APS Storage Ring Tunnel Temperature Stability
March 10 2016

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Goal is tunnel temperature of +/- 0.1 C or better for 1 week

History: our journey so far
Projects underway
Future plans

APS Tunnel temperature requirements in the beginning

- Original requirements for tunnel temperature were 78 degrees +/- 2^{o}F.
- Magnet cooling water temperature was 90 degrees +/- 2^{o} F.
- Water and air handling systems were designed around these parameters, equipment was installed to meet these requirements.

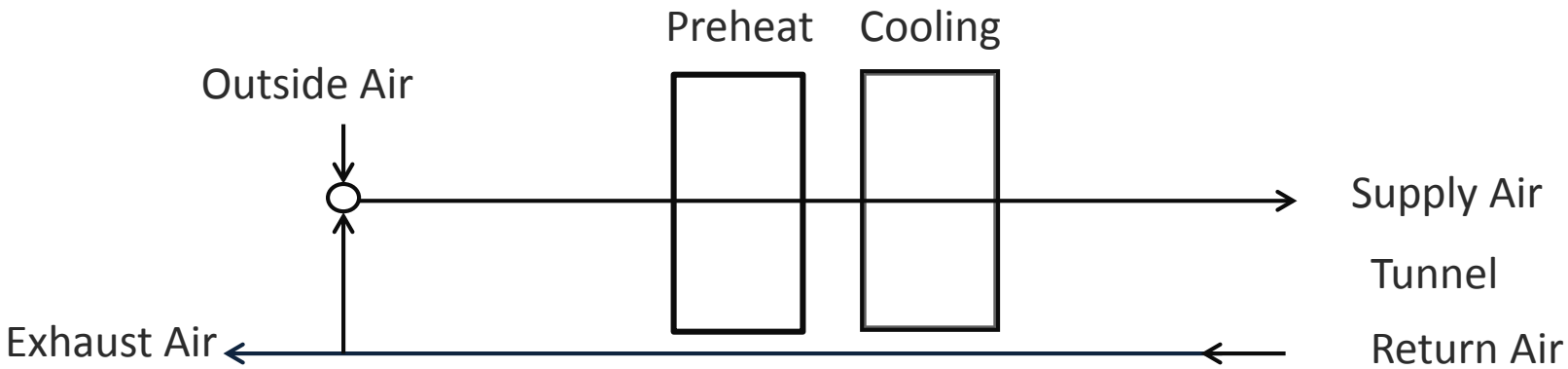
Before APS was commissioned the water system operating temperature was dropped to around 78 degrees F +/- 2^{o} F. This resulted in an air handling system that had too much cooling capacity for our needs. The AHUs in the SR RF areas may have benefited though.

Upgrades to SR AHUs around 2006-2008

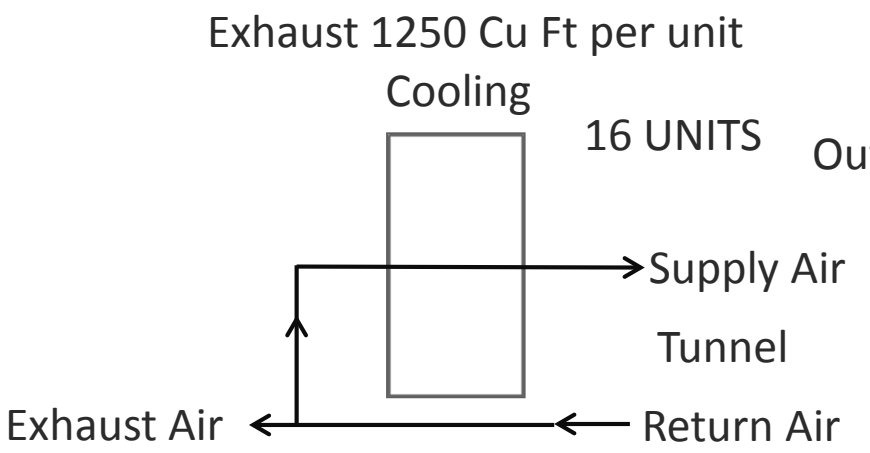
- A 2006 upgrade to the AHU systems improved temperature stability, while reducing energy consumption.
- New smaller cooling valves and actuators were installed on 16 of the 20 AHUs
- The system configuration was changed from all 20 units exchanging outside and inside air. To 4 units heating/cooling and supplying outside air with 16 units cooling and exhausting air.
- The 4 units performing the heating/cooling supply air use heat generated in the DI water from the tunnel and power supply components to heat the tunnel.

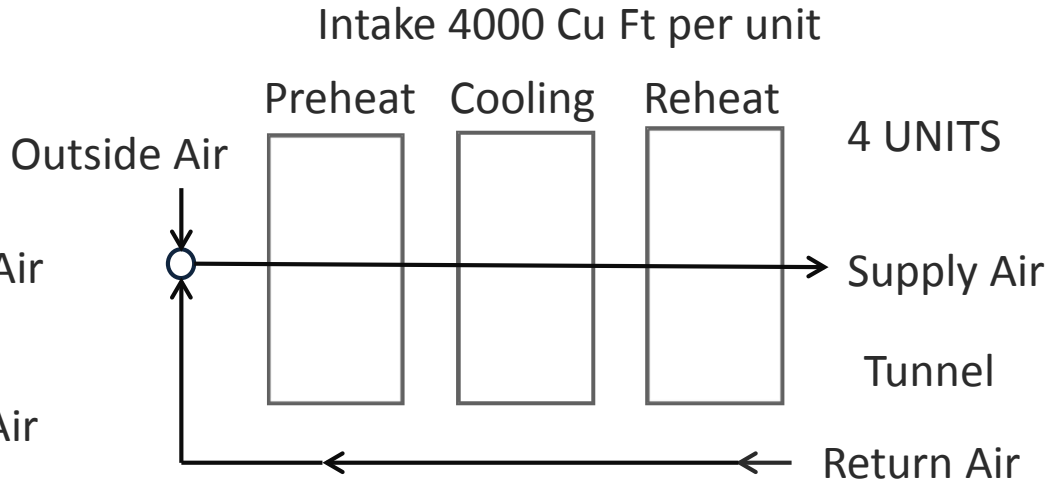
20 UNITS 1 per double sector

We are moving about 160,000 Cu Ft per minute, just for the tunnel.



SR Tunnel Air Handling Units, Original





2 Flavors Now: Exhaust/cooling, Intake mixed air

Upgrades after 2012

Reduce the number of variables effecting the SR tunnel air

1. During Dec 2013 and Jan 2014 shutdown dead bands were removed, this improved regulated temperature from +/- 0.5 to +/- 0.1 ^{o} F. Localized variations in space temperatures exceeding these values were discovered. Modification to the tunnel internal air distribution system to eliminate drafts is being implemented.

2. All 20 outside air intakes were sealed in Nov 2015

3. 4 outside AHU air exhausts were sealed in Dec 2015. 16 more were sealed in Feb 2016.

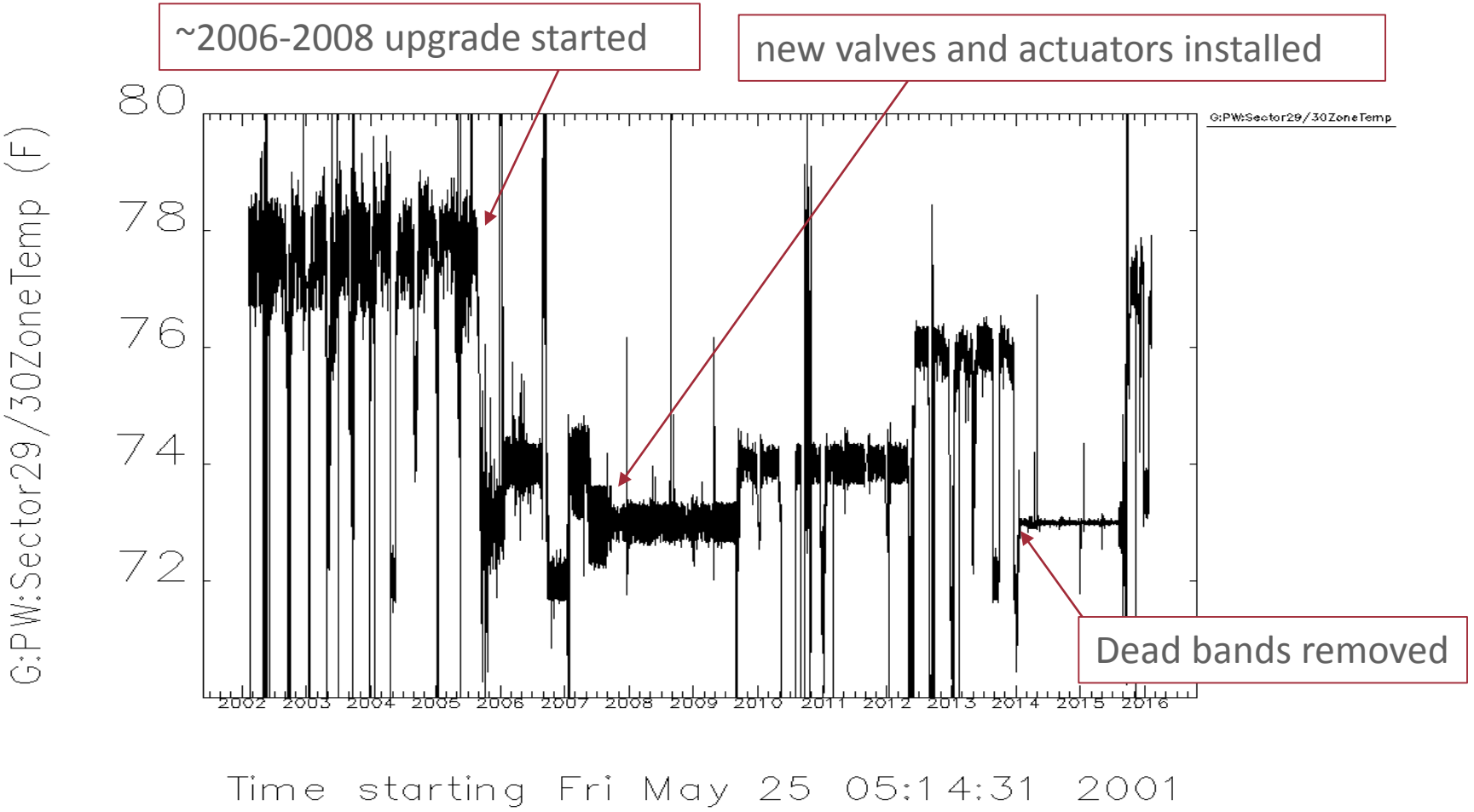
4. We ran only 7 out of 20 AHUs, during most of Oct to Dec 2015 run, no problems noticed.

