FLUKE®
Calibration

# Sales Guide

## 5128A RHapid-Cal Humidity Generator

**Fast, portable humidity sensor and logger calibration with accredited 1% RH system accuracy**


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## Introduction

The 5128A RHapid-Cal Humidity Generator is a portable humidity generator for calibrating a large workload of probes in the laboratory or on-site in the field. It provides fast, accurate multi-point calibration of humidity probes and data loggers.

The 5128A RHapid-Cal is backed by Fluke Calibration's world-class metrology and support. It comes standard with an ISO 17025 accredited system calibration. Support offerings include online chat, email, phone, and product service from Fluke and channel partners.

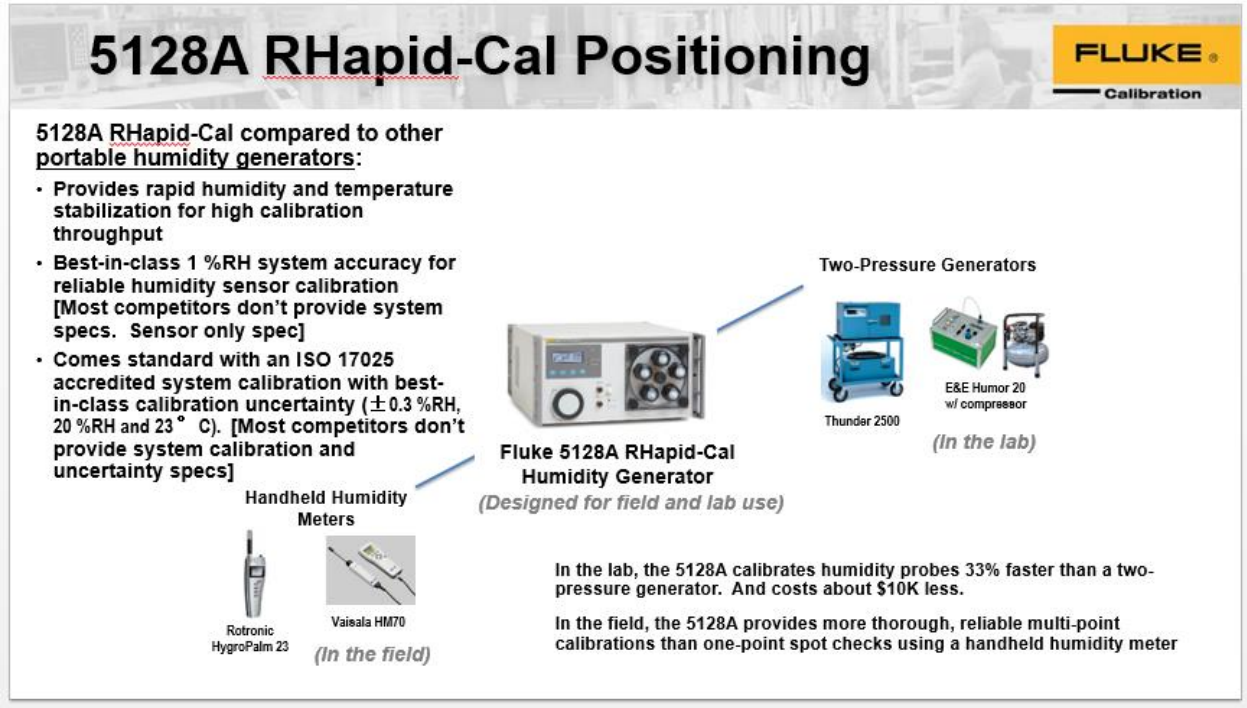
## Value Proposition

Compared to other portable humidity generators, the 5128A RHapid-Cal:

- Provides rapid humidity and temperature stabilization for high calibration throughput
- Offers best-in-class 1 %RH system accuracy for reliable humidity sensor calibration
  [Most competitors do not provide a system accuracy spec. Typically, they provide a sensor only humidity accuracy spec.]
- Comes standard with an ISO 17025 accredited system calibration
  [Most competitors do not include an accredited system calibration]

**In the lab**, the 5128A calibrates humidity probes 33% faster than a two-pressure generator (a typical six-point calibration: 5128A 2 hours, Thunder 2500 3+ hours). And costs about $10K less (e.g. U.S. list price 5128A $26.6K, Thunder 1200 $36K).

**In the field**, the 5128A provides more thorough, reliable multi-point calibrations than one-point spot checks using a handheld humidity meter (e.g. Rotronic HygroPalm 23, Vaisala HM70),




## Target Customers

Independent calibration labs, Corporate calibration and research labs where humidity measurement is critical to prevent spoilage of products (condensation, bacteria/germ growth, molding, electrostatic discharge, corrosion, warping):

- Pharmaceuticals
- Medical devices
- Semiconductors
- Chemicals
- Health care
- Aerospace
- Automotive
- Food processing

Customer personas and key motivators

- Lab managers:  lab throughput, cost/budget, trusted metrology
- Calibration technicians:  tool ease-of-use, portability, efficiency

Value Statement

Calibrate humidity probes and loggers 33% faster than a two-pressure generator with accredited 1% RH system accuracy, in the lab or in the field.

## Target Applications

### RH probes, meters & transmitters





Typical brands: many

- Characteristics
  - Must be long enough for 1" insertion through door
  - Generally 2-5% accuracy
- How to calibrate?
  - Insert up to 5 probes through ports in 5128A door
  - Select grommet to fit probe diameter snugly
  - Plug unused ports
- Solution to quote:
  - 5128A RHapid-Cal
  - Grommet kit
  - Extra desiccant(s) (optional)


### RH monitors & wall-mounted transmitters

Typical brands: Rotronic, Vaisala, E+E, many others

- Characteristics
  - Customers generally want/need to leave transmitter in place during calibration.
  - Sensor accuracy varies 1-3%

- How to calibrate?
  - Some models allow the probe to be detached for calibration. Connect the probe to transmitter by cable or to a handheld device to read it while inserted in 5128A chamber. Cables are supplied by the transmitter manufacturer.
  - For the most accurate probes, a chilled-mirror hygrometer reference may be used with 5128A generator to calibrate.

- Solution to quote:
  - 5128A RHapid-Cal
  - Grommet kit
  - Extra desiccant(s) (optional)

**RH data loggers**

Typical brands: Testo, Comark, Mesa Labs, Kaye, Lives, Ellab, etc.

- Characteristics
  - Don't usually have a long probe to insert through chamber door
  - RH accuracy varies, most are 2-3%

- How to calibrate?
  - Place loggers inside 5128A chamber. Use the clear door with shelf accessory for easy mounting and viewing in chamber.
  - Number of loggers depends on size and fit and output type.
  - Take logger readings either visually, wirelessly, or download after test.

- Solution to quote:
  - 5128A RHapid-Cal
  - Clear (no ports) square door with shelf accessory
  - Extra desiccant(s) (optional)


**FCAL 1620A DewK Precision Thermo-Hygrometer**

Typical brand: Fluke Calibration, Hart Scientific


- Characteristics
  - RH accuracy: "S" model: 2% ; "H" model: 1.5%
  - Calibrated range: 20 to 70 %RH

- How to calibrate?
  - Strategy 1 – Direct calibration with 5128A: Test accuracy ratio between 5128A and DewK is either 2.6:1 (S) or 1.9:1 (H).
    Customer must determine whether this meets their needs.
    Guidelines for uncertainty analysis of DewK calibration with 5128A will be provided post-launch.
    Can be inserted through door but challenging to seal. May be better to place in chamber and seal around cable entry through door.

  - Strategy 2: Use a chilled mirror reference (purchase from 3rd party, Michell Instruments S8000 Remote or RH Systems 473 with RP2 probe) for better uncertainty.

