3 FUNCTION PROBE

THERMAL COMFORT AND HVAC MULTI PARAMETER MEASUREMENT PROBE
2300 AHTS

GrayWolf Sensing Solutions
advanced environmental measurements
www.WolfSense.com
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1. INTRODUCTION

1.1 THE GRAYWOLF THERMAL COMFORT AND HVAC MULTI PARAMETER MEASUREMENT PROBE

The 2300AHTS is an extendable three sensor probe for use with the GrayWolf Surveyor or Zephyr II range of measurement display instruments. It monitors the three main parameters for human comfort in occupied spaces, namely air temperature, air speed (or drafts) and relative humidity. The probe is ideal for use by Heating Ventilation and Air Conditioning (HVAC) engineers when setting up and commissioning HVAC systems. Two important additional parameters, dew point and volume flow rate, are automatically calculated by the Surveyor or Zephyr instrument from the probe data, and are displayed with the main probe parameters.

The telescopic sections allow the airspeed, relative humidity and temperature sensors to be placed in 'hard to reach' or normally inaccessible places, e.g. inside ducts. The 2300AHTS is described as a 'smart probe' as it contains its own linearization and calibration data, factory and user-set alarm levels, and serial number. This means that the probe can be transferred to another Surveyor or Zephyr instrument without the need for time-consuming re-calibration or re-setting measurement units and alarm levels.

The probe is easily attached to the Surveyor or Zephyr II instrument by means of the two integral probe modelling clips on the probe handle, thus enabling it to be held in one hand when making measurements. The fast response, high precision, accurate sensors in the probe make it ideal for quick spot checks, high accuracy continuous monitoring, or data logging (not Zephyr II).
Before using your multi parameter probe, please read the operating manual supplied with the Surveyor or Zephyr instrument. These manuals explain how to use the instruments correctly. They also explain how to program the instrument, and how to set it up to take measurements and log data.
For satisfactory indoor air quality, relative humidity (RH) must be maintained between 30% and 60% RH (i.e. 1.7 to 16.7°C dewpoint, or 35 to 62°F dewpoint) and temperature between 20 and 27°C (68 to 80°F), with local ventilation typically between 10 and 15 litres/person/second (21.28 and 31.92 ft³/min).

The ideal temperature depends on season, airflow and dewpoint temperature. The air change rate can be measured to give an accuracy of +/- 20%; careful measurements can give +/-10%. Note that air change regulations vary not only from country to country but also with application. Published specifications depend on whether the occupied zone is an office, factory, auditorium or other type of space: sometimes defining air change rate in terms of changes per occupant and at other times defining it in terms of air change rate per unit floor area.
3. AIR TEMPERATURE

Air temperature is the most important thermal comfort measurement. Not only does temperature need to be controlled tightly (typically between 20 and 27°C, 68 and 80°F, depending on season), but sudden temperature changes (more than 2°F per hour) cause discomfort to occupants. Temperature also affects other comfort parameters such as relative humidity, which is very sensitive to ambient temperature.

To reduce radiant error when measuring air temperature, the sensor in your probe is as small as possible. This is because the convective heat transfer coefficient increases as size decreases, while the radiant heat transfer coefficient is constant.

By monitoring temperature for a week, you can follow the building’s air handling behavior:

- Check insulation efficiency by monitoring the temperature drop when the heating is turned off.
- Check cycling around the setpoint by monitoring the thermostat temperature.
- Monitor the temperature set-back thermostat.
- Check for temperature variation in workplaces and offices beyond that which would normally be expected when these areas have been vacated by monitoring temperature during lunch breaks, Saturday working and overtime working.
The quantity of outdoor air being added to the mixed air is calculated using the following formula:

\[
\text{Air mixture (\%) } = 100 \times \frac{(T_s - T_r)}{(T_o - T_r)}
\]

Where:
- \(T_s\) = supply/mixed air temperature
- \(T_r\) = return air temperature
- \(T_o\) = outside air temperature

The 2300AHTS probe includes a Pt100 temperature sensor for accurate air temperature measurements. The sensor stabilises rapidly when measuring in ducts or where there is forced air movement, but in an office, where airspeed is very low, the probe must be gently moved around to obtain rapid stabilization of the sensor.
4. RELATIVE HUMIDITY AND DEWPOINT

Both relative humidity (RH) and absolute humidity (or dewpoint, the temperature at which moisture in the air starts to condense onto a smooth surface) affect the comfort of people and the growth of micro-organisms, especially in duct systems. Additionally formaldehyde emissions increase when both RH and temperature increase. Most viruses grow best in low temperature high humidity environments, although lipid viruses prefer low humidity environments.