Getting better regulation with existing systems Removal of dead bands in Dec 2013/Jan 2014

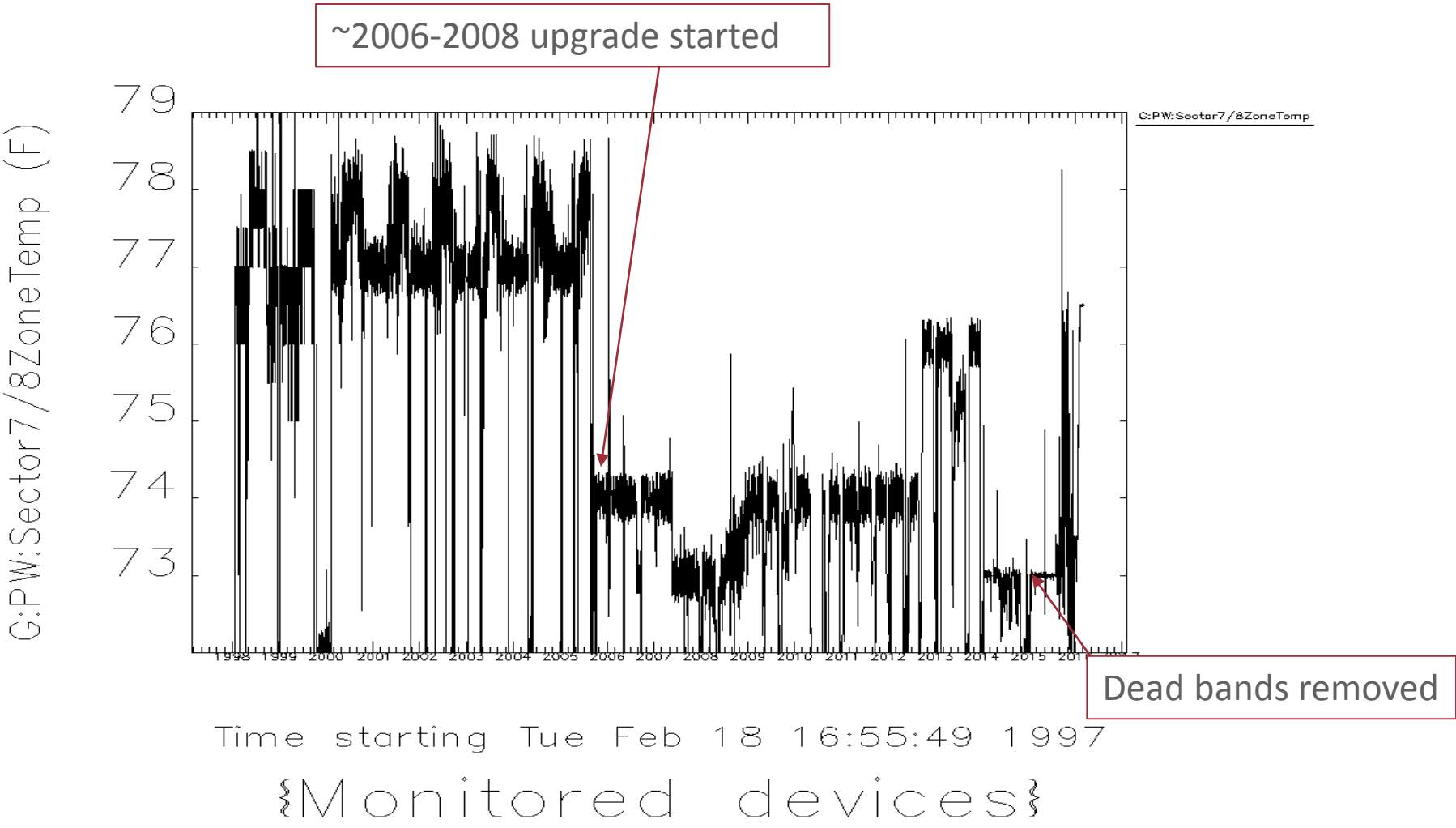
In addition, there are fixed 0.3° control dead bands below the Actual Heating Set point and above the Actual Cooling Set point. When the Zone temperature is within these dead bands, no proportional control action takes place, and integration, if used in the respective temperature loop, is held at its last value.

(This paragraph was taken from Johnson controls manual)

Progress with Air temperature regulation in the AHU, removal of dead bands in Dec 2013/Jan 2014

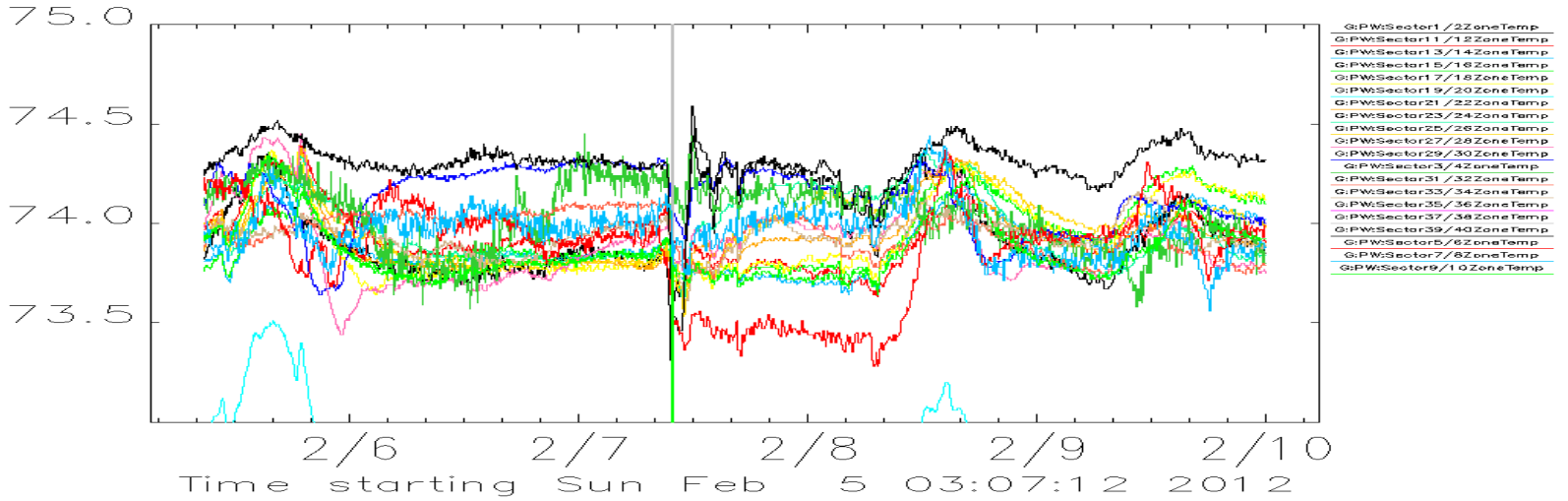


Long term temperature plot showing history from Feb 1997 until March 2016

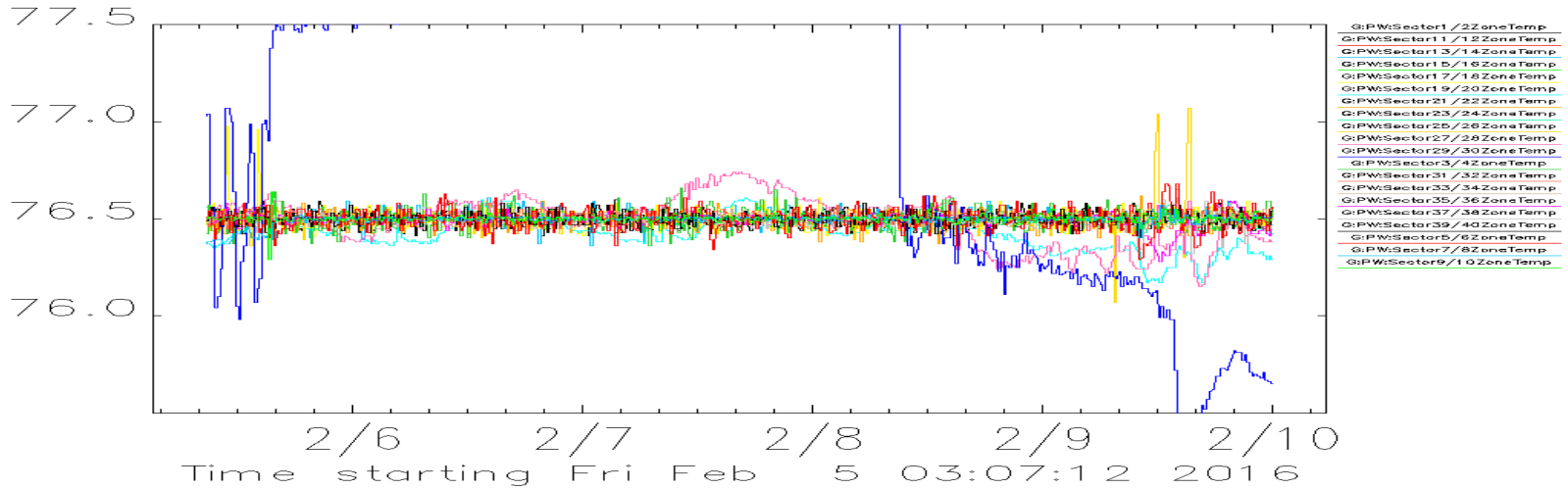


Top graph showing 2012. Bottom graph showing 2016. Both plots show all 20 AHUs with a range of 2ºF

