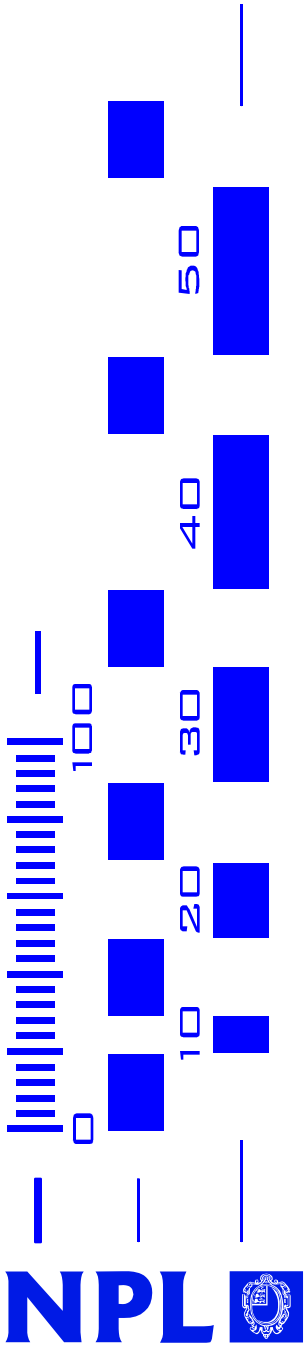
Presentation to: Thermal Team

The importance of humidity measurement

Mark Stevens
Humidity Group



I’m going to talk about ....

- Why we measure humidity
- How humidity is measured
- Our standards
- A few other interesting things

Definitions :

- ***relative humidity (in percent)*** $\psi = \frac{100\,p}{p_s}$

(p, is vapour pressure, p_s is saturation vapour pressure)

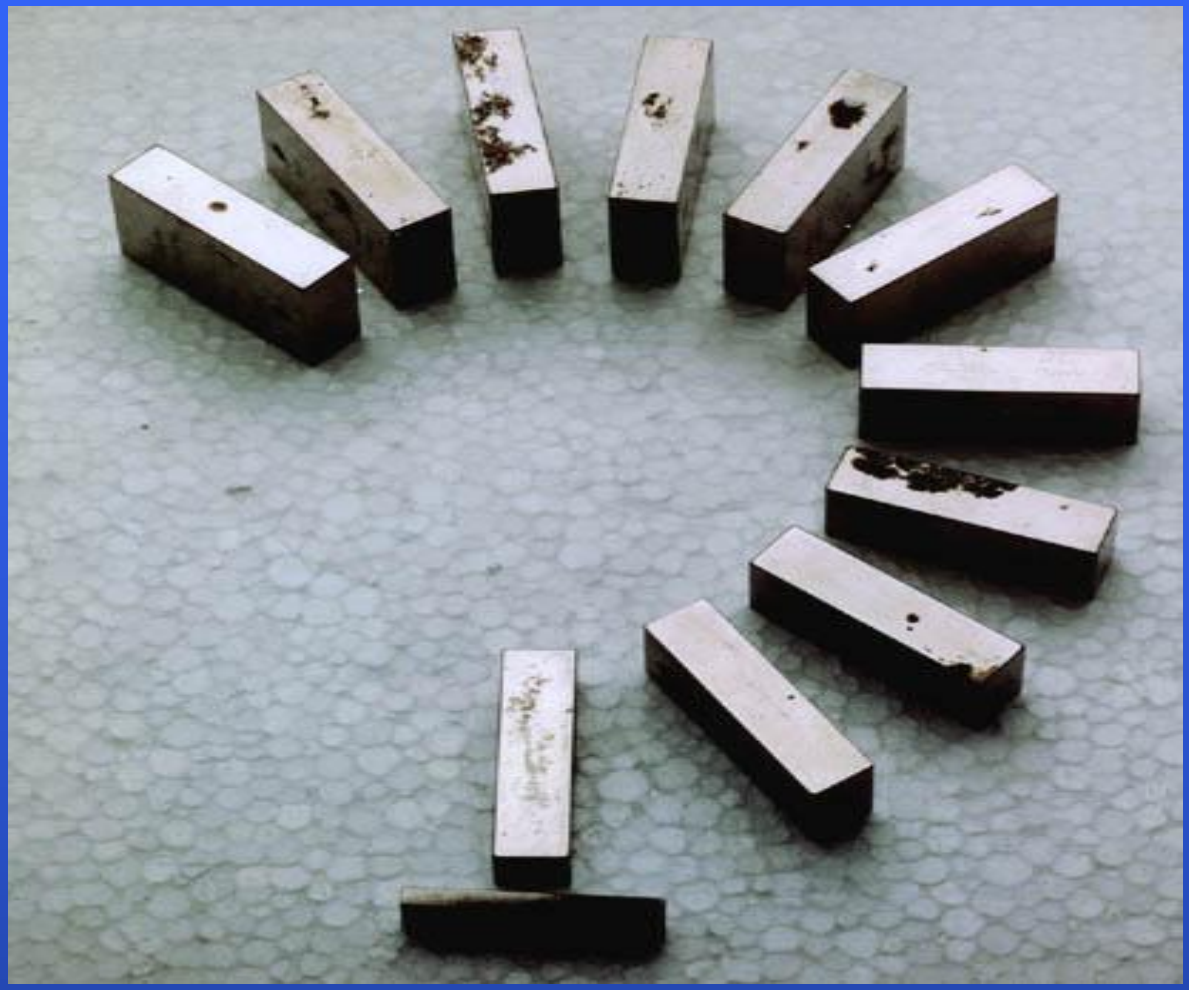
- ***dew point*** - the temperature at which condensation forms on cooling a gas (frost point where the condensate is ice)