Maintaining low RH is not the answer to all problems since eye and skin irritation, along with respiratory tract problems, can occur if the humidity is too low. Dust can also be a serious problem in low humidity environments. Relative humidity limits are therefore usually specified as between 30 and 60%.

Relative humidity increases with the number of occupants present, and decreases with increasing temperature; absolute humidity also changes with the number of occupants in a zone, but is independent of changing temperature.

The 2300AHTS probe measures relative humidity (RH) and temperature with a fast response thin film polymer capacitive sensor and a fast response Pt100 sensor respectively.

RH is sensitive to ambient temperature, so the humidity sensor must be thermally stable before an accurate humidity reading can be made.

The thin film polymer capacitive sensor used by the probe absorbs and transpires water rapidly, so that its capacitance changes rapidly in response to changes in RH. These sensors provide an accurate and fast response over very wide ranges. The 2300AHTS RH sensor is accurate to +/- 2% from 0 to 75% RH and +/- 3% from 75 to 100% RH.
4. RELATIVE HUMIDITY AND DEWPOINT

The Pt100 resistance temperature detector (RTD) is incorporated in the probe sensing head alongside the humidity sensor. This monitors the ambient temperature of the humidity sensor allowing automatic calculation of dewpoint (absolute humidity) by the Surveyor or Zephyr II instruments. The instrument displays humidity as % RH and the corresponding dewpoint temperature in °C, °F or K. Additionally, the ambient air temperature is displayed in °C, °F or K.

Since humidity measurement requires the sensor to absorb a trace amount of water, the sensor can also absorb other chemicals in the atmosphere. These may alter the probe's calibration or, in extreme cases, destroy the sensor. A simple rule is: if you can breath comfortably in the measuring environment, then the probe should operate accurately. However, if their concentration is high enough, the following chemicals are capable of destroying the sensor:

a. fungicides and bactericides,
b. organic catalysts and surfactants,
c. nitrous oxides,
d. chlorine (at high temperatures and high %RH),
e. sulfur dioxide (at high temperatures and high %RH),
f. ketones and acetones (at high temperatures),
g. ethylene oxide.

Certain other chemicals (ammonia, alcohol, formaldehyde) can cause the sensor to give a false high %RH reading.

Few, if any, of the above will be found in standard IAQ or HVAC environments; they are only likely to be met in special applications.
4. RELATIVE HUMIDITY AND DEWPOINT

The above information regarding chemical pollution is provided only as a guide. If you are concerned about the chemical environment you should contact GrayWolf or your distributor for advice. Specify the temperature and approximate humidity, along with the concentrations and types of chemicals present.

The following points provide general guidance for the successful use of the 2300AHTS probe:

- The humidity and temperature sensor will respond more rapidly if there is some air flow. In still air, gently wave the probe from side to side.

- Avoid contaminating the humidity sensor with cigarette smoke. The tar residue can alter the calibration.

- Relative humidity depends on temperature and, typically, will change by 3% for a 1°C (2°F) change in temperature. Always allow sufficient time for the sensor to reach thermal equilibrium when checking rooms at different temperatures. Note that when entering a colder room, the initial reading will be low; and for a warmer room it will be high.

- The usual lower temperature limit for humidity measurements is 0°C (32°F), but measurements at sub-zero temperatures can be made if certain corrections are applied to the displayed %RH reading. The displayed RH should be increased by 1% of the reading for each 1°C below zero. For example, at –5°C (23°F) the reading should be multiplied by 1.05. Calculated dewpoint readings are not affected.
5. AIRSPEED

WARNING

The sensor in this product operates at 180°C above ambient temperature. Do not use this probe where it could present a possible safety hazard. It is the user’s responsibility to ensure that equipment meets all relevant safety regulations. If in doubt contact GrayWolf.