- Solution to quote:
  - 5128A RHapid-Cal
  - Grommet kit
  - Extra desiccant(s) (optional)


## Key Features and Benefits

| 5128A Feature | Benefit |
|---|---|
| Best-in-class system accuracy for dependable humidity probe calibration<br><br>• Humidity accuracy:<br>System: ±1.0 % RH, 7 to 80 % RH<br>±1.25 % RH, >80 to 95 % RH | The 5128A RHapid-Cal offers a best-in-class humidity system accuracy of ± 1.0 % RH which includes all known sources of error such as stability, uniformity, drift, and calibration uncertainty. Calibrate with confidence using an instrument with comprehensive specifications.<br><br>Most competing generators don't specify system accuracy. Their specifications can be complicated and confusing, making it difficult to know how to apply them to a customer's particular calibration process.<br><br>The 5128A also provides the flexibility to improve calibration uncertainty by using an external humidity reference such as a chilled mirror hygrometer. |
| Rapid humidity and temperature stabilization time for high calibration throughput | The materials and air flow design used in the 5128A RHapid-Cal are selected to ensure that response time to a humidity or temperature step change is fast. Rate of change for temperature increase is typically 10 °C/minute and for temperature decrease is 1.5 °C/minute. Rate of change for humidity increase is typically 10% RH/minute and for humidity decrease is 5% RH/minute.<br><br>In the lab, the 5128A calibrates humidity probes 33 % faster than a two-pressure generator. A six-point calibration can be done in two hours using the 5128A RHapid-Cal. In contrast, a two-pressure humidity generator takes longer to respond to humidity or temperature changes. A similar six-point calibration with a typical two- |

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| | pressure generator takes more than three hours. |
| Supports on-site, multi-point calibration of humidity probes | Spot-check or one-point probe calibration using a handheld humidity meter in the field is convenient, but limited in value. Calibration with a handheld meter needs to be carefully managed. Temperature differences between the probe and its environment, technician body heat, and moisture from breath can all cause RH measurement errors.<br><br>Further, one-point tests may cause out of tolerance readings when ambient conditions change. Using the 5128A RHapid-Cal for a multi-point calibration gives a more reliable test and truer characterization of how a humidity probe actually operates over its working range in the field. |
| Versatile design accommodates a large workload | A large variety of humidity sensors can be accommodated in the 5128A test chamber. The 5128A comes with a five-port door for calibrating up to five RH probes, meters, and transmitters at a time. An optional transparent door with a shelf is available. Data loggers are placed on the shelf inside the chamber for calibration. The mixing insert can be removed to accommodate larger devices in the chamber. |
| Compact size and lightweight for easy transport | The 5128A RHapid-Cal measures 237 mm high x 432 mm wide x 521 mm deep (9.3 in x 17 in x 20.5 in) and weighs just 15 kg (33.06 lbs). It can be easily carried to any desired bench space in the lab or transported on-site to a field work location. Its front-loading internal desiccant cartridge design adds convenience and ruggedness.<br><br>In comparison, a two-pressure humidity generator is practically limited to laboratory use because of its large size. It includes a generator, compressor, and supporting equipment. A “small” two-pressure generator |

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| | requires about eight times the space that the 5128A RHapid-Cal does and weighs about four times as much.<br><br>The 5128A RHapid-Cal is easily placed on a small cart for plant-wide transport and a convenient wheeled transport case is offered for shipment or transport to on-site calibrations. |
| ISO 17025 accredited system calibration included standard | Prior to shipment, each 5128A RHapid-Cal receives an accredited system calibration by Fluke of the humidity chamber with its internal reference probe, using a chilled mirror hygrometer as the reference standard. This system calibration provides the assurance that the 5128A and its internal reference probe have been optimized for the best performance when they leave the factory. In contrast, some humidity generator suppliers only provide a reference probe calibration, but not a complete system calibration that ensures uniformity and accuracy delivered at the location of your device under test.<br><br>Most competitors do not include an accredited system calibration. |
| Easy to maintain | The 5128A RHapid-Cal uses a mixed-flow method to generate relative humidity. A desiccant cartridge provides a source of low humidity and an internal humidifier generates high humidity. A display light indicates when the desiccant cartridge needs to be replaced. The desiccant cartridge can be easily changed by unscrewing the front panel cap and replacing the old cartridge with a new one.<br><br>Lifetime testing of the desiccant cartridge in our lab showed that it lasted 133 cycles before failing (a complete cycle was measured from 18 °C / 7 %RH to 23 °C / 95 %RH and back). Assuming a typical customer |

| | |
|---|---|
| | cycles once per day, the cartridge should last over 6 months before replacement.<br><br>Only clean distilled water is needed to operate the 5128A RHapid-Cal. Compressed air or other additional fluids are not required. A water level indicator on the front panel shows status of water level in the humidity generator. When the water level falls below the minimum level, use clean distilled water to fill the reservoir.<br><br>No special shut-down routines are required after use, so you can move on to the next job quickly. |

## Common Sales Scenarios

### 1. Customer using or considering Handheld Humidity Meter (Vaisala HM70, Rotronic HygroPalm 23) for spot-check, 1-point probe calibrations in the field


Vaisala HM70


Rotronic
HygroPalm 23

Why buy a 5128A RHapid-Cal

- Does multi-point calibrations:
  - More thorough than a one-point test: A calibration with several test points gives a much truer characterization of an RH probe over its full working range. One-point tests may cause out of tolerance readings when ambient conditions change.
  - More reliable than a one-point test:
    - 5128A provides a very stable test environment with excellent accuracy, stability and uniformity. Temperature and humidity settings can be controlled over a wide range.
    - Handheld meters: Calibration process with a handheld meter needs to be carefully managed. Temperature differences between the probe and its environment, technician body heat, and moisture from breath can all cause RH measurement errors.

- Calibrates multiple sensors fast:
  - 5128A calibrates up to 5 probes at once. Fast stabilization time when changing temperature and humidity test points
  - Handheld meters: One sensor at a time

- Small unit that's easy to transport to the field
  - Height 237 mm (9.3 in) x Width 432 mm (17.0 in) x Depth 521 mm (20.5 in). Weight 15 kg (33.07 lb).

## 2. Using or considering a Compact/Portable Humidity Generator (Michell HygroCal 100 or Edgetech RH CAL) for humidity calibration/validation in the field

Michell
HygroCal 100

Edgetech
RH Cal

Why buy a 5128A RHapid-Cal

- Does multi-point calibrations:
  - 5128A controls both temperature and humidity. Compact generators may control RH but not temperature, giving an incomplete characterization. This may cause out of tolerance readings when ambient temperature changes.
  - Compact generators do not accommodate longer probe immersion or calibrating data loggers in the chamber.

- Compact unit that's easy to transport to the field
  - Height 237 mm (9.3 in) x Width 432 mm (17.0 in) x Depth 521 mm (20.5 in). Weight 15 kg (33.07 lb).

- Another low-cost solution is salt humidity standards
  - Fixed RH points, no temperature control, messy and inconvenient

## 3. Considering Thunder Scientific or other two-pressure generator

Thunder 1200

Thunder 2500

RH Systems G9

Why buy a 5128A RHapid-Cal

- Takes much less time to calibrate RH sensors (increases productivity): 5128A has faster temperature heating/cooling times and faster RH increase/decrease response time than Thunder
  - 5128A: 10 C/minute heating and 1.5 C/minute cooling time. 10% RH/minute increase and 5% RH/minute decrease response time.
  - Thunder 1200: 0.5 C/minute heating and 0.25 C/minute cooling time. Thunder does not specify their RH response times.
  - Thunder 2500: 0.4 C/minute heating and 0.4 C/minute cooling time.

- Excellent chamber uniformity specifications
  - 5128A: Uses a "mixing insert" that circulates air in the chamber in a manner that achieves excellent temperature and humidity uniformity. 5128A specifications (chamber temperature range 18 to 28 °C, 7 to 95 %RH) are humidity uniformity ±0.3 %RH and temperature uniformity ±0.12 °C.
  - Thunder: Chamber temperature uniformity is ±0.1 °C when operated at temperatures within 10 °C of room ambient temperature. Thunder doesn't publish a humidity uniformity spec. It is common practice to place a copper tube within the Thunder chamber as a "sweet spot" for taking measurements to compensate for a humidity and temperature uniformity gradient issue. The chamber area outside the copper tube does not give uniform readings and limits the volume available for doing calibrations.

- Small unit that's easy to transport to the field
  - 5128A: Height 237 mm (9.3 in) x Width 432 mm (17.0 in) x Depth 521 mm (20.5 in). Weight 15 kg (33.07 lb).
  - Thunder 1200 (generator, compressor, and cart): Height 44.8" (1138 mm) x Width 30.6" (777 mm) x Depth 20.0" (508 mm). Weight 140 lb (63.5 kg).
  - Thunder 2500 (generator, compressor, and cart): Height 53" (1346 mm) x Width 40" (1016 mm) x Depth 23" (584 mm). Weight not specified.

- Use 5128A with chilled mirror hygrometer reference for lower uncertainty

- Far more economical
  - 5128A is about half the cost of Thunder 2500. About $10k less than Thunder 1200.

## 4. Comparing against other transportable generators

Rotronic HygroGen2

Michell S904

Testo Huminator II

GEO 2000 SP

Why buy a 5128A RHapid-Cal

- Offers best-in-class 1 %RH system accuracy and 0.50 %RH expanded calibration uncertainty for reliable humidity sensor calibration
  - 5128A: Provides complete Fluke-backed specifications and accredited system calibration
  - Competitors: Most do not provide an extended calibration uncertainty or system accuracy. Typically, they provide a sensor only humidity accuracy spec. Most do not include an accredited system calibration.

