Comparison of Sling Psychrometer to Digital Weather Meters

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USDA United States Department of Agriculture

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Why Study?

- *"Feedback received by firefighters currently using electronic meters indicates a strong lack of confidence in the RH data they provide. The RH values from electronic meters often disagree with the sling psychrometer by as much as 20 percent.* (Maynard 2011)."

- *"I heard from several students and a fellow instructor that their Kestrel® hand-held weather instruments were giving consistently low relative humidity (RH) readings.* (White 2011)*"*

Why Study?

- *"…any time he got a RH reading on his Kestrel® that was below 25 percent, he simply added 6 or 7 percent to get the "correct" reading."*

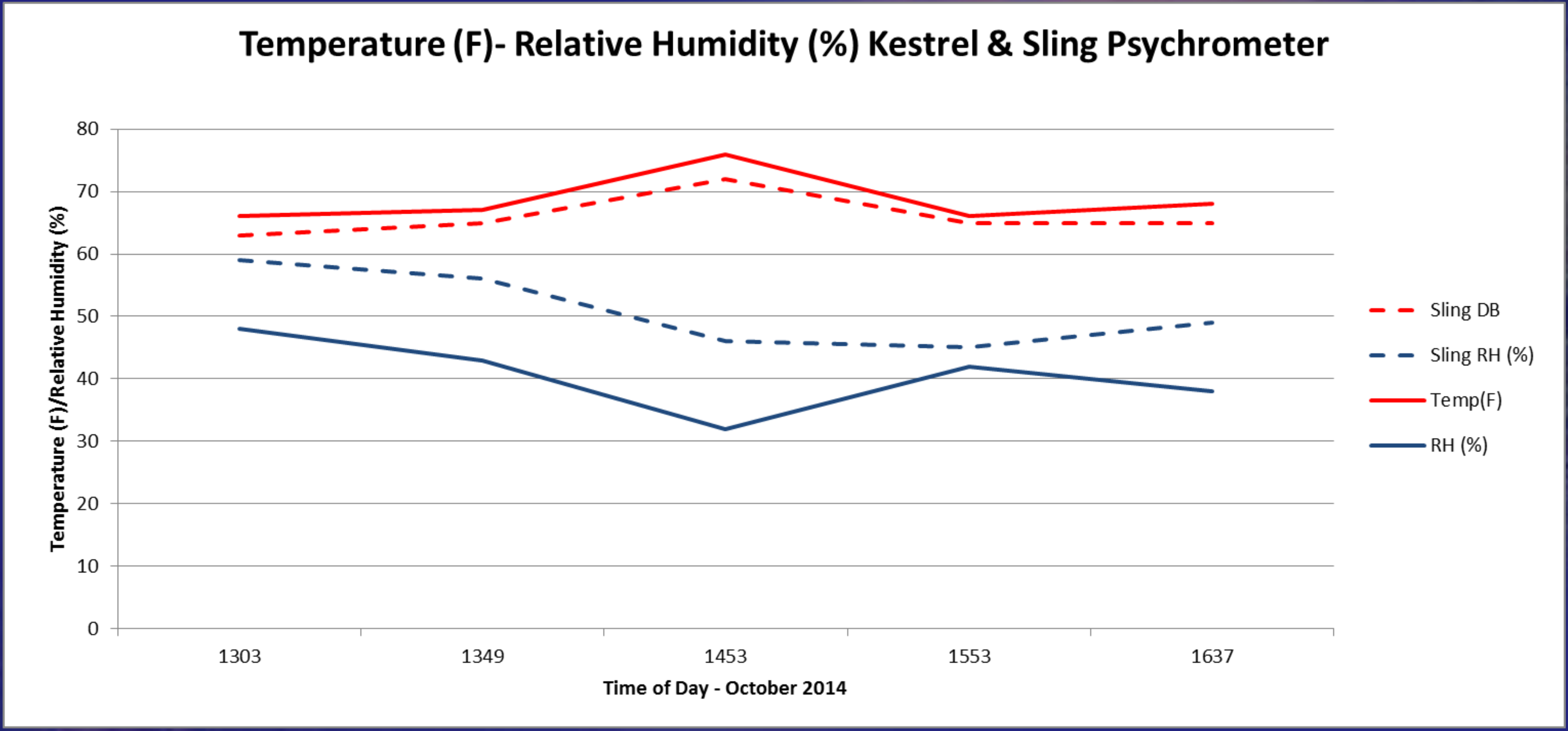
- *…": a prescribed fire manager in the Southwest refused to use the Kestrel® for weather observations because it consistently pushed him out of prescription conditions, and a fire behavior analyst in the Pacific northwest refused to use the Kestrel® because it always read lower than his sling psychrometer."*

From: White (2011)

Truthiness

"Truthiness is a quality characterizing a "truth" that a person making an argument or assertion claims to *know intuitively "from the gut" or because it "feels right" without regard to evidence, logic, intellectual examination, or facts."*

Field Readings Kestrel - SP



Paul Sopko, CC Divide Prescribed fire, Lolo N.F., October 2014

Instrument Accuracy

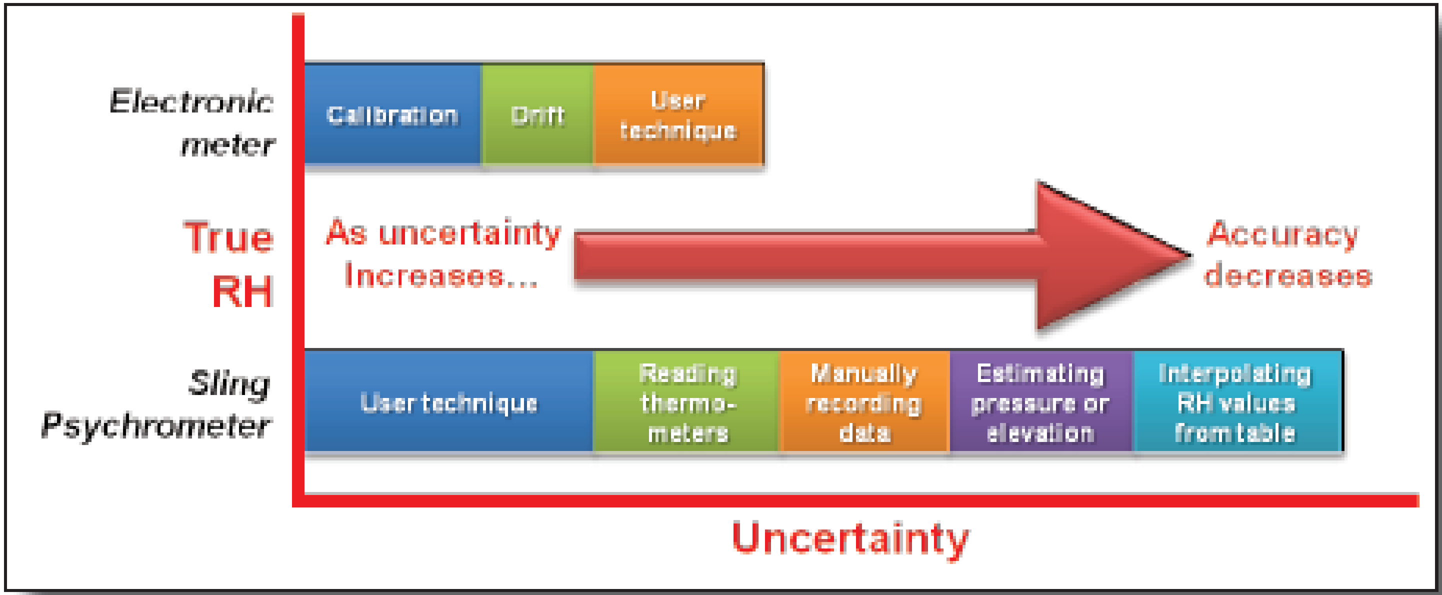


Figure 4—Sources of uncertainty in relative humidity measurement.

