LINXON myRGA

THEORY AND OPERATION

Module 600:
Specification Definitions

PURPOSE

- Demonstrate knowledge of RGA product specifications
- Understand RGA specifications for comparing RGAs with customer requirements
- Understand RGA specifications for RGA competitive positioning

OBJECTIVES

Upon completion of this module, you will be able to describe the meaning and significance of several important specifications that apply to RGAs.

OUTLINE

LINXON

1. Maximum Operating Pressure
2. Mass Range
3. Sensitivity
4. Linearity
5. Minimum Detectable Partial Pressure
6. RGA Resolution

OUTLINE (Continued)

LINXON

7 Abundance Sensitivity

8 Detection Limit

9 Zero Blast

10 Electronics Operating Temperature

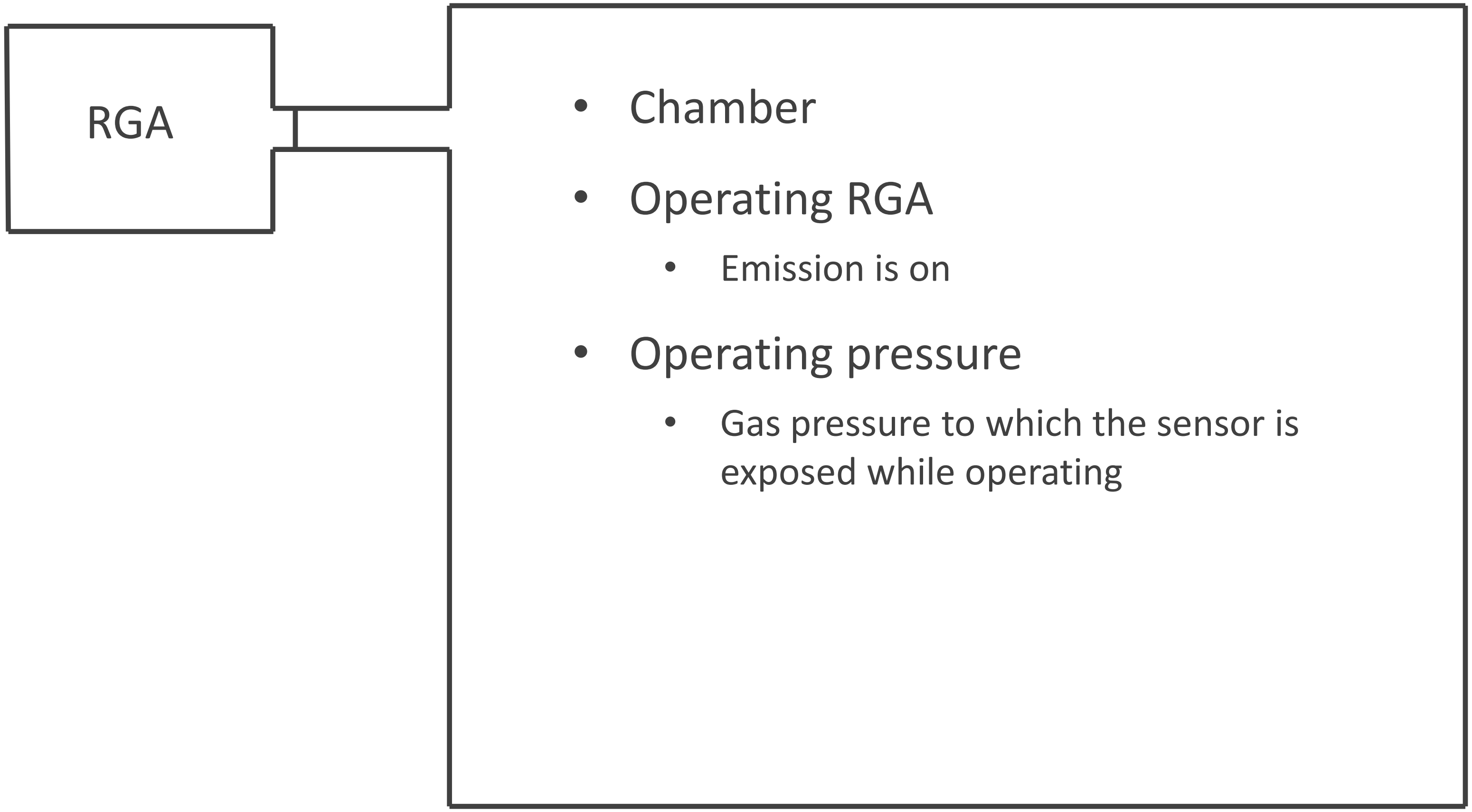
11 Sensor Operating Temperature

12 Sensor Bakeout Temperature

LINXON

1 MAXIMUM OPERATING PRESSURE

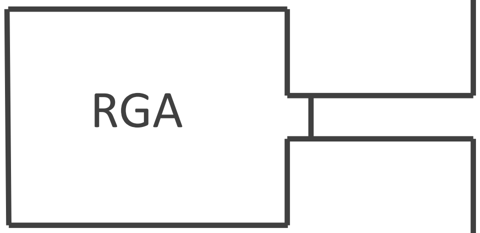
OPERATING PRESSURE



- Chamber
- Operating RGA
  - Emission is on
- Operating pressure
  - Gas pressure to which the sensor is exposed while operating

MAXIMUM OPERTING PRESSURE

LINXON

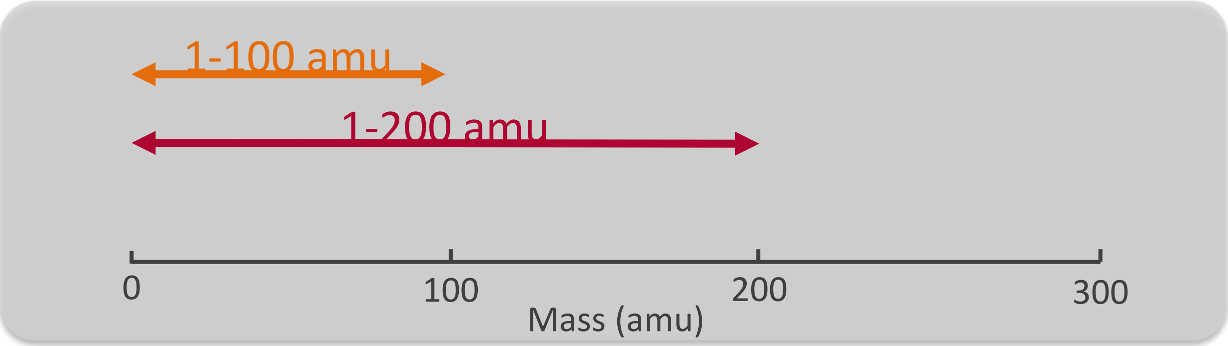


- Operating an RGA above its maximum operating pressure can cause the filament to break
- An application's operating pressure should not be higher than the RGA's specified maximum operating pressure
- myRGA specified maximum operating pressure is 5×10^{-4} Torr