- Fast time to calibrate RH sensors (increases productivity):
  - Five probe UUT capacity
  - 5128A is designed for fast temperature and humidity stabilization times
  - 5128A: 10 C/minute heating and 1.5 C/minute cooling time. 10%RH/minute increase and 5% RH/minute decrease response time.
  - Competitors: Rotronic HygroGen2: 5.4C/minute heating and 18%RH/minute increase response time, 0.92C/minute cooling, but no spec for RH decrease. Michell S904 & OptiCal 1.5 C/minute heating and 0.7 C/minute cooling time. Many do not publish RH response times.

- Backed by world-class support (online chat, email, phone, local service from Fluke and channel partners)

## 5. Customer owns Thunder Scientific 2500 in lab

Thunder 2500

Why buy a 5128A RHapid-Cal

- Add 5128A to fleet:
  - Add throughput and portability
  - Reduce backlog and wear & tear on Thunder system
  - Use Thunder chamber for reference to calibrate 5128A internally

- Takes less time to calibrate RH sensors (increases productivity):
  - 5128A: 10 C/minute heating and 1.5 C/minute cooling time. 10% RH/minute increase and 5% RH/minute decrease response time.
  - Thunder 2500: 0.4 C/minute heating and 0.4 C/minute cooling time. Thunder does not specify their RH response times.

- Excellent chamber uniformity specifications
  - 5128A: Uses a "mixing insert" that circulates air in the chamber in a manner that achieves excellent temperature and humidity uniformity. 5128A specifications (chamber temperature range 18 to 28 °C, 7 to 95 %RH) are humidity uniformity ±0.3 %RH and temperature uniformity ±0.12 °C.
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- Small unit that's easy to transport to the field:
  - 5128A: Height 237 mm (9.3 in) x Width 432 mm (17.0 in) x Depth 521 mm (20.5 in). Weight 15 kg (33.07 lb).
  - Thunder 2500 (generator, compressor, and cart): Height 1346 mm (53 in) x Width 1016 mm (40 in) x Depth 584 mm (23 in). Weight not specified.

## 6. Customer does not currently do Humidity Calibration

Why buy a 5128A RHapid-Cal

- Most monitors and sensors are specified at 2-5% RH accuracy and can be properly tested by 5128A
- It may take only 35 calibrations per year for 5128A to pay for itself in 3 years (@ $250 per calibration)
- Consolidate vendor approval, service and support with your other instruments

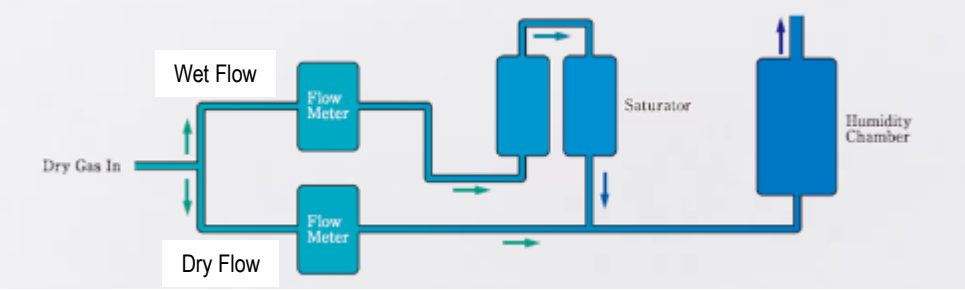
## Humidity Generator Technology

Most humidity generators are based on one of two designs:

- Mixed-flow (also called Divided-flow and Split-stream)
- Two-pressure (or a Two-pressure, Two-temperature variation)

### Mixed-Flow Generator

The Mixed-flow generator uses a "split-stream" principle to accurately control the humidity of the air leaving the system. A very accurate internal control probe continuously monitors the RH and temperature in the test chamber. If the air coming out of the system is too humid, then more air (at the same temperature) is mixed in to reduce the relative humidity.




**Mixed-Flow Humidity Generator Design**
Diagram source: Shinyei

In the split-stream method, the dry air stream is divided into two parts. One of these is then saturated (or partially saturated) with water vapor. The still dry air is then mixed in to achieve the desired humidity output after the saturation process. The humidity achieved will depend on

the humidity of the wet air, and the ratio of mixing. A high volume fan inside the test chamber provides the uniformity of temperature and humidity essential for calibrating multiple sensors.

Some mixed-flow generators also employ a "double dilution" principle where the air being input after humidification comes from a different source.

Examples of Mixed-Flow Humidity Generators:


Fluke 5128A RHapid-Cal


Rotronic Hygro-Gen 2


Michell S904


Testo Huminator II


GEO 2015-TS


GEO 2000 SP


Kaymont 2000 SP


General Eastern Humilab


Shinyei SRG

**Two-Pressure Generator**

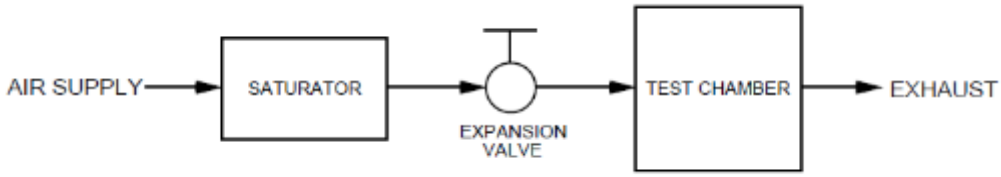



Diagram source: Thunder Scientific

In a two-pressure generator, there are two chambers maintained at the same temperature. In the first chamber, known as the saturator, air is saturated with water vapor at high pressure. The air then passes to the test chamber, which is at a lower pressure. As the air reduces in pressure, its relative humidity drops as well, so the relative humidity in the test chamber is given by

$$RH = \frac{P_T}{P_S} \times 100\%$$

- RH is the relative humidity
- $P_T$ is the test chamber pressure
- $P_S$ is the saturation chamber pressure

Humidity generation in a two-pressure system does not depend on measuring the amount of water vapor, but is dependent on temperature and pressure measurements alone. The precision of the system is determined by the accuracy of temperature and pressure throughout the system.

Since the relative humidity is given by the ratio of the two chamber pressures, if the test chamber pressure is set to the desired condition, then the desired relative humidity can be achieved by simply varying the saturation chamber pressure. This means that the humidity in the chamber doesn't need to be measured directly.

Examples of Two-Pressure Humidity Generators:

Thunder 1200

Thunder 2500

RH Systems G9

E+E Humor 20

A variation of the two-pressure design is a "two-pressure, two-temperature" generator. This design is based on the "two-pressure principle" where humidity is generated by fully saturating air at a known temperature and pressure, then reducing the pressure in the test chamber to a lower value (typically ambient). Then the test chamber is cooled or warmed to an alternate temperature. So, in this "two-pressure" design, the air in the saturator and the test chamber are at two different temperatures.

A two-pressure, two-temperature generator generates a particular relative humidity by first selecting a suitable saturation temperature ($T_s$), then determining the saturation pressure ($P_s$),

required to establish the correct %RH at test temperature ($T_t$), and test pressure ($P_t$). Relative humidity is dependent on both the test temperature and test pressure.

Examples of Two-Pressure, Two-Temperature Humidity Generators:

Thunder 3900

RH Systems G2

## Humidity Generator Technology Summary

| | Mixed-flow Generator | Two-pressure Generator |
|---|---|---|
| Calibration speed | Fast<br><br>Fluke 5128A: 10C/minute heating and 1.5C/minute cooling time. 10%RH/minute increase and 5%RH/minute decrease response time. | Slow<br><br>Thunder 2500: 0.4C/minute heating and 0.4C/minute cooling time. Thunder does not specify their RH response times. |
| Humidity specs | Good<br><br>Fluke 5128A:<br>Humidity accuracy:<br>1% (7–80% RH)<br>1.25% (80–95% RH)<br>Humidity uniformity:<br>0.3% RH (18C to 28C) | Better<br><br>Thunder 2500:<br>Humidity accuracy: 0.5%<br>Humidity uniformity: Not specified |
| Temperature specs | Good<br><br>Fluke 5128A:<br>Temperature accuracy:<br>0.2C (18C to 28C)<br>Temperature uniformity:<br>0.12C (18C to 28C) | Better<br><br>Thunder 2500:<br>Temperature accuracy: 0.06C<br>Temperature uniformity: 0.1C |
| Portability | Compact, single piece of equipment. For lab use or easy transport to the field.<br><br>Fluke 5128A: Height 237 mm (9.3 in) x Width 432 mm (17.0 in) | Two large pieces of equipment with cart. Requires compressed air. Suited for lab use.<br><br>Thunder 2500 (generator, compressor, and cart): Height 1346 mm (53 in) x Width 1016 |

| | | |
|---|---|---|
| | x Depth 521 mm (20.5 in). Weight 15 kg (33.07 lb). | mm (40 in) x Depth 584 mm (23 in). Weight not specified. |
| Chamber size | Good<br>1 to 2 liters typical | Better<br>Thunder 2500: 23.5 liters |
| Price | More economical<br>$18K to $32K | Expensive<br>Thunder 2500: $50K |

**Sources:**

- Methods of Humidity Generation by Owlstone (http://www.owlstonenanotech.com/humidity/generation-methods)
- Shinyei SRG Series Datasheet
- Thunder Scientific 1200 Model Manual
- Thunder Scientific 3900 Model Manual
- RH Systems G2 Humidity Generator Brochure

**Chilled Mirror Hygrometer Reference**

A chilled mirror hygrometer (CMH) can be employed as a reference to calibrate humidity generators. Chilled mirror instruments have been used as a NIST-referenced humidity transfer standard in metrology laboratories for the past four decades. Its principle of operation is simple, but is highly precise, stable and provides repeatable results.