From: Maynard (2011). Electronic Weather Meters. 1151 1303—SDTDC

Why SP Higher than Kestrel

- Sock on the wet bulb not clean or wet enough
- Water not clean
- Not swung long enough – wet bulb depression
- Thermometer readings not read quickly enough - rebounding
- Not reading the thermometer correctly
- Calculating incorrectly from the tables
- Elevation Differences

From: White (2011) and Maynard (2011)

How It Works - RH

- Polymer capacitive humidity sensor mounted in thin-walled chamber external to case. Shielded diffuser (Kestrel Specifications)
- As the polymer absorbs water, the dielectric constant changes incrementally and is nearly directly proportional to the relative humidity of the surrounding environment. Thus, by monitoring the change in capacitance, relative humidity can be derived.
  - http://www.ist-usadivision.com/sensors/humidity/

How It Works - Temp

- Hermetically sealed, precision thermistor mounted externally and thermally isolated for rapid response. (Kestrel Specifications)
- Thermistors, are thermally sensitive semiconductors whose resistance varies with temperature.
  - either a negative temperature coefficient (NTC) or a positive temperature coefficient (PTC).
  - NTC, more common, has a resistance that decreases with increasing temperature while the latter (PTC) exhibits increased resistance with increasing temperature.
  - http://www.ni.com/tutorial/7112/en/

Issues Digital Weather Meters

- Operational Environment
- Need time equilibrate
- Maintenance
- Calibration

Fire

Tech

Evaluating D

Greg

In the past few years, digital m
ture, relative humidity, and w
developed and marketed. T
and Development Center (MTD
instruments to see whether a d
the sling psychrometer and an
weather kit commonly used by w
crews are already using a few d
success. Some of the units cur
used are the Amprobe digital p
chrometer and the Extech
humidity/temperature pen.

Changes in weather are
important to wildland fire-
fighters. A digital unit
must be very accurate.
In some types of fuels,
a humidity drop of 2 per-
centage points could
significantly alter the way
a fire burns. The unit must
also be easy to use. Crews
on the fireline may take temper-
ature readings every half hour du
the peak burning period.

For years the sling psychromete
been used for taking weather ob
sling psychrometer is slow and
belt weather kit is not very prec
compare the accuracy of new d
psychrometer and anemomete

A suitable replacement for the s
be easy to use, accurate, and re
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For additional information co
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How Accurate Is Y

Gary L. White

Since the late 1950s, when the belt weather kit was first being developed (USDA Forest Service 1959), firefighters have been using the sling psychrometers from the kits to measure relative humidity on the fire line. Because humidity has such a great effect on fire behavior, knowing the relative humidity and how it is changing over time is a critical piece of information for any wildland firefighter. With the advent of 21st century technology, the sling psychrometer is gradually being replaced by digital hand-held weather meters, such as the Kestrel®.

Several years ago, while teaching at a wildland fire investigation training program, I heard from several students and a fellow instructor that their Kestrel® hand-held weather instruments were giving consistently low relative humidity (RH) readings. The instructor told me that any time he got a RH reading on his Kestrel® that was below 25 percent, he simply added 6 or 7 percent to get the "correct" reading. That practice struck me as inconsistent with good scientific data collection, so I thought

Gary White is a retired U.S. Bureau of Land Management criminal investigator with more than 30 years of wildland fire suppression, investigation, and natural resource law enforcement experience. Currently, he works in central Oregon as the fire marshal for Crooked River Ranch Fire and Rescue and as an independent wildland fire investigator specializing in origin and cause determinations for public agencies and private clients.

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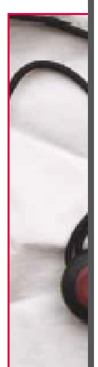

The Kestrel

Fire Management Tech Tips

United States Department of Agriculture
Forest Service
National Technology & Development Program

June 2011

5100 1151 1303—SDTDC

ELECTRONIC WEATHER METERS

by

Trevor Maynard, Mechanical Engineer

HIGHLIGHTS

- Electronic weather meters provide numerous benefits over the belt weather kit, including greater ease of use, accuracy, data storage, and reduced weight.
- Most electronic meters are calibrated to industry-accepted standards and can eliminate errors that occur with traditional instruments.
- Suggested features for wildland fire weather meters are discussed, and technical details of several commercially available models are provided.

INTRODUCTION

For decades, the belt weather kit has been an indispensable tool for fire crews and fire weather analysts. In the hands of a skilled observer, the kit provides accurate and repeatable measurements of wind, temperature, and relative humidity. Despite its strengths, the belt weather kit does have drawbacks. The observer must use several instruments to obtain the required data, and some, such as the sling psychrometer, can present pitfalls for inexperienced users. The kit is bulky and adds to the already demanding load carried by the wildland firefighter. Advances in measurement technologies over the past decade have led to the development of all-in-one digital instruments that provide accurate meteorological data. Electronic weather kits provide the opportunity for weather observers to collect data with an easy-to-use and lightweight device. The purpose of this Tech Tip is to introduce the reader to digital weather meters. Instrument features, accuracy, and applicability to the fire environment will be discussed.

WHAT ARE WE MEASURING?

Before considering the benefits and disadvantages of electronic weather devices, a brief discussion of important weather factors is necessary. The basic measurement principles of devices in the belt weather kit also will be introduced.

Wind

Accurate wind measurements are critical in the wildland and prescribed fire environment. Changes in wind speed and/or direction may indicate a significant change in weather, which could require adjustments to fireline tactics. Knowledge of wind conditions also is important for air operations (helicopters, airtankers, and smokejumpers).

The belt weather kit features a simple analog wind meter (anemometer) (figure 1). The user faces the meter into the prevailing wind (a compass is used to determine wind direction). Oncoming air enters a calibrated hole, pressurizing the inner tube and causing

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Lotus Notes: Mailroom WO SDTDC@FSNOTES • Intranet (web site): http://fsweb.sdtdc.wo.fs.fed.us • Internet e-mail: mailroom_wo_sdtdc@fs.fed.us

Previous Studies

- Lemon & Mangan (2000)
  - Compared many digital weather meters
  - A single Sling Psychrometer reading reported (45°F, 53% RH)
  - Uncontrolled Environment

Lemon & Mangan (2000)

- When the unit was tested against the sling psychrometer (45°F, 53% RH).
- Results – Kestrel 3000
  - Temperature was 2.8 degrees higher
  - Relative humidity was 6.5% lower

From: Lemon & Mangan. Evaluating Digital Meters for Fire Weather Observations. 0051-2315–MTDC.

White (2011)

- White (2011)
- Random field comparisons SP & Kestrel 3000
  - *"RH of 5 to 6 percent below my sling psychrometer."*
- Kestrel certified to 3 set points of RH
  - Kestrel matched up to the certified

Maynard (2011)

- Maynard (2011)
  - Specifically address Kestrels
  - Recommendations on use
  - No comparisons or evaluations
  - Discusses their features & functions

HIGHLIGHTS

- ❑ Electronic weather meters provide numerous benefits over the belt weather kit, including greater ease of use, accuracy, data storage, and reduced weight.
- ❑ Most electronic meters are calibrated to industry-accepted standards and can eliminate errors that occur with traditional instruments.
- ❑ Suggested features for wildland fire weather meters are discussed, and technical details of several commercially available models are provided.