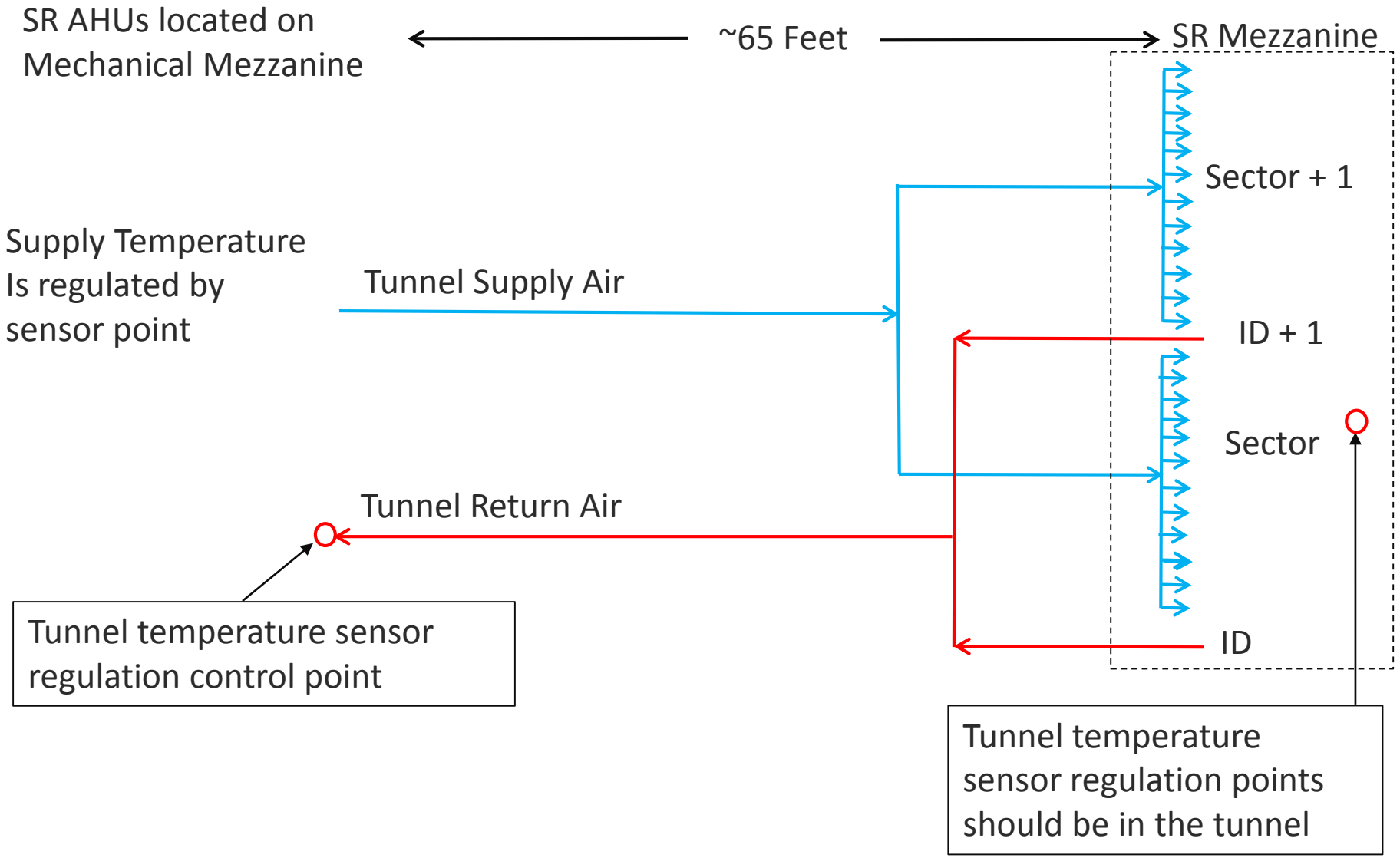
2ºF



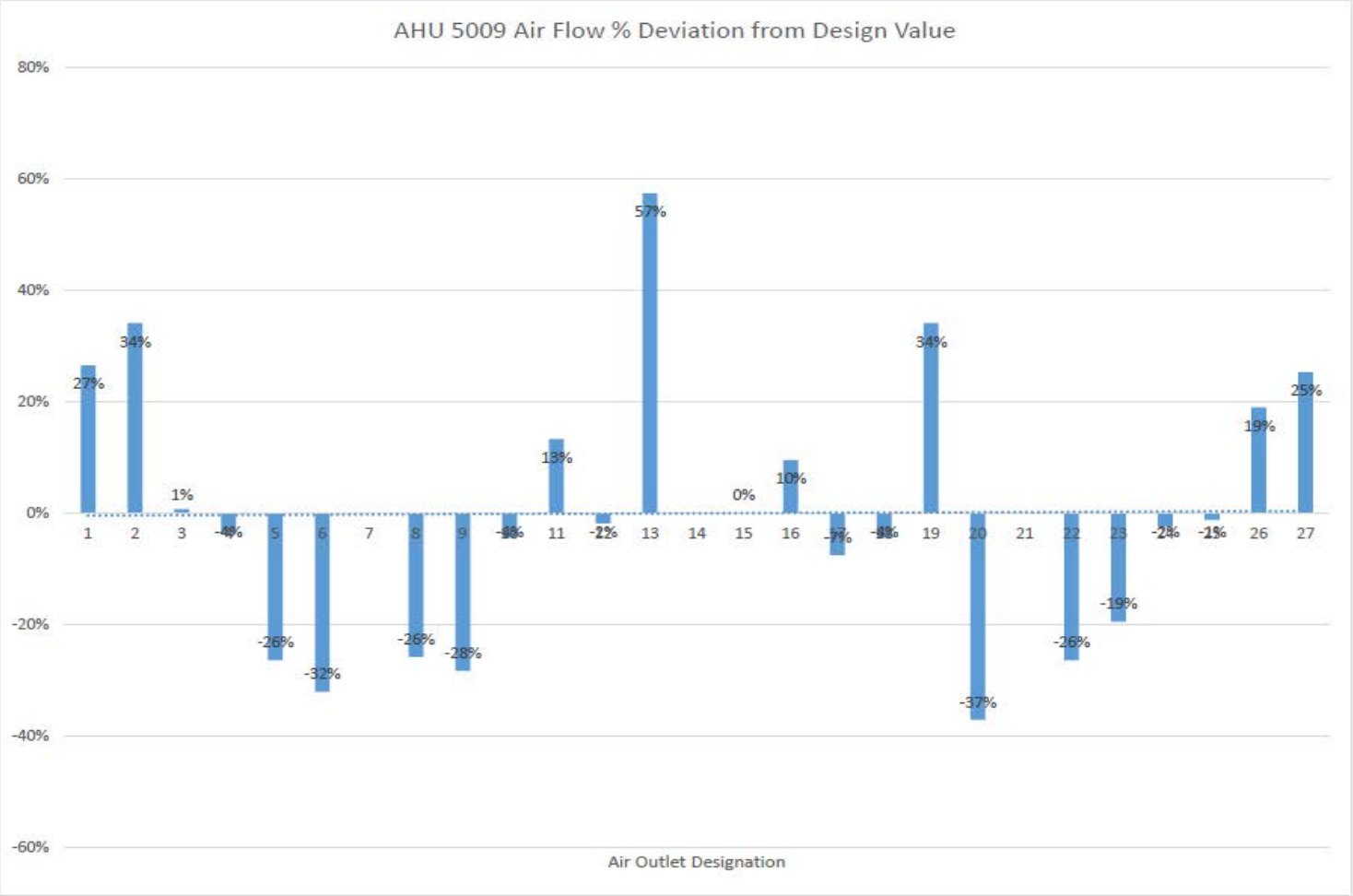
2ºF



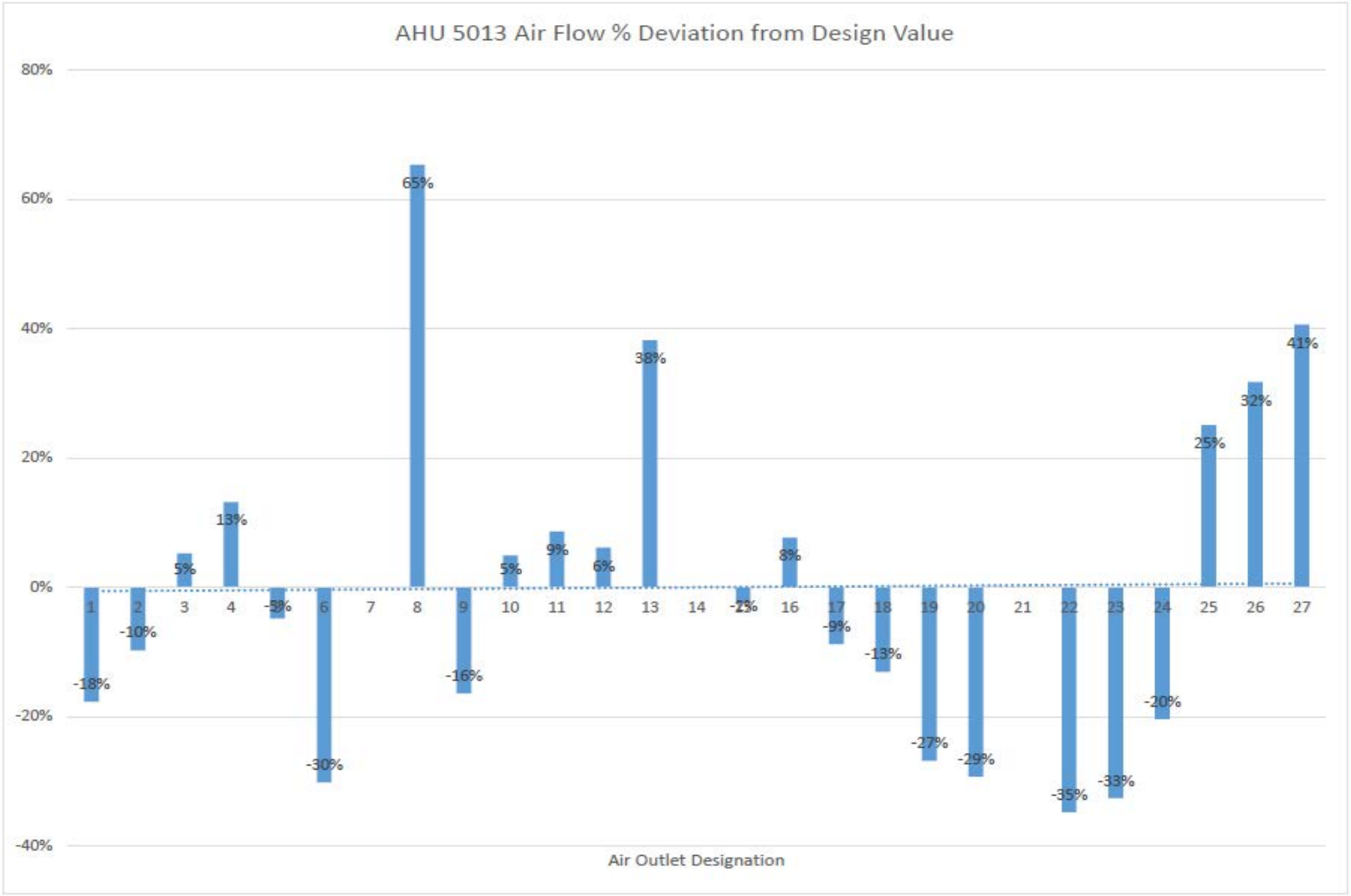
APS SR AHU Air Flow breakdown



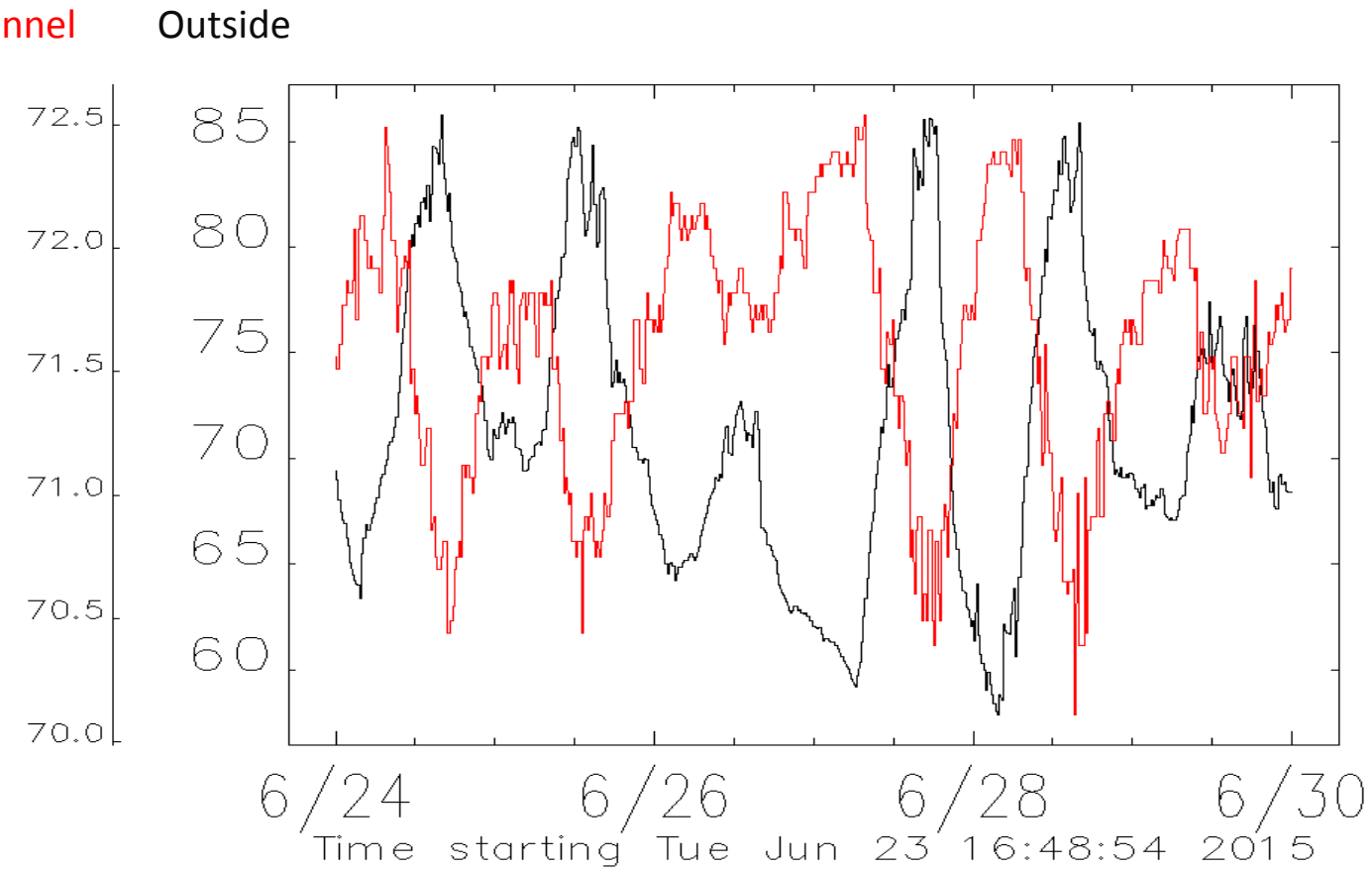
Measured air flow from diffusers in tunnel for sectors 19 and 20



Measured air flow from diffusers in tunnel for sector 27 and 28



Outside air temperature versus tunnel supply air. The fight in the tunnel, why?

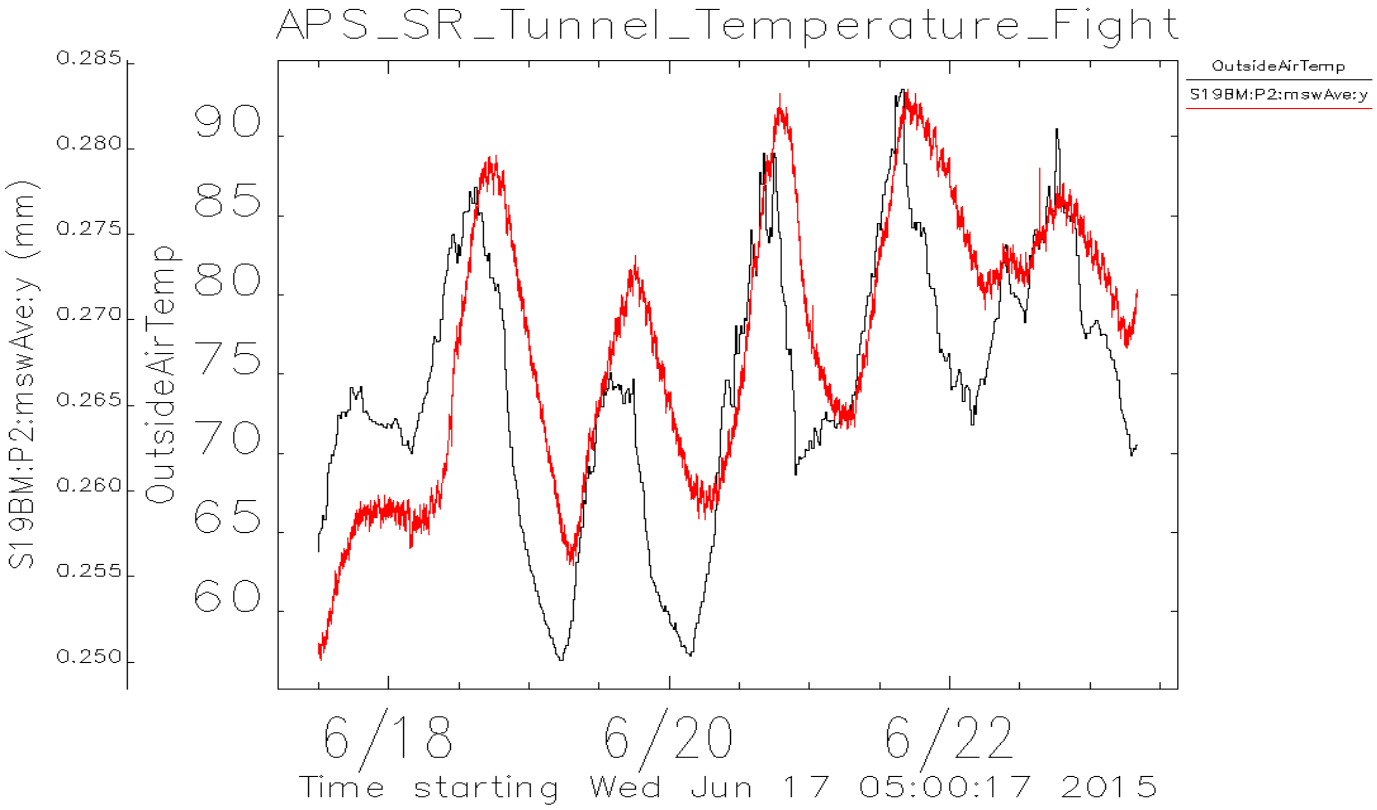


Tunnel Supply Air

Outside Air

19BM outside air versus XBPM position