- ***mole fraction*** (of water vapour) - ratio of the number of moles of water vapour to the total amount of substance present.

Humidity phenomena

- Humidity affects the thermal, electrical, optical and transport properties of gases
- The moisture content of liquids and solid materials are influenced by humidity of the surroundings
- Corrosion, microbial growth, deformation of materials, and more …

Humidity phenomena



NPL

Humidity phenomena

NPL

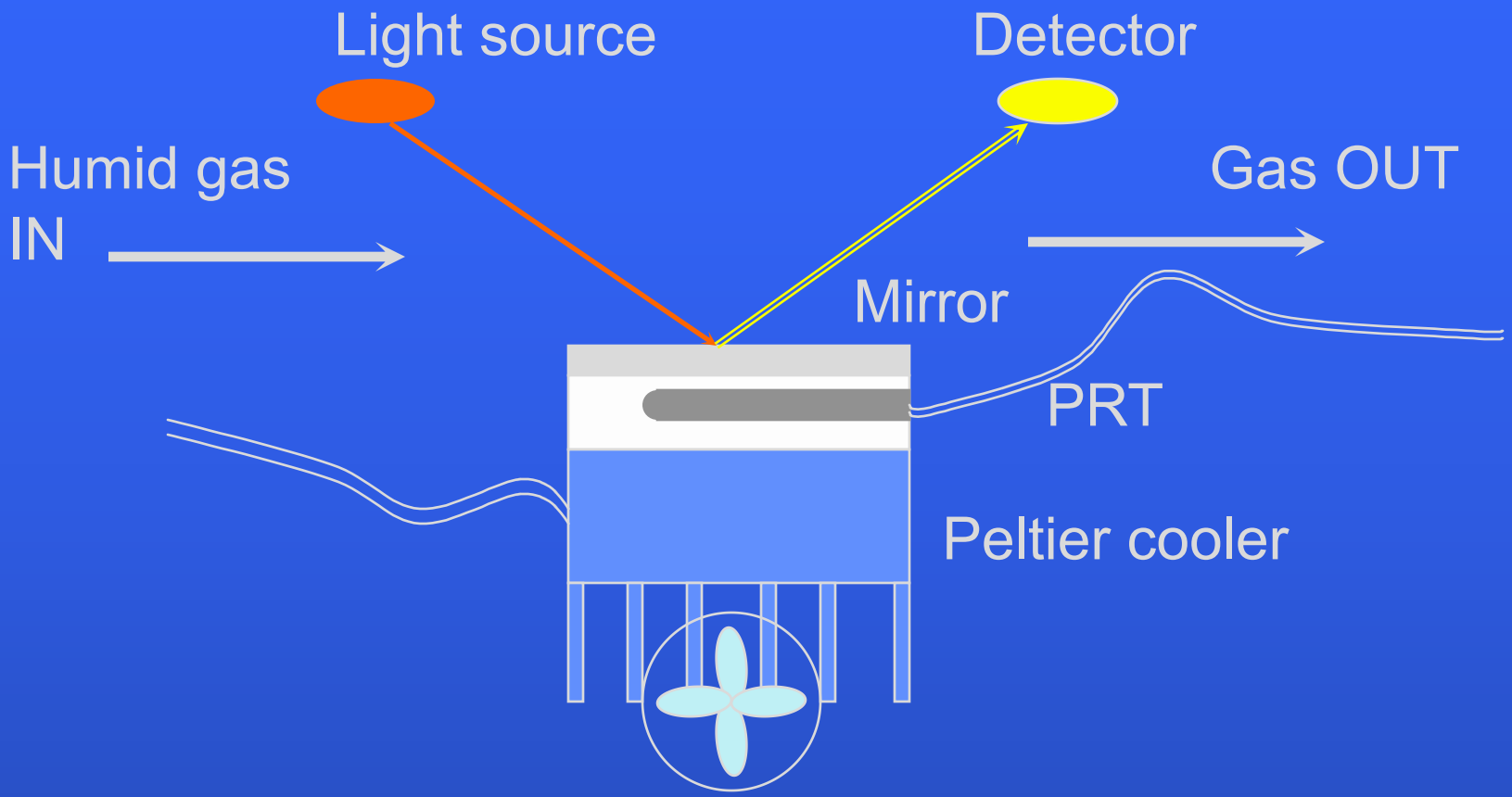
Humidity phenomena

NPL

Sensing principles for humidity measurement