Approach

- Compare SP and Kestrel Readings
- Controlled Environment
- 2 Kestrel 3000 & 2 Kestrel 4500
- 2 Sling Psychrometer's
- Set Point Temperature and RH%
  - Temperature: 60 °, 80 °, 100° F
  - Relative Humidity: 5, 10, 30, & 50%
  - 3 readings at each set point

Data Range

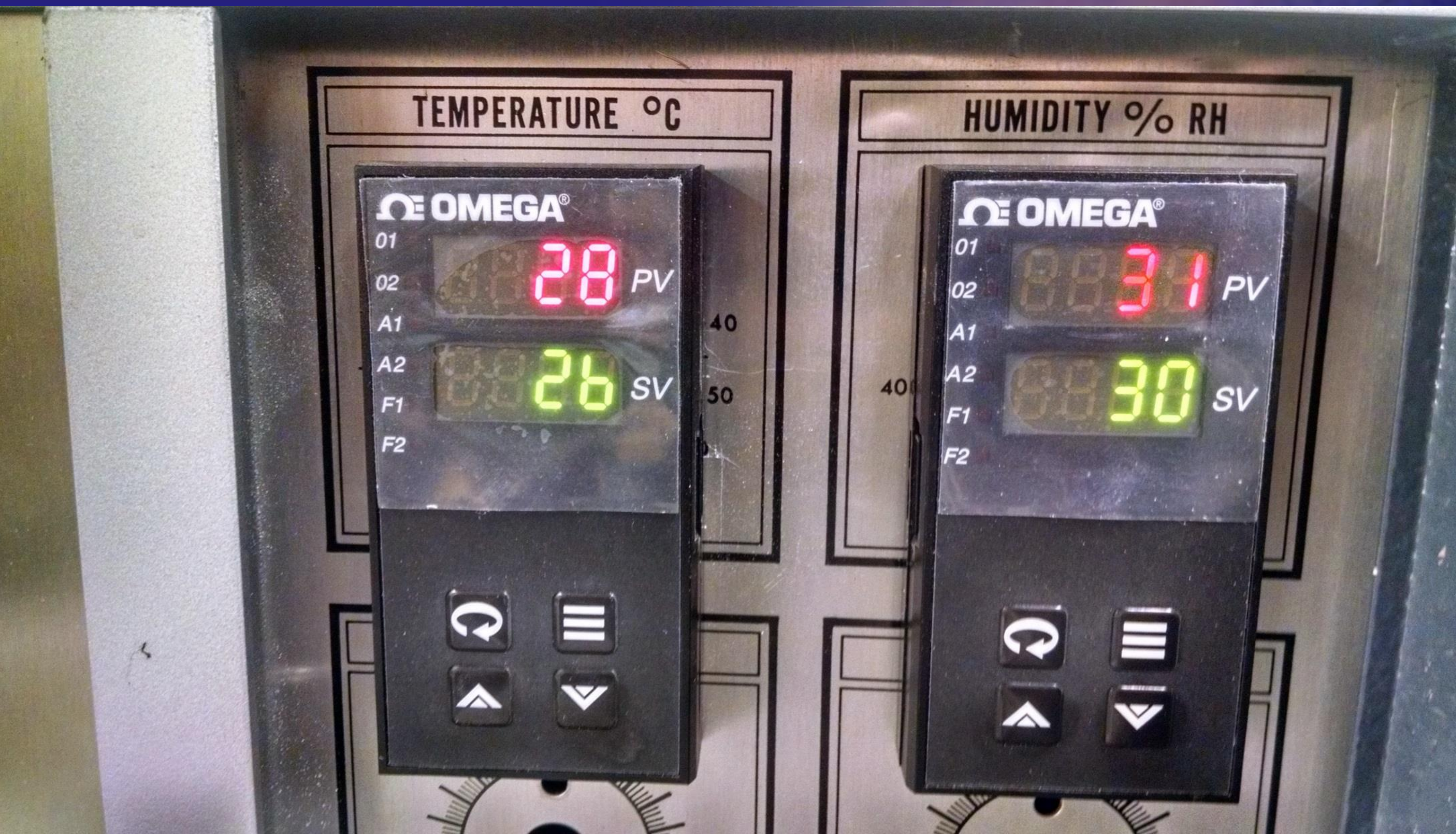
Case	Set Point Relative Humidity (%)	Set Point Temperature (°F)
1	5	80
2	5	100
3	10	60
4	10	80
5	10	100
6	30	60
7	30	80
8	30	100
9	50	60
10	50	80
11	50	100

Approach

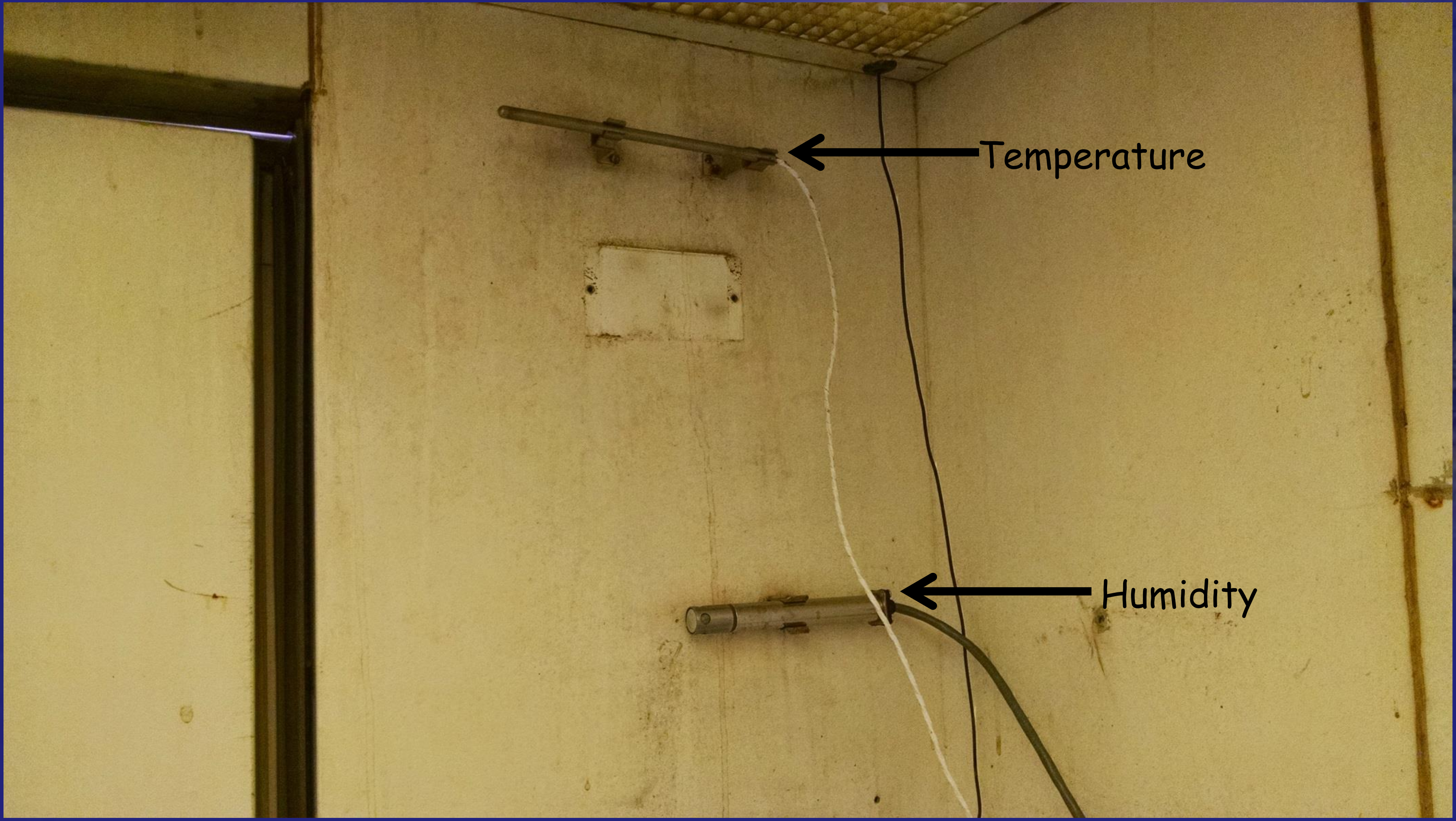
- Two Phases of Data Collection
  - Phase 1 – Kestrels "as is"
  - Phase 2 – Kestrels calibrated/certified
    - Repeat Measurements at the set points
- Analysis and then publish as an RMRS Station Research Note