Why do we need better tunnel temperature stability? User requirements have changed, requiring us to have more stable beam.

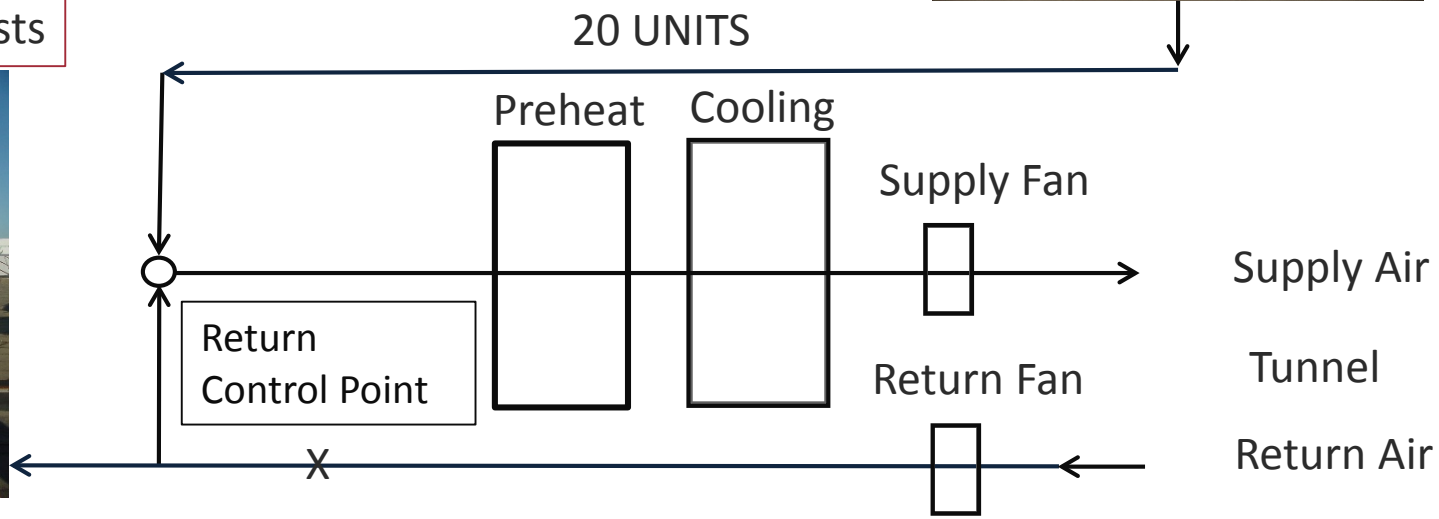


SR Tunnel Air Handling Units

A glimpse of part of SR EAA and Experimental hall roof

Outside Air Intakes

Outside Air Exhausts



All Outside air intakes were sealed off in Nov 2015, 4 outside air exhausts were sealed off on Dec 3 2015, 16 more to go. This is being done to limit the number of variables that affect the SR tunnel temperature.