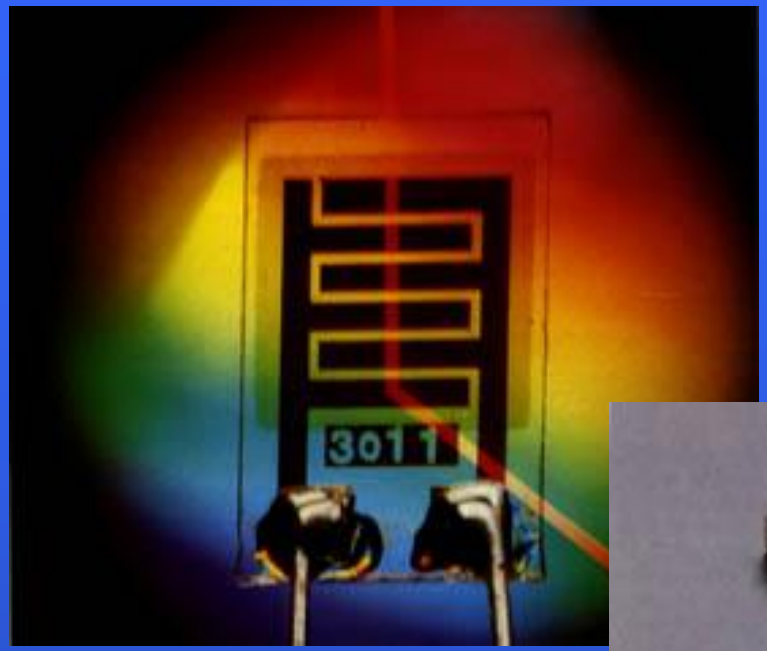
- dimensional change of materials
- condensation (detected optically, electrically, or by change of resonant frequency)
- gravimetric determination
- spectrometry
- rate of evaporative cooling
- thermal conductivity
- adiabatic expansion cooling
- pneumatic bridge
- acoustical transmission of air
- electrical impedance
- rate of electrolysis of phosphorus pentoxide
- transmission of optical fibre
- optical refractive index
- heat of sorption by a desiccant
- colour change of chemicals ...and others...