Do not touch the thermistor sensor – it is very delicate. Avoid mechanical shock to the probe. Do not use the probe if the sensing head is wet. Take care not to pinch the protective cap when removing it.

5.1 INTRODUCTION

A fundamental requirement for air comfort is that there is sufficient ventilation for either the number of people or the number of square metres (or square feet) in the occupancy zone. The ventilation rate can be expressed either as cubic feet/minute/person (or litres/sec/person) or cf/min/ft² (or l/sec/m²).

Since air speed velocities normally fluctuate, the mean air speed value in an occupied zone should be measured over a single period of time (typically 3 minutes). Fluctuations in airspeed, with frequency up to 1 Hz, also significantly affect human comfort.

5.2 THE ANEMOMETER

The 2300AHTS probe uses a hot wire thermistor to measure air speed. A small thermistor is heated to a constant temperature of approximately 180°C above ambient temperature. The passing air cools the thermistor and electronic circuitry monitors the additional power required to maintain the thermistor temperature. The additional power signal is thus a measure of the air speed. A second, unheated, thermistor provides
5. AIRSPEED

compensation to correct for changes in ambient temperature.

Airspeed is a vital parameter in production areas, environmental studies, ventilation system, air quality audits and refrigeration.

The hotwire anemometer is fast and very sensitive, making it suitable for measuring turbulence and local ventilation as part of an indoor air quality audit.

The hotwire anemometer on the 2300AHTS probe can be comfortably held in one hand when used to detect draughts, check fume hoods or measure air flow and air change rates in offices and work places. The telescopic wand allows the sensors to reach up to 745mm from the handle. It must be remembered that a hotwire anemometer is not suitable for use where the air flow ambient temperature is liable to exceed 50°C (122°F) or fall below 0°C (32°F).

The user instrument displays the airspeed from 0–12 m/s in steps of 0.1 m/s or 0-2500 ft/min in steps of 22 ft/ min.

Remember to remove the protective dust cap carefully before use, and to replace it after use.

To optimise the accuracy of your airspeed measurement, the probe must be oriented so that the blue arrows on either side of the sensing head point in the same direction as the airflow.

For making measurements in air flows with changing direction, it is permissible to unscrew and carefully remove the black oval arch moulding protecting the sensor. Extreme care must be taken as the sensor will now be totally exposed and susceptible to damage.

Note: Probes are calibrated with the sensor arch firmly screwed in place. The calibration may shift by 3% (of the reading) when the arch is removed.
5. AIRSPEED

When measuring airspeed in the rain, be aware that the force of a falling raindrop can damage the sensor.

5.3 TRAVERSING A DUCT

The hotwire anemometer is ideal for traversing air ducts or for determining face velocity at registers or filters when measuring volume flow rate. By entering the duct dimensions into the Surveyor or Zephyr instrument a display of volume flow rate (VFR) is given. An averaging facility is also available on the Zephyr II, Zephyr II+ and IAQ Surveyor Pro.

To determine the airflow through a circular or rectangular duct correctly, the air velocity must be measured at several points. Use some tape or a black felt tip pen to mark the correct measurement positions when traversing the duct.

1. If there is significant swirl in the air stream you may wish to use flow straighteners, located upstream of the measurement by at least five times the duct diameter.

2. To obtain an approximate volume flow measurement that is normally accurate to 5%: measure the airspeed at the center, then multiply by 0.9 to get an average airspeed before converting to volumetric flow.

   Alternatively, measure at 10% (from the edge) of the duct diameter: this should be the average velocity in ducts with fully developed flow.

   You can also measure to an accuracy of 2% by measuring each grid point and then averaging, before calculating the air volume.

3. You can also measure volumetric flow directly by programming your instrument with your duct cross section. See the manual supplied with the instrument.
5. AIRSPEED

TRAVERSING A DUCT

Position of alternative measuring points and traverse lines, relative to side lengths, for rectangular ducts

NOTE: Distance between measuring stations should not exceed 200 mm

<table>
<thead>
<tr>
<th>No. of points or traverse lines</th>
<th>Position relative to inner wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.074, 0.268, 0.5, 0.712, 0.926</td>
</tr>
<tr>
<td>6</td>
<td>0.061, 0.235, 0.437, 0.563, 0.765, 0.939</td>
</tr>
<tr>
<td>7</td>
<td>0.053, 0.203, 0.366, 0.5, 0.634, 0.757, 0.949</td>
</tr>
</tbody>
</table>

Log Tchebycheff Rule for rectangular ducts

Log Linear Rule for traverse points on three diameters in a circular duct

NOTE: Should difficulty in access make it impossible to traverse on more than two diameters, these should be mutually at right-angles, and the number of points on each line should be increased to ten.

