Considerations in Anemometer Calibration

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Outline

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- Anemometer Calibration
- Quality Control
- Calibration Comparisons
- Calibration Standard Considerations
- Summary

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Current Standards and Test Protocols

Current Test Standards for cup and propeller anemometers

- **ASTM D5096-02**
- **ISO 17713**

- **starting threshold**
- **distance constant**
- **transfer function ****
- **off-axis response**

Non-standard Protocols

- **Measnet**
- **Otech Engineering, Inc.**
  - **…moving vehicle method**
  - **…wind tunnel method**

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Anemometer Calibration

Background

- 30 year history
- Most widely used instrument in wind industry (over 150,000+ units installed)
- Most tested anemometer in the world

Performance characteristics

- Rugged and survives high wind environments
- Linear range matches wind turbine energy producing speed range
- Independent of temperature
- Maintains performance for extensive periods

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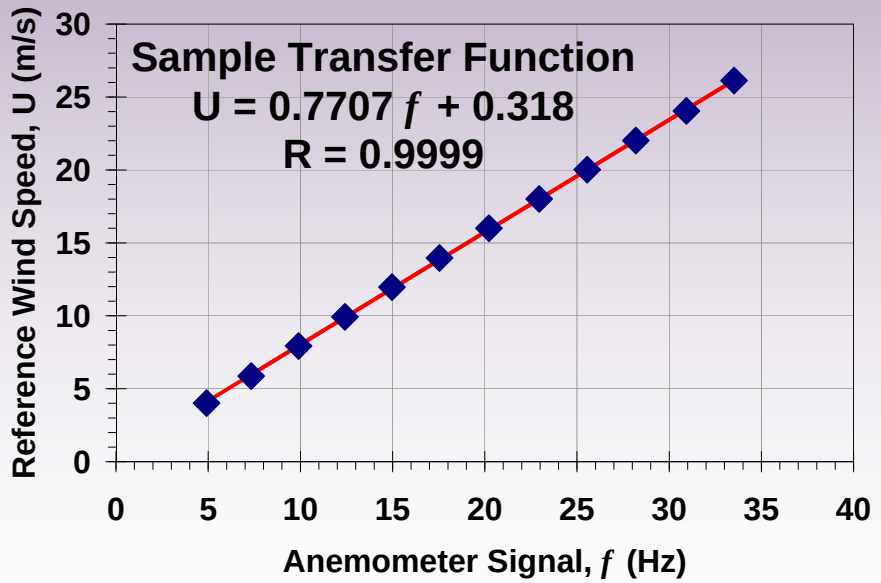
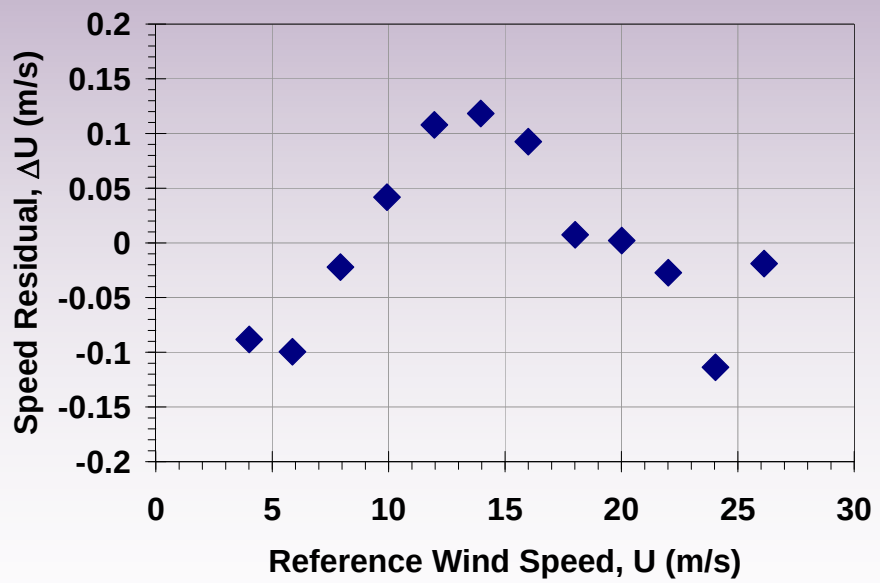
Anemometer Calibration