SR ring tunnel outside exhausts appeared to be letting outside air into the SR AHUs, below is the fix, 4 AHUs were sealed like this below on Dec 3 2015

Rain cap

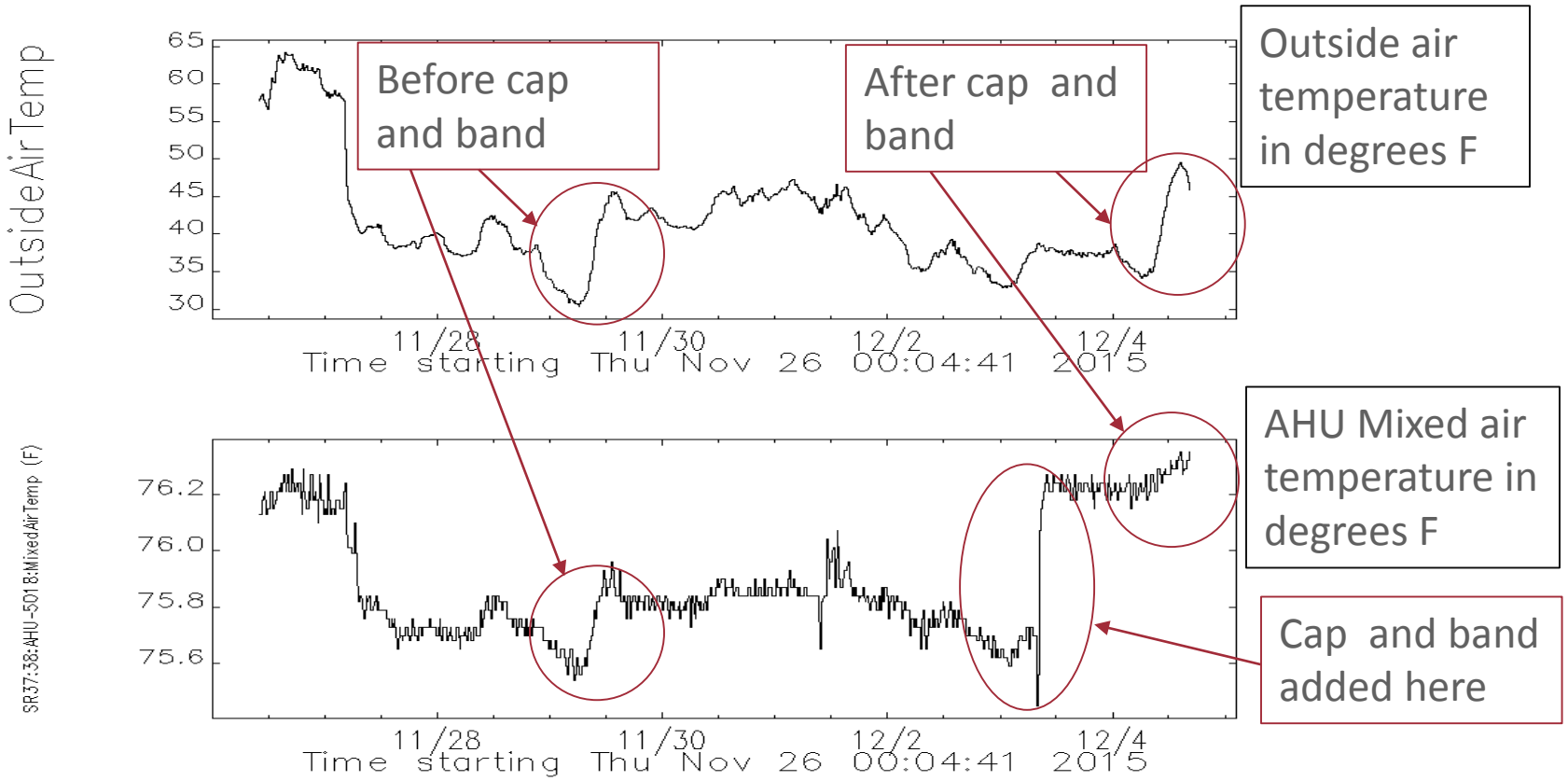
Rain gap opening

Before sheet metal cap and band were installed

New sheet metal cap and band added here

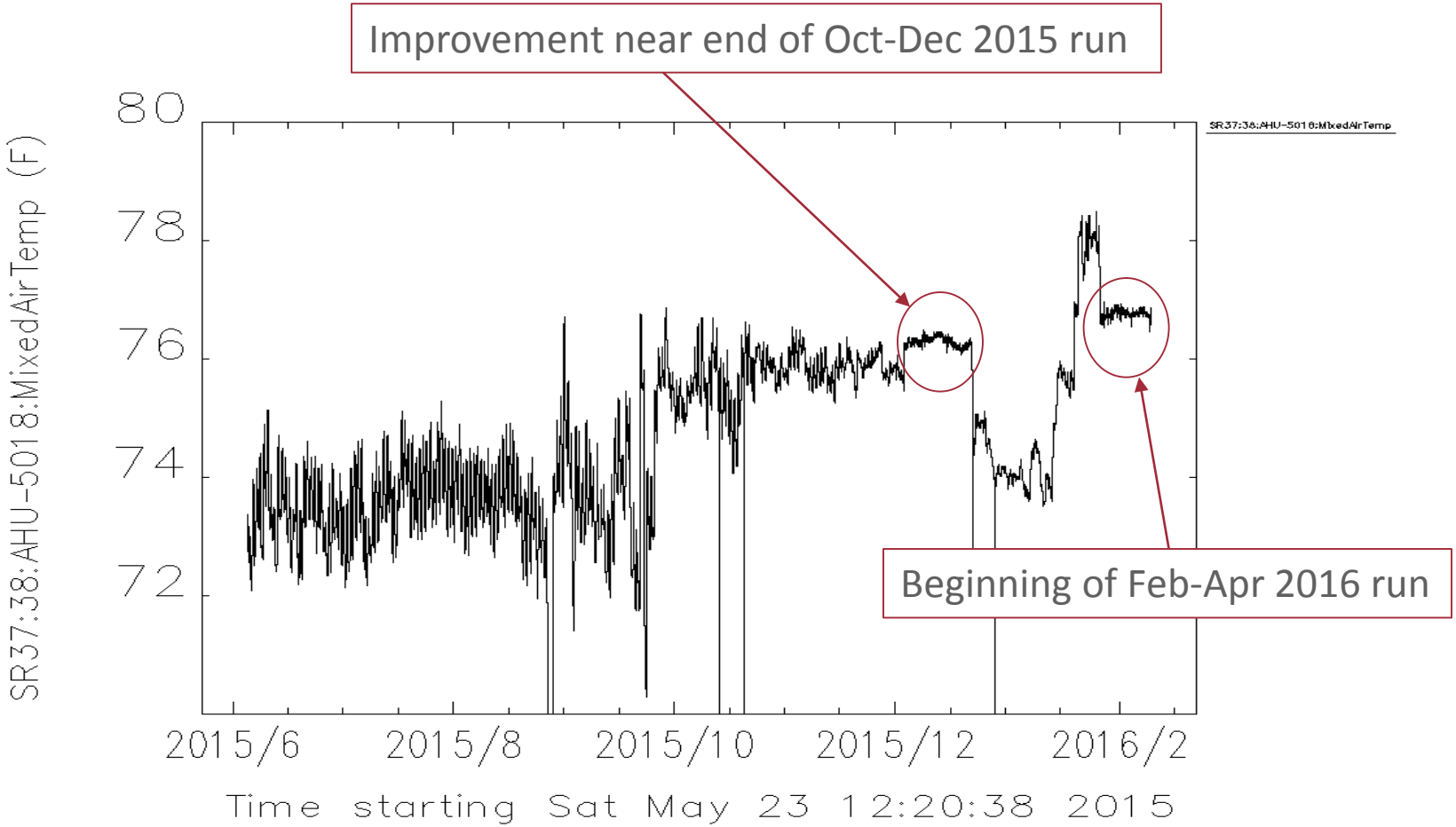
After sheet metal cap and band were installed on Dec 3 2015

Data showing improvement in the mixed air temperature inside SR AHU 5018 for sectors 37 & 38



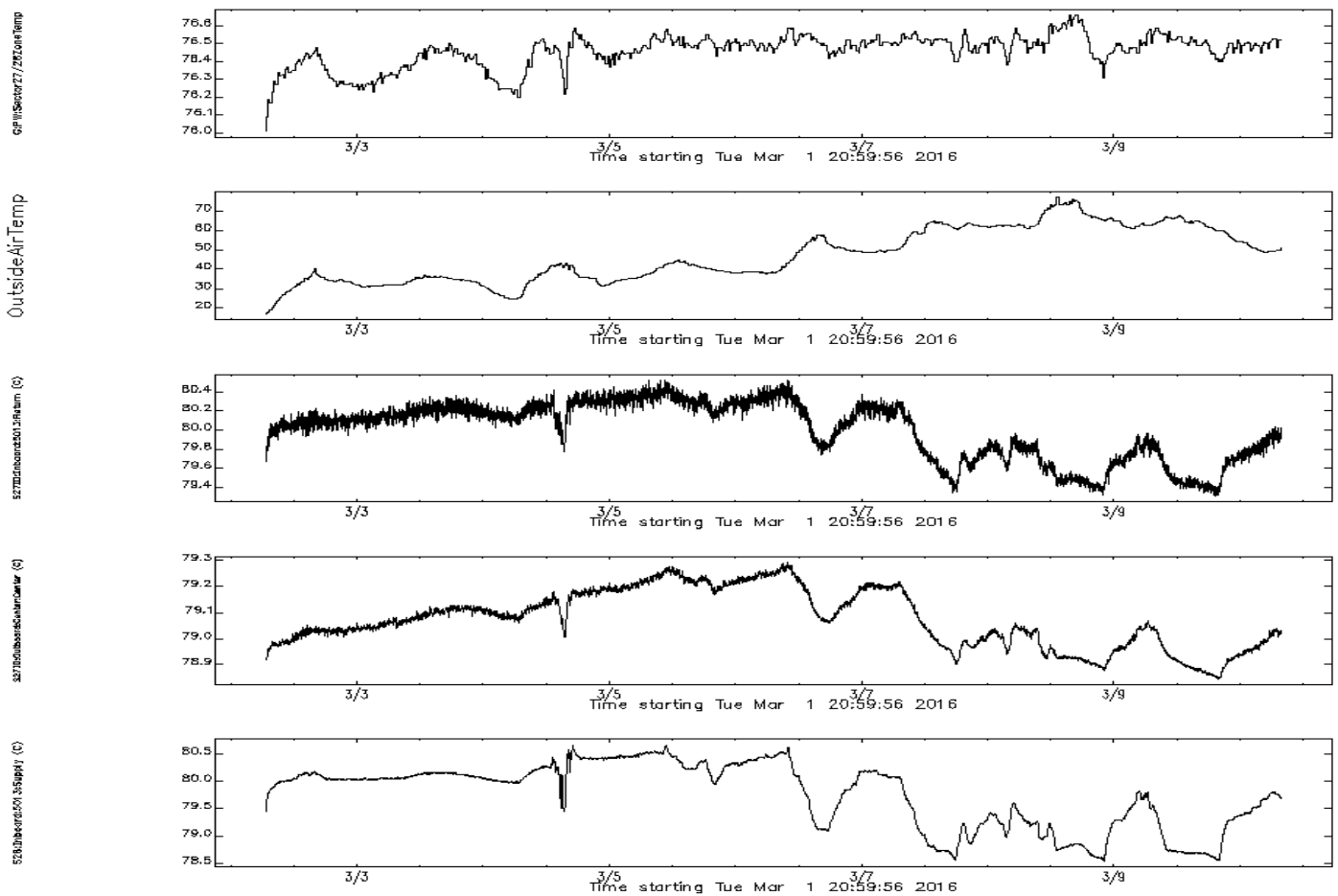
Before: Outside air temperature change of ~ 15 ^{o} F versus ~0.35 ^{o}F
After: Outside air temperature change of ~ 15 ^{o} F versus ~0.15 ^{o}F

Plot showing about ~8 months mixed air temperature inside SR AHU 5018 for sectors 37 & 38



We are starting to achieve isolation from the outside air!