NPL

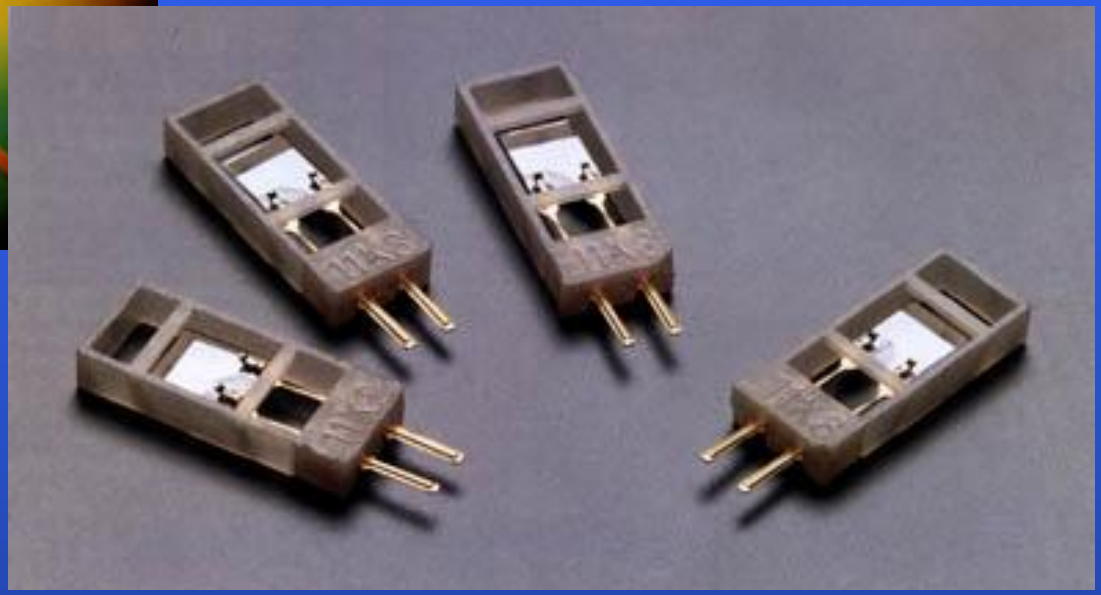


Optical Dew-point Hygrometer

Humidity impedance sensors



Source: Vaisala



Industrial significance of humidity

Applications include:

- semiconductor manufacture,
- food and pharmaceutical industries,
- power generation,
- weather forecasting, climate studies,
- air conditioning, conservation of historic artefacts
- packaging of goods, goods sold by weight, and many others.

- Industrial interests span perhaps 9 or 10 orders of magnitude.

- Routine relative humidity measurements may have uncertainty of ±2% to ±5% of reading

National standards for humidity

- We hold standards for
  - dew-point temperature (including frost point)

    using dew-point generators
  - relative humidity

    using dew-point generator or transfer standards with temperature-controlled chamber
  - mixing ratio