Generation of an anemometer transfer function

- Steady state wind speeds at set intervals
- Increasing and decreasing speeds
- Include specified speed range
- Produce slope and offset from linear transfer function
- Provide a measure of uncertainty





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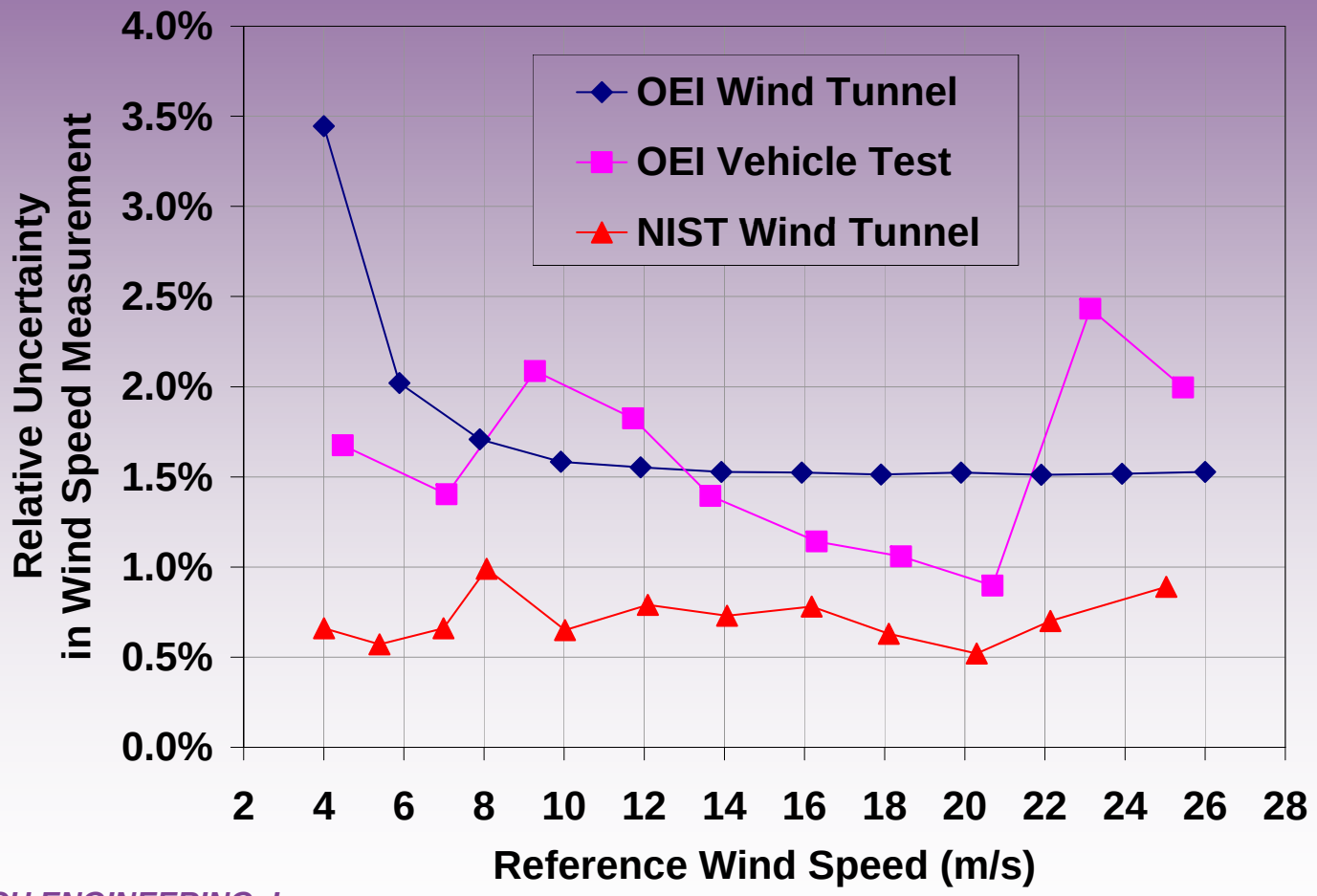
Anemometer Calibration