Environmental Chamber

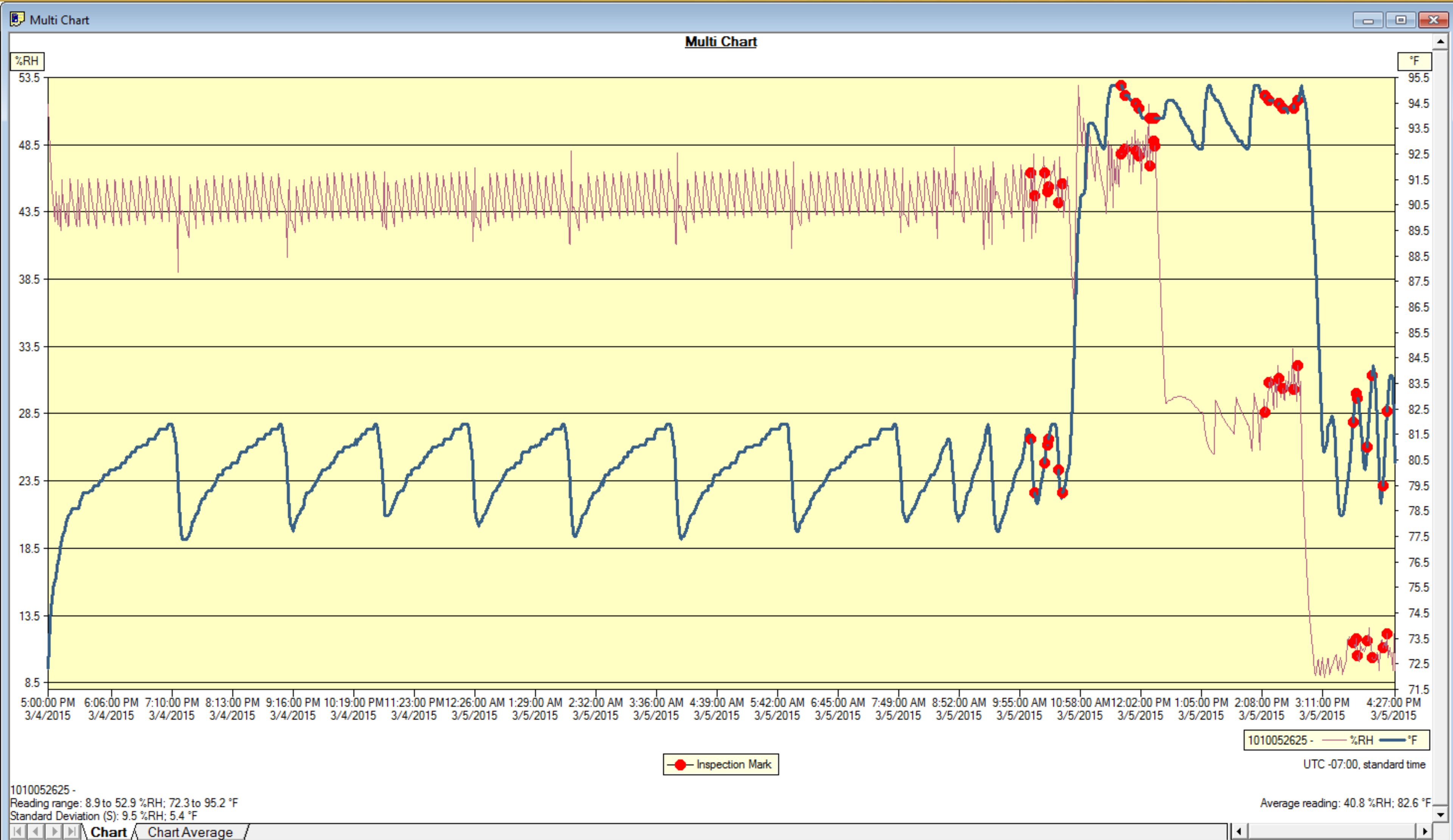
Chamber - Controls



Chamber – Temp/RH Sensors



LogTag Readings

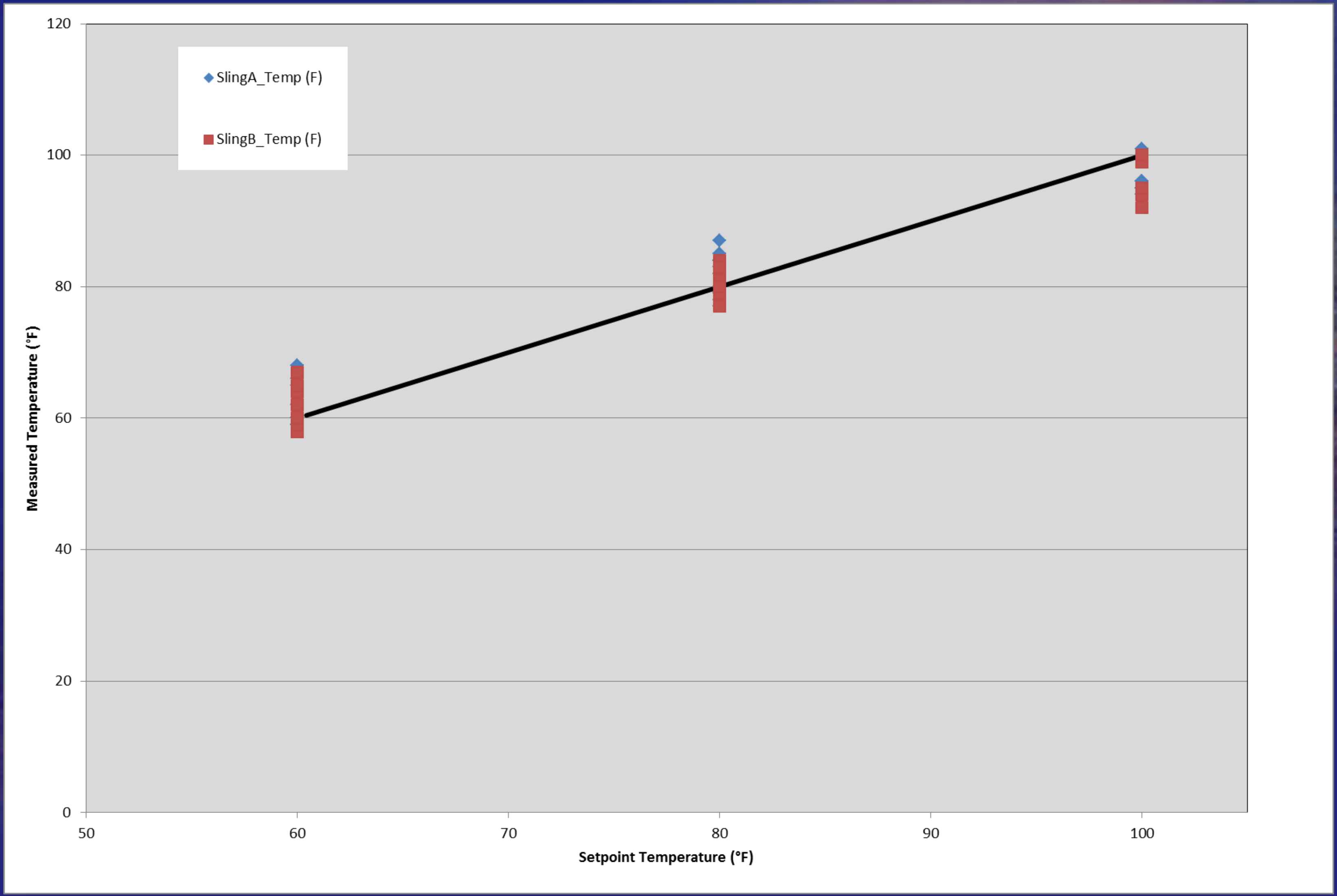


Instruments

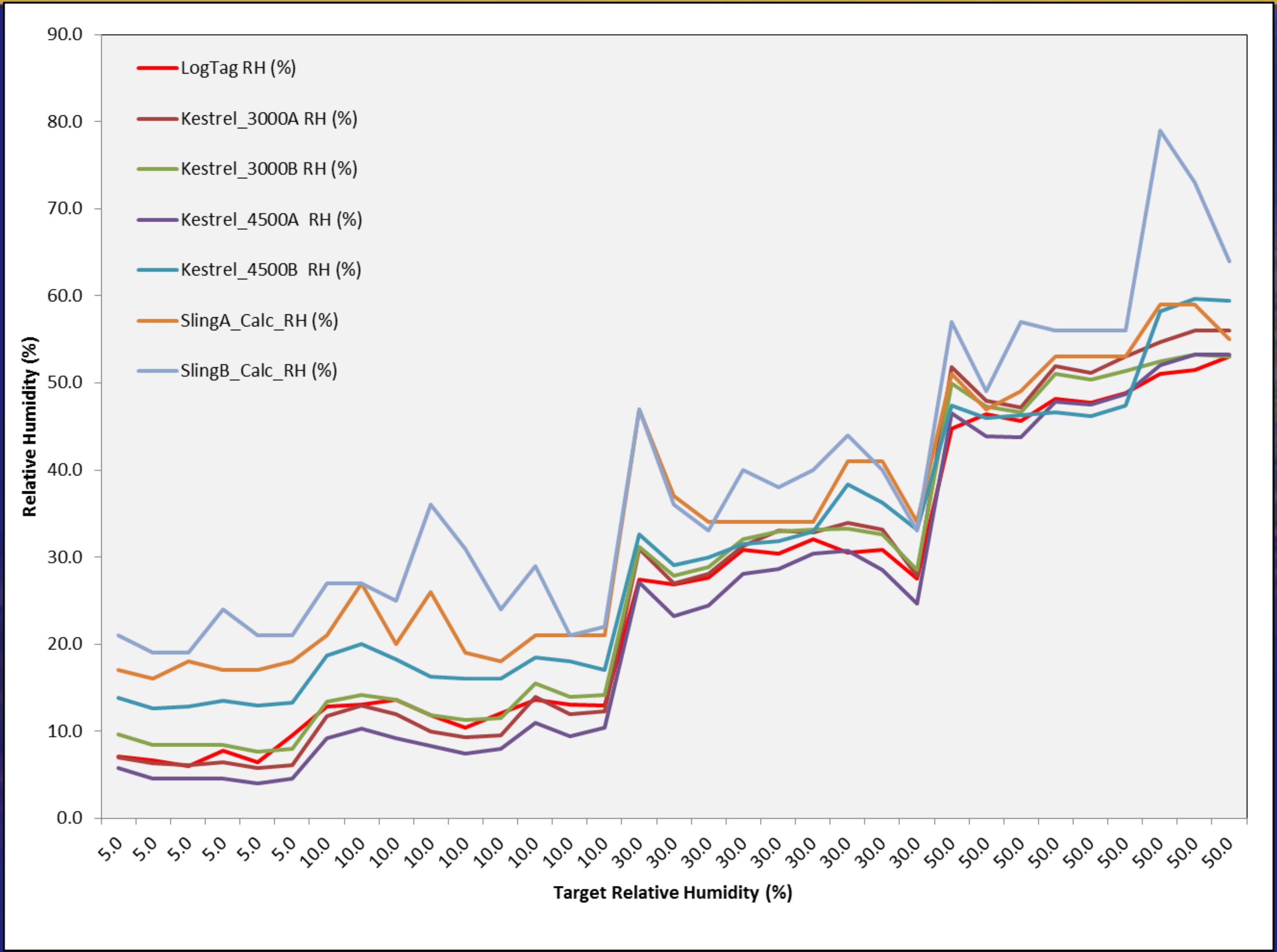