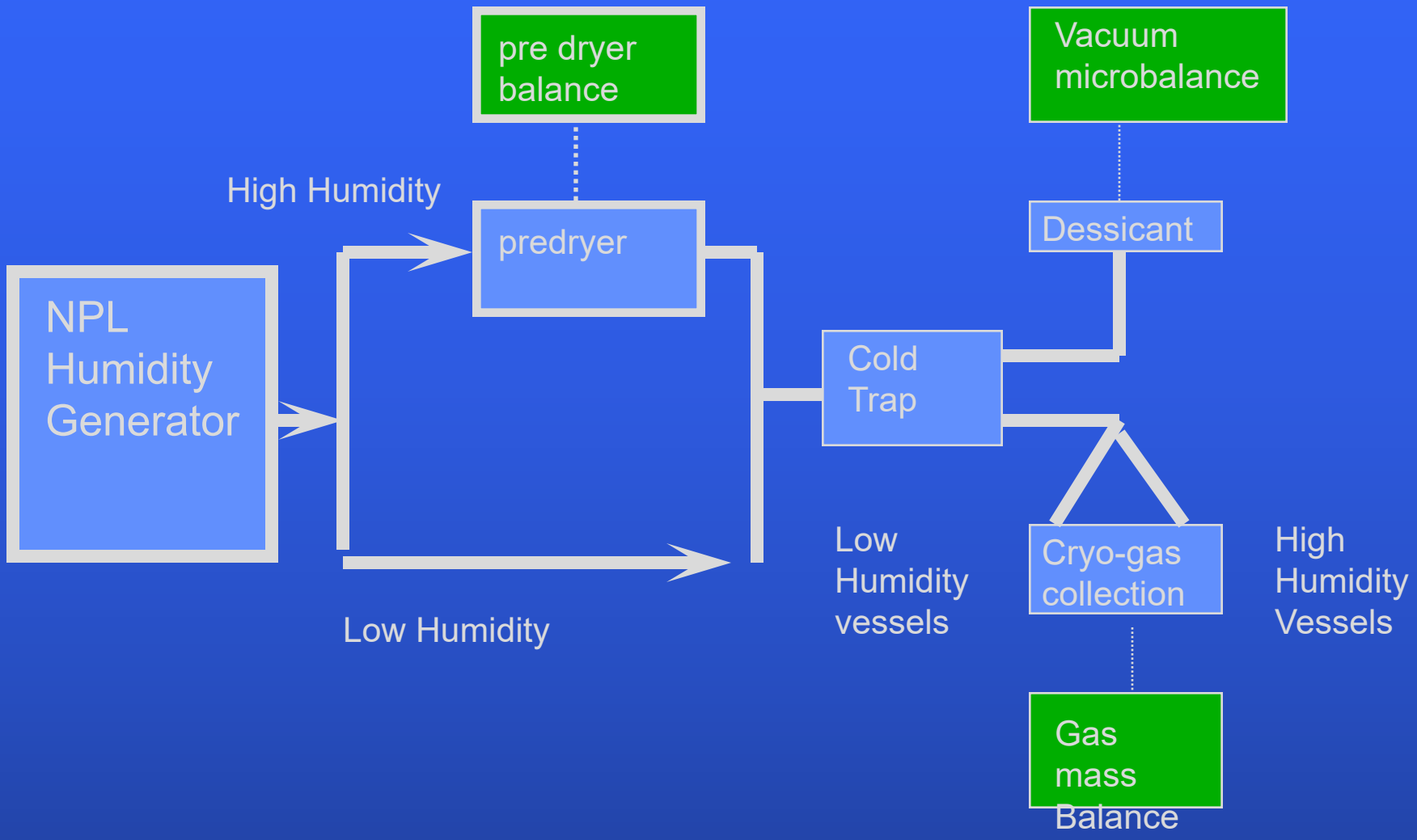
    using gravimetric hygrometer

NPL

NPL Primary Gravimetric Hygrometer

NPL

Block diagram of the PGH



Gravimetric hygrometer

- Mixing ratios 0.007 to 170 gram/kilogram)
  (Equivalent dew-point range -60 °C to +60 °C
  at atmospheric pressure)

- Uncertainty
  ±0.015% to ±1.3% of mixing ratio
  (dew-point equivalent uncertainty
  ±0.003 °C to 0.84 °C)