2 MASS RANGE

MASS RANGE

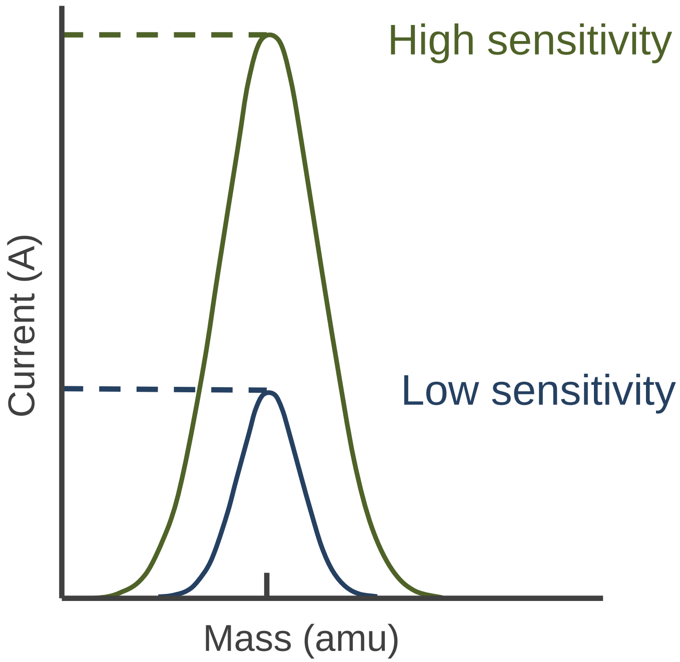
- Range of mass-to-charge ratios that an RGA can detect
- Mass ranges: 1-100 or 1-200 amu
- Important for choosing best RGA for application
- Select smallest range that will span the gases to be monitored
- Mass range will affect other RGA performance specifications



3 SENSITIVITY

RGA SENSITIVITY

- Applications of Sensitivity
  - Calculating partial pressure requires a sensitivity value
  - Calculating minimum detectable partial pressure requires a sensitivity value
  - RGA performance monitor
  - Compare different RGAs
- Higher sensitivity produces higher measurement signal at a given gas pressure



RGA SENSTIVITY – DEFINTION

- RGA measurement current per unit of pressure
- I is RGA measurement current (A)
- P is partial pressure (Torr)
- S is sensitivity of the RGA (A/Torr)
- Sensitivity is equal to current divided by pressure
- Sensitivity is gas specific

$$S = \frac{I}{P}$$

CALIBRATING (OR MEASURING) SENSTIVITY

LINXON

- At a known partial pressure P
- Measure RGA current I
- Calculate RGA sensitivity S
- Use a pure gas if possible
- Using a pure gas allows you to measure the pressure with a total pressure gauge
- Nitrogen is commonly used as calibration gas for sensitivity
- A different gas would produce a different value for sensitivity

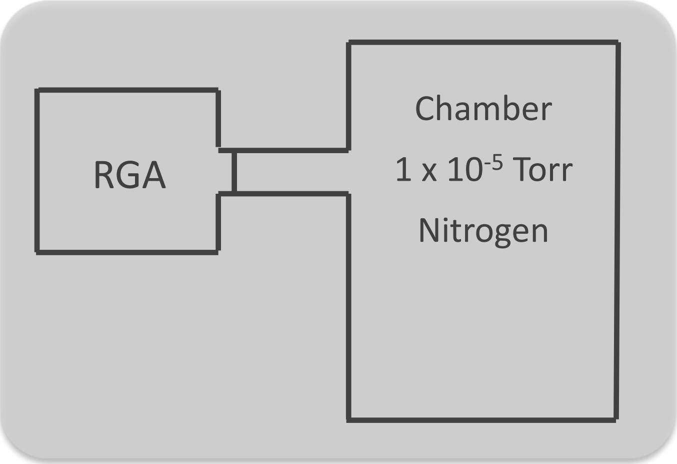
$$S = \frac{I}{P}$$

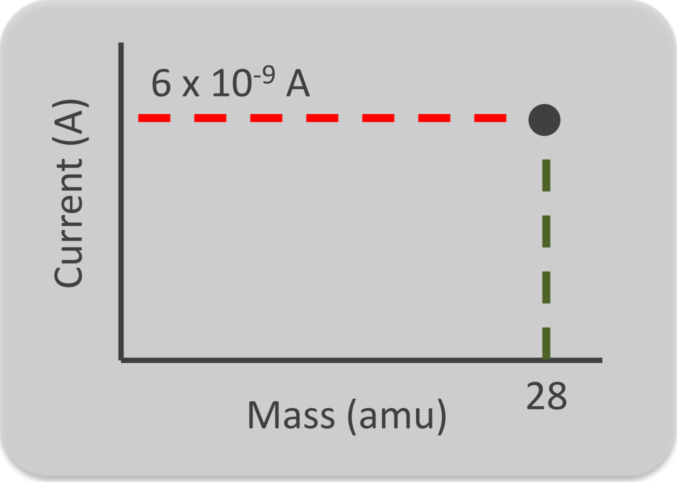
SENSITIVITY –

RGA CURRENT AT A GAS PRESSURE

Example 1

- $P = 1 \times 10^{-5}$ Torr, pure nitrogen
- RGA current measurement
- $I = 6 \times 10^{-9}$ A, for example
- Sensitivity = Current / Pressure
- S = I / P
- $S = (6 \times 10^{-9}\ A) / (1 \times 10^{-5}\ Torr)$
- $S = 6 \times 10^{-4}$ A/Torr

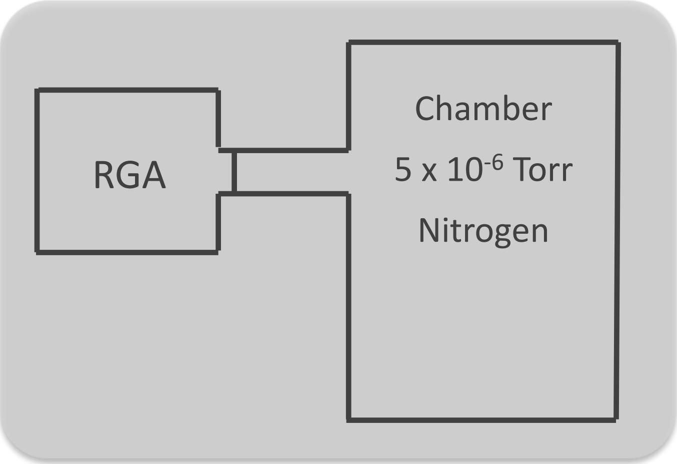


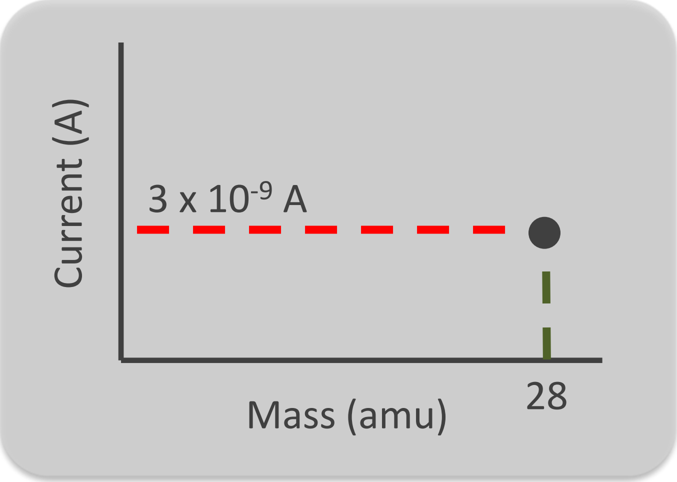


HALF THE PRESSURE, HALF THE CURRENT

Example 2

- Half the pressure in the chamber
- 5×10^{-6} Torr nitrogen
- Results in half the current
- 3×10^{-9} Amperes
- S = I / P
- S = $(3 \times 10^{-9}$ A) / $(5 \times 10^{-6}$ Torr)
- S = 6×10^{-4} A/Torr
- RGA sensitivity same as Example 1

