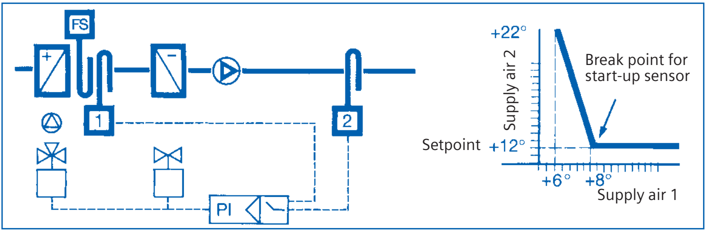
2. If the air temperature is still below the 2 °C switch-off point, (e.g. due to insufficient heating), the frost alarm will trip.

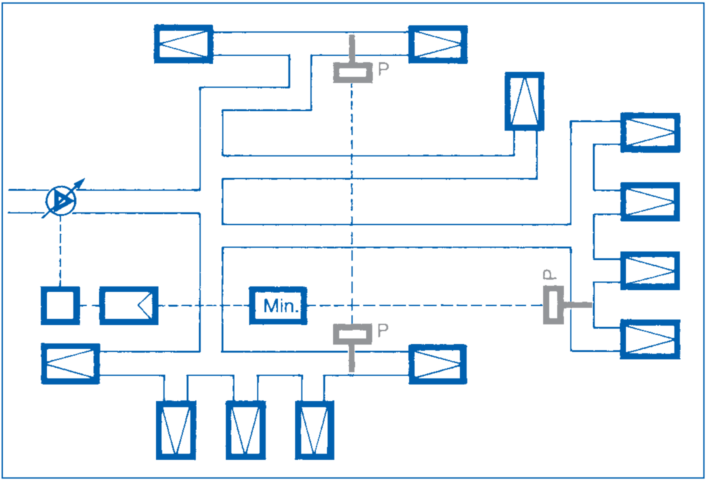
The stabilised start function and setpoint-regulated start-up control are used if there are additional heat exchangers (heat stores) installed downstream of the preheater.

Stabilised start function:
The stabilised start function maintains the air downstream of the heating coil at a minimum temperature. To achieve this, an averaging sensor must be installed directly adjacent to the frost-thermostat capillary. The minimum-temperature controller can be set independently of the frost thermostat and acts directly on the preheater valve.



Setpoint-regulated start-up control:
Setpoint-regulated start-up control requires an averaging sensor, installed directly adjacent to the frost-thermostat capillary. If its temperature falls below the value selected on the out-of-limits sensor, the latter adjusts the setpoint used for control of the supply air.





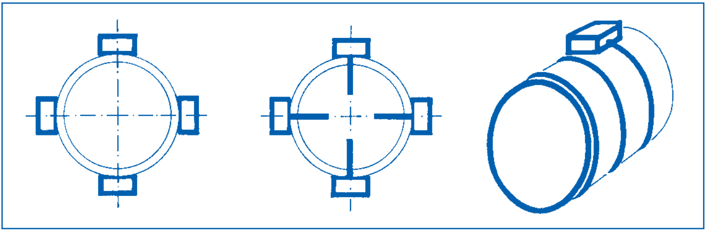
Pressure control in VAV systems

The sensing point must be sited at the most remote point in the duct system. In duct systems with a large number of branches, the use of several sensing points is recommended (the lowest pressure is used for control). If some parts of the ductwork (zones) are shut off by dampers, the relevant sensors must be disconnected.

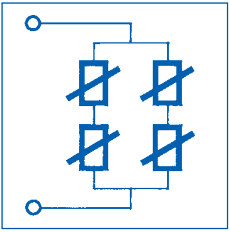
The setpoint can only be maintained at the sensing point.

Average measurements in water pipes

Average measurements are recommended in all pipes where stratification occurs (e.g. downstream of a mixing point), or where the sensor needs to be installed as close as possible to the mixing point (to reduce lag).
For averaging purposes, either four sensors can be distributed round the circumference of the pipe or an averaging sensor can be wrapped round the pipe.



These arrangements should be used in systems with large pipe diameters and variable volumes of water.



Electrical connection of 4 averaging sensors for measurement of the average temperature.