Lecture #5

Instrumentation and Safety

Instrumentation

- **Think about entire system not just sensor**

- **Things to consider about sensors**

  - **Accuracy**

  - **Time response**

  - **Sensor environment (e.g. presence of magnetic or radiation fields)**

  - **Precision – what is the smallest change detected by the sensor?**

  - **Reliability**

  - **Cost**

- **Don't use more accuracy & precision than required**

- **Use commercially produced sensors whenever possible**

- **Install redundant sensors inside of cryostats whenever feasible**

Temperature Measurement

- **Temperature Sensing Options**

  - **Silicon Diodes**

  - **Pt Resistors**

  - **Ge Resistors**

  - **Carbon Glass resistors**

  - **Cryogenic Linear Temperature Sensors**

- Thermocouples

- Compare using dimensionless sensitivity $S_T = (T/V)(dV/dT)$

- Other Issues

  - Self Heating

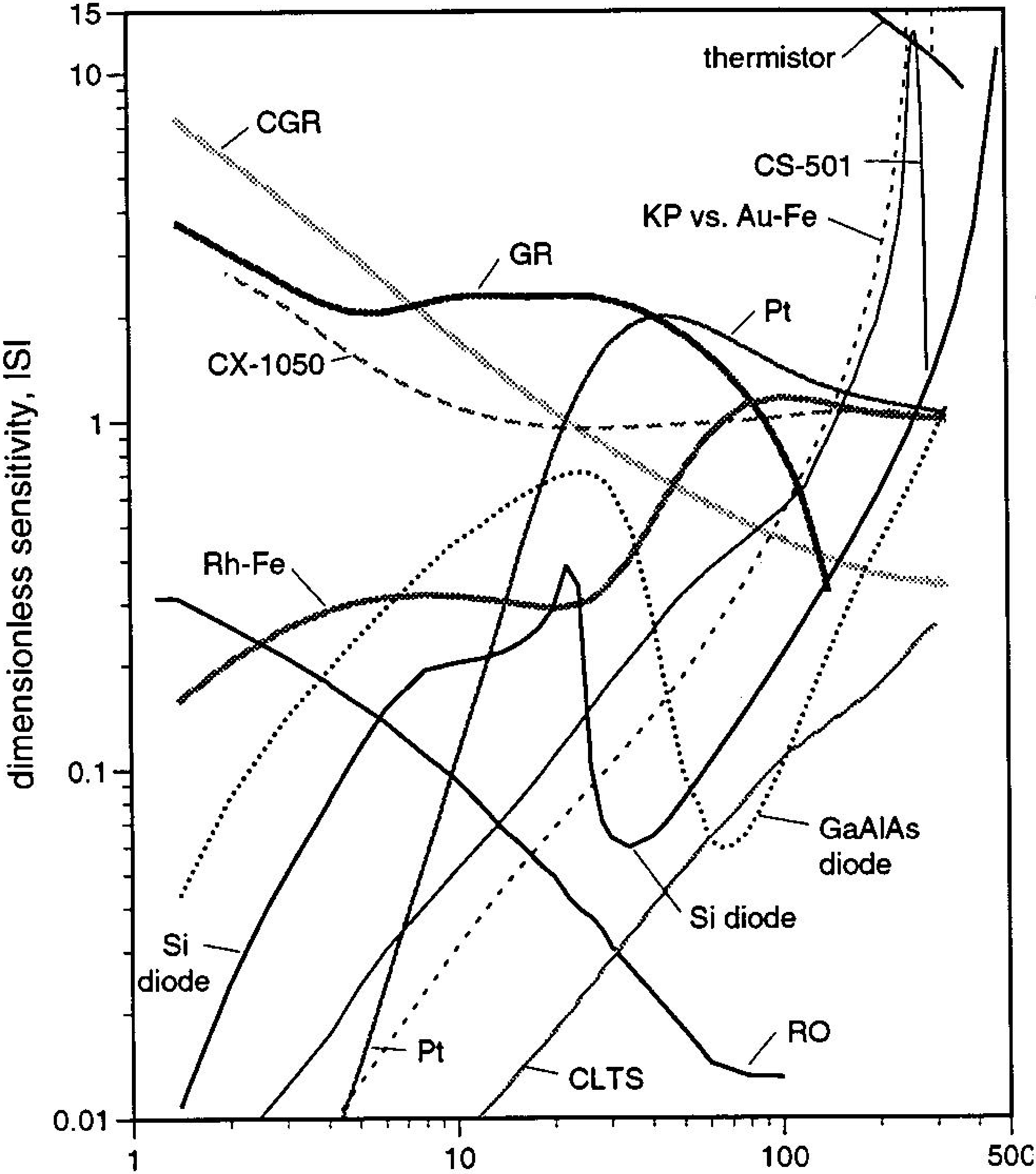
  - Heat Sinking

    32 gauge copper wire (0.032 mm^2) between 300 K and 4 K requires 233 mm of heat sinking. Solution: use lower conductivity wire such as SS or manganin wherever possible