Notice we are still fighting outside air temperature changes. We need control points to be in tunnel to fully realize system capability



Tunnel return control point (Tunnel Temperature)

Outside Air

Tunnel return air

Tunnel wall behind 27ID

Tunnel Supply

Keys to better temperature regulation in SR APS tunnel

Understanding the following 2 points

1. Placement of temperature control sensors

2. Air flow in tunnel

System capability versus System Implementation What needs to be done now?

1. Setup systems to control on temperature sensor regulation points in the tunnel. (we need to install all new temperature control sensors in the SR tunnel)

2. Continue to experiment with VFDs and air flow to find optimum flow with minimum temperature differential between supply air and space temperature set point

3. Install new air supply diffusers in tunnel to provide more uniform temperature distribution.

4. Upgrade of Johnson controls system. System is over 20 years old. (system interface is slow, to talk with Operations/EPICs rate is 20,000 points per ~15 minutes, we only get an update every 15 minutes)

Work planned and needed for 2016

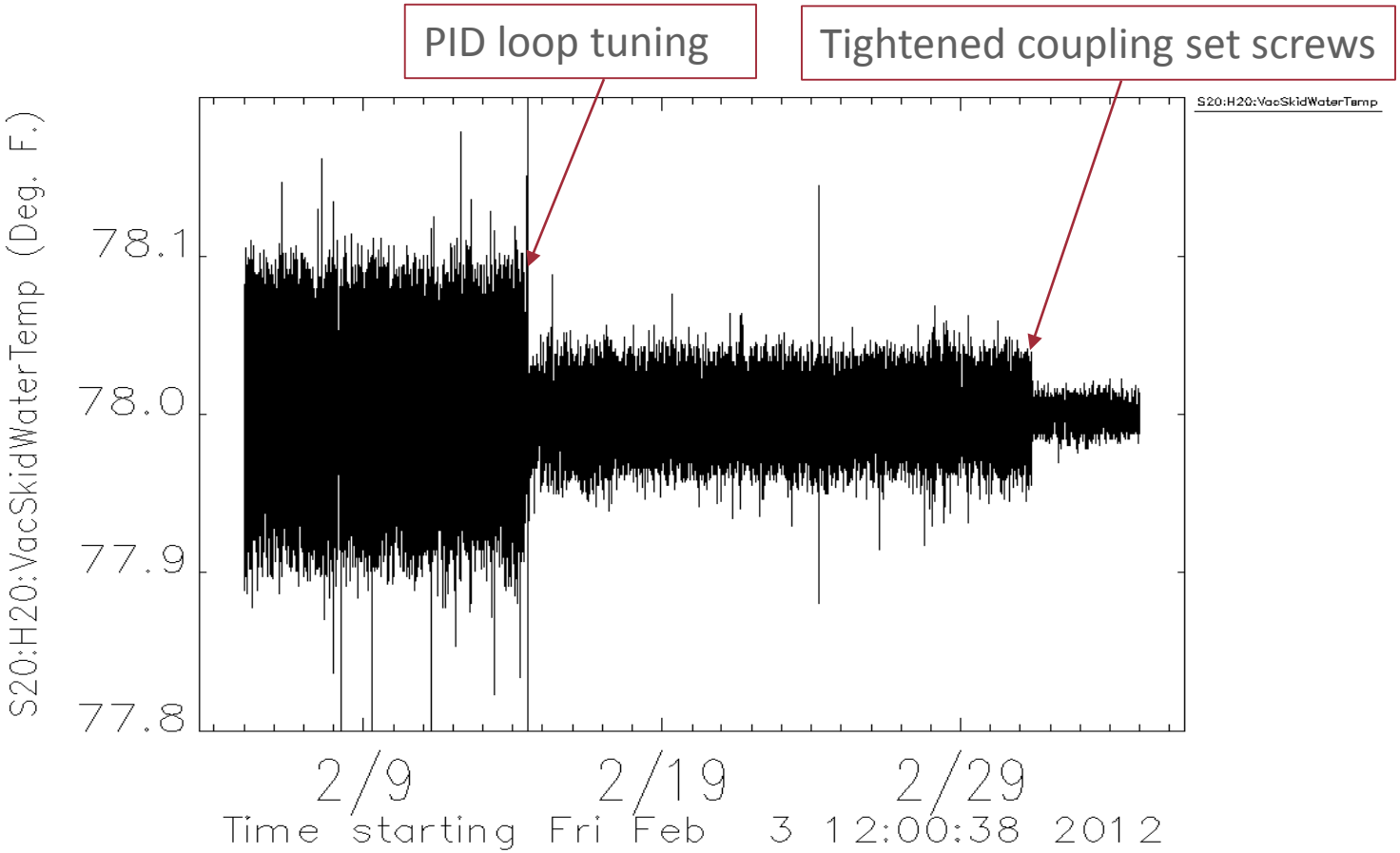
- A VFD (variable frequency drive) was installed in AHU 5009 . This will allow us to change the air flow through the AHU used to control the temperature for sectors 19 and 20. System installation has not been completed yet.
- Determine tunnel space air temperature balance point.
- Finish installation and commissioning of 3 more VFDs. April-May shutdown Sectors 5/6, and 27/28. Aug-Sept Shutdown sectors 37/38.
- Experiment with new air flow vents in tunnel sectors 19 and 20
- Calibrate SR AHU sensors every 4 months with NIST traceable standard
- Perform routine SR AHU maintenance and testing yearly on a 4 month cycle
- Add more temperature monitoring systems and sensors

Conclusion

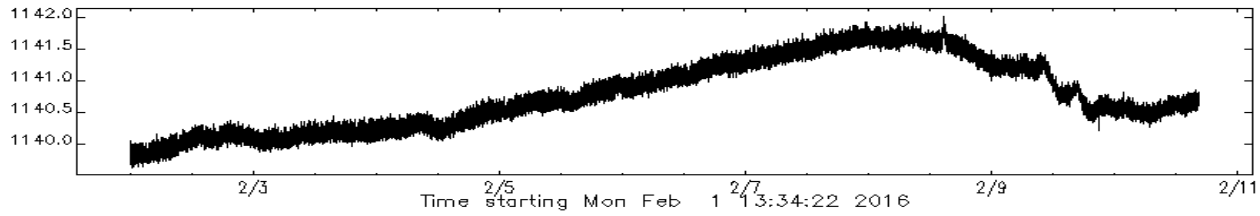
- We need to understand how we should prepare the present AHUs for the MBA upgrade. What temperature regulation can we achieve? What temperature is required for the MBA upgrade?
- The system has the capability to achieve better temperature regulation with the implementation of additional modifications.
- This will require an investment in the existing AHUs, before the upgrade starts. This will allow us to determine the true system capability with proper system implementation.
- We should be able to do better then +/- 0.1^{o}C (+/- 0.18 ^{o}F) over 7 days

Extra slides after this point

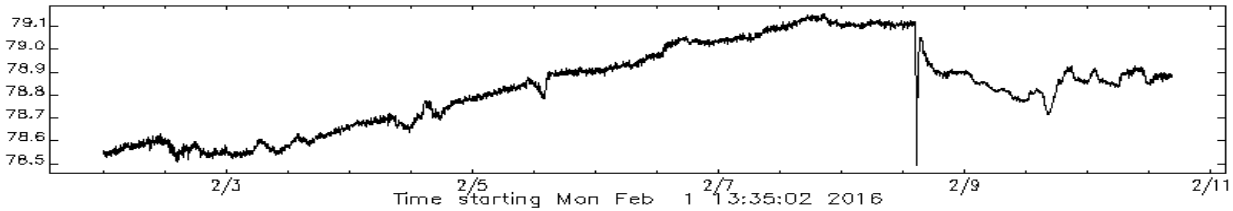
Example of improvements to water skid temperature regulation for SR chambers



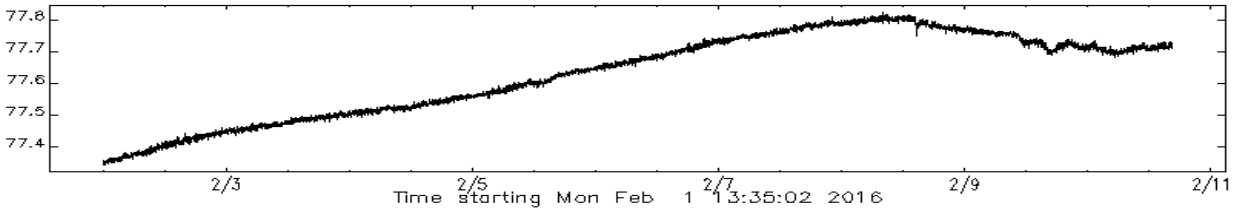
27ID Grid XBPM vertical MMS, floor, and air temps