- Gas sampling rate up to 1 litre/minute

NPL

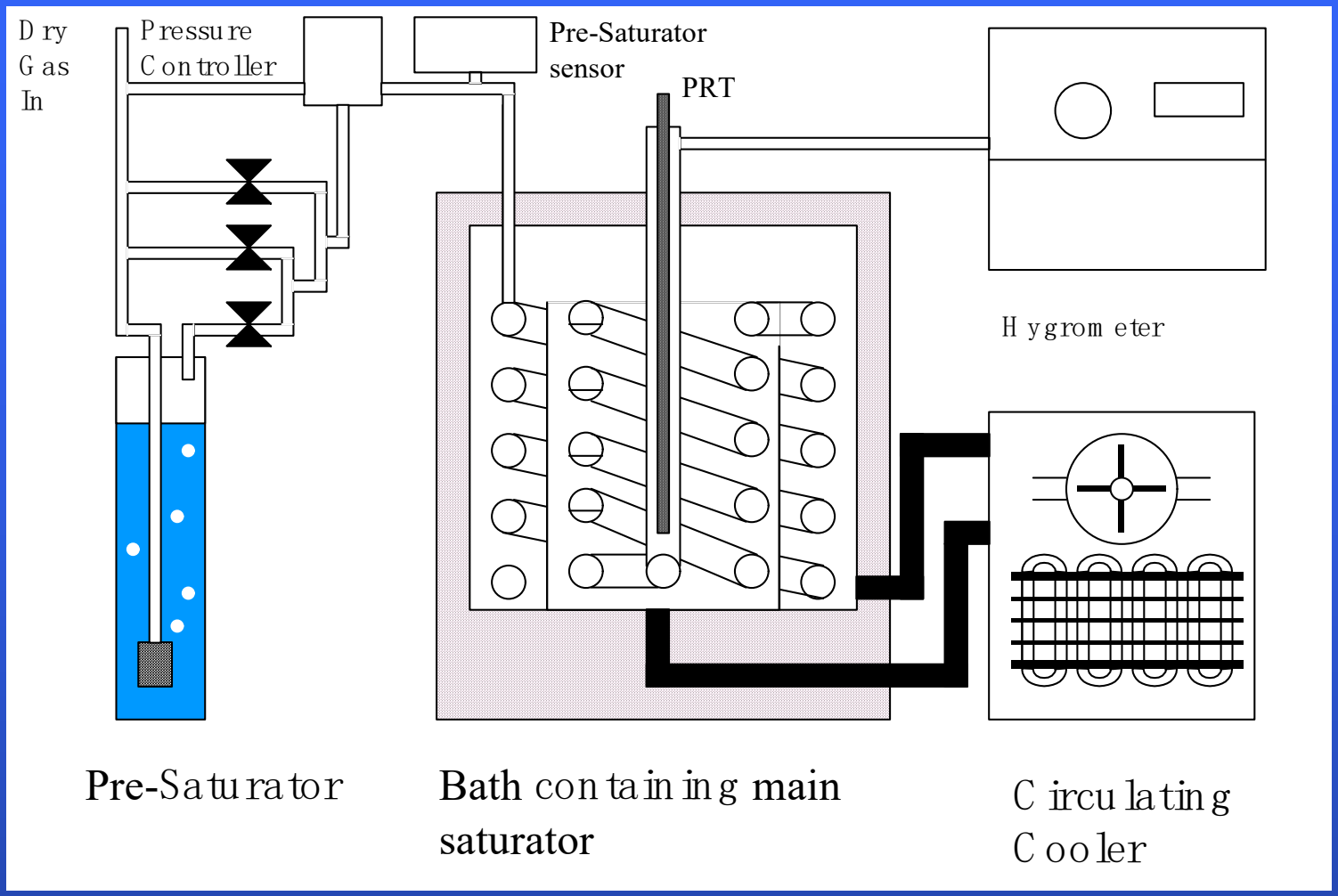
THE NPL HUMIDITY GENERATOR

HUMIDITY GENERATORS AT THE NATIONAL PHYSICAL LABORATORY

- The humidity generators at NPL are traceable to the base unit of temperature
  - Standard Humidity Generator (SHG)
    - Range -75 °C to +90 °C
    - 2 % to 98 % relative humidity at -20 to 82 °C
  - High Dew Point generator (HDG)
    - Range -3 °C to +90 °C (or higher (not yet accredited))
    - 20 % to 98 % relative humidity at 20 °C to 90 °C
    - high flow rates
  - New Low Frost point generator (under evaluation)
    - Range (at least) -90 °C to +20 ° C

NPL

FROST POINT SATURATOR


Dry
Gas
In
Pressure
Controller
Pre-Saturator
sensor
PRT
Hygrometer
Pre-Saturator
Bath containing main
saturator
Circulating
Cooler

Interesting questions we have been asked

- “How can I stop condensation dripping from the ceiling of my Turkish bath?”
- “Can you advise on humidity control for my cello?”
- “I have 2000 tonnes of potatoes to keep at optimum humidity – what should I do?”
- “Condensation in our abattoir keeps dripping on the carcasses and contaminating them – what can we do?”
- “Why is humidity relevant in cricket?”

Cross-industrial significance of humidity (1)

- Drying processes:
  - drying optimised by identifying the end point, when moisture ceases to be driven off
  - dramatic energy savings
  - savings in processing exhaust emissions
  - needs techniques that are robust against high temperatures and reactive gases - a difficult challenge for electronic sensors.

Cross-industrial significance of humidity (2)

- Environmental testing.
  - Many (prototype) manufactured items are tested
  - Range of humidities and temperatures, sometimes with other conditions, such as vibration
  - Demonstrate that the product can withstand certain extreme conditions without failing
  - “Stress screening” environmental tests test a product to destruction and find the modes of failure
  - Water vapour penetrates cracks, and accelerates the appearance of flaws
  - Debate about which humidity sensors to use

Trace moisture in semiconductor manufacture

- Water vapour is a chief cause of failures in electronics manufacture.
- High dielectric constant of water relative to other substances
- Process molecules used in low concentrations, but water vapour abundant
- Process gases need <10 ppb of water vapour
- Even lower concentrations in the future, to produce larger wafers with smaller features
- “Facility isolation” may be the way ahead