Ultra High Vacuum Measurements in Particle Accelerators

Ron Reid
Group Leader, Vacuum Science Group
CCLRC Daresbury laboratory
Pressure

Pressure = Force per Unit Area
Pascal = Newton per Square Metre

- So if we wish to measure pressure directly by measuring the force exerted on some sort of transducer, and the area of that transducer is 1 cm², then the force is

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Measuring Pressure

Fig. 4.1  Physical quantities measured in gas for low total pressure determination.
Measuring Pressure

Fig. 4.64 Range of pressures covered by vacuum gauges.
Ionisation Gauges

Hot Cathode
- Bayard Alpert Gauge (BAG)
- Extractor gauge

Cold Cathode Discharge Gauges
- Penning Gauge
- Inverted Magnetron Gauge

Important point
- All such gauges must be calibrated!
Ionisation Gauges - BAG

\[ I^+ = I^- S_p \]

Some “Spurious” Effects
Ionisation Gauges - BAG
Ionisation Gauges - Improved
Ionisation Gauges - Improved
Ionisation Gauges – BAG

Advantages
- Wide range $10^{-3}$ – $10^{-11}$ mbar
- Simple

Disadvantages
- Need calibration for each gas species
- Sensitivity variation
  - Gauge to gauge
  - With time, history
- X-rays, ESD, TSD give pressure independent currents
- Fragile
Ionisation Gauges – Cold Cathode

Penning Gauge
- Crossed electric and magnetic fields
- Self sustaining discharge
Ionisation Gauges – Penning

\[ I^+ = S p^\alpha \quad 1.0 < \alpha < 1.4 \]
Ionisation Gauges – Penning

$I^+ = S p^\alpha \quad 1.0 < \alpha > 1.4$
Ionisation Gauges – Cold Cathode

Advantages

- Wide range
  - Penning: $10^{-3} - 10^{-9}$ mbar
  - IMG $10^{-3} - 10^{-11}$ mbar
- Robust

Disadvantages

- Need calibration for each gas species
- Striking at low pressures
- Non linear
- Mode jumping
- They pump!
- Susceptible to sputter coatings and contamination
Residual Gas Analysis

Partial pressures as important as total pressure
Residual Gas Analysis

Partial pressures as important as total pressure
Residual Gas Analysis
Residual Gas Analysis
Accelerators

What’s special?

- Big!
- Must operate reliably
- Hostile environment
  - Noisy
    - Aural; electrical
  - Warm, humid
  - Magnetic fields
  - Radiation
  - Stray electrons
  - RF structure on beams
- Conductance limited
  - No space for vacuum equipment
Diamond

Picture courtesy of JacobsGIBB Ltd/Crispin Wride Architectural Design Studio.)
LHC, CERN