  - Thermal emfs

    Can be eliminated via polarity switching. $V = (V_+ - V_-)/2$

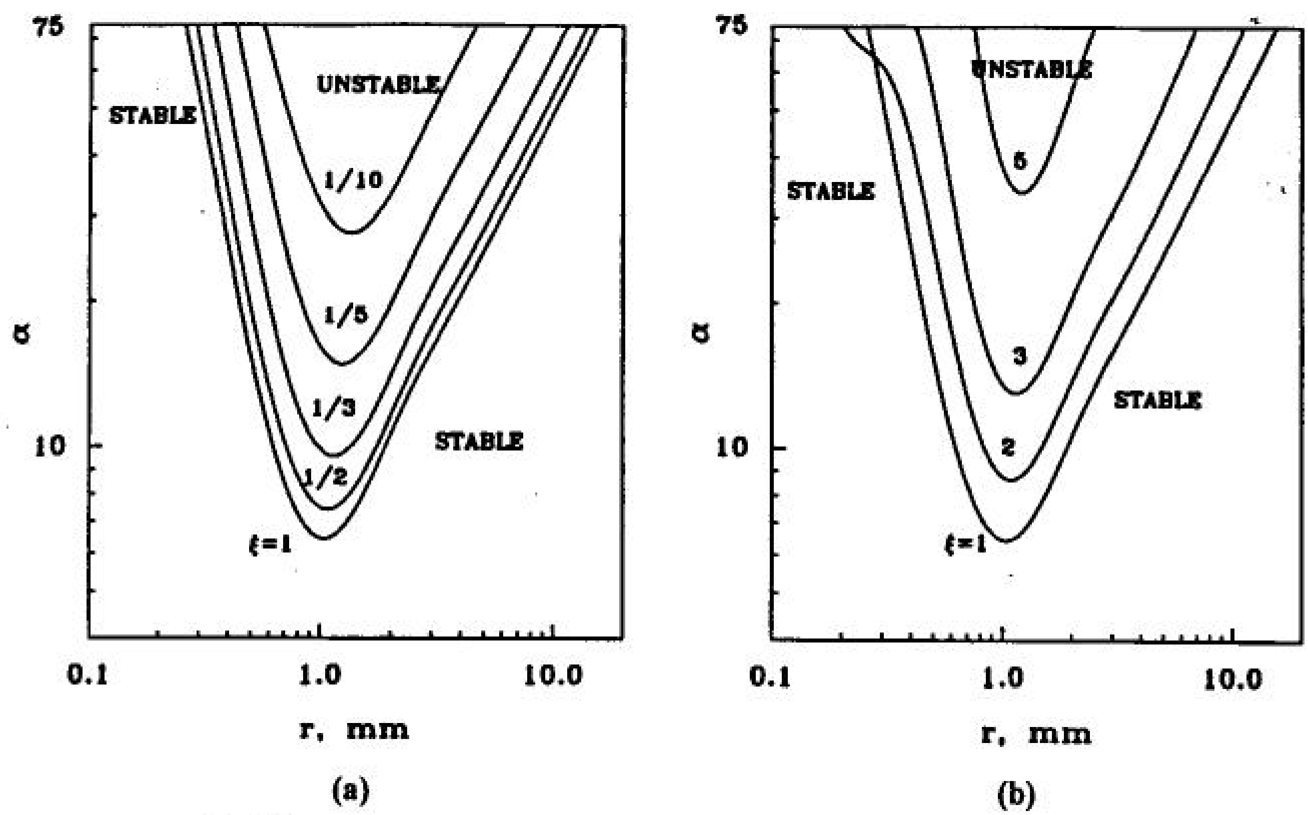
  - Calibration



dimensionless sensitivity, |S|
temperature (K)
15
10
1
0.1
0.01
1
10
100
500
thermistor
CGR
CS-501
KP vs. Au-Fe
GR
Pt
CX-1050
Rh-Fe
GaAlAs
diode
Si diode
Si
diode
RO
Pt
CLTS

Pressure Measurement

- Room temperature where possible
- Problems with room temperature Pressure measurement
  - Thermal acoustic Oscillations
  - Time response
- Some cold pressure transducers exist



. Stability curves for TAOs in a helium system with a continuous temperature profile along the length of the tube. (a) $\xi \leq 1$; (b) $\xi \geq 1$.

