Frost Point Hygrometers
and
GRUAN

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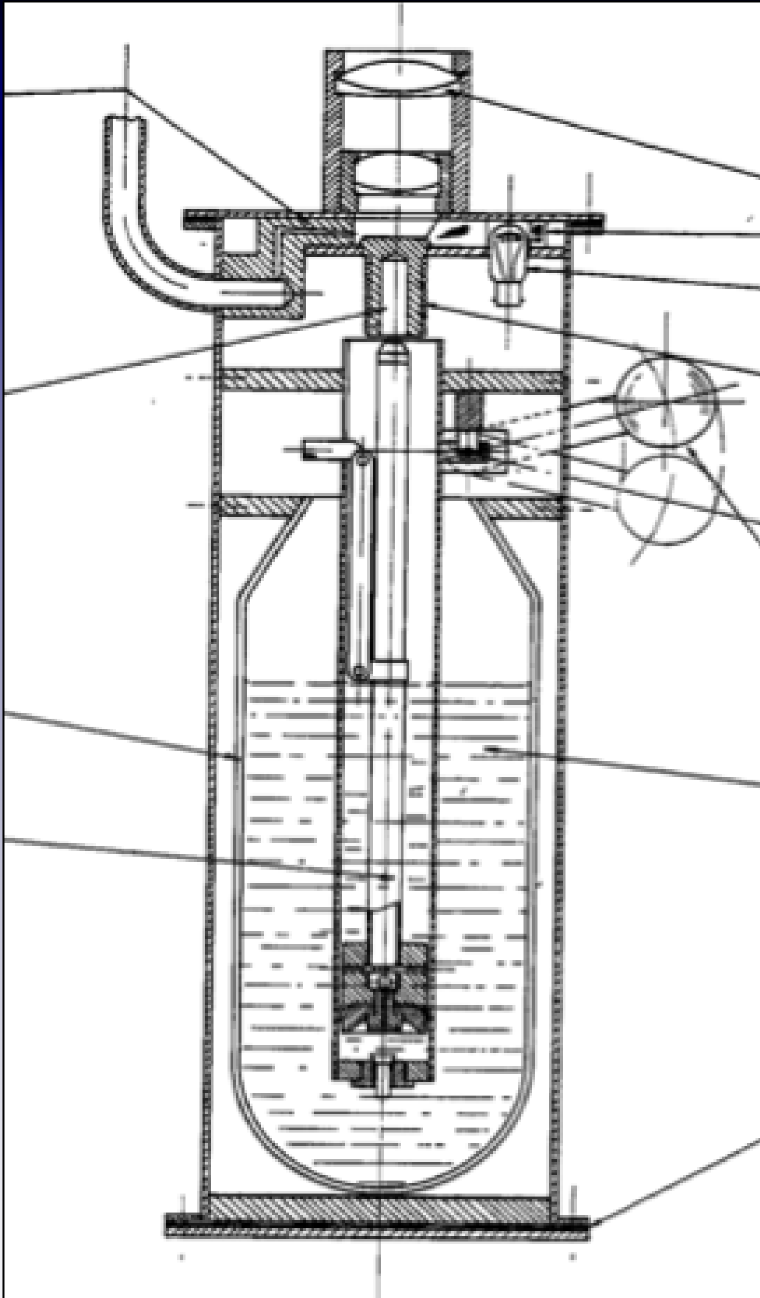


Frost Point Hygrometry

is not new!

Some Big Names!