Uncertainty in Velocity Measurement

$$U_V = \sqrt{(B_V)^2 + (tS_V)^2}$$



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Quality Control

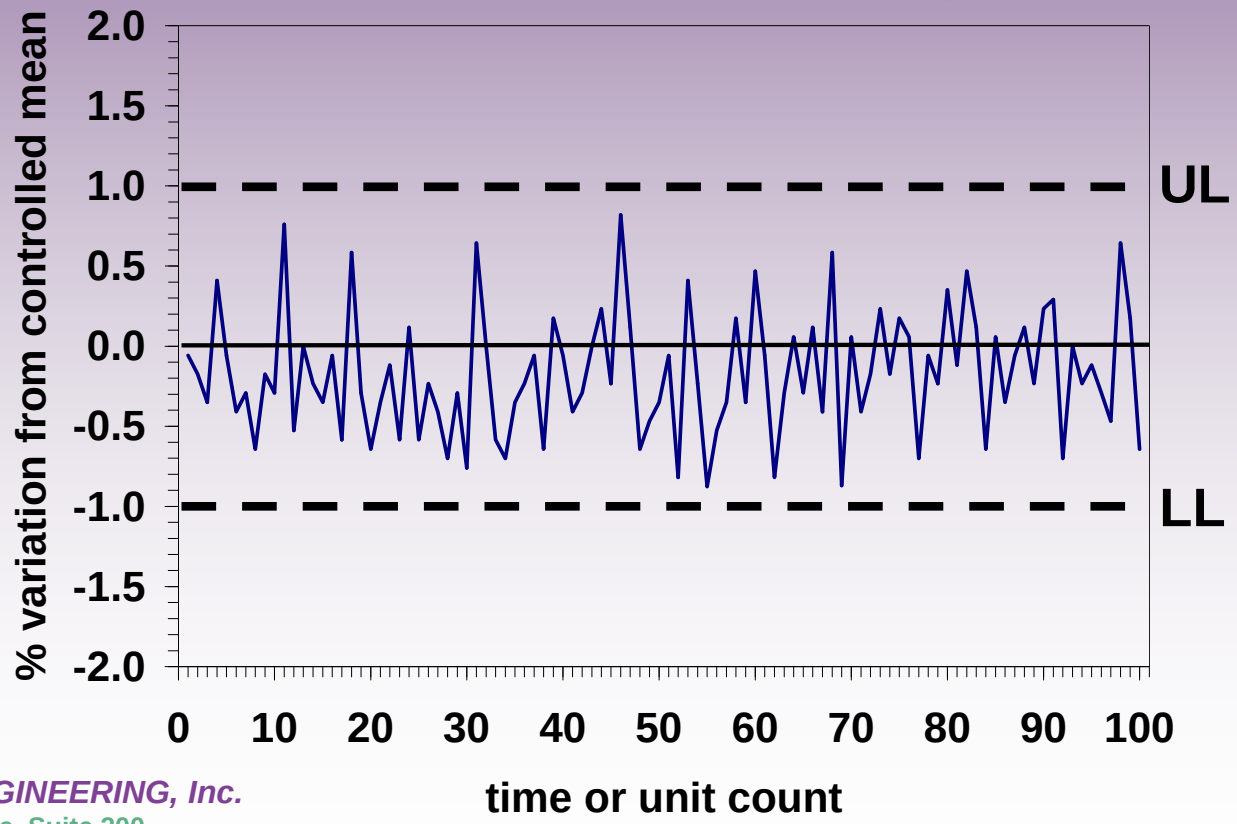
Recall sample transfer function

$U = 0.7707\ f + 0.318$

Converted transfer function using forced intercept

$U = 0.7693\ f + 0.35$

"slope+k" value