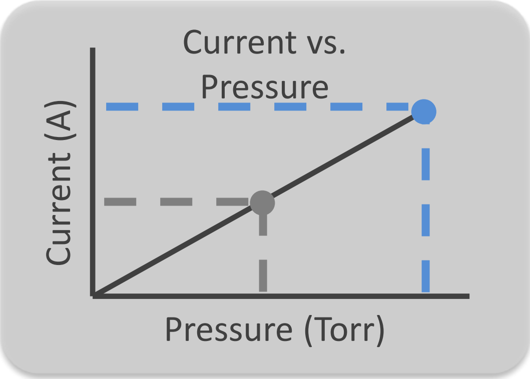


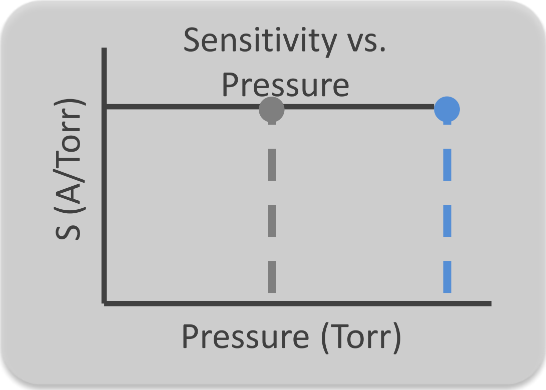


IDEAL SENSITIVITY

- Current proportional to pressure
- Sensitivity constant with pressure
- However, real performance is not perfectly ideal

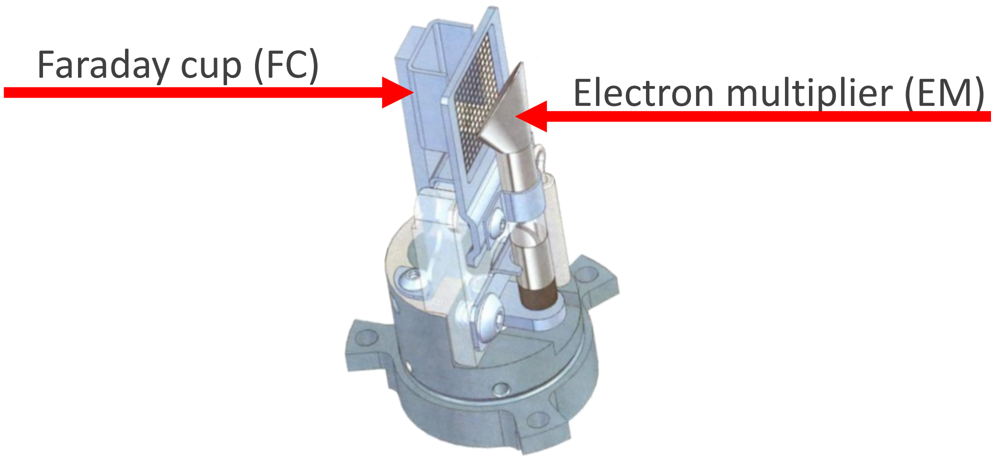
Example	Current, I	Pressure, P	Sensitivity, S=I/P
1	3×10^{-9} A	1×10^{-5} Torr	3×10^{-4} A/Torr
2	1.5×10^{-9} A	5×10^{-6} Torr	3×10^{-4} A/Torr





SENSITIVITY AND SENSOR TYPE

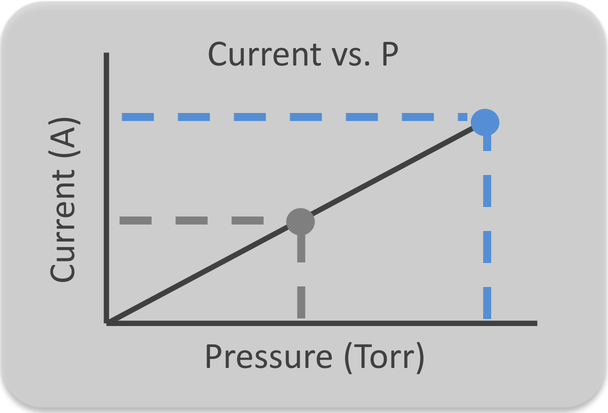
- FC sensitivity is the sensitivity in FC mode
- EM sensitivity is the sensitivity in EM mode
- EM sensitivity = FC sensitivity x EM gain
- EM sensitivity is greater than FC sensitivity

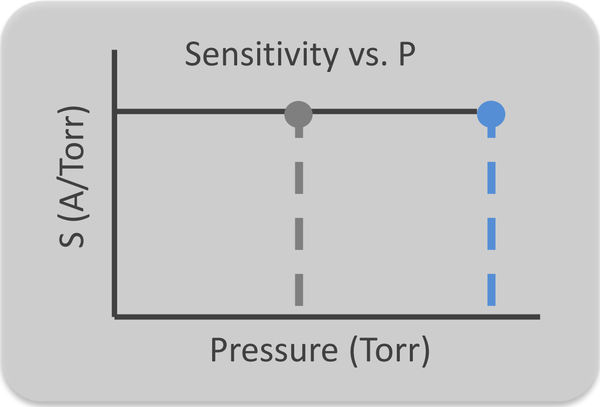


4 LINEARITY

LINEARITY

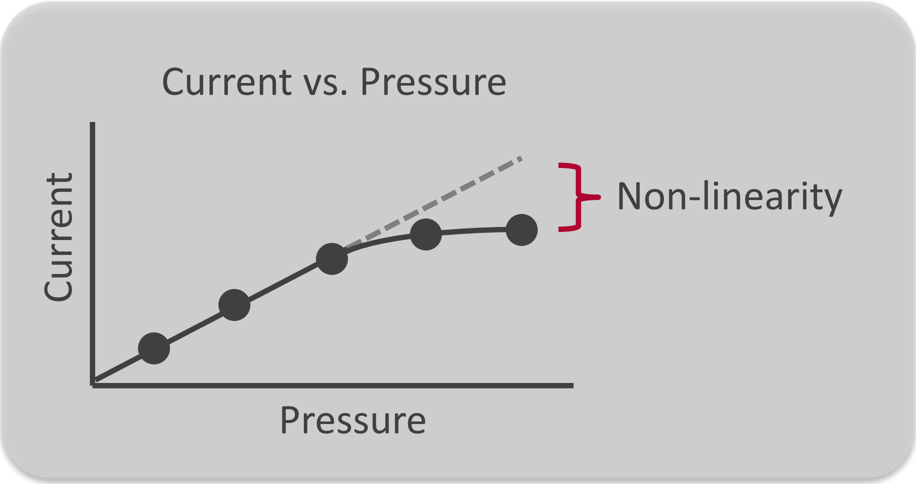
- Consistency of measurements at different pressures
- Perfectly linear behavior is like ideal sensitivity
  - Measured signal proportional to gas pressure
  - Sensitivity constant across a range of pressures
- Real measurements are not perfect
- There will be some deviation from the ideal straight line





NON-LINEARITY

- Non-linearity is deviation from the ideal linear relationship between measurement current and gas pressure
- Common to occur at high end of RGA's operating pressure range, where densities of gas particles and ions are relatively high
- Not a concern for applications at constant pressure