Chilled mirrors measure "dew point", which is a measure of water vapor concentration and is the temperature at which dew will form on a surface. Since dew point is specific to water vapor concentration and not temperature dependent, measurement precision is consistent across the full application range including high temperature and humidity conditions in climatic test chambers.

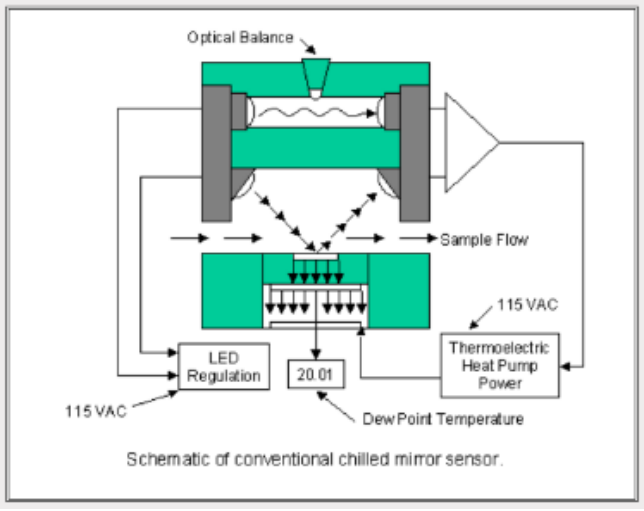



Diagram source: Thunder Scientific

Chilled mirrors detect dew point by cooling a reflective "mirror" surface until water begins to condense. The mirror is maintained at a temperature where the rate of dew condensation exactly equals the rate of the dew evaporation. In this state, the mass of the dew layer is neither increasing nor decreasing, and is in equilibrium with the water vapor pressure of the surrounding gas sample, which is the dew point temperature. Under these conditions, the surface temperature of the mirror represents the saturation temperature for the water vapor in the gas under measurement.

**Pros and Cons of Chilled Mirror Hygrometers**

Pros:

- Best measurement capability
- Highly stable. Do not drift significantly.
- Operates over a broad range of humidity conditions

Cons:

- Expensive $20K-$30K
- Long stabilization time
- Requires very clean environment
- High level of maintenance
- Requires a skilled, trained operator

Examples of Chilled Mirror Hygrometers:

RH Systems 473

Michell S8000 RS

General Eastern OptiSonde

**Sources:**


- RH Systems 473 Dew Point Hygrometer Datasheet
- Michell S8000 RS High-Precision Chilled Mirror Hygrometer Datasheet
- Rotronic HygroGen 2 Instruction Manual
- The Chilled Mirror Hygrometer: How It Works, Where It Works-and Where It Doesn't by David J. Beaubien (Sensors Online)
- Pros & Cons of Humidity Measurement Technologies Webinar by Rotronics

## Competitive Comparison

### Fluke 5128A RHapid-Cal vs. Portable Humidity Generators

| Feature | Fluke 5128A RHapid-Cal | Rotronic HygroGen2-S | Michell S904 | Testo Huminator II | GEO 2015-TS | Michell OptiCal (w/ chilled | GEO 2000 SP |
|---|---|---|---|---|---|---|---|
| |  |  |  |  |  |  |  |
| Expanded Calibration Uncertainty | ±0.50 %RH at 23 °C and 80% RH | Not specified | Not specified | ±1.5 %RH at 25 °C and 10% to 85% RH | Not specified | Not specified | Not specified |
| Humidity Range | 7% to 95% RH | 5% to 95% RH | 10% to 90% RH | 5% to 95% RH | 7% to 95% RH | 10% to 90% RH | 7% to 95% RH |
| Humidity Accuracy | System: ±1.0 %RH, 7 to 80 %RH ±1.25 %RH, >80 to 95 %RH Sensor only: Not specified | System: ±1.59 %RH at 23 °C and 80% RH* Sensor only: ±0.8 %RH, 10 to 30 °C | System: Not specified Sensor only: ±1.0 %RH | System: Not specified Sensor only: 1% + 0.007 x measured value (0-90 % RH) | System: Not specified Sensor only: ±1.0 %RH | System: Not specified Sensor only: ±1.0 %RH | System: Not specified Sensor only: ±1.0 %RH |
| Humidity Uniformity ** | ±0.05 %RH at 7 % RH ±0.3 %RH at 45 %RH ±0.7 %RH at 95 %RH | 0.1%RH gradient | | ±0.5 %RH | ±0.2 %RH | | ±0.2 %RH |
| Humidity Stability | ±0.15 %RH | <±0.1%RH | ±0.2 %RH | ±0.3 %RH | ±0.3 %RH | ±0.2 %RH | ±0.3 %RH |
| Temperature Range | 5 °C to 50 °C | 0 °C to 60 °C | 10 °C to 50 °C | 5 °C to 50 °C | 10 °C to 55 °C | 10 °C to 50 °C | 10 °C to 55 °C |
| Temperature Accuracy | System: ±0.2 °C, 18 to 28 °C Sensor only: Not specified | System: Not specified Sensor only: ±0.1 °C, 18 to 28 °C | System: Not specified Sensor only: ±0.1 °C | System: Not specified Sensor only: ±0.15 °C | System: Not specified Sensor only: ±0.1 °C | System: Not specified | System: Not specified |
| Temperature Stability | ±0.05 °C, 18 to 28 °C | <±0.01 °C | ±0.1 °C | ±0.02 °C | ±0.1 °C | ±0.1 °C | ±0.1 °C |
| Temperature Uniformity *** | ±0.12 °C, 18 to 28 °C | <±0.05 °C gradient | | ±0.2 °C | ±0.1 °C | | ±0.1 °C |
| Response time, RH increasing | 10 %RH/minute | 18 %RH/minute | | 15 %RH/minute | | | |
| Response time, RH decreasing | 5 %RH/minute | | | | | | |
| Response time, temp increasing | 10 °C/minute | 5.4 °C/minute | 1.5 °C/minute | | 10 °C/minute | 1.5 °C/minute | 10 °C/minute |
| Response time, temp decreasing | 1.5 °C/minute | 0.92 °C/minute | 0.7 °C/minute | | 1.5 °C/minute | 0.7 °C/minute | 1.5 °C/minute |
| Sensor under test capacity | 5 max | 6 max | 5 max | 5 max | 4 max | 5 max | 4 max |
| Chamber working volume | 1.33 liters | 1.5 liters | 2 liters | 4.2 liters | 1 liter | 2 liters | 1 liter |
| System calibration | 17025 accredited system calibration standard | No | No | No | No | UKAS accredited system calibration | No |

* See the Rotronic HygroGen2 Instruction Manual, E-M-HG2-S-V2.1 document code, page 72 for details.

** Humidity uniformity varies with RH value and temperature. The 5128A has humidity uniformity as low as 0.05 %RH (at 18 °C, 7 %RH). At 23C 45% RH, the 5128A uniformity is 0.33%. Rotronic does not list their temperature and humidity test assumptions for their 0.1%RH gradient specification.