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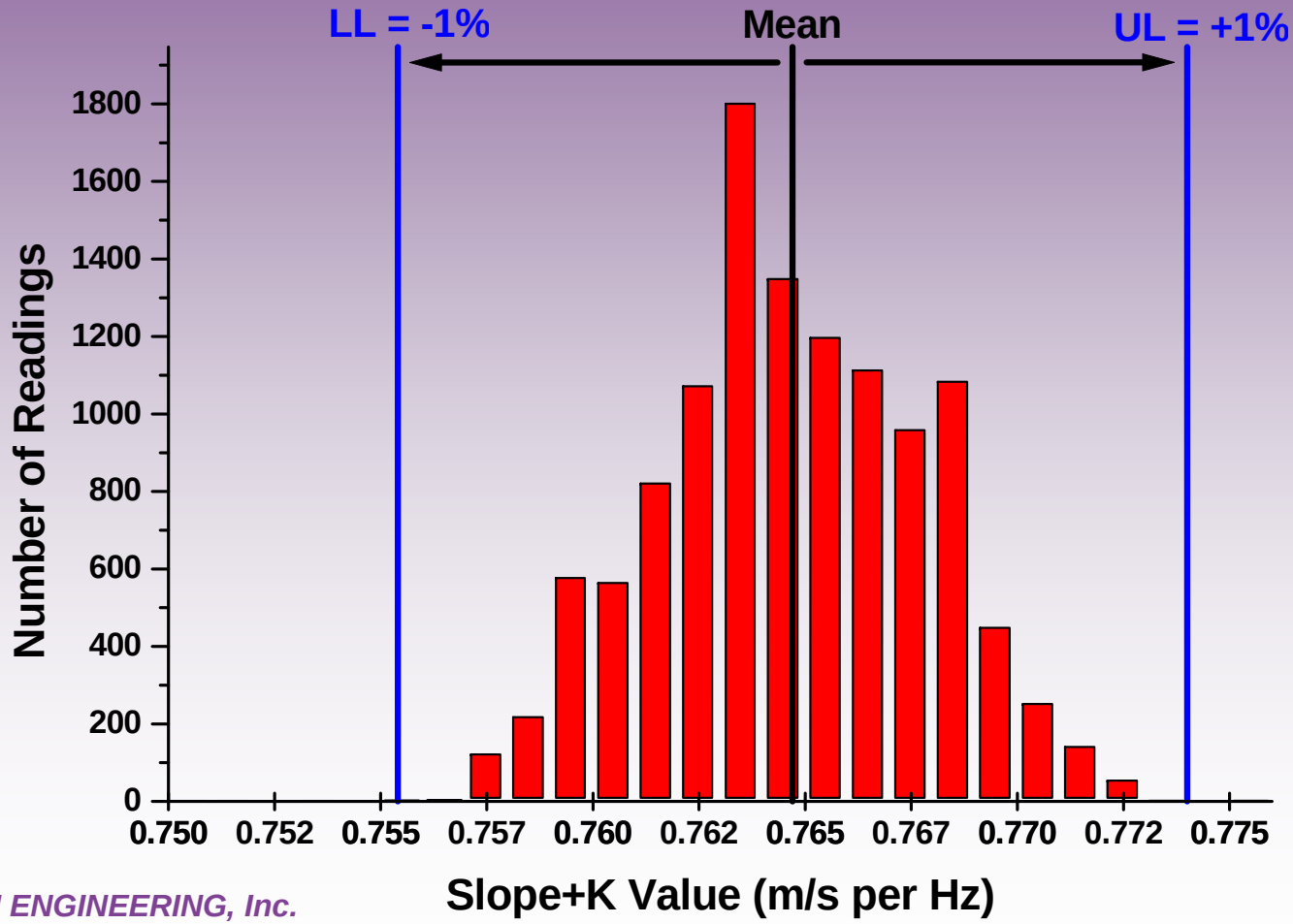
Quality Control

Histogram of Slope+K Values from OEI Vehicle Tests
Dec 2002 – Jul 2005 (11,834 new NRG #40 Cup Anemometers)
Standard Deviation = 0.0031 m/s per Hz
95 % of the distribution are included within ± 0.8 % of the mean