Instrument Array

Phase 1 - Preliminary Results

Temp (F°) - SP to Known

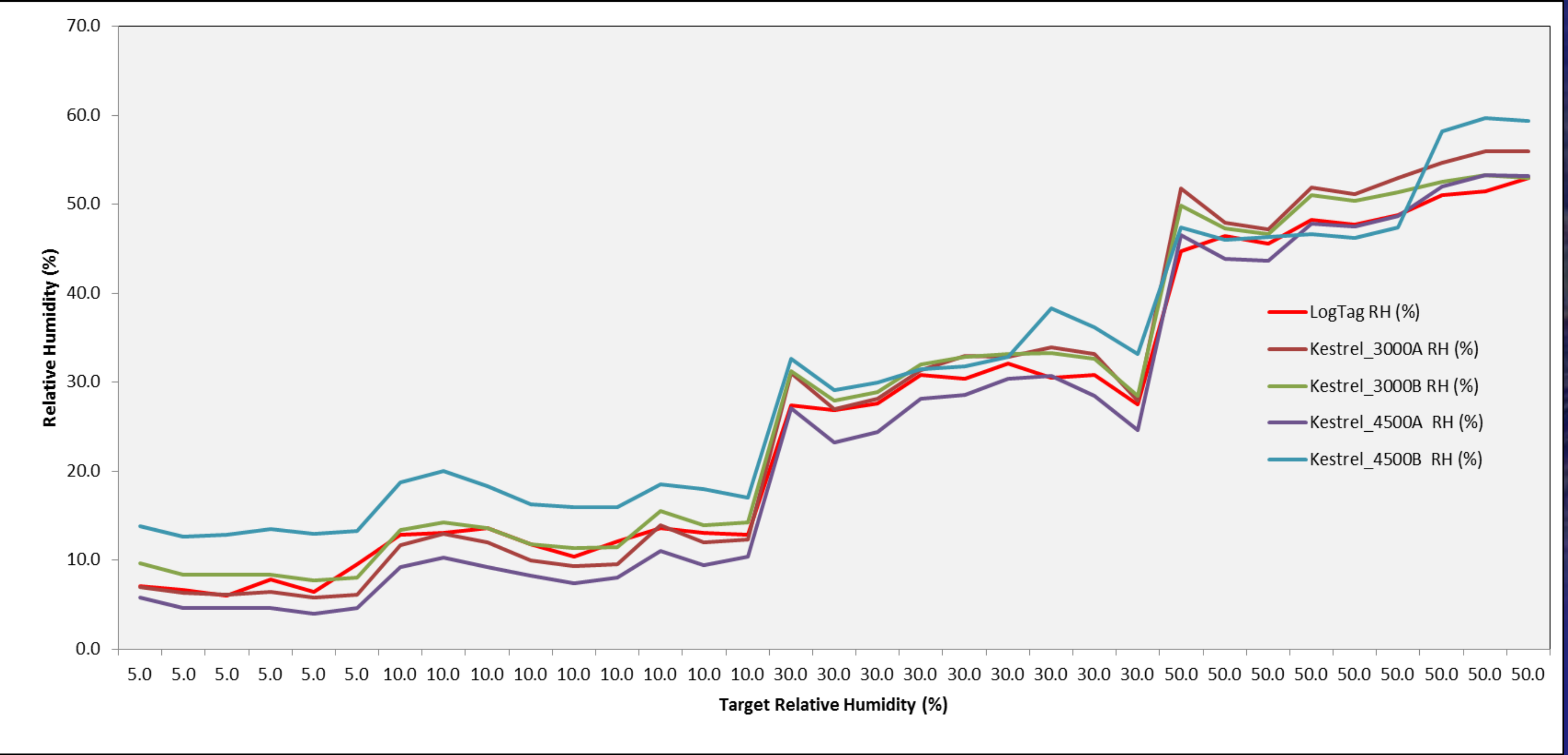


RH (%) - All

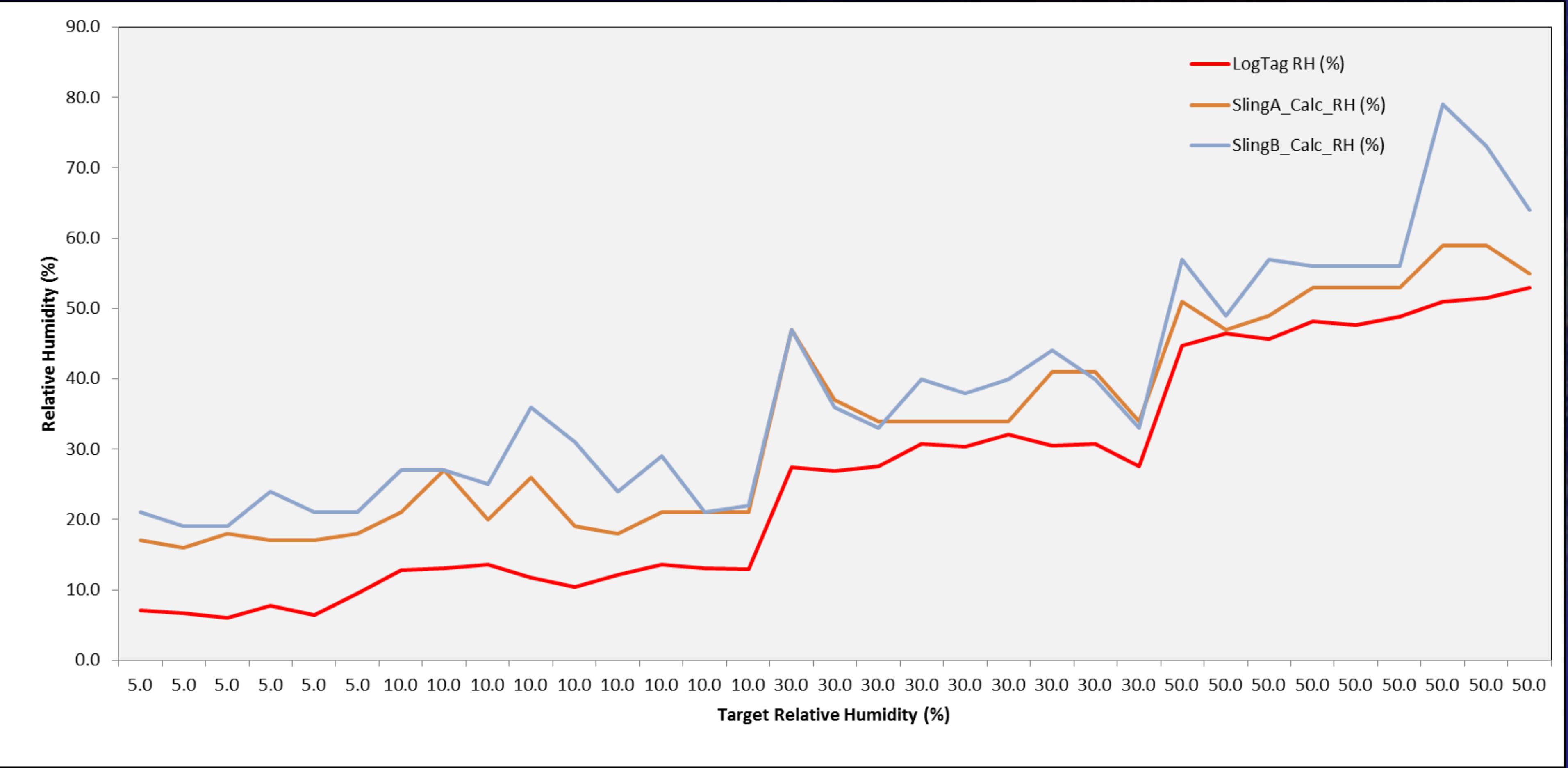


LogTag RH (%)
Kestrel_3000A RH (%)
Kestrel_3000B RH (%)
Kestrel_4500A RH (%)
Kestrel_4500B RH (%)
SlingA_Calc_RH (%)
SlingB_Calc_RH (%)
Relative Humidity (%)
Target Relative Humidity (%)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
5.0
10.0
30.0
50.0