The spacing should be as follows: 0.019D, 0.077D, 0.153D, 0.217D, 0.361D, 0.693D, 0.763D, 0.847D, 0.923D, 0.981D

Figure 1 Traversing a duct to calculate volume flow
6. PROBE MAINTENANCE

The probe requires no routine maintenance other than to ensure that it is clean and dry after use. Ensure that the telescopic tube is closed up and the hotwire sensor protective cap is fitted, when the probe is not in use.

The most common cause of probe failure is accidental damage to one of the sensors, or extreme chemical pollution of the humidity sensor. In these cases the probe must be returned to GrayWolf or one of their service agents for repair.
7. SENSOR CALIBRATION

7.1 HOTWIRE ANEMOMETER AND Pt100

There is no fixed calibration period for the hotwire anemometer, since the measuring environment and the amount of usage both affect the need to recalibrate. For example, continuous usage at high airspeeds (at the upper end of the specified range) will cause earlier loss of calibration accuracy. Hotwire anemometers require a wind tunnel to calibrate them and so must be returned to GrayWolf or one of their service agents for recalibration.

The Pt100 Platinum temperature sensor is mechanically and electrically stable and resistant to contamination or oxidation. As such, it does not require routine calibration.

7.2 HUMIDITY SENSOR

Calibration of the humidity sensor at 6-month intervals should usually be adequate for normal ambient room temperature measurements. In high humidity / temperature applications, or in polluted or smoky environments, more frequent calibration is recommended, up to 2 or 3 monthly intervals depending on the severity of the conditions. Humidity calibration is available as an accessory kit.

7.3 HUMIDITY SENSOR CALIBRATION REFERENCES

Calibration consists of a full 2-point adjustment, referred to as zero (low cal) and gain (high cal). See the sensor calibration section in the instrument manual. Normally, the sensor retains its accuracy over long periods and the reading displayed following calibration should not change significantly from the factory calibration settings. If they do, it could indicate a contaminated sensor; the probe must then be returned to GrayWolf or one of their service agents for repair.

Calibration requires the exposure of the sensor to a molecular sieve desiccant (0%) or low humidity salt solution for the zero
7. SENSOR CALIBRATION

(Lo Cal) setting, and to a higher humidity salt solution (sodium chloride) for the span (Hi Cal) setting. Two calibration jar assemblies are therefore required, containing respectively the desiccant or 'low' salt solution and the high salt solution. A suitable calibration kit containing desiccant and sodium chloride salt for 0% and 75% RH calibration can be purchased from GrayWolf. These %RH figures are for the prescribed calibration temperature of 24.5 to 25.5°C (76 to 78°F). If the temperature is outside this range, an appropriate correction must be made to the reference %RH (see table 2). Accessory kits containing high purity salts for calibration at various RH levels are also available (see table 1).

Table 1 Salt solution accessory kits

<table>
<thead>
<tr>
<th>Accessory Reference</th>
<th>Part No.</th>
<th>Salt</th>
<th>Nominal %RH</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC11</td>
<td>P144 HC11/00</td>
<td>Lithium Chloride</td>
<td>11%</td>
</tr>
<tr>
<td>HC33</td>
<td>P144 HC33/00</td>
<td>Magnesium Chloride</td>
<td>33%</td>
</tr>
<tr>
<td>HC53</td>
<td>P144 HC53/00</td>
<td>Magnesium Nitrate</td>
<td>53%</td>
</tr>
<tr>
<td>HC75</td>
<td>P144 HC75/00</td>
<td>Sodium Chloride</td>
<td>75%</td>
</tr>
<tr>
<td>HC85</td>
<td>P144 HC85/00</td>
<td>Potassium Chloride</td>
<td>85%</td>
</tr>
<tr>
<td>HC97</td>
<td>P144 HC97/00</td>
<td>Potassium Sulphate</td>
<td>97%</td>
</tr>
</tbody>
</table>