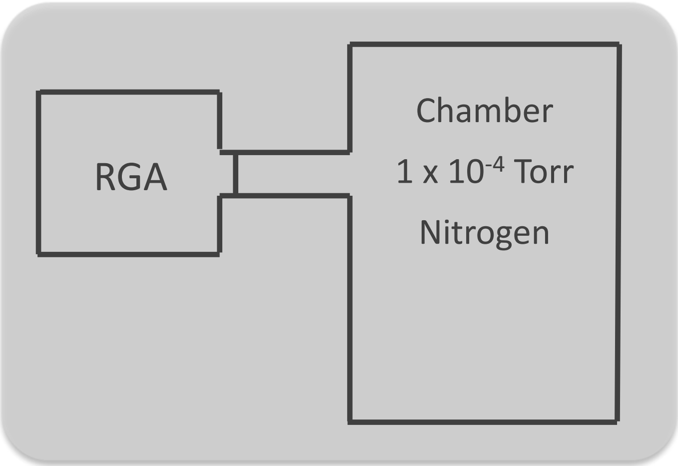


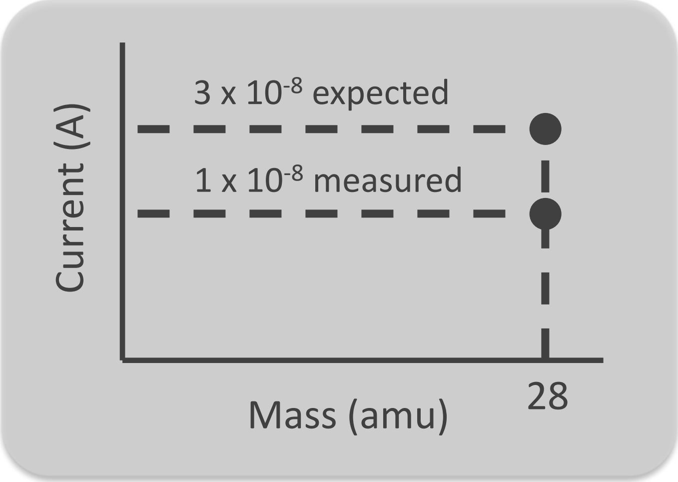
EXAMPLE NON-LINEAR MEASUREMENT

LINXON

Example 3

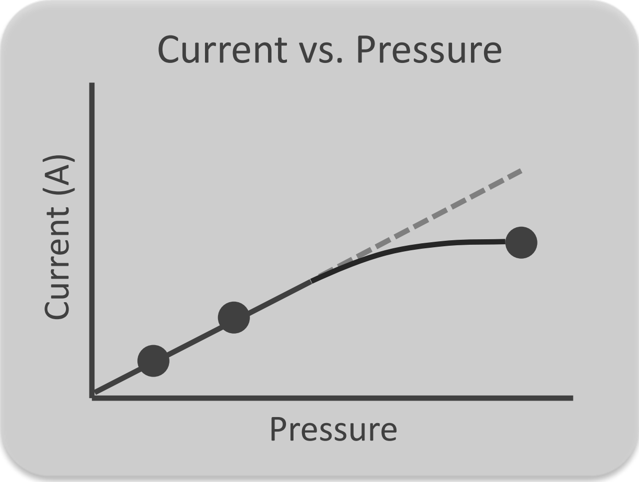
- $P = 1 \times 10^{-4}$ Torr nitrogen
- Expected current, if linear
  - $S = 3 \times 10^{-4}$ A/Torr
  - $I = S \times P$
  - Expected current $= 3 \times 10^{-8}$ A
- Measured current $= 4 \times 10^{-8}$ A
- Measured 33% lower than expected

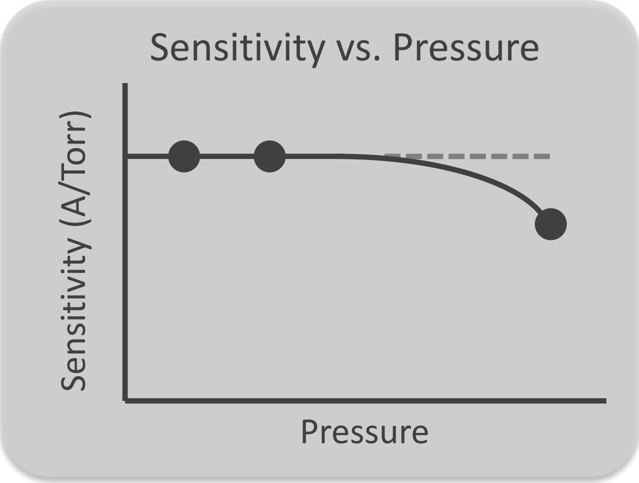




NON-LINEAR EXAMPLE, CURRENT AND SENSTIVITY VS. PRESSURE

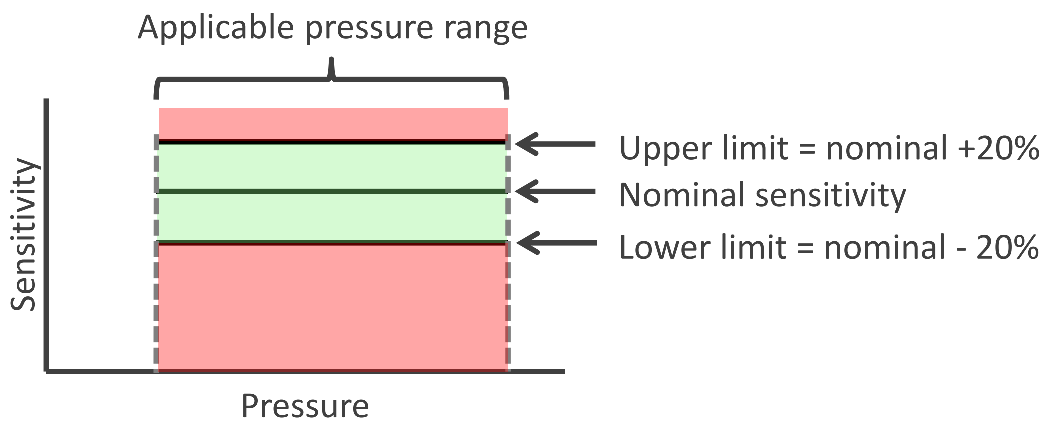
- Expected Sensitivity = 3×10^{-4} A/Torr (linear assumption)
- Measured Sensitivity = 1×10^{-4} A/Torr (non-linear result)
- Both current and sensitivity are lower than expected





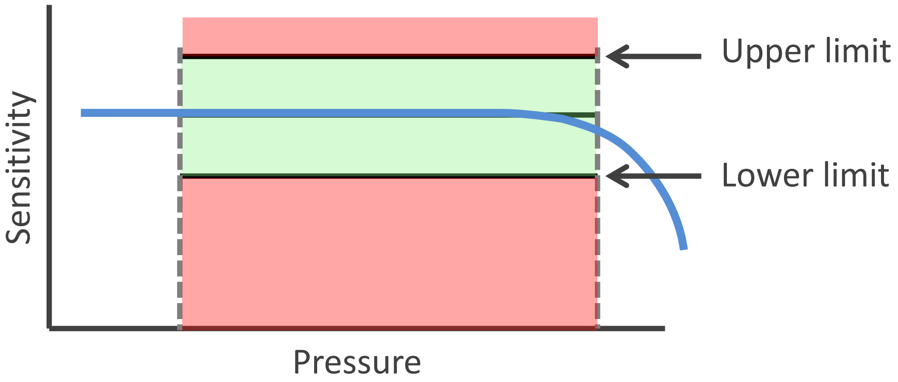
LINEARITY – EXAMPLE SPECIFICATION

- Linear to +/-20% across a specified pressure range
- Provides a tolerance envelope on the consistency of measurements over the defined pressure range



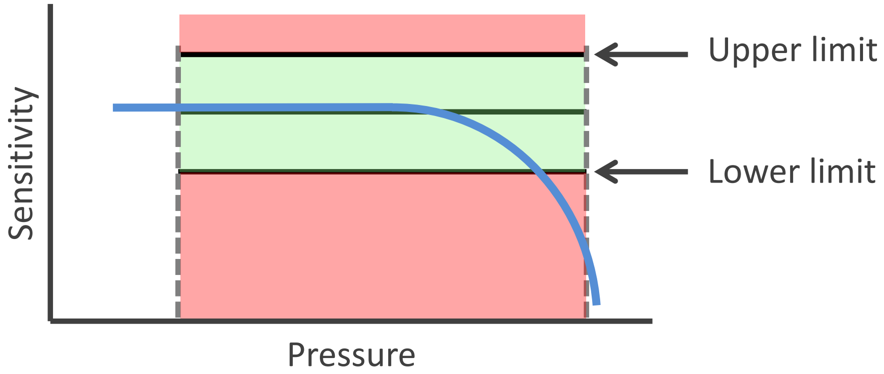
EXAMPLE – WITHIN SPECIFICATION

Within the specified pressure range, the sensitivity does not go above or below the sensitivity tolerance.