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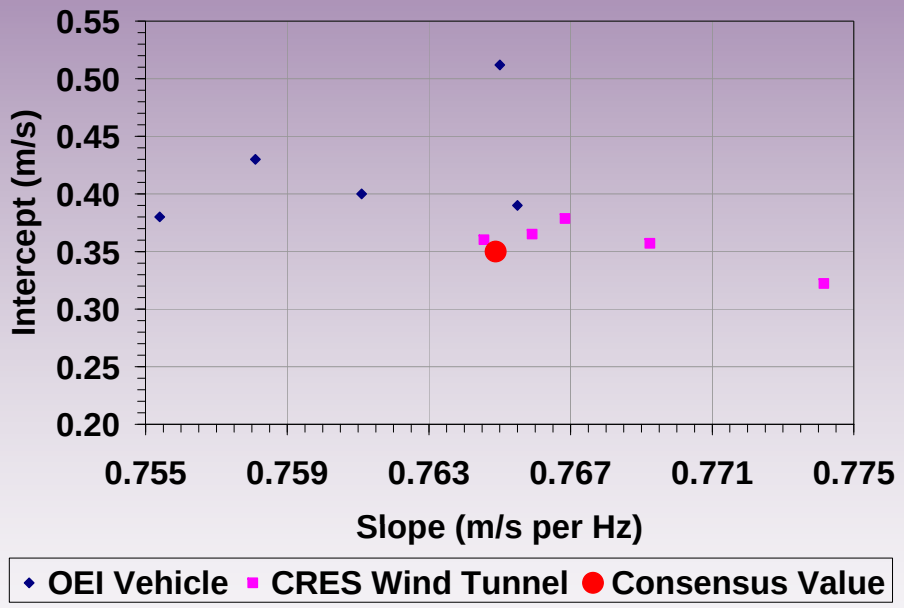
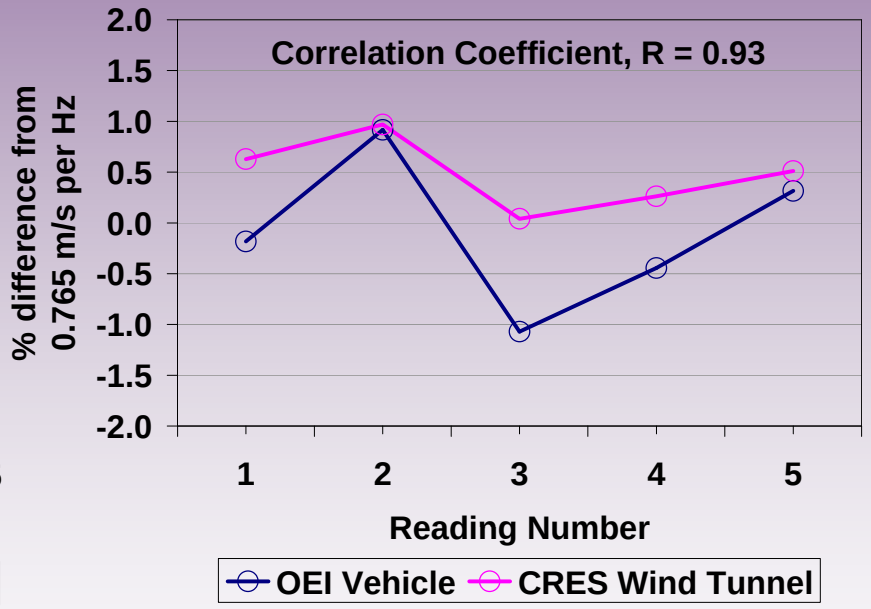
Calibration Comparisons

Comparison of five NRG #40 anemometer calibrations (year 2002) between the OEI Vehicle and CRES Wind Tunnel test methods