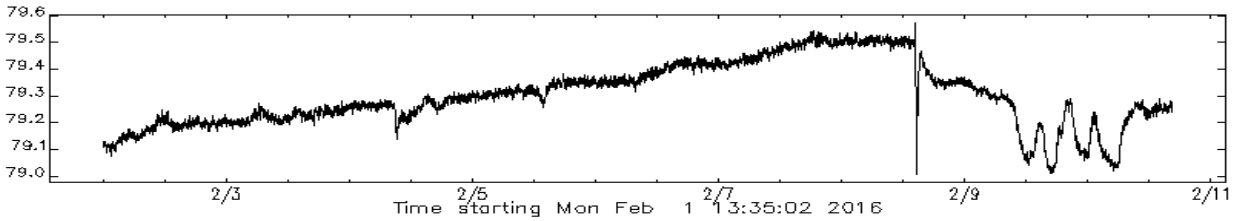
MMS
In
microns



27ID
Air Temp ^{o}F

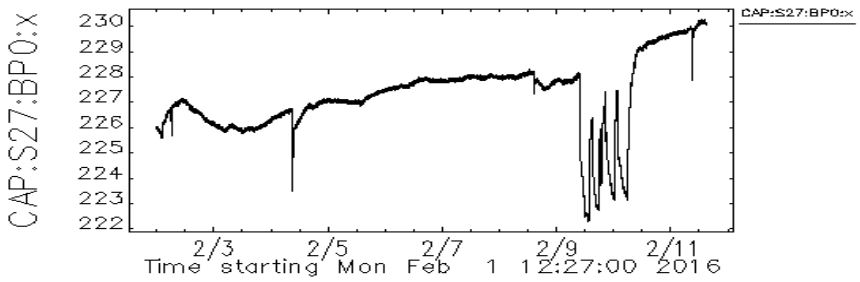


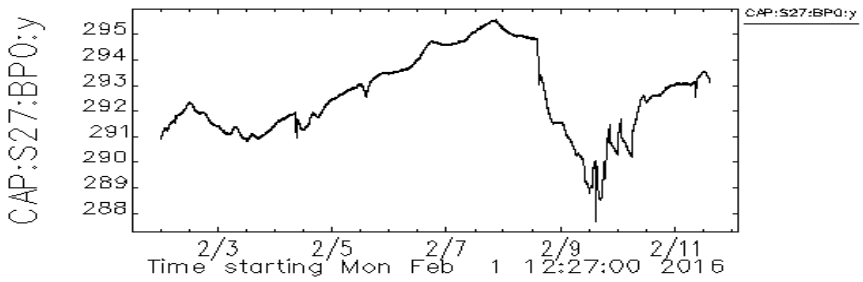
Floor
Temp ^{o}F

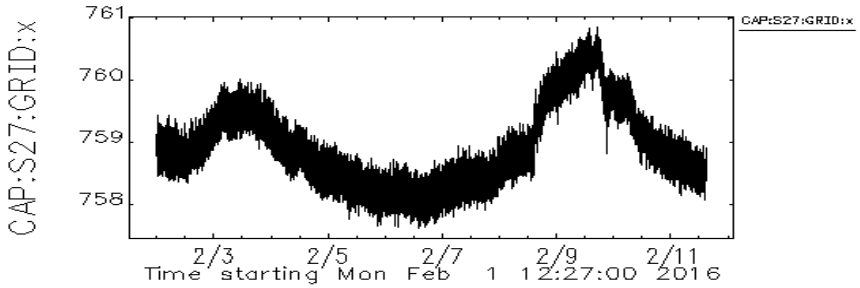


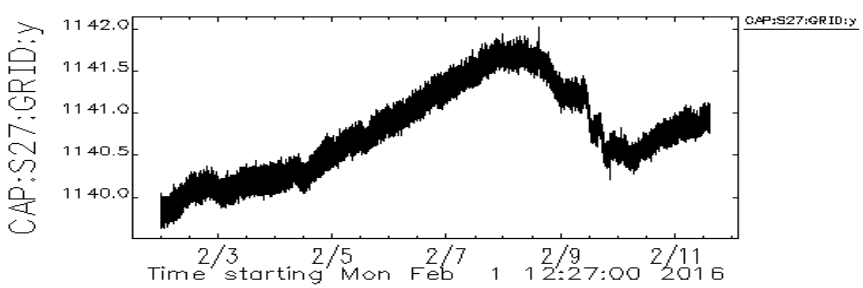
Sector 28
Air Temp ^{o}F

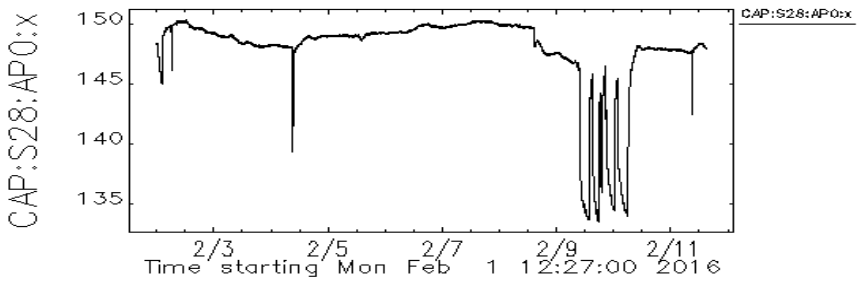
Mechanical Motion Measurement system plots Feb 2 to Feb 11 2016

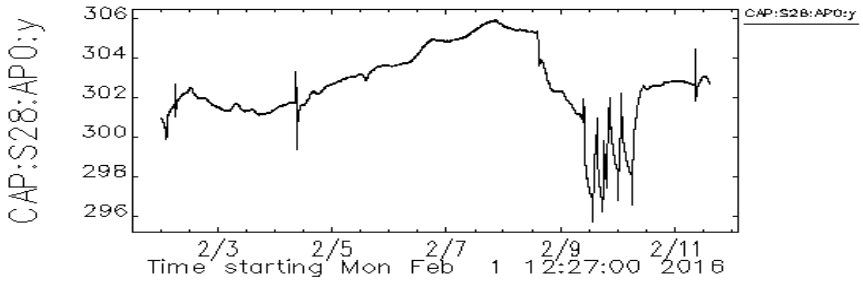




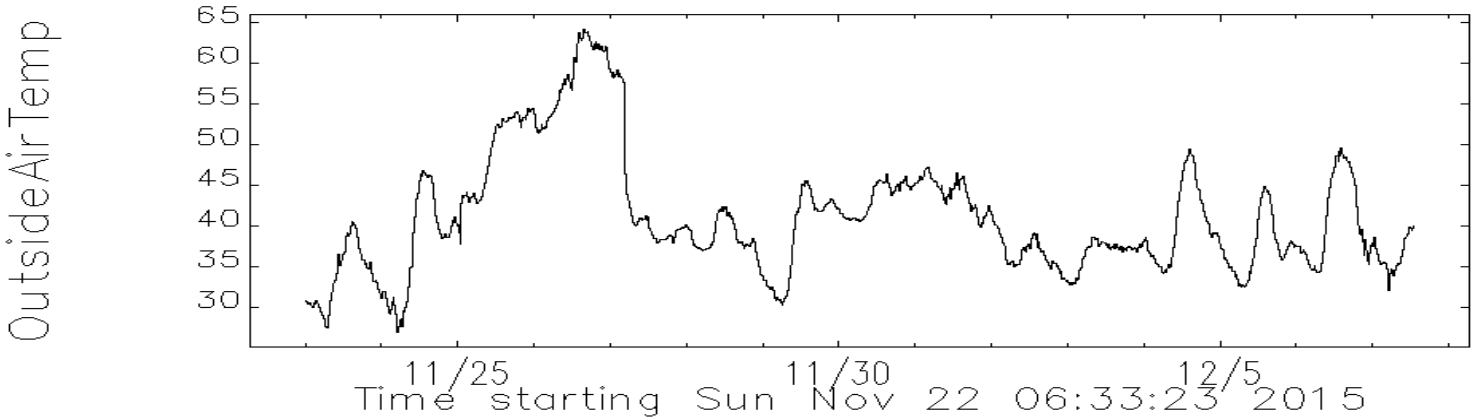




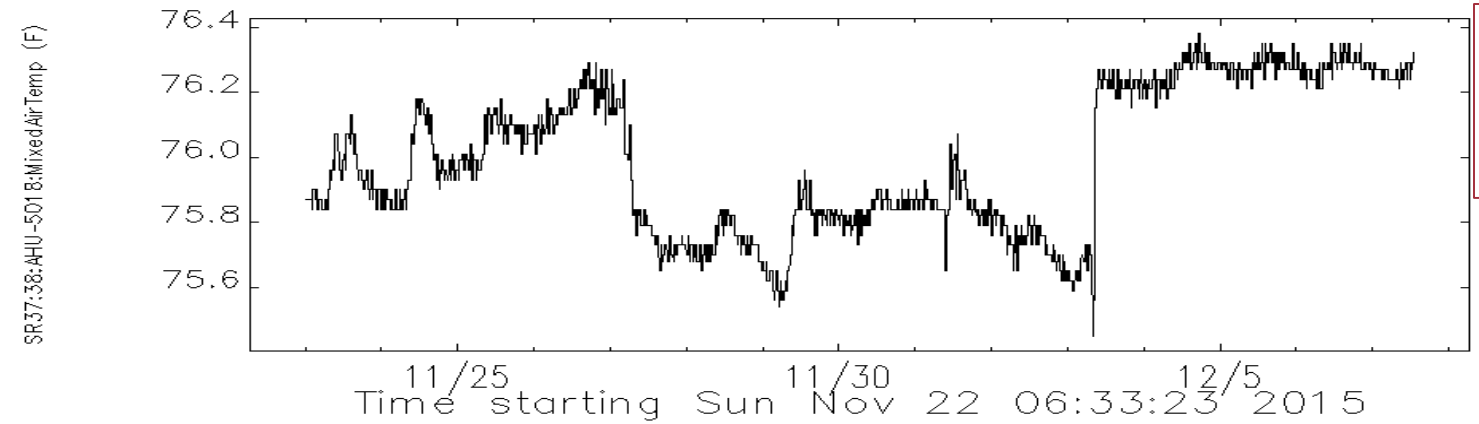




Data showing improvement in the mixed air temperature inside SR AHU 5018 for sectors 37 & 38