*** Applies to 5128A working volume and specified temperature range. Competitors do not specify working volume and temperature range.

| Legend |
|---|
| Best |
| Better |
| Good |

### Evaluating Specifications of Portable Humidity Generators

It is always a challenge to compare specifications of calibration instruments from different manufacturers. This is especially true for portable humidity generators. One reason for the extra complexity is that humidity is a relational parameter involving measurement of temperature and measurement of water content in the air. And frankly, high-accuracy humidity measurement is difficult. The purpose of this information is to help you educate customers about how the Fluke Calibration 5128A RHapid-Cal Humidity Generator compares with other competing models on key measurement specifications. In particular, it will help you communicate the important performance areas where the 5128A RHapid-Cal compares very favorably with leading competitors and will help fill in the gaps from the side-by-side Competitive Comparison summary.

First, it is important to consider that Fluke Calibration seeks to provide instruments to our customers that operate at a high level of quality and are specified in a manner to support this. Comprehensive detail and adherence to requirements for establishing traceability were two of the main considerations in the development of the 5128A specifications. It is safe to say that

the 5128A is a high-performing and metrologically-sound portable humidity generator compared to other products in the market place.

Typically a calibration customer is most interested in accuracy specifications. Other specifications such as uniformity and stability are also often considered but usually secondarily as compared with accuracy. In the humidity calibration industry, it is common practice to focus on these three important parameters but often calibration uncertainty is not specified or discussed in marketing literature. Or, calibration uncertainty is inappropriately large, when compared with humidity accuracy specifications, to properly support metrology best practice. For this reason, this discussion includes calibration uncertainty as a topic to help customers get a complete view of a portable humidity generator's performance, especially as it pertains to traceability and providing confidence in calibration results.

## Calibration Uncertainty

Calibration uncertainty is a net sum of the measurement uncertainties (sources of error) that occur when calibrating an instrument and establishing traceability to reference standards. Normally calibration uncertainty is not a leading specification because it is typically at least four times less (4:1 TUR) than the overall accuracy specification of the instrument and is built into the product accuracy specification. However, in the humidity measurement industry it is common to see an accuracy specification that is advertised without including calibration uncertainty or the advertised accuracy represents just one of possibly several sources of uncertainty.

It is critical for an instrument user to know the calibration uncertainty because it is a requirement for establishing traceability and because it provides important information such as reliability of the measurement result and reliability of Pass/Fail tolerance determinations made during calibration.

The 5128A RHapid-Cal is calibrated with world-class calibration uncertainties that have been reviewed and accredited by NVLAP for compliance with ISO/IEC 17025 requirements. The uncertainties are achieved by calibrating each 5128A against a reference chilled-mirror hygrometer that is calibrated by NIST. The temperature side of the calibration is provided by Fluke Calibration temperature standards. The resulting calibration uncertainties represent the best humidity uncertainties that can be achieved in the calibration of a portable humidity generator.

**Table 1: 5128A accredited calibration uncertainties**

| *% RH* | *T (°C)* | *Uncertainty (%RH, k=2)* |
|---|---|---|
| *7* | 18 | 0.30 |
| *20* | 18 | 0.30 |
| *20* | 23 | 0.30 |
| *20* | 28 | 0.30 |
| *45* | 18 | 0.31 |
| *45* | 23 | 0.30 |

| | | |
|---|---|---|
| *45* | 28 | 0.30 |
| *80* | 18 | 0.51 |
| *80* | 23 | 0.50 |
| *70* | 28 | 0.50 |
| *95* | 23 | 0.60 |

**Humidity Accuracy**

Even in other measurement disciplines with more consistent metrology, accuracy can be a very difficult specification to analyze because the definition of accuracy varies tremendously from one manufacturer to the next. To be clear and comprehensive, and to comply with guidelines in the VIM (International Vocabulary in Metrology), Fluke Calibration expresses 5128A accuracy with the term "Absolute Instrumental Uncertainty" which includes calibration uncertainty, stability, uniformity, long-term drift, linearity, etc. to ensure the user can use the 5128A specifications with great confidence.

Close inspection of accuracy claims show that most portable humidity generator manufacturers state the accuracy (or uncertainty) of the chamber humidity sensor only. Uncertainty or accuracy of the entire humidity generator system is difficult to assess. These other sources of uncertainty such as, chamber temperature non-uniformity, stability, and long-term drift, are significant and have to be considered when using the instrument. It is left to the user to evaluate the overall uncertainty or accuracy of the humidity generator system which is very difficult because many manufacturers don't specify the temperature and humidity range or chamber area that pertains to the advertised specifications. Refer to the Rotronic HygroGen2 Instruction Manual, E-M-HG2-S-V2.1 document code, page 72 for an uncertainty framework of how the total systematic uncertainty is calculated and is much larger than the sensor-only specification.

In regards to humidity accuracy, the 5128A is the most clearly specified instrument on the market. Plus, the 5128A specifications are verified at 11 different temperature/humidity combinations in an accredited calibration which will provide confidence for the user when using the 5128A in their calibration program.

**Chamber Humidity Uniformity**

Chamber humidity uniformity is another specification that is difficult to compare. As with previously mentioned specifications, the competitors don't make it clear to what temperature and humidity points the humidity uniformity specification applies and they don't describe the area in the chamber where uniformity is defined.

To evaluate this specification it is important to first understand that humidity uniformity is estimated based on temperature uniformity and that this relationship varies depending mostly on the level of humidity and somewhat on the temperature of the sampled air. To calculate humidity uniformity from temperature uniformity, a temperature to humidity conversion factor

is used. Table 2 lists conversion factor values for several humidity values. To calculate the humidity uniformity of the 5128A operating at 45 %RH, multiply the temperature uniformity specification by 2.73 (the conversion factor for 45 %RH, 23 °C). This example results in humidity uniformity of 0.33 %RH (Uniformity_%RH = 0.12 °C x 2.73 %RH/°C = 0.33 %RH).

**Table 2: 5128A RHapid-Cal Humidity Uniformity**

| Humidity (%RH) | 7% | 45% | 80% | 95% |
|---|---|---|---|---|
| Temperature Uniformity (±°C) | 0.12 | 0.12 | 0.12 | 0.12 |
| Sensitivity Factor (%RH/°C) | 0.44 | 2.73 | 4.66 | 5.76 |
| Humidity Uniformity (±%RH) | 0.05 | 0.33 | 0.56 | 0.69 |

As previously stated, comparing the Fluke 5128A humidity uniformity specification of 0.3 %RH (at 23 °C, 45 %RH) with other instruments is difficult because competitors don't explain whether their specification is for the entire operating range or for a particular temperature and humidity and they don't make it clear what the physical area is to which the specification applies. From Table 2, we see that the 5128A has humidity uniformity as low as 0.05 %RH (at 18 °C, 7 %RH) and as high as 0.69 %RH.

## Summary

Hopefully, this information will help you make sense of some of the complex specifications associated with portable humidity generators. When looking at the entire picture and understanding all of the specifications involved in the analysis, the 5128A RHapid-Cal clearly has specifications that are both comprehensive and competitive.

## Fluke 5128A RHapid-Cal vs. Two Pressure Generators

| Feature | Fluke 5128A RHapid-Cal | E+E Humor 20 | Thunder 1200 | Thunder 2500 |
|---|---|---|---|---|
| |  |  |  |  |
| Expanded Calibration Uncertainty | ±0.50 %RH at 23 °C and 80% RH | | | |
| Humidity Range | 7% to 95% RH | 10% to 90% RH | 10% to 90% RH | 10% to 90% RH |
| Humidity Accuracy | System:±1.0 %RH, 7 to 80 %RH<br>±1.25 %RH, >80 to 95 %RH<br>Sensor only: Not specified | | ±0.5 %RH | ±0.5 %RH |
| Humidity Uniformity | ±0.05 %RH at 7 % RH<br>±0.3 %RH at 45 %RH<br>±0.7 %RH at 95 %RH | | | |
| Humidity Stability | ±0.1 %RH | | | |
| Temperature Range | 5 °C to 50 °C | | 10 °C to 60 °C | 0 °C to 70 °C |
| Temperature Accuracy | System: ±0.2 °C, 18 to 28 °C<br>Sensor only: Not specified | ±0.3 °C | ±0.05 °C | ±0.06 °C |
| Temperature Stability | ±0.05 °C, 18 to 28 °C | | ±0.04 °C | |
| Temperature Uniformity | ±0.12 °C, 18 to 28 °C | | ±0.1 °C | ±0.1 °C |
| Response time, RH increasing | 10 %RH/minute | | | |
| Response time, RH decreasing | 5 %RH/minute | | | |
| Response time, temp increasing | 10 °C/minute | | 0.5 °C/minute | 0.4 °C/minute |
| Response time, temp decreasing | 1.5 °C/minute | | 0.25 °C/minute | 0.4 °C/minute |
| Sensor under test capacity | 5 max | 4 max | | |
| Chamber working volume | 1.33 liters | 0.34 liter | 3.5 liters | 23.5 liters |
| Calibration | 17025 accredited system calibration | OEKD accredited system calibration | Accredited system calibration | Accredited system calibration |