EXAMPLE – OUT OF SPECIFICATION

Within the specified pressure range, the sensitivity drops below the lower tolerance limit.



5

MINIMUM DETECTABLE PARTIAL PRESSURE (MDPP)

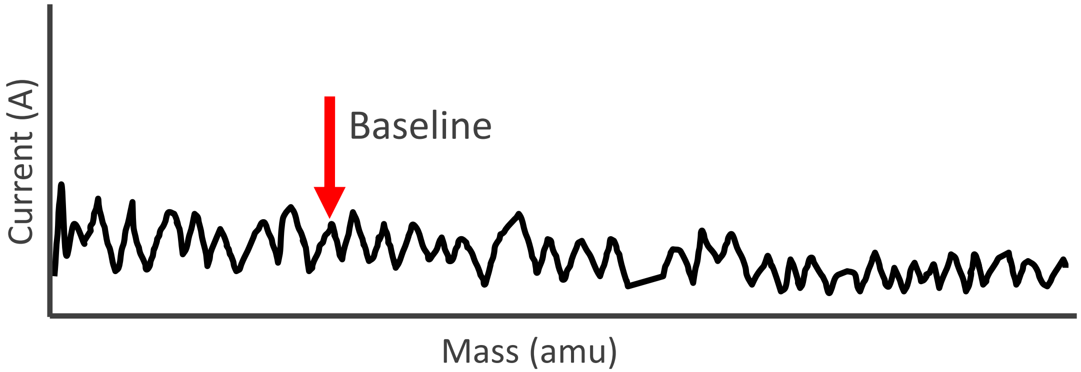
MDPP – DETECT SMALL AMOUNT OF GAS

LINXON

- MDPP indicates ability to detect small amount of gas
- Leading RGA applications
  - Leak detection
    - For example, detect very small air leak
  - Contamination detection
    - For example, detect hydrocarbon contamination from a wafer
- The lower the MDPP of an RGA, the better

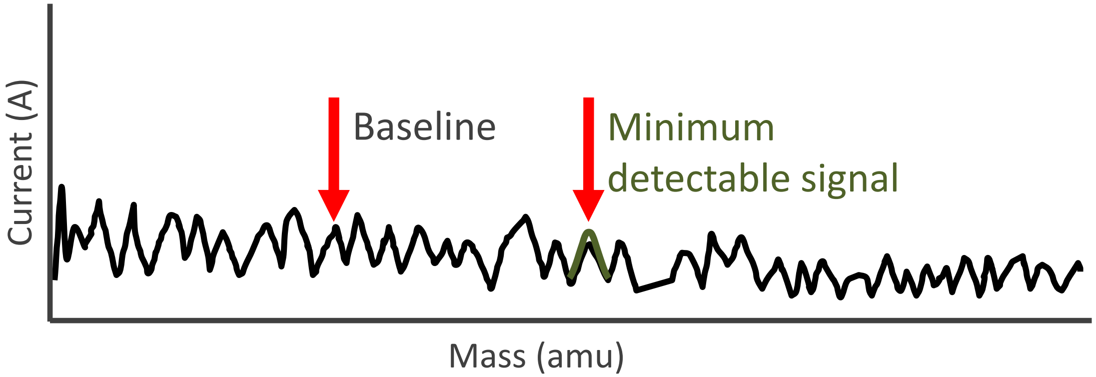
RGA BASELINE, WITH NOISE

- Measurements at masses where no gas is present
- Measurement values change over time
- Noise calculated as standard deviation over time, σ (sigma)
- myRGA baseline is measured at base pressure, less than 10^{-7} Torr



MINIMUM DETECTABLE PARTIAL PRESSURE

- Smallest signal RGA can detect above baseline
- MDPP specifications apply at base pressure
- Good (low) MDPP achieved by RGA with low noise and high sensitivity



DEFINITION OF MDPP

$$MDPP = \frac{\sigma}{S}$$

- σ (sigma) is the baseline noise
  - Standard deviation of baseline measurements (Amperes)
  - Low noise is good, contributes to low MDPP
- S is sensitivity
  - Sensitivity (A/Torr)
  - High sensitivity is good, contributes to low MDPP
- MDPP equals baseline noise divided by sensitivity
  - Units of pressure (Torr)
  - The lower the MDPP specification, the better the RGA

MDPP – COMPARE RGAS

- Use MDPP specifications to compare RGA models
- Important to carefully consider the specification conditions
  - RGA mass range
  - Detector type
  - Dwell time

DETECTOR TYPE AND MDPP

- Detector type (FC or EM) affects MDPP
- 100 amu mass range myRGA
- 4 second dwell time
- FC has higher MDPP, EM has lower (better) MDPP
- EM increases RGA sensitivity more than it increases RGA noise
- EM better than FC for detecting small amounts of gas

	LIN100F	LIN100M
Detector Type	FC	EM
MDPP (Torr)	2.6×10^{-12}	1.5×10^{-14}

DWELL TIME AND MDPP

LINXON

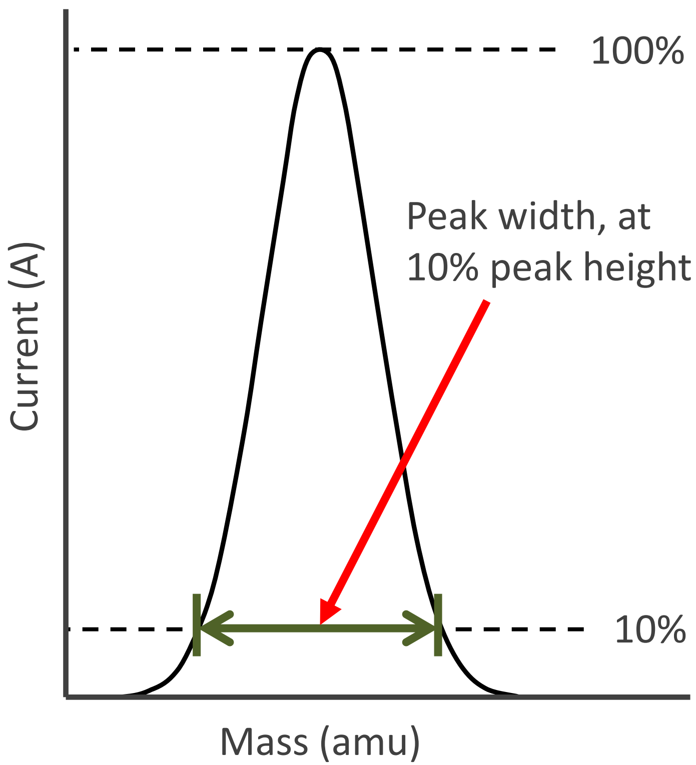
- Dwell time affects MDPP
- myRGA with 100 amu mass range, EM detector on
- Longer dwell time:
  - Lower (better) MDPP
  - Due to increased effective averaging, reduced measurement noise
  - Better for detecting small amounts of gas
  - Increases measurement time by larger factor than the MDPP improvement