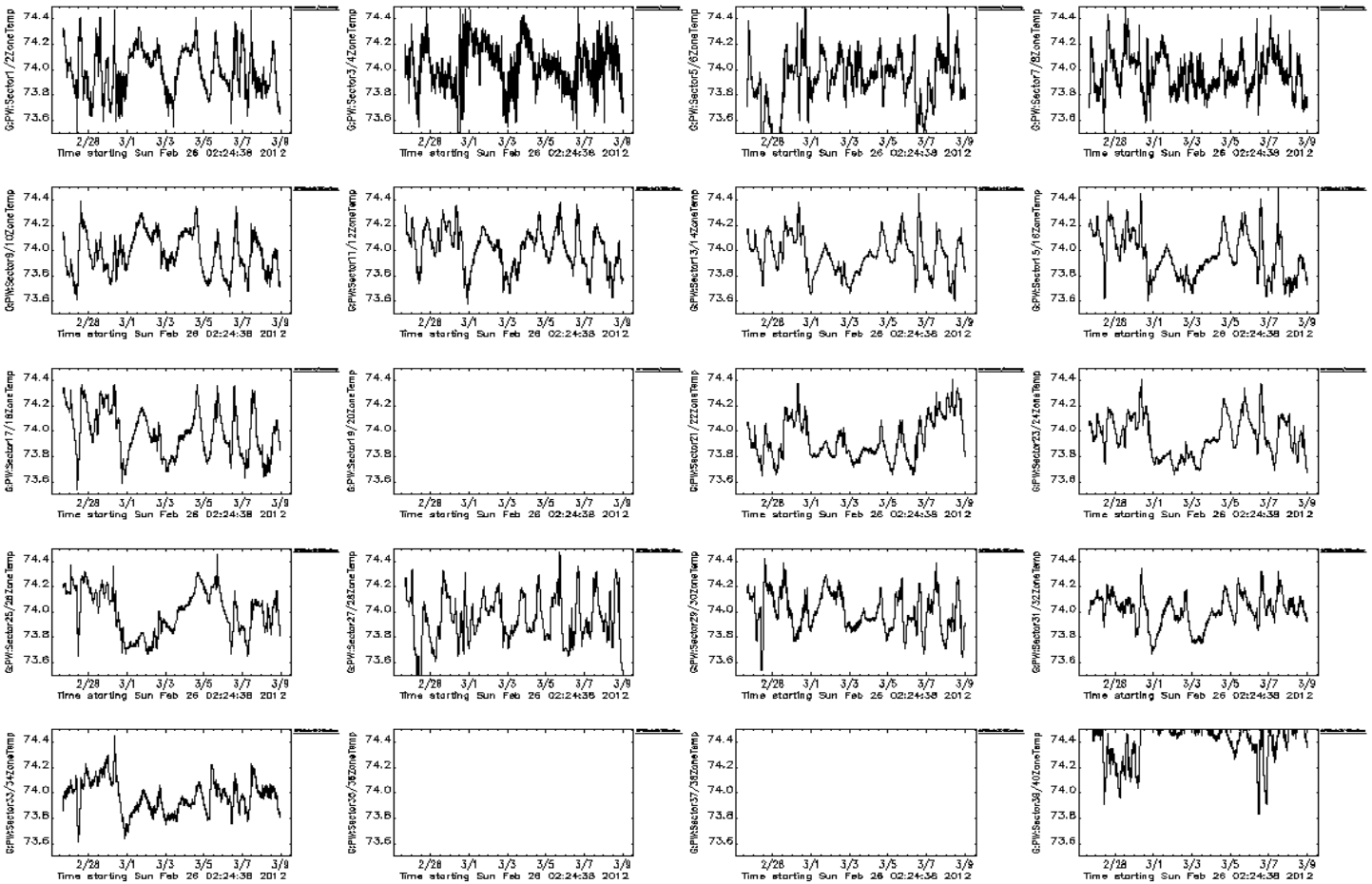
Outside air temperature in degrees F



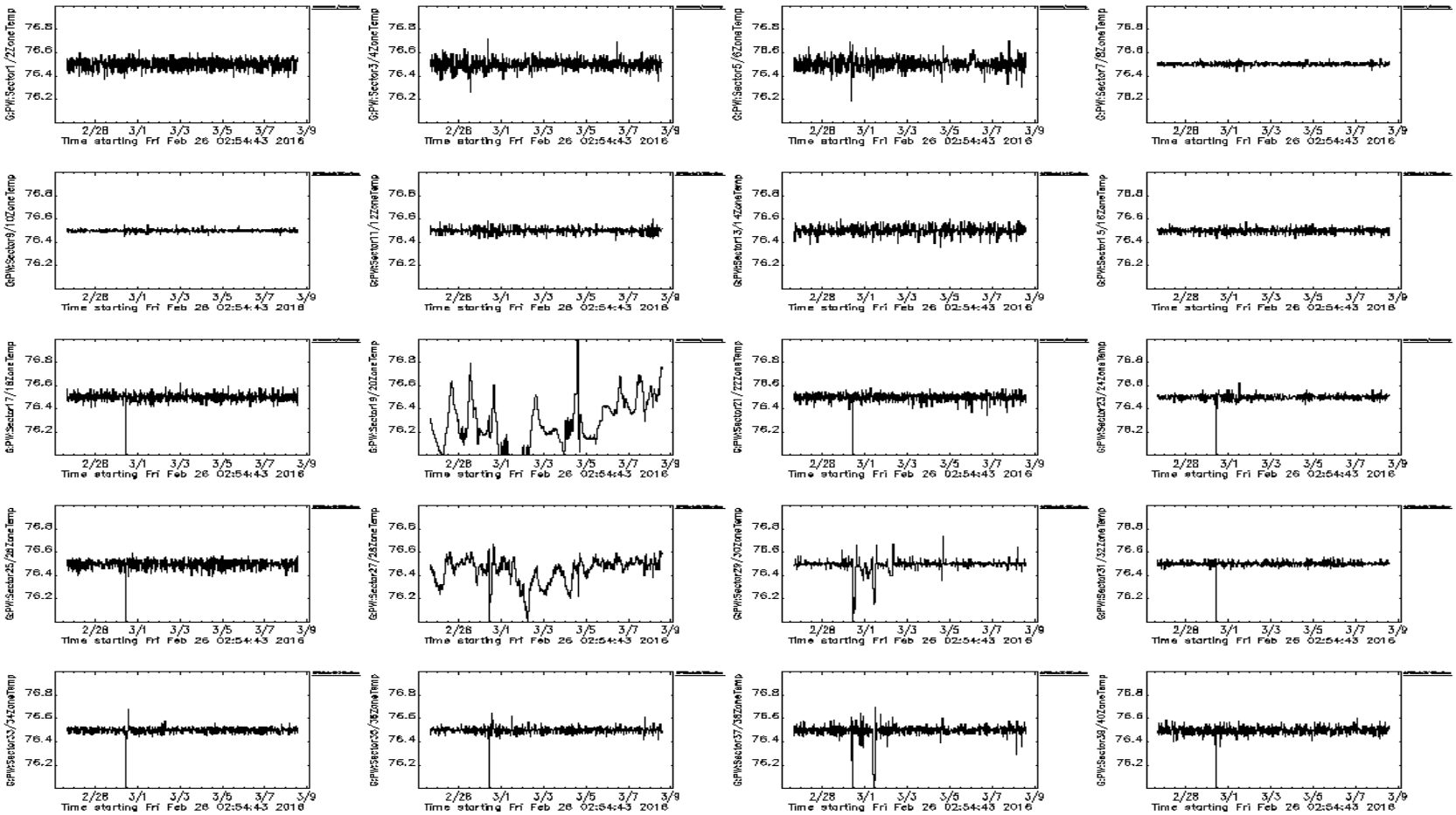
AHU mixed air temperature in degrees F

Plot is ~2 weeks notice we still some diurnal, but long term maybe gone

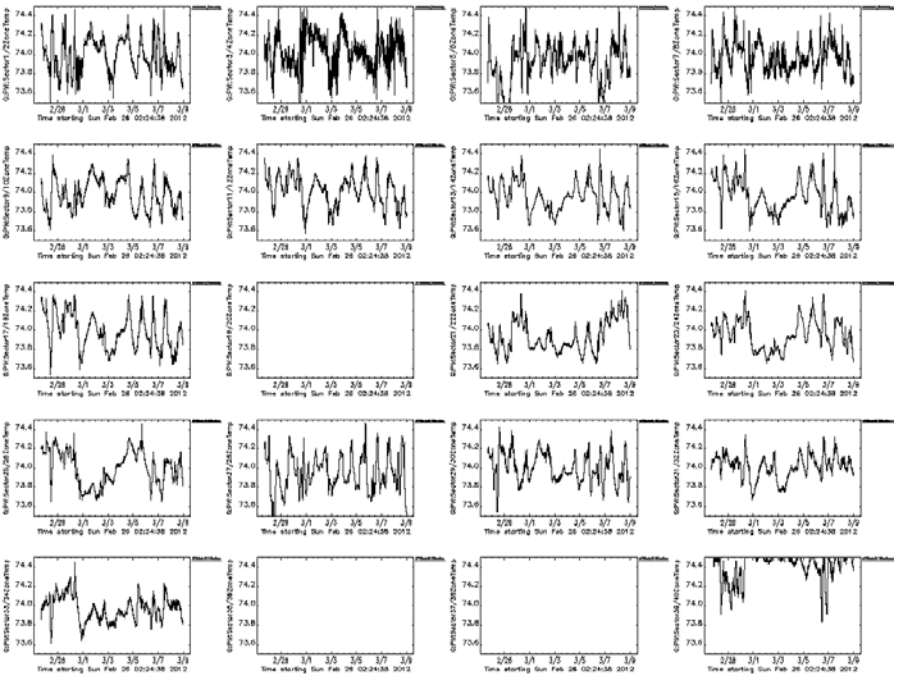
Before Dead Band removal with 1 degree temperature range

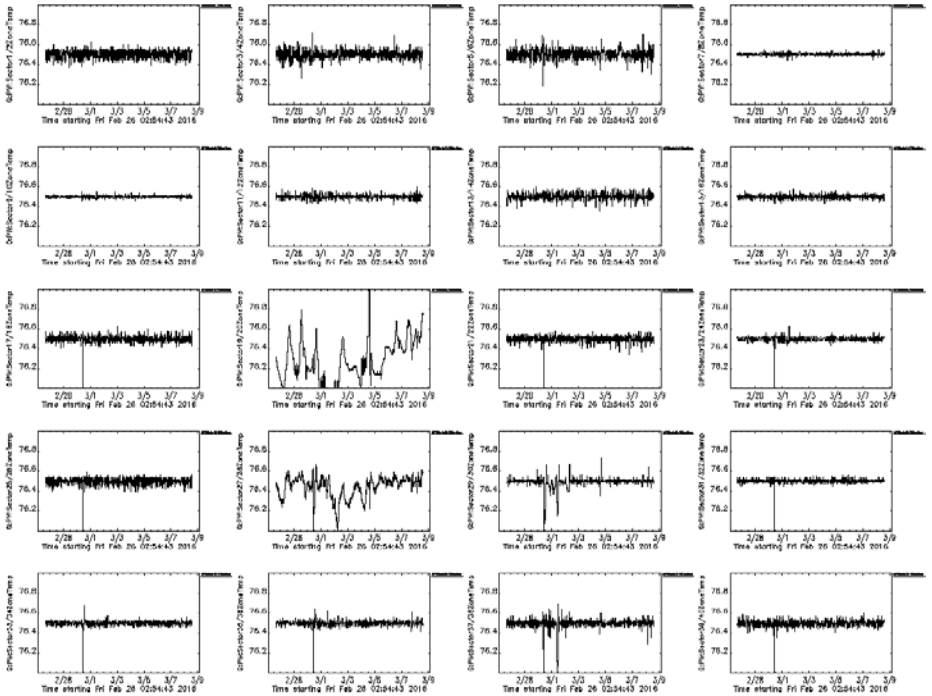


After Dead Band removal with 1 degree temperature range



All 20 SR AHUs before and after dead band removal with a 1 degree temperature range





More cap and band data; showing before, after, and shutdown period. Sector 37 & 38 mixed air