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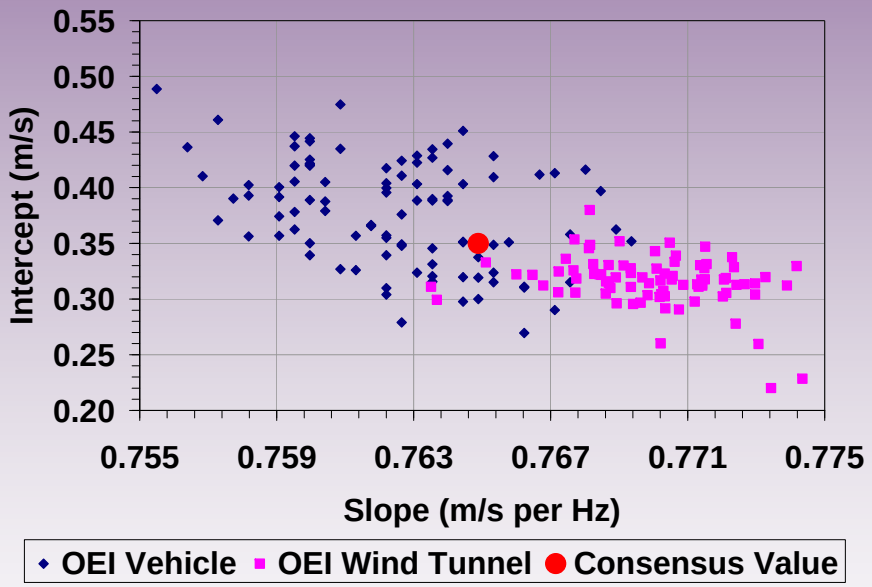
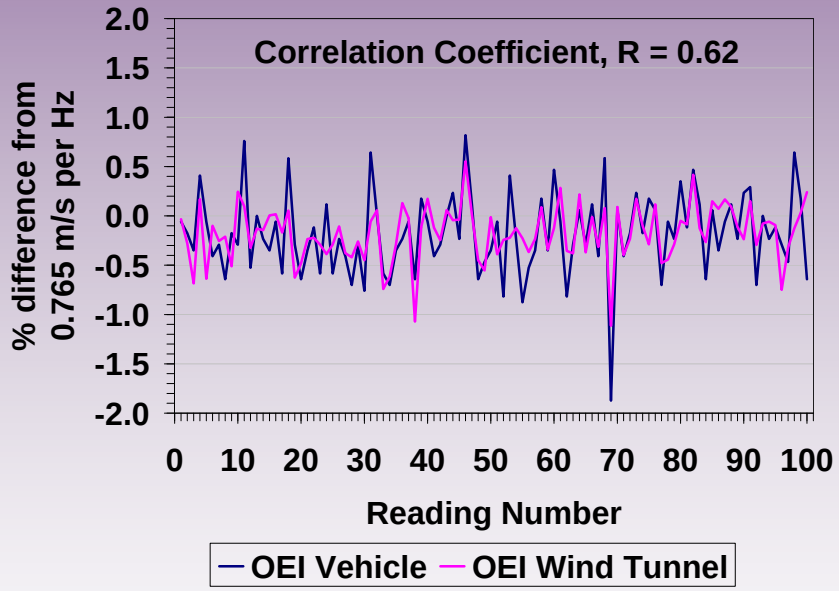
Calibration Comparisons

Comparison of 100 NRG #40 anemometer calibrations (year 2005) between the OEI Vehicle and OEI Wind Tunnel test methods





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Calibration Standard Considerations

- Must agree upon a consensus standard anemometer calibration procedure and report process (i.e. Measnet).
- Consensus must remain an open process.
- Maintain a relation to a standard instrument via round robin comparisons (i.e. RR-3 experiment).

Test Protocol	Range (m/s)	# Points	Dwell Time (sec)	Hysterises Check	Interval Duration (sec)
ASTM D 5096-02	0 - 50% FS	10	300 - 1000	yes	30 - 100
OEI Vehicle Test	4.5 - 25	10	396	yes	18 - 98
OEI Wind Tunnel	4 - 26	12	360	yes	30
Measnet	4 - 16	13	390	yes	30