Dwell Time	16 ms	256 ms
MDPP (Torr)	6.5×10^{-14}	1.5×10^{-14}

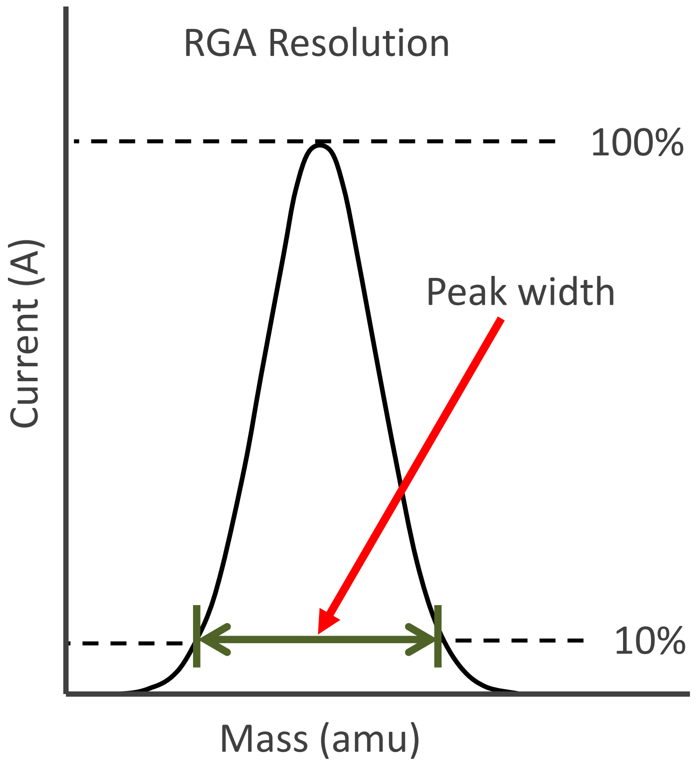
6 RGA RESOLUTION

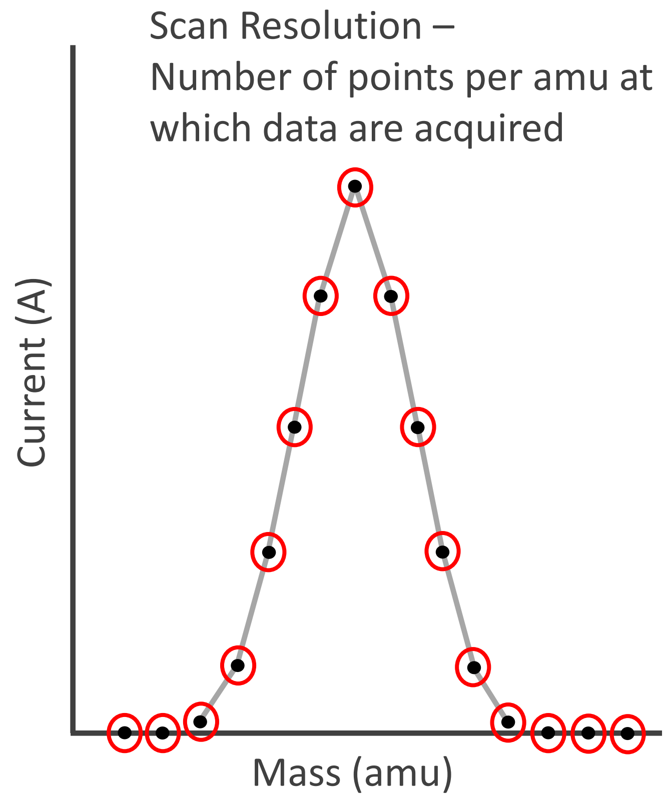
RGA RESOLUTION (PEAK WIDTH)

- Defined as peak width, at 10% of peak height
- Measured in units of amu
- Characteristic of mass filter's pass bandwidth
- The actual mass distribution of ions being detected is much narrower than the peak width or mass filter pass bandwidth
- Peak shape is the shape of the filter's response, not the distribution of ion masses



RGA RESOLUTION AND SCAN RESOLUTION

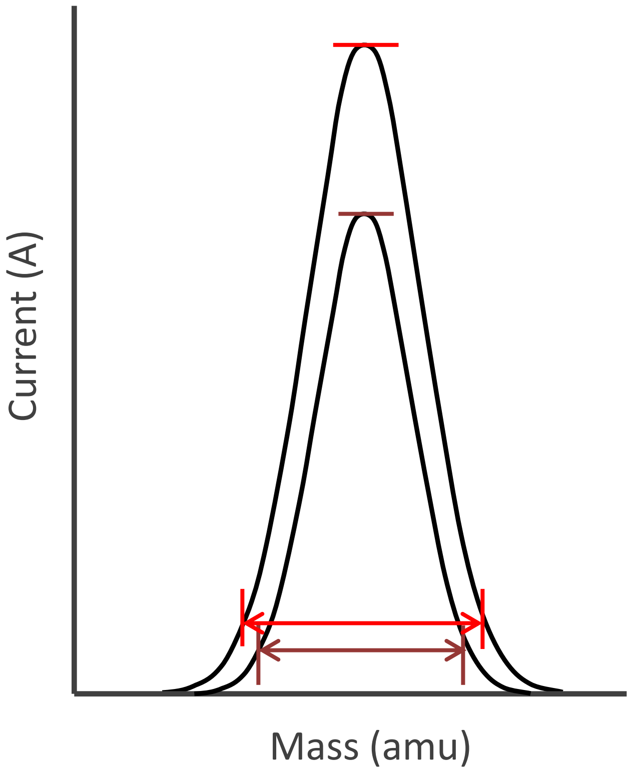




ADJUSTING RGA RESOLUTION – TUNING

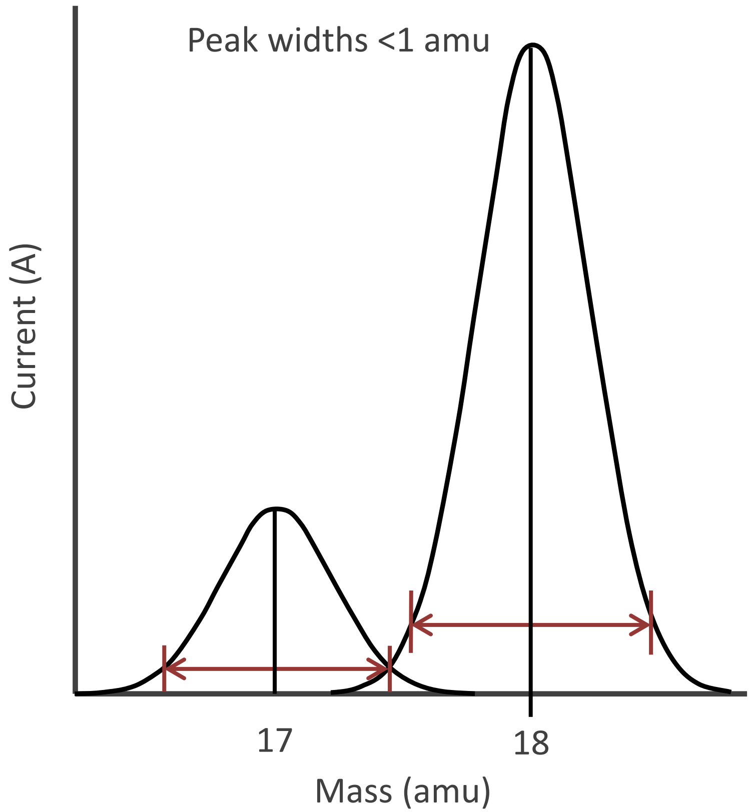
LINXON

- Adjusting the resolution affects the peak width and the peak height
- Narrow the peak, the peak gets shorter (lower sensitivity)
- Widen the peak, the peak gets taller (higher sensitivity)
- Tuning adjusts mass filter’s pass bandwidth
- The wider the pass bandwidth, the more ions that reach the detector



