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Eastern North Atlantic (ENA) Aerosol Observing System (AOS) Instrument Handbook

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ARM

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Acronyms and Abbreviations

AC	alternating current
ACSM	aerosol chemical speciation monitor (Aerodyne Research Inc.)
AMF	ARM Mobile Facility
AOS	Aerosol Observing System
ARM	Atmospheric Radiation Measurement
BNL	Brookhaven National Laboratory
CAPS	cavity attenuated phase shift monitor (Aerodyne Research Inc.)
CCN	cloud condensation nuclei particle counter (Droplet Measurement Technologies)
CO/N_2O	carbon monoxide/nitrous oxide monitor (Los Gatos Research Inc.)
CPC	condensation particle counter (TSI Inc.)
DAQ	data acquisition board
ENA	Eastern North Atlantic
GHG	greenhouse gas analyzer (Picarro)
HTDMA	humidified tandem differential mobility analyzer (Brechtel Manufacturing Inc.)
IOPO	intensive operational period
IS	instrument shelter
Neph, Amb	nephelometer, ambient (TSI Inc.)
Neph, Dry	nephelometer, dry (TSI Inc.)
O_3	ozone monitor (Thermo Scientific Inc.)
PID	proportional, integral, derivative
PSAP	particle soot absorption photometer (Radiance Research)
RH	relative humidity
RTD	resistance temperature detector
SCFD	standard cubic feet per day
UHSAS	ultra-high-sensitivity aerosol spectrometer (Droplet Measurement Technologies)
UV	ultraviolet
VAC	volts alternating current
VI	virtual instrumentation
WXT520	weather transmitter (Vaisala)

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Eastern North Atlantic (ENA) Aerosol Observing System (AOS) (AOS06)

Figure 1. The Eastern North Atlantic (ENA) AOS06 set up at Brookhaven National Laboratory.

2.0 Mentor Contact Information

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4.0 Instrument Description

The U.S. Department of Energy ARM user facility's ENA AOS, designated AOS06, entered service in October of 2013 at the ARM Facility on Graciosa Island, Azores. The Aerosol Observing System is meant to be a standalone, completely autonomous, aerosol sampling system. It requires only power, 208VAC 1ϕ or 440 VAC 1ϕ, and an internet connection to be operational. The physical structure is a standard-sized shipping container, 20 feet long by 8 feet wide. Inside, the walls, ceiling, and floors are insulated using >3.5" of spray polyurethane foam with an R-value of 6.2/inch of insulation. The interior walls, floor, and ceiling are lined with ¾" plywood for durability and have integrated unistrut for mounting equipment.

Figure 2. AOS06 in operation on Graciosa Island, Azores.

5.0 Measurements Taken

The instruments installed in the AOS06 at ENA and the measurements made are:

1. ACSM (aerosol chemical speciation monitor): Particle mass for non-refractory aerosols

2. CAPS (cavity attenuated phase shift monitor): Single wavelength, extinction
3. CCN-100 (cloud condensation nuclei particle counter): Aerosol concentration as function of supersaturation
4. CO/N_2O (carbon monoxide/nitrous oxide monitor): Gas concentration
5. GHG (greenhouse gas monitor: $C0_2$, CH_4): Gas concentration
6. CPC (condensation particle counter): sizes from 20 nm–1000 nm
7. HTDMA (humidified tandem differential mobility analyzer): Particle size distribution, growth factor
8. Neph, Amb (nephelometer, ambient): Three-wavelength aerosol light scattering
9. Neph, Dry (nephelometer, dry):Three-wavelength aerosol light scattering
10. O_3 (ozone monitor): Gas concentration
11. PSAP (particle soot absorption photometer): Three-wavelength aerosol light absorption
12. UHSAS (ultra-high-sensitivity aerosol spectrometer): Particle size and number concentration from 50–500 nm
13. WXT520 (weather transmitter): Wind speed, direction, temperature, pressure, relative humidity, and rain.

6.0 A System of Subsystems

The ARM AOSs are not instruments in and of themselves, but rather each is a collection of instruments that make up what is termed the “ARM Baseline Instrumentation”. The AOS06 at ENA consists of the instruments listed above as well as any “guest” instruments that may be present during any given intensive operational period (IOP). A series of subsystems operate in the background and are essential to the operation of the instruments and the AOS as a whole.

6.1 Aerosol Inlet

The aerosol inlet is made up of two 10-foot sections of 8” aluminum irrigation pipe that have been modified to be mounted in a vertical orientation using guy wires for stability. The aluminum pipe is powdered-coated gray to prevent the formation of aluminum oxide.