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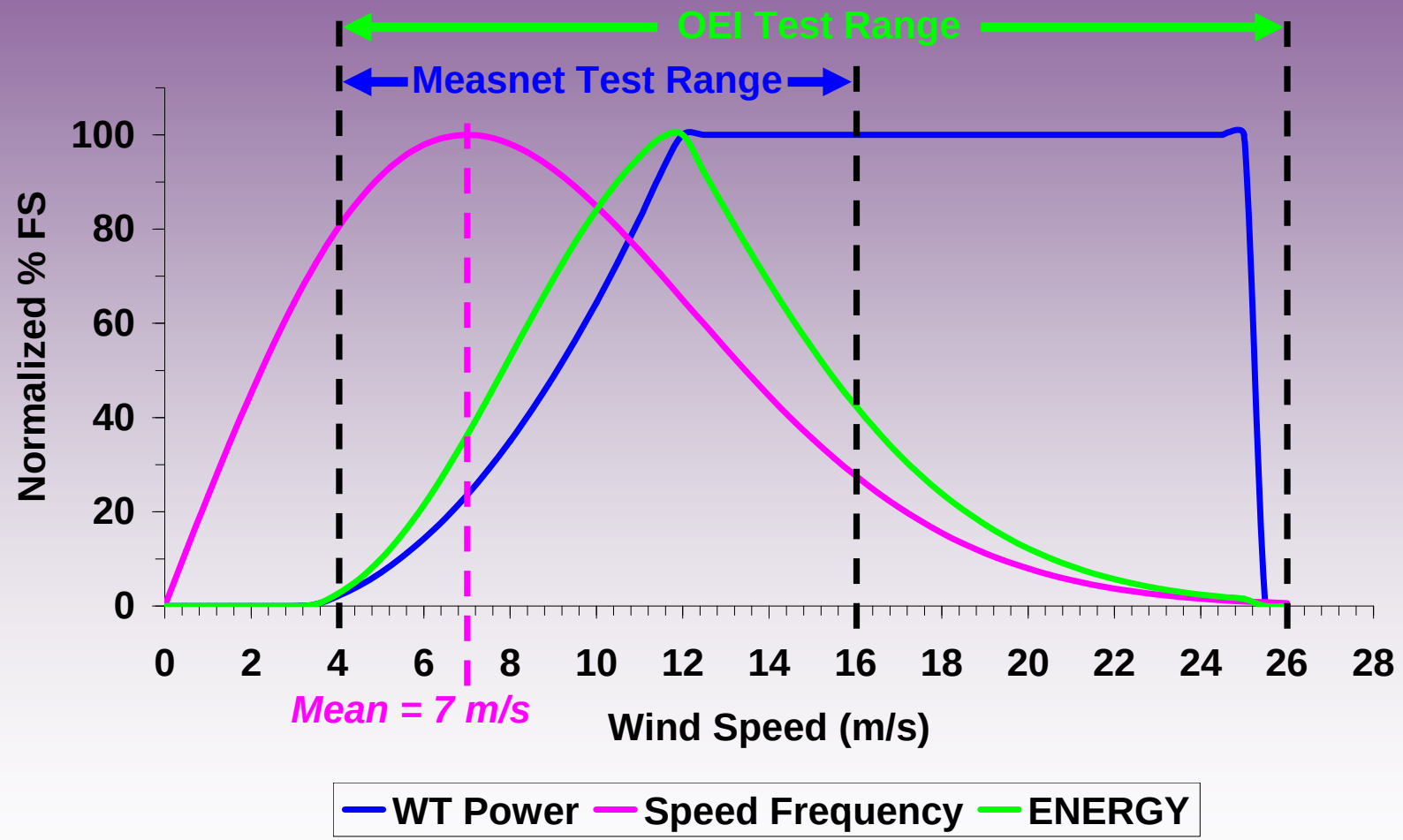
Calibration Standard Considerations

Power, Speed Frequency, and Energy Distribution for a range of wind speeds (using GE 1.5 MW wind turbine power curve)



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Calibration Standard Considerations

Considerations for advanced calibrations:

- **Over-speeding**

  Definition: a cup anemometer's over-estimation of the mean wind due to its faster dynamic response at the initial exposure to the wind than at the decrease of the same wind.

- **Off-axis**

  ASTM D5096-02 recommended testing
  - **test range ± 30° off-axis**
  - **increments of 5° angles**

- **Temperature dependence**

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Summary

- To add value in the manufacture of an anemometer, it is recommended to maintain quality control by using anemometer calibration and a statistical guideline ("Slope+K"). This assures buyers that the product clearly conforms to a defined performance criteria.
- When a reliable calibration transfer function is available, it is recommended that users apply the tested transfer function rather than a generic transfer function.
- Uncertainty in reference wind speeds for anemometer calibration are in the range of 2%. Uncertainty claims lower than NIST using LDA technology should be questioned.
- An anemometer calibration standard needs to be defined.

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Related Measurement Standards and References

- ASTM D5096-02 Standard Test Method for Determining the Performance of a Cup Anemometer and Propeller Anemometer
- ASTM D4430-00e1 Standard Practice for Determining the Operational Comparability of Meteorological Measurements
- ASTM D6011-96(2003) Standard Test Method for Determining the Performance of a Sonic Anemometer/Thermometer
- ASTM D7145-05 Standard Guide for Measurement of Atmospheric Wind and Turbulence Profiles by Acoustic Means
- ASTM D5741-96(2002)e1 Standard Practice for Characterizing Surface Wind Using a Wind Vane and Rotating Anemometer
- ASTM D5527-00(2002)e1 Standard Practices for Measuring Surface Wind and Temperature by Acoustic Means
- "The Maximum Type 40 Anemometer Calibration Project" Thomas J. Lockhart, CCM. Cnet, April 1998

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