| Legend |
|---|
| Best |
| Better |
| Good |

## Ordering Information

| Models | Description | |
|---|---|---|
| 5128A | RHapid-Cal Humidity Generator with one Square 5-Port Door, one Desiccant Cartridge, one Fill Syringe with Extension Tube, five Grommets (one each of 1/4 inch, 3/8 inch, 1/2 inch, 3/4 inch, 1 inch sizes), one Mains Power Cord 2-meter, Fluke ISO 17925 Accredited System Calibration, 115 VAC/230 VAC | |
| **Accessories** | **Description** | |
| 5128-2680 | Desiccant Cartridge (including desiccant) * | |
| 5128-2681-R5 | Round Door, 5 ports | |
| 5128-2681-S0 | Square Door, clear with shelf | |
| 5128-2681-S5 | Square Door, 5 ports (spare) | |
| 5128-CASE | 5128A Case with wheels | |
| 5128-2682-1/4 | Port Grommets Kit, 1/4", 5 each | |
| 5128-2682-3/8 | Port Grommets Kit, 3/8", 5 each | |
| 5128-2682-1/2 | Port Grommets Kit, 1/2", 5 each | |
| 5128-2682-3/4 | Port Grommets Kit, 3/4", 5 each | |
| 5128-2682-1 | Port Grommets Kit, 1", 5 each | |
| 5128-2683 | Port Plugs Kit, 5 each | |
| 5128-2684 | Fill Syringe with Extension Tube | |
| | | |
| | | |
| | | |

* Lifetime testing of the desiccant cartridge in our lab showed that it lasted 133 cycles before failing (a complete cycle was measured from 18 °C / 7 %RH to 23 °C / 95 %RH and back). Assuming a typical customer cycles once per day, the cartridge should last over 6 months before replacement.

| | |
|---|---|
| **General specifications** | |
| AC mains voltage | 100 V to 240 V ± 10 % |
| Standard frequency range | 47 Hz to 63 Hz |
| Power consumption | 300 VA |
| Required test fluid | Distilled water |
| Warm-up period | Twice the time since last warmed up, to a maximum of 30 minutes |
| Mains fuse rating | F 4A 250 V (fast blow) |
| Operating ambient relative humidity range, 18 °C to 28 °C | Up to 80 % RH |
| Storage temperature and relative humidity | -20 °C to 50 °C, 0 % to 95 % RH, non-condensing |
| Transducer power output | 12 V dc, 1 A maximum, fuse: F 1A 250V (fast blow) |
| Computer interface | USB |
| Safety | IEC 61010-1, Installation Category II, Pollution degree 2, Indoor use only |
| Altitude | 2000 m |
| **Electromagnetic compatibility (EMC)** | |
| International | IEC 61326-1: Controlled electromagnetic environment<br><br>*CISPR 11: Group 1, Class A*<br>*Group 1: Equipment has intentionally generated and/or uses conductively-coupled radio frequency energy that is necessary for the internal function of the equipment itself.*<br><br>*Class A: Equipment is suitable for use in all establishments other than domestic and those directly connected to a low-voltage power supply network that supplies buildings used for domestic purposes. There may be potential difficulties in ensuring electromagnetic compatibility in other environments due to conducted and radiated disturbances.* |
| Korea (KCC) | Class A Equipment (Industrial, broadcasting, and communication equipment)<br><br>*Class A: Equipment meets requirements for industrial electromagnetic wave equipment and the seller or user should take notice of it. This equipment is intended for use in business environments and not to be used in homes.* |
| USA (FCC) | 47 CFR 15 subpart B. This product is considered an exempt device per clause 15.103. |
| **Weight** | |
| Chassis only | 15 kg (33.06 lbs) |
| **Dimensions** | |
| Chassis | 237 mm × 432 mm × 521 mm (9.3 in × 17 in × 20.5 in) (height × width × depth) |
| Overall chamber dimensions | 200 mm (7.87 in) (depth) x 150 mm (5.90 in) (diameter) |
| Working volume dimensions | 109 mm (4.3 in) (depth) x 125 mm (4.92 in) (diameter) |
| **Temperature resolution** | |
| Display | 0.1 °C |
| USB data | 0.1 °C |
| **Humidity resolution** | |
| Display | 0.1 % RH |
| USB data | 0.1 % RH |
| **Dew point** | |
| Resolution | 0.1 °C (for indication only) |

Note: The displayed dew point reading (DP) is calculated from the Product's actual temperature and % RH readings. It is calculated as a dew point (water vapor over water) over the entire range, regardless if dew point is equal to or lower than 0 °C, and at a nominal pressure of 101.325 kPa (1 atmosphere).

The Product specifications describe the Absolute Instrumental Uncertainty of the Product. The Product specifications include stability, ambient temperature, and humidity (within specified limits), linearity, line regulation, the reference standard measurement uncertainty and long term stability of one year. The product specifications are provided at a 99 %, k=2.58, normally distributed level of confidence, unless otherwise noted.

**Chamber specifications**

One year, ambient temperature range 23 °C ±3 °C[1]

| Chamber temperature range | Chamber humidity range | Humidity specification | Temperature specification |
|---|---|---|---|
| 18 °C to 23 °C | 7 % to 80 % RH<br>>80 % to 95 % RH | ±1.0 % RH<br>±1.25 % RH | ±0.2 °C<br>±0.2 °C |
| >23 °C to 28 °C | 7 % to 80 % RH<br>>80 % to Hmax[2] % RH | ±1.0 % RH<br>±1.25 % RH | ±0.2 °C<br>±0.2 °C |

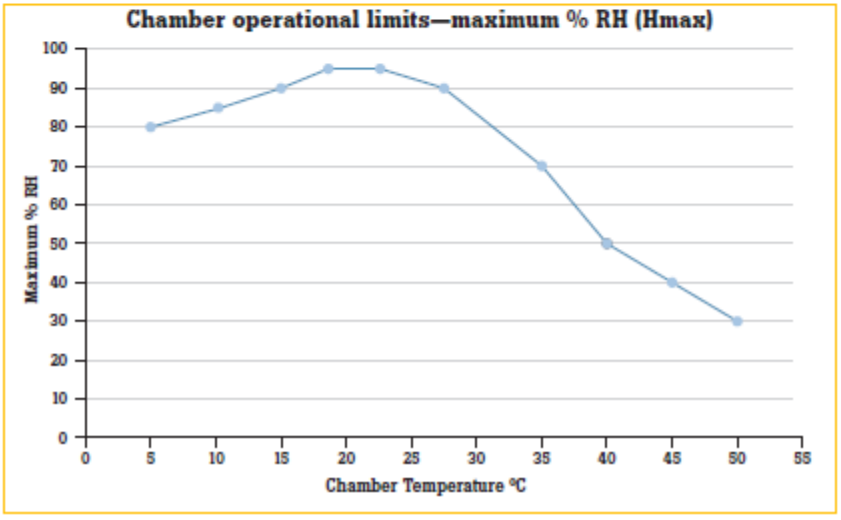
[1] For ambient conditions of 23 °C ± 5 °C, multiply the specifications by 1.5.
[2] Hmax is the maximum humidity value at which the specification applies. See the Chamber Operational Limits graph below for Hmax.
Note: Specifications apply to the Working Volume shown in the Working Volume Template found at the end of the Operators Manual, and is referenced to the "Actual" reading on the Product display.

**Chamber uniformity and stability**

Ambient temperature range: 23 °C ±3 °C[1]

| Chamber temperature | Chamber humidity range | | Chamber temperature uniformity[2] | Chamber humidity uniformity[2] | Chamber humidity stability[3] | Chamber temperature stability[3] |
|---|---|---|---|---|---|---|
| | Min RH | Max RH | | | | |
| 18 °C to 28 °C | 7 % | See chamber operational limits below | ±0.12 °C | ±0.3 % RH | ±0.15 % RH | ±0.05 °C |
| The following specifications are typical for chamber conditions shown[4] | | | | | | |
| 5 °C to <18 °C[5] | 15 % | See chamber operational limits below | ±0.5 °C | ±1.5 % RH | ±0.5 % RH | ±0.5 °C |
| >28 °C to 30 °C | 7 % | | ±0.2 °C | ±0.6 % RH | ±0.3 % RH | ±0.2 °C |
| >30 °C to 35 °C | 7 % | | ±0.3 °C | ±0.9 % RH | ±0.4 % RH | ±0.3 °C |
| >35 °C to 40 °C | 7 % | | ±0.5 °C | ±1.5 % RH | ±0.5 % RH | ±0.5 °C |
| >40 °C to 50 °C | 7 % | | ±0.5 °C | ±1.5 % RH | ±0.5 % RH | ±0.5 °C |

[1] For ambient conditions of 23 °C ± 5 °C, multiply the specifications by 1.5.
[2] Defined as the uniformity of the Working Volume.
[3] Defined as 1-sigma standard deviation of measurement readings over a 5-minute span.
[4] Chamber humidity uniformity is listed for mid-level humidity settings. Lower humidity settings will give better uniformity while higher humidity settings will give worse uniformity.
[5] The chamber control range is 5 °C to 50 °C. Achievable low temperature may be limited to 15 °C below ambient dependent upon stabilization time and temperature and humidity settings.