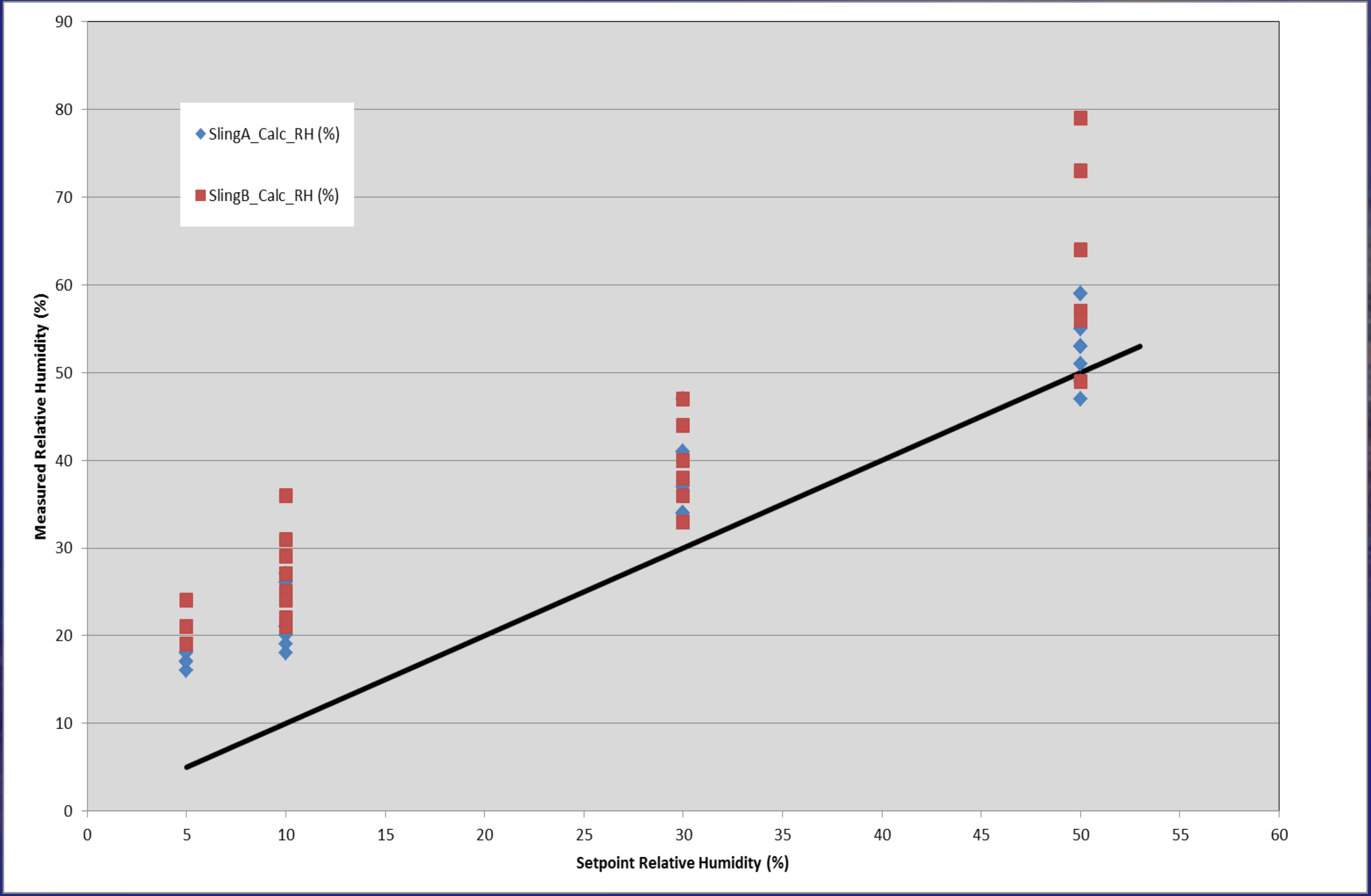
RH (%) - Digital Readings



RH (%) - Sling Psychrometer



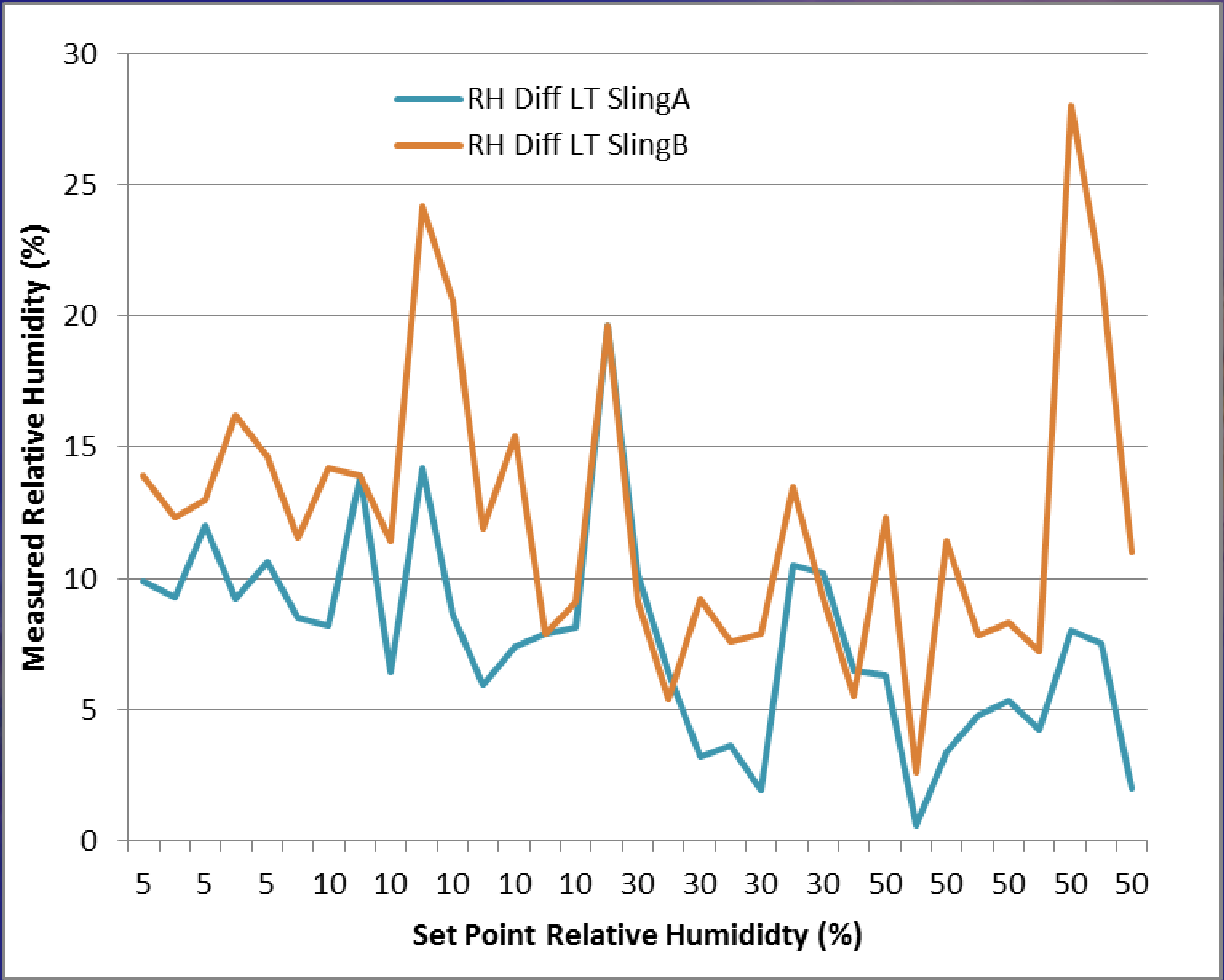
RH (%) - SP to Known



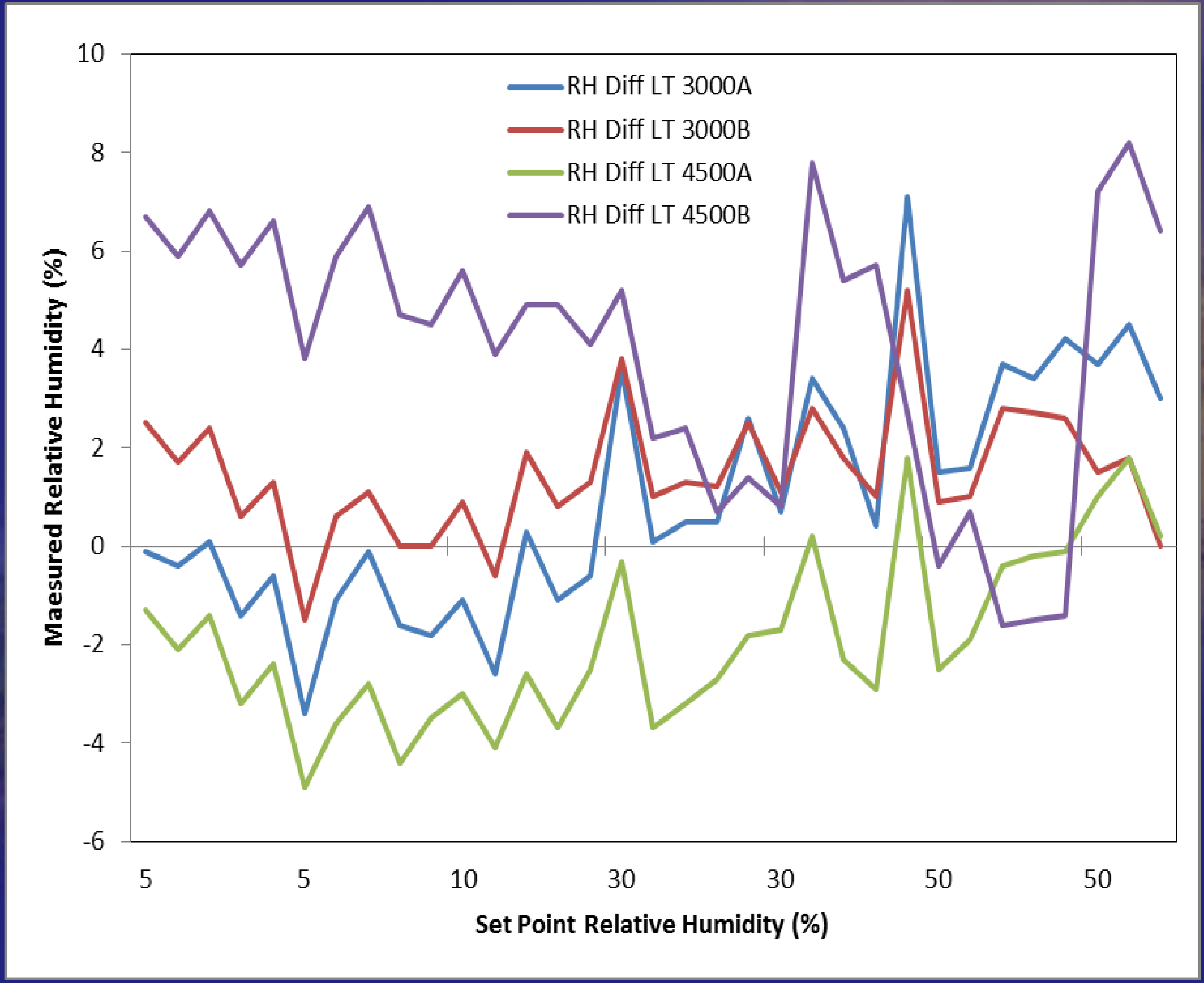
RH Differences

Target RH (%)	LogTag RH (%)	RH Diff LT 3000A	RH Diff LT 3000B	RH Diff LT 4500A	RH Diff LT 4500B	RH Diff LT SlingA	RH Diff LT SlingB
5	7.1	-0.1	2.5	-1.3	6.7	9.9	13.9
5	6.7	-0.4	1.7	-2.1	5.9	9.3	12.3
5	6	0.1	2.4	-1.4	6.8	12	13
5	7.8	-1.4	0.6	-3.2	5.7	9.2	16.2
5	6.4	-0.6	1.3	-2.4	6.6	10.6	14.6
5	9.5	-3.4	-1.5	-4.9	3.8	8.5	11.5
10	12.8	-1.1	0.6	-3.6	5.9	8.2	14.2
10	13.1	-0.1	1.1	-2.8	6.9	13.9	13.9
10	13.6	-1.6	0	-4.4	4.7	6.4	11.4
10	11.8	-1.8	0	-3.5	4.5	14.2	24.2
10	10.4	-1.1	0.9	-3	5.6	8.6	20.6
10	12.1	-2.6	-0.6	-4.1	3.9	5.9	11.9
10	13.6	0.3	1.9	-2.6	4.9	7.4	15.4
10	13.1	-1.1	0.8	-3.7	4.9	7.9	7.9
10	12.9	-0.6	1.3	-2.5	4.1	8.1	9.1
30	27.4	3.6	3.8	-0.3	5.2	19.6	19.6
30	26.9	0.1	1	-3.7	2.2	10.1	9.1
30	27.6	0.5	1.3	-3.2	2.4	6.4	5.4
30	30.8	0.5	1.2	-2.7	0.7	3.2	9.2
30	30.4	2.6	2.5	-1.8	1.4	3.6	7.6
30	32.1	0.7	1.1	-1.7	0.8	1.9	7.9
30	30.5	3.4	2.8	0.2	7.8	10.5	13.5
30	30.8	2.4	1.8	-2.3	5.4	10.2	9.2
30	27.5	0.4	1	-2.9	5.7	6.5	5.5
50	44.7	7.1	5.2	1.8	2.7	6.3	12.3
50	46.4	1.5	0.9	-2.5	-0.4	0.6	2.6
50	45.6	1.6	1	-1.9	0.7	3.4	11.4
50	48.2	3.7	2.8	-0.4	-1.6	4.8	7.8
50	47.7	3.4	2.7	-0.2	-1.5	5.3	8.3
50	48.8	4.2	2.6	-0.1	-1.4	4.2	7.2
50	51	3.7	1.5	1	7.2	8	28
50	51.5	4.5	1.8	1.8	8.2	7.5	21.5
50	53	3	0	0.2	6.4	2	11

SP – RH Difference



Digital – RH Difference



RH - Does it Matter?

Does it Matter?

Fine Dead Fuel Moisture - Exposed

BehavePlus 5.0.5 Fine Dead Fuel Moisture Content Tool	
Dry Bulb Temperature	90 -109 oF
Relative Humidity	15 - 19 %
Reference Fuel Moisture	2%
Month	Feb Mar Apr Aug Sep Oct
Time of Day	14:00 - 15:59