RESOLUTION AND ADJACENT PEAKS

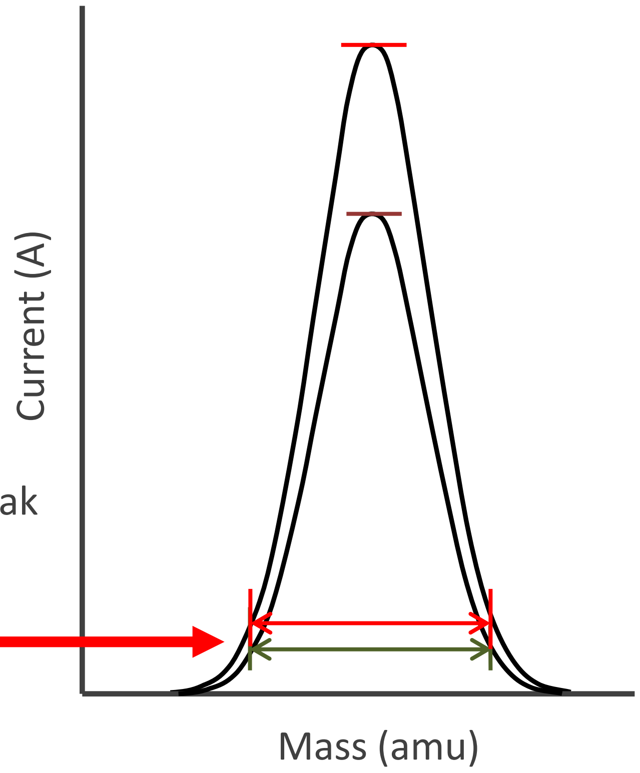
- Peaks located at integer values on the mass scale
- RGAs typically tuned to peak width less than 1 amu, with factory tune to 0.90 amu
- Allows RGA to measure peak height with minimal interference from tail of adjacent peak



PARTIAL PRESSURE AFFECTS PEAK HEIGHT, NOT RGA RESOLUTION

- Change partial pressure of gas
- Peak height changes in proportion
- RGA measures partial pressure
- Peak width should not change much

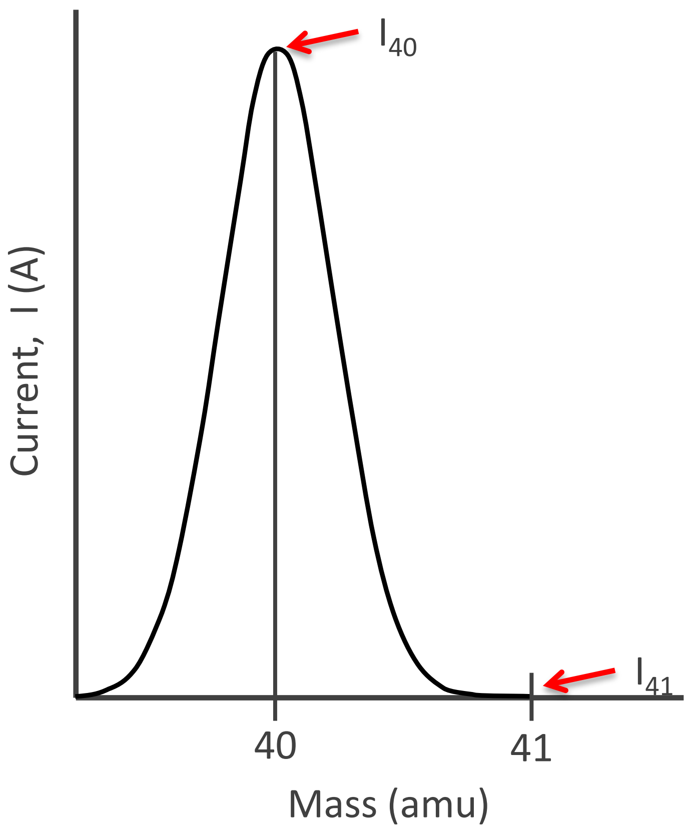
As gas partial pressure changes, peak width at 10% of respective peak height does not change



7 ABUNDANCE SENSTIVITY

ABUNDANCE SENSTIVTY (AS)

- Measurement contribution caused by gas at adjacent mass
- Example: current measured at mass 41, due to Argon-40
- AS = $(I_{41} / I_{40}) \times 10^6$ (ppm)
- RGA's limit for detecting a small peak while gas is present at an adjacent mass
- Lower AS is better
- Mass filter's ability to reject ions

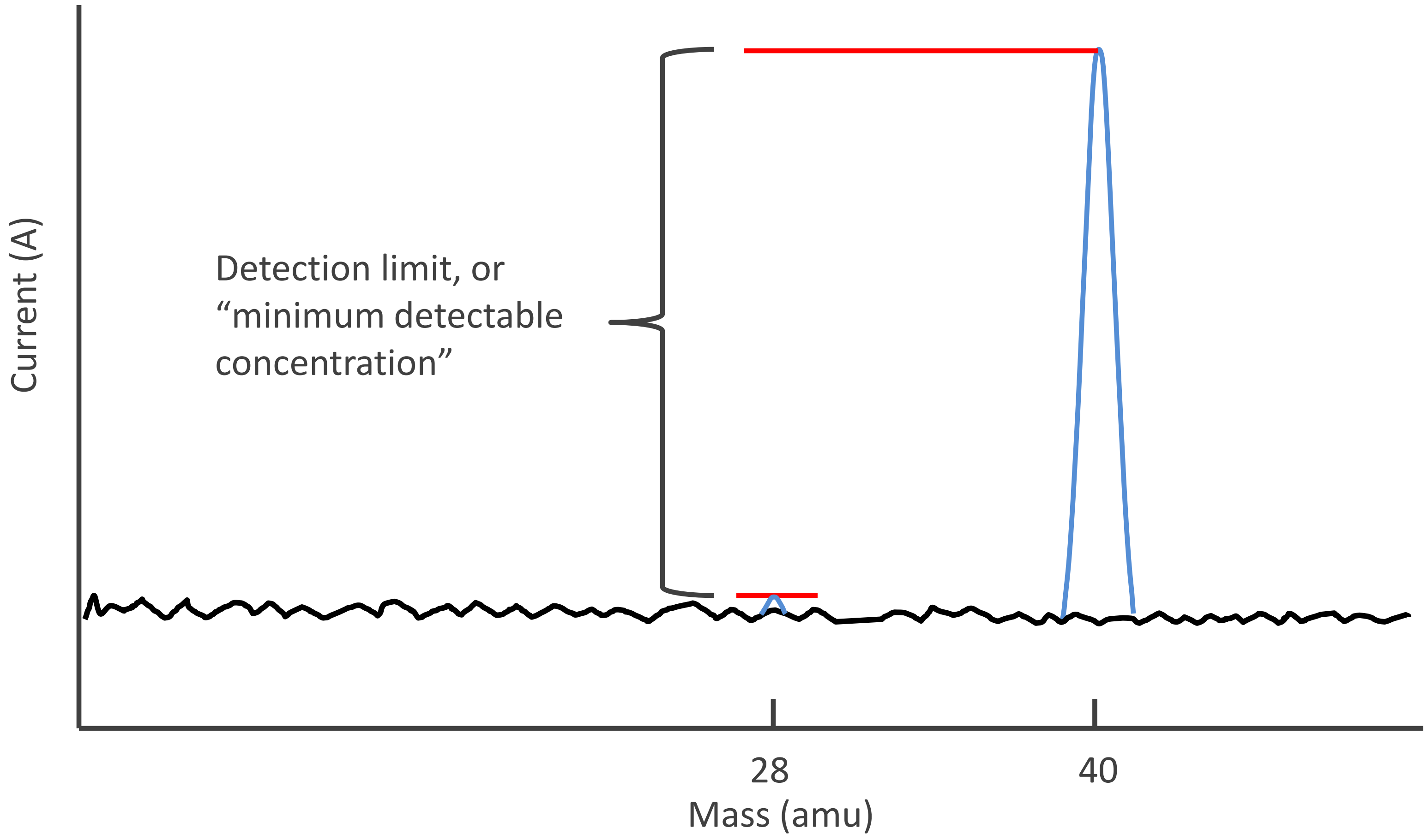


8 DETECTION LIMIT

DETECTION LIMIT (DL)

- Detection limit – Also called “minimum detectable concentration”
- Smallest concentration of gas RGA can detect in presence of a larger amount of gas
- Similar to MDPP in one respect, small signal detection
- Different from MDPP (gas pressure)
  - MDPP is at base vacuum pressure
  - DL is at higher pressure
- Different from MDPP (units of measure)
  - MDPP is in units of pressure (Torr)
  - DL is in units of concentration (ppm)

