Washington Division

Hydrogen Detection Instrument Uncertainty at a Nuclear Facility

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DOE Nuclear Facility Setpoints

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- **Requirement.** 10 CFR 830: *Nuclear Safety Management*
  - Establish technical safety requirements to ensure safe operation (e.g., safety limits & operating limits)
- **Guidance.** DOE G 423.1-1: *Implementation Guide for use in Developing Technical Safety Requirements*
  - Set points must account for calibration uncertainty, uncertainty during operation, drift & uncertainty during accident conditions
- **Methodology**
  - ANSI/ISA-67.04.01-2006, *Setpoints for Nuclear Safety Related Instrumentation*
  - ANSI/ISA-RP67.04.02-2000, *Methodologies for the Determination of Setpoints for Nuclear Safety-Related Instrumentation*

Limits, Setpoints & Ranges

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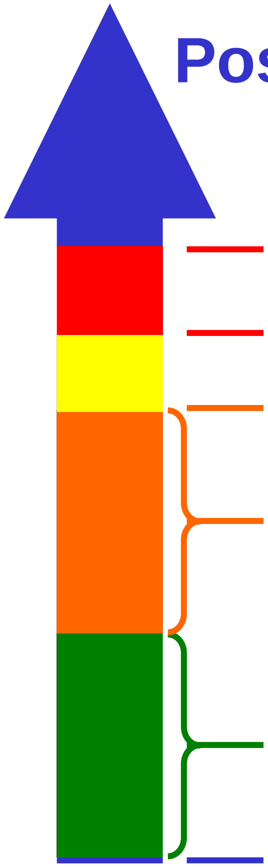

Possible range of operation

Safety Limit – Chosen to maintain system integrity

Analytical Limit – Accounts for event transient

Limiting Trip Point – Least conservative setpoint

Range for Trip Points

Range for Operating Transients

Normal operation

Limiting Trip Point = Analytical Limit – Uncertainty

ANSI/ISA-67.04.01-2006

Maximum Uncertainty Terms

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- U Combined uncertainty
- R_i Random independent terms
- S_i Biases of unknown sign
- B^+_i Biases of known sign – positive
- B^-_i Biases of known sign - negative

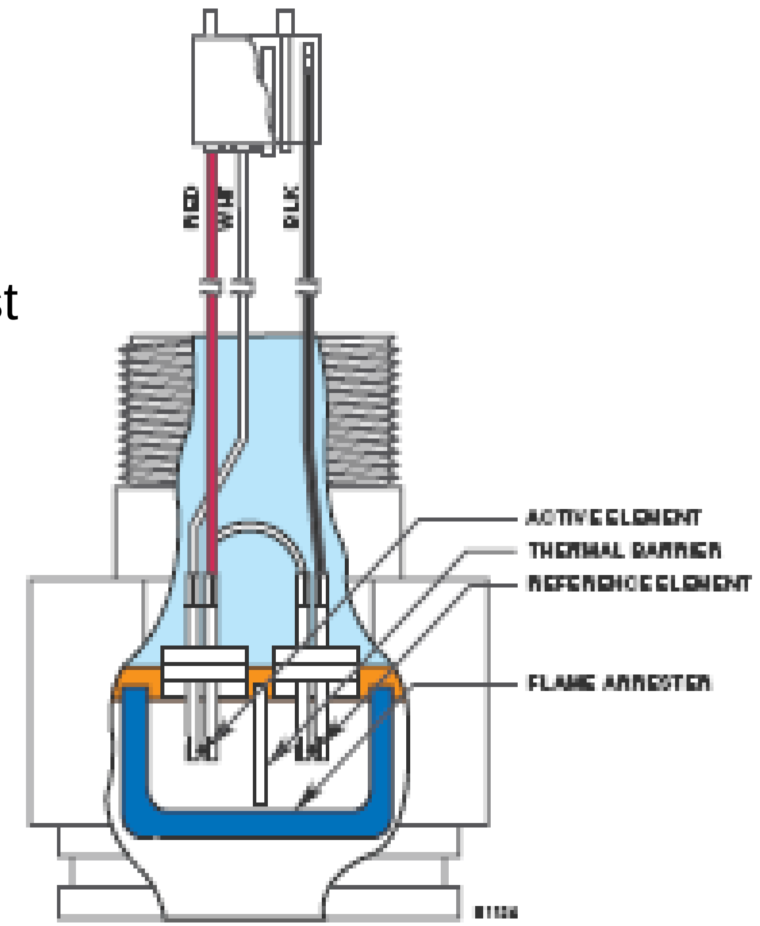
$$U^+ = \sqrt{\sum_{i=1}^{i=j} R_i} \pm \left| \sum_{i=1}^{i=k} S_i \right| + \sum_{i=1}^{i=m} B_i^+$$

$$U^- = \sqrt{\sum_{i=1}^{i=j} R_i} \pm \left| \sum_{i=1}^{i=k} S_i \right| + \sum_{i=1}^{i=n} B_i^-$$

ANSI/ISA-RP67.04.02-2000

Example

- Waste Tank Vapor Space Hydrogen Setpoint
- Detection Method
  - Catalytic Oxidation
- Principal of Operation
  - Active Element coated with catalyst
  - Catalytic reaction releases heat so element resistance increases
  - Reference element uncoated so element resistance unchanged
  - Resistance change measured by Wheatstone Bridge circuit
  - Instrument displays %LFL



Analysis Starting Point

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- Assumptions
  - Hydrogen Monitor is calibrated using hydrogen
  - Sufficient oxygen in sample for catalytic reaction to occur
  - Hydrogen Monitor is calibrated at approximately same pressure as that at which it is used
- What Affects Accuracy?
  - Process Measurement Effects
  - Instrument Effects
  - Calibration / Functional Test Effects

Process Measurement Effects

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- Process Composition
  - Need > 10% oxygen for catalytic reaction
  - Measurement affected if other combustible gases are present
    - Monitor calibrated for gas of interest (hydrogen)
    - Heat from catalytic oxidation of other gases will add to that from hydrogen resulting in higher reading
- LFL based on 25˚C
  - If process temperature > 25˚C, the monitor will read low (non-conservative)
  - If monitor calibrated with calibration gas > 25˚C, the monitor will read low (non-conservative)

Instrument Effects

- Reference accuracy
  - Linearity
  - Repeatability
- Calibration acceptance tolerance
- Drift
- Environmental effects
  - Temperature
  - Pressure
- Reading resolution

Calibration / Functional Test Effects

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- Calibration gas accuracy
  - Calibration accuracy is dependent upon accuracy of the gas used for calibration
- Calibration frequency
  - Sensor degrades with time
  - Drift is time dependent

Uncertainty Values for Example

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• Reference accuracy	± 3% LFL for reading < 50% LFL ± 5% LFL for reading > 50% LFL
• Calibration tolerance	± 2 – 3 % LFL
• Calibration gas accuracy	± 1 – 3 % LFL
• Drift	± 1% LFL per month for zero ± 1% LFL per month for span
• Temperature effects	± 4% LFL
• Reading resolution	± 1% LFL
• Overall uncertainty	± 6 – 11 % LFL

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Conclusion

- Presented a systematic approach to establishing safety setpoints based on instrument uncertainty
- Provide an example of how the method can be applied