Measurement of Absolute Humidity in Extremely Dry Air

By A. W. BREWER, B. CWILONG and G. M. B. DOBSON,
Oxford

MS. received 29 *May* 1947

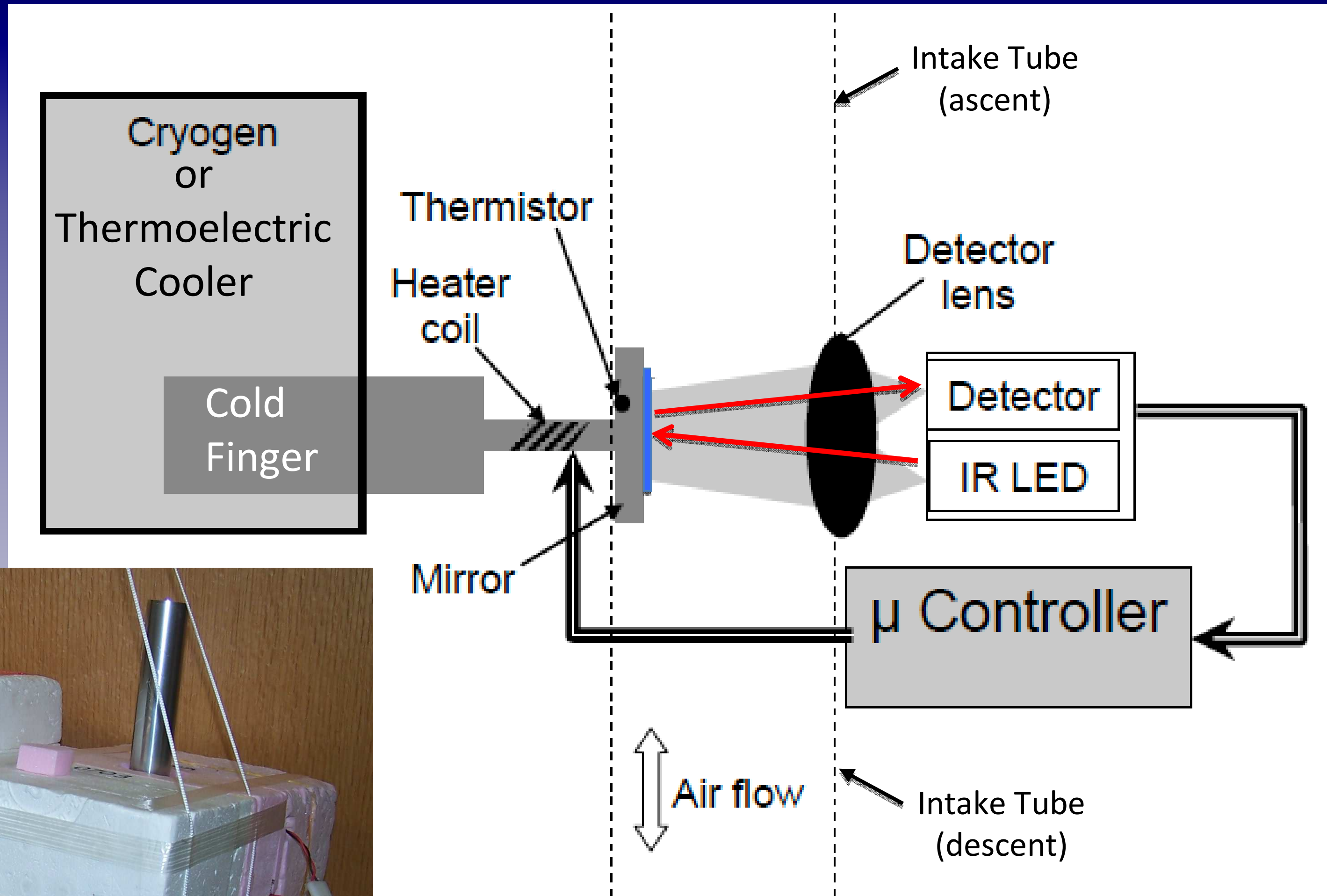
ABSTRACT. To meet an urgent demand for a hygrometer capable of use at all heights in the atmosphere, the dew-point hygrometer, which is shown to have many advantages, has been developed primarily for use in aircraft to measure dew-points, or rather frost-points, down to −90° c.

It is necessary that the instrument should operate at the lowest possible frost-points as it has been discovered that the air in the stratosphere is very dry Laboratory studies of the deposition of water and ice from the vapour at low temperature are described.

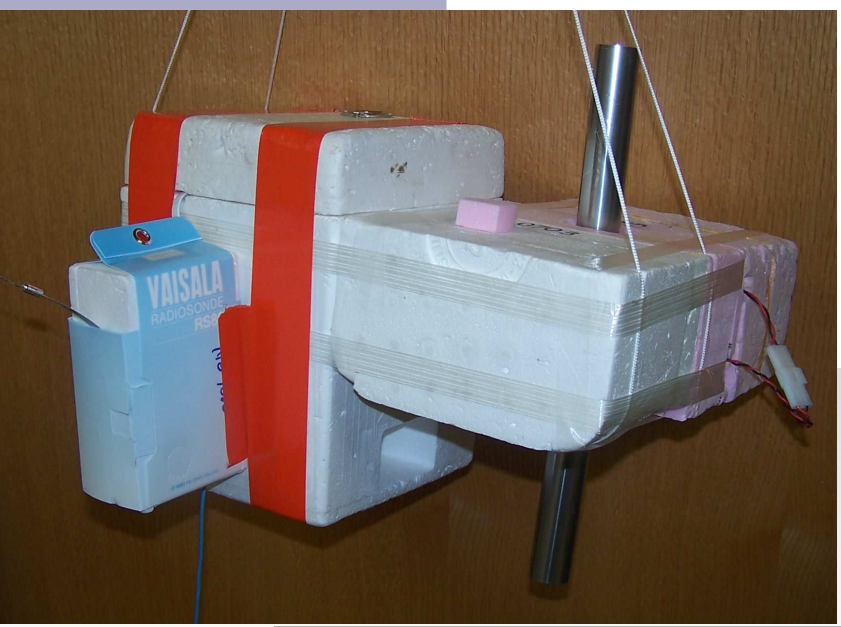
Below −90° c. it is not possible to operate a frost-point hygrometer because the deposit is in the form of an invisible glassy layer, but the instrument gives correct results at temperatures close to this limit.