**Operational specifications**

| | |
|---|---|
| Temperature rate of change—down | 1.5 °C/minute (typical) |
| Temperature rate of change—up | 10 °C/minute (typical) |
| Humidity rate of change—down | 5 % RH/minute (typical) |
| Humidity rate of change—up | 10 % RH/minute (typical) |

## Humidity Principles

### What is humidity?

Humidity is the presence of water vapor in air (or any other gas). In normal room air there is typically about 1 % water vapor, but it can be present in greater or lesser amounts. High humidity makes hot days feel even hotter. Low humidity can give you a feeling of a dry throat, or sensations of "static" when touching things. Humidity is measured using a hygrometer.

### Why is humidity important?

Humidity affects many properties of air and materials in contact with it. Water vapor is key agent in both weather and climate. It is an important atmospheric greenhouse gas. A large number of manufacturing, storage and testing process are humidity-critical. Humidity measurements are used wherever there is a need to prevent condensation, corrosion, mold, warping or other spoilage of products. This is important for foods, pharmaceuticals, chemicals, fuels, wood, paper, and many other products.

### What's the difference between Absolute and Relative Humidity?

**Absolute humidity** is the measure of water vapor (moisture) in the air, regardless of temperature. It is expressed as grams of moisture per cubic meter of air ($g/m^3$). The maximum absolute humidity of warm air at 30°C/86°F is approximately 30g of water vapor ($30g/m^3$). The maximum absolute humidity of cold air at 0°C/32°F is approximately 5g of water vapor (5g/m3).

**Relative humidity** also measures water vapor but relative to the temperature of the air. It is expressed as the amount of water vapor in the air as a **percentage** of the total amount that **could** be held at its current temperature. Warm air can hold more moisture than cold air meaning that the relative humidity of cold air is far higher than warm air if their absolute humidity levels are equal.

A relative humidity of 100% means that the air can't hold any more water vapor. It's totally saturated. When this occurs, it can rain. In fact, the relative humidity must be 100% where clouds are forming for it to rain. However, at ground level where the rain lands, the relative humidity can be less than 100%.

Relative humidity is cited in weather forecasts since it affects how we **"feel"** temperature. So how does humidity affect us on a hot day? Humans are sensitive to changes in humidity, because our skin uses the air around us to get rid of moisture in the form of sweat. If the relative humidity is very high, the air is already saturated with water vapor and our sweat won't evaporate. When this happens, we feel hotter than the actual temperature.

Likewise, very low humidity can make us feel cooler than the actual temperature. This happens because the dry air helps sweat evaporate more quickly than usual.

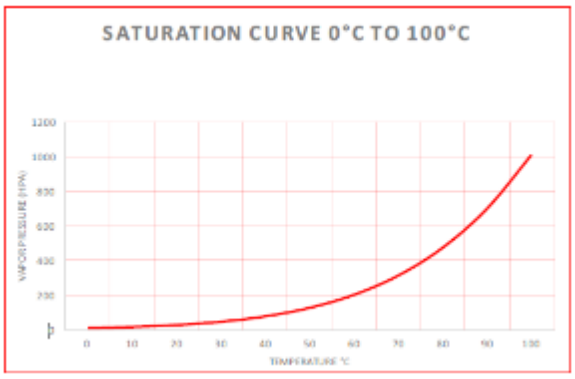
If the temperature outside is 24°C/75°F, humidity can make it feel warmer or cooler. A relative humidity of 0% would make it feel like it's only 21°C/69°F. On the other hand, a relative humidity of 100% would make it feel like it's 27°C/80°F.

## How do you calculate Relative Humidity?

Relative humidity (RH) is the ratio of the partial water vapor pressure ($P_w$) to the water vapor saturation pressure ($P_{ws}$) at a particular temperature:

$$\%RH = 100\% \times P_w / P_{ws}$$

The water vapor saturation pressure ($P_{ws}$) solely depends on temperature. The higher the temperature, the higher the water saturation vapor pressure and the more water vapor the air can hold. Warm air has a greater capacity to hold water vapor than cold air.




Relative humidity is strongly temperature dependent since the denominator in the definition ($P_{ws}$) is a function of temperature. For example, in a room with an RH of 50% and a temperature of 20°C/68°F, increasing the temperature of the room to 25°C/77°F will decrease the RH to about 37%. That's because the partial pressure of the water vapor remains the same, but the water vapor saturation pressure increases with the rising temperature. So, RH of the room decreases as the temperature increases.

## How do temperature and pressure affect Relative Humidity?

Temperature is critical for measuring RH.
$P_w$ (partial water vapor pressure) **does not** change as temperature changes.
$P_{ws}$ (water vapor saturation pressure) **does** change as temperature changes.

The following table shows how a temperature change affects RH.

| T | p | $p_s$ | RH | △ |
|---|---|---|---|---|
| 40℃ | 40 hPa | 73.8 hPa | 54.2% | |
| 39℃ | 40 hPa | 69.9 hPa | 57.2% | + 3.0% |
| 41℃ | 40 hPa | 77.8 hPa | 51.4% | - 2.8% |
| 38℃ | 40 hPa | 66.3 hPa | 60.3% | + 6.1% |
| 42℃ | 40 hPa | 82 hPa | 48.8% | - 5.4% |

Changes to pressure in a closed container also impact RH

- $P_w$ (partial water vapor pressure) **does** change as the pressure changes.
- $P_{ws}$ (water vapor saturation pressure) **does not** change as pressure changes.

Principles to keep in mind about RH, temperature, and pressure:

- As temperature increases, RH decreases
- As temperature decreases, RH increases

In a closed container:

- As pressure increases, RH increases
- As pressure decreases, RH decreases

## What is Dry Bulb Temperature?

The dry bulb temperature ($T_{db}$), usually referred to as air temperature, is the air property that is most common used. When people refer to the temperature of the air, they are normally referring to its dry bulb temperature.

The dry bulb temperature refers basically to the ambient air temperature. It is called "dry bulb" because the air temperature is indicated by a thermometer not affected by the moisture of the air.

Dry bulb temperature can be measured using a normal thermometer exposed to the air but shielded from radiation and moisture. The temperature is usually given in degrees Celsius (°C) or degrees Fahrenheit (°F). The SI unit is Kelvin (K). Zero Kelvin equals to -273°C.

## What is Wet Bulb Temperature?

Wet bulb temperature ($T_{wb}$) is the adiabatic saturation temperature. The term "adiabatic" refers to a process or condition in which heat does not enter or leave the system concerned.

Wet bulb temperature can be measured by using a thermometer with the bulb wrapped in wet cloth. The adiabatic evaporation of water from the thermometer bulb and the cooling effect is indicated by a "wet bulb temperature" lower than the "dry bulb temperature" in the air.

The rate of evaporation from the wet cloth on the bulb, and the temperature difference between the dry bulb and wet bulb, depends on the humidity of the air. The evaporation is reduced when the air contains more water vapor.

The wet bulb temperature is always between the dry bulb temperature and the dew point. For the wet bulb, there is a dynamic equilibrium between heat gained because the wet bulb is cooler than the surrounding air and heat lost because of evaporation. The wet bulb temperature is the temperature of an object that can be achieved through evaporative cooling, assuming good air flow and that the ambient air temperature remains the same.

## What are Dew Point and Frost Point?

The **dew point temperature** ($T_d$) is the temperature at which water vapor starts to condense out of the air (the temperature at which air becomes completely saturated). Above this temperature the moisture stays in the air.

- if the dew point temperature is close to the dry bulb temperature - the relative humidity is high
- if the dew point temperature is well below the dry bulb temperature - the relative humidity is low

If moisture condenses on a cold bottle taken from the refrigerator the dew point temperature of the air is above the temperature in the refrigerator.

The dew point temperature is always lower than the dry bulb temperature and will be identical with 100% relative humidity (the air is at the saturation line). As air temperature changes the dew point tends to remain constant unless water is added or removed from the air.