Flow Measurement

- Frequently done at room temperature
- Standard techniques work
  - Use correct materials & calibration
  - Hot wire anemometry doesn't work with He II

Level Measurement

- Superconducting level gauges for LHe service
- Differential pressure techniques
- Capacitive technique
- Self heating of sensors
- Floats (e.g. LN_2)

Safety

Warning: This is NOT a complete safety class

- **Safety considerations should be designed in from the beginning of the experiment. Retrofits are time consuming & expensive**

- **Independent safety reviews are invaluable**

- **Understanding the unique safety issues associated with cryogenics is vital**

- **Safety concerns apply to both large and small systems**

Over Pressurization Hazards

- **Large volume expansion when going from a cryogenic liquid to 300 K gas means large pressure rises are possible**

Table 5-3 Change in volume from liquid at normal boiling point to ambient temperature gas at 1 atmosphere

Substance	V_{gas} / V_{liquid}
Helium	701
Para hydrogen	788
Neon	1341
Nitrogen	646
Argon	779
CO_2	762
Oxygen	797

It takes 1000 atm to maintain LHe density at 300 K

The solution is to <u>always</u> install relief devices

- **Redundant devices should be used. Typically relief valve + burst disc**
- **The device should be set to open at or below the MAWP of the vessel**
- **Valves should be sized for worst case scenarios**
- **Valves should be tested & certified before installation**
- **Ensure that there are no trapped volumes. Remember – valves may leak or be operated incorrectly and cryogenic systems may warm up unexpectedly**
- **Do not put shut off valves between system and reliefs**
- **Ask What if ? questions**

Asphyxiation Hazards

Inert gases can displace oxygen from an area resulting in rapid unconsciousness & death **Without Warning**

Oxygen content (volume %)	At rest symptoms and effects
15–19	Possible impaired coordination; may induce early symptoms in persons with lung, heart, or circulatory problems.
12–15	Deeper respiration, faster pulse, and impaired judgment, coordination, and perception.
10–12	Further increase in respiration depth and rate, lips blue, poor coordination, and judgment.
8–10	Nausea, vomiting, ashen face, mental failure, fainting, unconsciousness.
6–8	4–5 minutes, all recover with treatment; 6 minutes, fatal in 25 to 50% of cases; 8 minutes, fatal in 50 to 100% of cases.
4–6	Coma in 40 seconds and then convulsions, breathing failure, and death.

Anything below 19.5% is considered oxygen deficient

To mitigate this hazard

- **Always do an ODH analysis before hand.**
  - **What will the O_2 level go to if all the cryogens are suddenly boiled off?**
  - **What will the O_2 level go to under normal boil off?**
  - **Are you depending on regular ventilation? How do you ensure it stays on?**
  - **What happens in a power failure?**
- **Commercial ODH monitors are available and properly installed provide a great deal of additional safety. Hand held devices are also available**
- **ODH can be a problem for small systems as well depending on their location**

- **Storage of large amounts of compressed gas can also pose a ODH hazard**

Hydrogen Safety

- **Hydrogen is extremely flammable**
(4 – 75 % by volume in air)

- **Ignition energy is 0.02 mJ**

- **47 l of LH_2 ~ 8 kg of TNT**

Recent strategies at SLAC:

- **The system was designed so that in all credible accident scenarios, all hydrogen was vented safely into the outside air away from people and buildings.**

- **A hazardous atmosphere detection (HAD) system was installed that continuously monitored the building air for the presence of hydrogen.**

- **If hydrogen was detected the system would:**

  - **Sound an evacuation alarm,**
  - **Turn off all electrical sources near the experiment**
  - **Close the hydrogen supply valves**
  - **Turn on high speed ventilation fans**
  - **Notify the fire department.**

- **No open flames, cutting, welding, or grinding is allowed in the experimental hall once hydrogen is present**

- **The entire hydrogen system was leak checked and the detection system was thoroughly tested.**

- **The design of the hydrogen system and its safety components was reviewed both by a SLAC safety committee and an external committee of hydrogen safety experts.**