Elevation Difference	Above (1000 - 2000 ft)
Slope	0 - 30%
Aspect	South
Fuel Shading	Exposed (< 50% shading)
Fuel Moisture Correction	1%
Fine Dead Fuel Moisture	3%

BehavePlus 5.0.5 Fine Dead Fuel Moisture Content Tool	
Dry Bulb Temperature	90 -109 oF
Relative Humidity	5 - 9 %
Reference Fuel Moisture	1%
Month	Feb Mar Apr Aug Sep Oct
Time of Day	14:00 - 15:59
Elevation Difference	Above (1000 - 2000 ft)
Slope	0 - 30%
Aspect	South
Fuel Shading	Exposed (< 50% shading)
Fuel Moisture Correction	1%
Fine Dead Fuel Moisture	2%

Does it Matter?

Fine Dead Fuel Moisture - Sheltered

BehavePlus 5.0.5 Fine Dead Fuel Moisture Content Tool		BehavePlus 5.0.5 Fine Dead Fuel Moisture Content Tool	
Dry Bulb Temperature	90 -109 oF	Dry Bulb Temperature	90 -109 oF
Relative Humidity	15 - 19 %	Relative Humidity	5 - 9 %
Reference Fuel Moisture	2%	Reference Fuel Moisture	1%
Month	Feb Mar Apr Aug Sep Oct	Month	Feb Mar Apr Aug Sep Oct
Time of Day	14:00 - 15:59	Time of Day	14:00 - 15:59
Elevation Difference	Above (1000 - 2000 ft)	Elevation Difference	Above (1000 - 2000 ft)
Slope	0 - 30%	Slope	0 - 30%
Aspect	South	Aspect	South
Fuel Shading	Shaded (>=50% shading)	Fuel Shading	Shaded (>=50% shading)
Fuel Moisture Correction	5%	Fuel Moisture Correction	5%
Fine Dead Fuel Moisture	7%	Fine Dead Fuel Moisture	6%

Thoughts So Far

- Even in a controlled environment easy to get whacky SP readings
- Differences between the same type of instrument
- SP Calculated RH% always higher than "truth"
- At lower RH values the SP was much higher than at higher RH ranges.
- More agreement amongst the digital instruments than the SP

What's Next

- Kestrels
  - Tested, Calibrated, Certified
- Repeat Measurements
  - Late May – Early June
- Analysis
- RMRS Research Note

Questions