The dew point temperature can be measured by filling a metal can with water and some ice cubes. Stir by a thermometer and watch the outside of the can. When the vapor in the air starts to condensate on the outside of the can, the temperature on the thermometer is pretty close to the dew point of the actual air.

Dew point is a useful measure for two reasons:

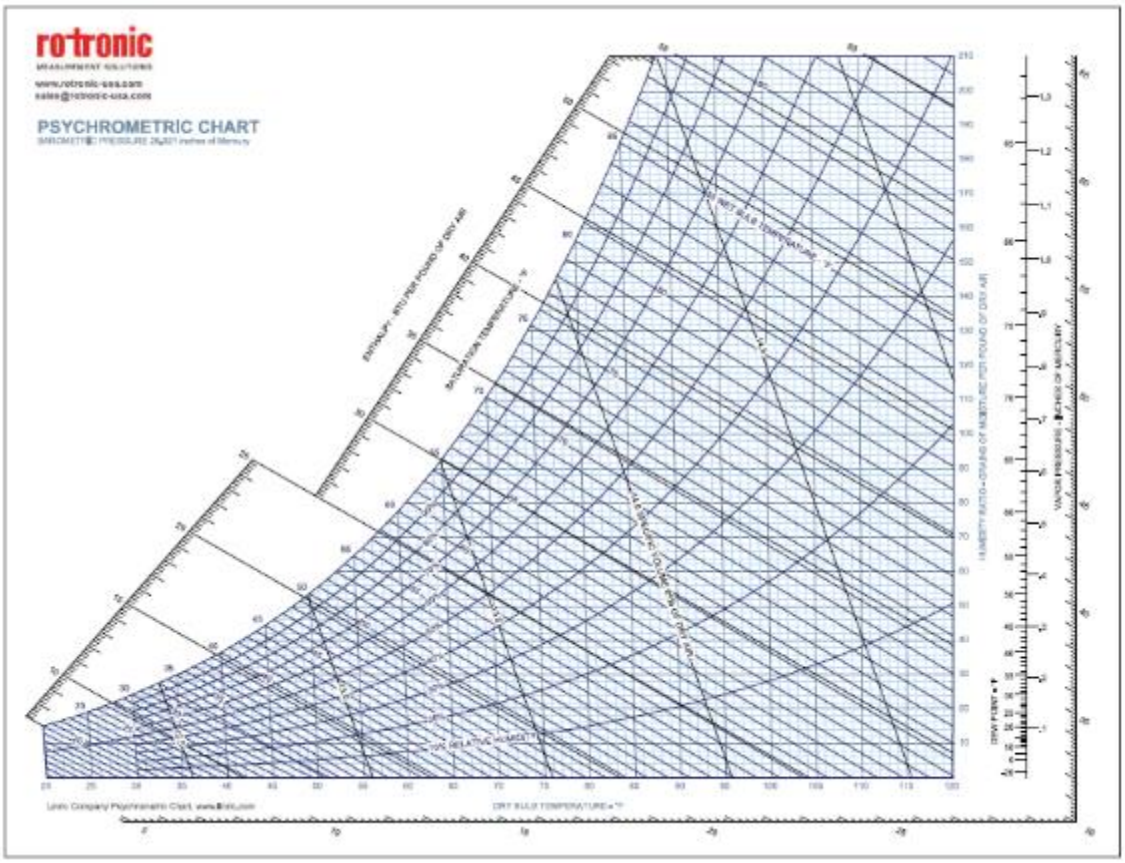
- The dew point tells us what temperature to keep a gas, to prevent condensation. The farther the dew point is from the ambient temperature, the smaller the risk for condensation and the drier the air.
- Dew point is an absolute measure of the gas humidity (at any temperature) and relates directly to the amount of water vapor present (partial water vapor pressure).

Dew point is expressed in temperature units, for example "Today the dew point in my office is 10 °C." If the condensation would be ice (below 0°C) then the term **frost point** is used.

If the dew point is below freezing, the term frost point ($T_f$) is sometimes used to state that the condensing phase is ice. The frost point is always slightly higher than the dew point below 0°C as the water vapor saturation pressure of ice is different than water. People also often refer to dew point for subzero values, even though they mean frost point.

## What is a Psychrometric Chart?

A Psychrometric Chart is a graphical representation of the psychrometric processes of air. Psychrometric processes include physical and thermodynamic properties including dry bulb temperature, wet bulb temperature, relative humidity, dew point temperature, enthalpy (total heat content of a system), vapor pressure, humidity ratio, saturation curve (100%RH), and specific volume (dry air). Download the Rotronic Technical Note "How to Read a Psychrometric Chart" at http://content.rotronic-usa.com/psych-charts to obtain a Psychrometric Chart.



In other words, a Psychrometric Chart is a visual representation of the properties of a moist gas. It's an important tool used by engineers in designing heating and air conditioning systems that will ensure comfortable conditions inside a building. Or by HVAC technicians in carrying out heat load or cooling load calculations and find solutions to various air condition related problems.

It's also a handy tool that anyone can easily use to identify the properties of air at a particular state. As long as you know any two properties of air, you can determine all the other parameters from the chart. For example, let's say you know the dry bulb temperature is 21°C/70°F and the dew point is 10°C/50°F. Take a ruler and draw a vertical line at the dry bulb temperature of 70 and draw a horizontal line where the dew point is 50. The point where these two lines intersect is known as a 'state point'. Plot the state point and you can also read the relative humidity, wet bulb temperature, enthalpy, vapor pressure and humidity ratio.

## What's the relationship between Dew point and Relative Humidity?

Dew point is closely linked to relative humidity, which is the ratio of the partial water vapor pressure ($P_w$) to the water vapor saturation pressure ($P_{ws}$) at a specific temperature. Relative humidity (RH) is expressed as a percentage.

The relative humidity is 100 percent when the dew point and the temperature are the same. If the temperature drops any further, condensation will result, and liquid water will begin to form.

Compared to relative humidity, dew point is frequently cited as a more accurate way of measuring the humidity and comfort of the air, since it is an absolute measurement (unlike relative humidity).

Most people are comfortable with a dew point temperature of 16°C/60°F or lower. At a higher dew point of 21°C/70°F, most people feel hot or "sticky" because the amount of water vapor in the air slows the evaporation of perspiration and keeps the body from cooling.

## How do you calculate Dew Point from Relative Humidity?

The exact conversion from relative humidity (RH) to dew point ($T_d$) is very complex and not easily done without the help of a calculator or computer. However, there is a simple rule of thumb to approximate the conversion between RH and dew point for moist air (RH > 50%). Dew point decreases by about 1°C for every 5% decrease in RH (starting at $T_d$ = T, the dry bulb temperature, when RH = 100%):

$$t_d \approx t - \left(\frac{100 - \mathrm{RH}}{5}\right),$$

or

$$\mathrm{RH} \approx 100 - 5\left(t - t_d\right),$$

There are several good calculators available on the internet to convert between RH and dew point. For example, the "Dew Point Calculator" developed by Image Permanence Institute is a handy reference for visualizing the relationship between temperature, relative humidity and dew point. See http://www.dpcalc.org/index.php. This calculator is also a useful tool to understand the risk a specific temperature/humidity environment poses to material decay, mechanical damage, mold growth, and metal corrosion.

**Sources:**


- The Beginner's Guide to Humidity Measurement, National Physical Laboratory, Stephanie Ball
- Absolute vs. Relative Humidity - What's the Difference?, blog post by Dustin De Torres
- What is Humidity?, blog post by Wonderopolis
- Humidity Definitions, Rotronic Technical Note
- Relative Humidity and Dew Point, the Basics, Rotronic Webinar Presentation
- What Is Dew Point?, blog post by Marc Lallanilla
- How to Choose the Right Instrument for Measuring Humidity and Dew Point, published by Vaisala
- The Relationship between Relative Humidity and the Dewpoint Temperature in Moist Air, A Simple Conversion and Applications, Mark G. Lawrence
- Dry Bulb, Wet Bulb, and Dew Point Temperatures, blog post by The Engineering Toolbox
- Rotronic Technical Note "How to Read a Psychrometric Chart"
- Dew Point Calculator" by Image Permanence Institute

## Sales and Marketing Documents

The following sales and marketing documents are available from the 5128A RHapid-Cal Launch Page at http://eu.flukecal.com/5128A-Launch-EMEA:

- Press Release
- Advertisement
- Customer HTML email
- Introduction video
- Product page
- Web banners
- Google ads
- Product brochure/datasheet
- Sales guide
- Value selling sheet
- Product announcement
- Sales presentation
- TCAL Solutions for Pharma/Biotech Sales Note
- Customer presentation
- Catalog copy
- Rep email