7.4 ZERO CALIBRATION REFERENCE

The molecular sieve desiccant used as a zero RH reference absorbs any water in the air to produce a very dry atmosphere at any temperature. This will maintain a relative humidity of <5% as long as its container jar is well sealed, and can absorb up to 5% of its own weight before starting to lose effectiveness. A quick drying will rejuvenate the desiccant, giving the reference a typical life of three years or more. The jar must be sealed with its rubber stopper when not in use.
7. SENSOR CALIBRATION

If it is found that the molecular sieve dessiccant cannot maintain 0% RH (if, for instance, the jar has been left unsealed), it can be rejuvenated by drying it at 250/300°C (480/570°F) for three hours in an oven and then immediately transferring it to its jar and sealing the jar. Allow the desiccant to cool in the jar before use.

7.5 SALT SOLUTION CALIBRATION REFERENCES

The sodium chloride salt supplied with the calibration kit allows you to re-calibrate the probe high cal at (nominally) 75%RH. However if the %RH normally measured is always at a much higher or lower level, then, instead, use one of the other high purity salts available from GrayWolf (see table1 above). These will provide a %RH closer to your particular application. Table 2 lists the alternative salts that may be used, with details of the salt to distilled water proportion for the correct solution, and the variation in the resultant RH for different ambient temperatures.

To prepare the salt solution, measure the correct volume of distilled water (see table 2) into the calibration jar. Slowly pour in the correct weight of salt while stirring with a glass or plastic rod. Stir until there is approximately 2 mm (1/10 in) depth of water on top of the salt slush after settling. This will ensure the recommended condition of a thin layer of saturated water above a salt precipitate. Remove excess water with the syringe and then seal the jar.

Take care when preparing Lithium Chloride solutions as heat is generated when the Lithium Chloride is added to the water. Add the salt slowly and stir thoroughly. Allow the salt solution to stabilize for 24 hours at a constant temperature before attempting to calibrate the probe. To minimise temperature changes, do not remove the jar from
7. SENSOR CALIBRATION

The accuracy of the salt reference depends on the specific salt and is typically +/- 2%RH, but can be as low as +/- 20% if the salt is incorrectly prepared. Certain precautions should be followed to ensure an accurate salt reference:

- The salt solution should be kept at a constant temperature (<1°C/hr variation) during stabilization and calibration.

- Once the salt solution is prepared, keep it at a constant temperature (ideally the same as the calibration room) so that it is always ready for use. The 24 hour stabilization period is necessary only when first preparing the solution.

- Excessive temperature cycling of the salt solution will form crystals and the solution may not remain saturated. If it has been subjected to an excessively high temperature, prepare a fresh solution.

- Always ensure that the calibration jar is sealed with its rubber stopper, when not in use.

- Before using sodium chloride solution, check that it has not lost so much water that it has become dehydrated.

- When using lithium chloride solution, ensure that its temperature never falls below 18°C (64°F); otherwise it must be replaced.

- Salt solutions have a finite life. It is recommended that high RH solutions (>70%RH) are renewed at monthly intervals, and low RH solutions (<70% RH) at two monthly intervals.

A humidity sensor cannot be calibrated quickly. First, the calibration room temperature must be stable, ideally at
7. SENSOR CALIBRATION

Table 2: %RH of saturated binary salts at different temperatures

<table>
<thead>
<tr>
<th>Salt</th>
<th>Solution</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Salt</td>
<td>10 C</td>
</tr>
<tr>
<td></td>
<td>(g)</td>
<td>50 F</td>
</tr>
<tr>
<td>Lithium Chloride (anhydrous)</td>
<td>80</td>
<td>36</td>
</tr>
<tr>
<td>Magnesium Chloride (hexahydrate)</td>
<td>95</td>
<td>10</td>
</tr>
<tr>
<td>Magnesium Nitrate (hexahydrate)</td>
<td>100</td>
<td>12</td>
</tr>
<tr>
<td>Sodium Chloride</td>
<td>100</td>
<td>28</td>
</tr>
</tbody>
</table>

25 +/- 0.5°C (77 +/- 1°F); then, at least 24 hours must be allowed after mixing fresh salts for the salt reference to stabilise; the probe must then be allowed to stabilise, without power applied; (if power is applied during this period the hot wire will heat the salt solution); finally, allow at least another 2 hours to calibrate the probe.