Details are given of the construction of different forms of hand-operated hygrometers, and work is now going on to develop a fully automatic frost-point hygrometer.

How It Works



Cryogen
or
Thermoelectric
Cooler
Cold
Finger
Thermistor
Heater
coil
Mirror
Detector
lens
Detector
IR LED
μ Controller
Intake Tube
(ascent)
Air flow
Intake Tube
(descent)



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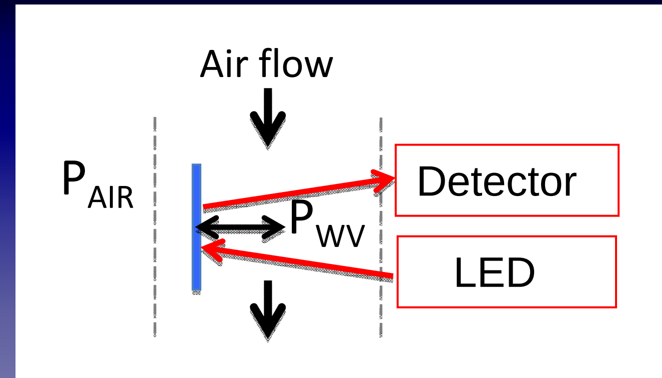

Stable reflectivity signal

Stable frost layer

Equilibrium between P_{WV} and Frost Layer

$T_{FP} = T_{mirror}$

$$X_{H2O} = P_{WV} / (P_{AIR} - P_{WV})$$

No water vapor calibration standards or scale are required!

P_{WV} is calculated from T_{mirror}

Need only accurate calibration of T_{mirror}

Quantifying Frost Point Hygrometer Measurement Uncertainties

1. Stability of the frost layer
   - PID or PI control feedback loop problems – wrong parameters (poor tuning)
   - Must maintain equilibrium for Clausius-Clapeyron equation to be accurate
   - Instability adds imprecision, but does it contribute to inaccuracy?

2. Changes in frost layer coverage and morphology
   - Signal is simple reflectivity of the IR beam
   - Reflectivity signal is function of:
     frost layer coverage (area and thickness) - patchiness of frost coverage?
     crystal structure of ice: cubic vs hexagonal ice – motivation for mirror clear
     phase of mirror condensate

3. Phase of mirror condensate
   - When T_{FP} > 0°C at the surface, mirror collects liquid instead of frost
     Dewpoint relationship between T_{mirror} and P_{WV}
   - As T_{FP} drops < 0°C mirror can maintain supercooled water to about -30°C
   - Identify condensate change(s) in profile: help from radiosonde RH measurements

4. Are mirror thermistor readings representative of the frost layer temperature?
   - Thermistor position: Uniformity of mirror temperature and frost layer coverage
   - Thermistor depth: is temperature measured at the mirror surface or beneath it?

Quantifying Frost Point Hygrometer Measurement Uncertainties

5. Mirror thermistor calibration
    - Accurate readings of slush bath temperatures – is bath temp uniform? (stirring)
    - Accurate logging of thermistor resistances at different bath temperatures
    - Strain on mirror-mounted thermistor can change its resistance calibration

6. Fit to mirror thermistor calibration data
    - Curve fitting uncertainties related to:
      Is functional form of the fit appropriate for the calibration data?
      Goodness of fit – magnitude of residuals
      Uncertainties of any extrapolations to cover full dynamic range of T_{FP}

7. Time of response to a perturbation in P_{WV}
    - What is the time required to adjust and re-stabilize the frost layer?
    - Does the adjustment cause ringing? (imprecision)

8. Coincident pressure and temperature measurements
    - Mixing ratio calculation requires ambient air pressure measurement
      Relative inaccuracy is directly proportional to relative pressure bias
    - Relative humidity calculation requires ambient air temperature measurement
      Absolute inaccuracy from temperature bias is greater at higher temperatures

Requirements for implementation of FPH and CFH at GRUAN sites

- Cryogen for mirror cooling
- RS80 or iMet radiosonde with interface board
- 403 MHz receiver and 1200 baud modem
- Computer software: STRATO or SkySonde

Pre-Launch checks and meta data recording at sites

- Adjust baseline (no frost) reflectivity signal
- Holger will describe new pre-launch check

Post-flight data handling (by processing center)

- Upload ASCII file to data plotting and flagging program
- Flag data recorded during mirror clear(s)
- Flag contamination-affected data and/or problematic data
- Assign condensate type (liquid/ice) to low-altitude data
- Apply solar radiation corrections to radiosonde T data
- Recalculate RH, geopotential altitude (using corrected T data)

GRUAN data products

- Vertical profiles of X_{H2O} , RH and geopotential height at 5-10 m resolution
- Uncertainties for each measurement (in progress)