DETECTION LIMIT – GRAPHIC DEPICTION



DETECTION LIMIT SPECIFICATION

LINXON

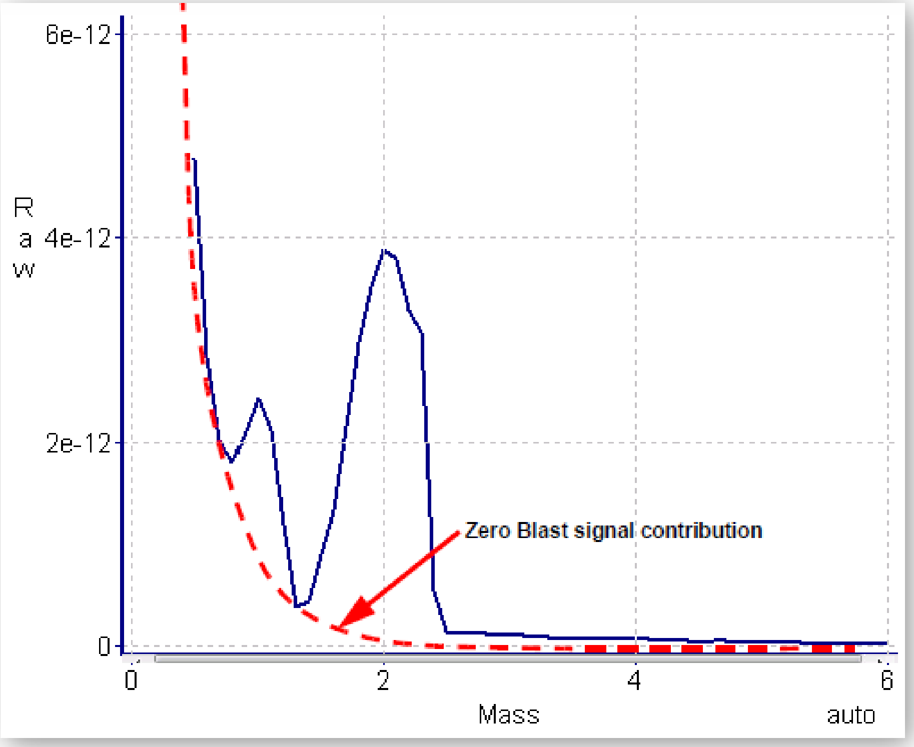
- Detection limit is a key requirement for many applications
- Detection limit depends on:
  - Gas species
  - Operating pressure
  - Dwell time
  - RGA mass range

9 ZERO BLAST

ZERO BLAST

LINXON

- Measuring hydrogen in presence of other gas
- Mass filter set to low mass
- Some higher mass ions reach the detector
- False contribution to hydrogen measurements
  at masses 1 and 2



LINXON

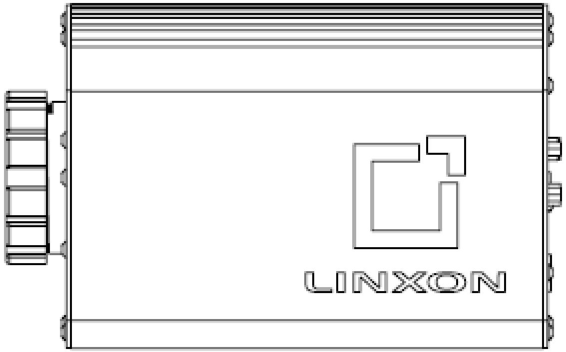
10

ELECTRONICS OPERATING TEMPERATURE

OPERATING TEMPERATURE

LINXON

- Electronics exposed to environment outside of vacuum chamber
- Temperature range for ambient environment for operating myRGA is 5 – 50°C
- Lower temperatures – performance may fall out of specification
- Higher temperatures – RGA will enter thermal protection shutdown mode, stopping operation until temperature is reduced

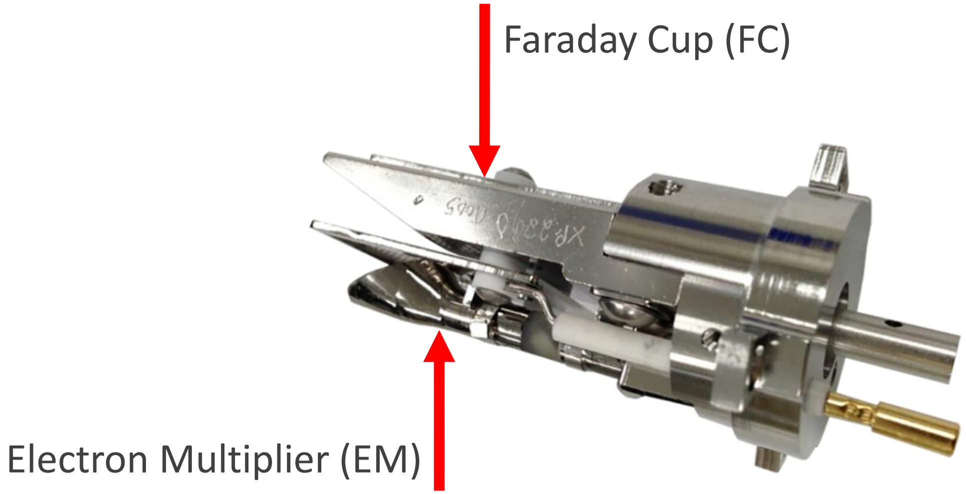


LINXON

11 SENSOR OPERATING TEMPERATURE

MAXIMUM SENSOR OPERATING TEMPERATURE

- myRGA sensors can operate in Faraday cup mode at temperatures up to 200°C
- myRGA sensors can operate in electron multiplier mode at temperatures up to 150°C
- Operation at higher temperatures will degrade performance



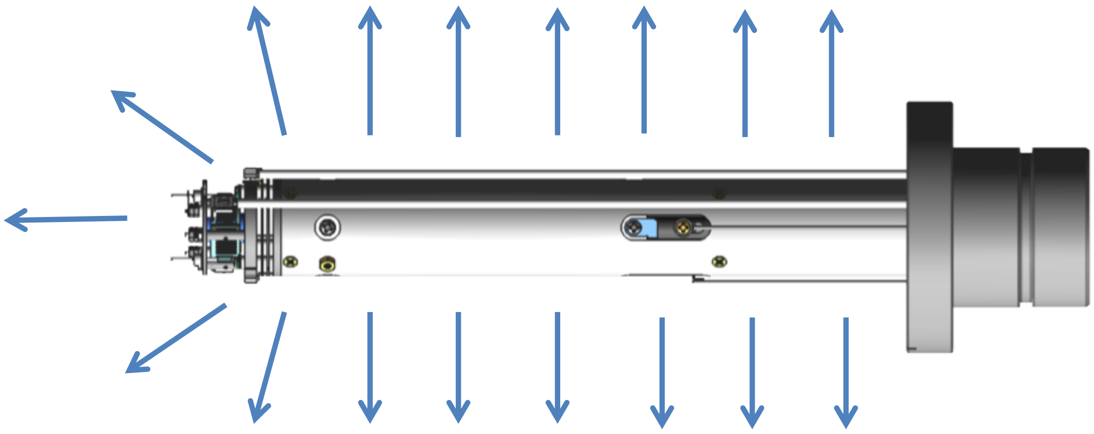
LINXON

12 SENSOR BAKEOUT TEMPERATURE

MAXIMUM BAKEOUT TEMPERATURE

LINXON

- Bakeout used to clean the sensor
- myRGA sensor, with electronics box removed, bake to maximum temperature of 300°C
- myRGA heating jacket, heats to 150°C



THANK YOU!

You have completed the

RGA Hardware and How an RGA Works module!

You may come back and review

the content of this module at any time.