Calibration of the 2300AHTS is carried out with the probe connected to a Surveyor or Zephyr instrument running in its channel calibration mode.

When calibration is complete the instrument writes the calibration information to the 2300AHTS probe memory. The probe can subsequently be connected to any Surveyor or Zephyr instrument and maintain its calibration settings.

7.6 CALIBRATION PROCEDURE
7. SENSOR CALIBRATION

Refer to the instrument manual for details of running the probe calibration mode.

- Connect the 2300AHTS probe to the instrument. Ensure that the instrument is switched off at this moment in time.

- Fit the probe into the zero reference calibration jar and allow for the probe sensor to stabilise for 60 minutes.

- Switch the instrument on and via the menu system enter calibration mode.

- Check that the Low Cal and High Cal points are correct for the salt solutions being used, taking into consideration any variations in ambient temperature. If necessary, adjust the calibration points in the Do Standard Cal Setup screen.

- Proceed with the Low Cal (zero) calibration on the instrument.

- Remove the probe from the calibration jar and allow it to stabilize in ambient air for 10 minutes.

- Switch the instrument off.

- Fit the probe into the gain reference calibration jar (75.3%RH salt solution) and allow the probe sensor to stabilize for 60 minutes.

Caution
7. SENSOR CALIBRATION

Do not expose the 2300AHTS probe to the sodium chloride solution for more than 75 minutes as this may cause the sensor to saturate, indicated by the reading increasing continuously instead of stabilizing.

- Switch the instrument on and proceed with the gain calibration on the instrument.
- Remove the probe from the calibration jar and switch off the instrument.
8. SERVICE

A probe fault may manifest itself in two different ways. Firstly, the instrument may be unable to calibrate the probe. The instrument informs the user of this by displaying WARNING – PROBE FAILED TO CALIBRATE. If this occurs, please ensure that the calibration method is correct; for example the probe is seated correctly in the calibration jar.

Secondly, a channel may display an overflow or underflow indication (3 arrows) in place of the sensor reading. This may indicate that the sensor is faulty, or it may be because the sensor is outside its specified operating range.

If the probe is being used in its correct environment, but 3 arrows are still being displayed, or the probe will not calibrate:

- Notify GrayWolf's Service Department (the address is on the back cover of this manual, the telephone number is on the back of the instrument) or your nearest distributor, and give full details of the problem or the required servicing, together with the probe serial number. You will then be given shipping instructions.

- Forward the probe as instructed with shipping prepaid. GrayWolf or your distributor will repair and calibrate the probe, and return it, shipping prepaid.

For probe returns, please contact your nearest service location for a 'Return Authorization Number' before despatching the probe. This procedure helps GrayWolf to provide you with a speedy response and accurate tracking of your probe.
# 9. SPECIFICATION

## 2300AHTS

Operating Temperature Range: 0°C to 50°C  
32°F to 122°F

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sensor</th>
<th>Range / Resolution (Instrument + Probe)</th>
<th>Accuracy</th>
</tr>
</thead>
</table>
| Relative Humidity      | Polymer Capacitor                | 0.0 to 98.0 %RH                        | +/- 2%RH (<75%RH)  
                         |                                  |                                        | +/- 3%RH (>75%RH) |
| Dewpoint               | Calculated from %RH and temperature | -33.0 to +70.0°C  
                         |                                  | (-27.4 to +158.0°F)  
                         |                                  | (240 to 343K)  
                         |                                  |                            |
| Temperature            | Platinum Pt100                   | -26.0 to +70.0°C  
                         |                                  | (-15.0 to +158.0°F)  
                         |                                  | (247 to 343K)  
                         |                                  |                            |
| Air Velocity           | Hotwire bead                     | 0 to 2500 f/m  
                         |                                  | (0.00 to 12.00 m/s)  
                         |                                  |                            |
| Volume Flow Rate       | Calculated from air velocity and duct dimensions | 0 to 10,000 ft³/m  
                         |                                  | 0 to 10,000 ft³/h  
                         |                                  | 0 to 50.8 m³/sec  
                         |                                  | 0 to 167 m³/m  
                         |                                  |                            |
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