There are eight points on the stack sections, four on one end of each, used to attach 3/16” stainless steel wire rope using ¼” pin shackles. These shackles are attached to eight wire ropes that attach to four hard points used to level and secure the stack during operation. Eight, 10-inch-long, stainless steel turnbuckles are used to adjust the tension in the cables.

Atop the 20-foot-tall aerosol inlet is a stainless steel rain cover, aka “hat”. Mounted on top of the hat is the WXT520 meteorological weather station. Installed around the edge of the rain cover is a small thermistor and a 1-inch wide, 175-watt band heater. This heater prevents the buildup of ice around the edge of the inlet. This thermistor and heater are controlled using an Omega I16D34-EIT PID (proportional, integral, derivative), a programmable logic controller.

Figure 3. The junction box and the rain hat at the top of the aerosol inlet.

The cables for both the WXT520 and the hat heater are connected to a Hoffman 6”x6”x4” stainless steel enclosure via Conxall IP67 all-weather connectors. This weatherproof enclosure is mounted on top of 2” aluminum conduit fastened to the side of the main stack using stainless steel pipe clamps. This conduit mates to a fitting on the roof flange using approx. 2.5 feet of UV-resistant flexible tubing. The cabling needed for the hat heater and the WXT520 resides inside this conduit and enters the AOS through the roof flange.

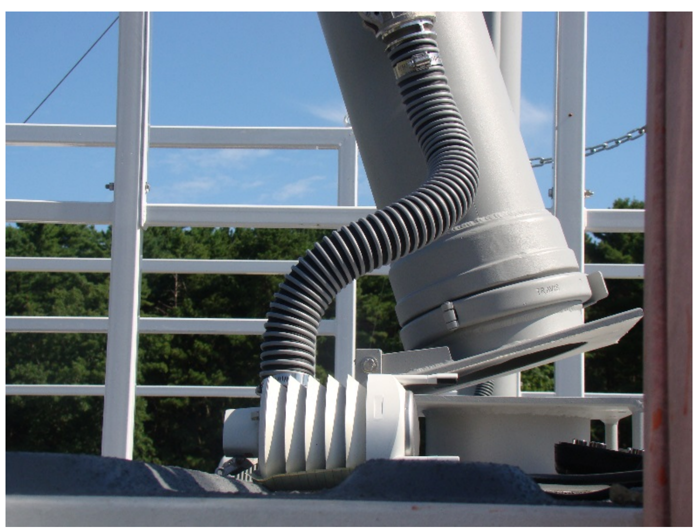


Figure 4. The base of the aerosol inlet, where it mates to the roof of the mobile laboratory.

The roof flange, custom made to Brookhaven National Laboratory (BNL)'s specifications, hinges on one side to allow for lowering the stack. Polyurethane gaskets seal between the roof flange and the roof, forming a weatherproof seal.

6.2 Blower Enclosure

The blower box houses the pumps, blowers, and the air drier needed for all the systems in the AOS. The blower box is mounted in the rear vestibule of the AOS on the right side.

Figure 5. The rear vestibule that houses the air conditioners (left) and the pump enclosure (right).

The air drier is a Pentras AIR 3100PM, recently replaced by the Puregas P5000PM, designed to intake wet ambient air and remove the moisture for delivery to applications requiring a constant, on-demand source of dry, pressurized air. The process is fully automatic and relatively maintenance free. The output capacity is normally 2000 standard cubic feet per day (SCFD), with a maximum capability of 3100 SCFD. The HTDMA, the humidigraph, and the PSAP dilution system require the dry air supplied by the air dryer.

There are two blowers: a manifold blower and a stack blower. The manifold blower is a 120VAC, 4.5A Ametek constant-velocity blower. The bypass blower is an Ametek 120VAC, 5A variable-speed blower used to maintain a constant aerosol flow down the stack. These blowers are mounted in the top right-hand side of the cabinet. (See pictures below.)

Two vacuum pumps and one compressor are located in the blower box. The main vacuum pump is a carbon vane pump that supplies vacuum to all of the instruments that require vacuum as well as the

Nafion driers that dry sample air. The other vacuum pump and the compressor are specific to the HTDMA instrument. These pumps are mounted on shelves inside of the blower box. In the back, left-hand corner of the blower enclosure is a quad receptacle box to plug in the pumps. This further simplifies pump replacement. With all of these pumps and motors running, a lot of heat is generated in the enclosure. To monitor this, temperature sensors are mounted on each of the pumps as well as near the top of the air drier. These readings are part of the “housekeeping” measurements that monitor the instruments and support equipment. Four 5” fans circulate air into and out of the enclosure to prevent the equipment overheating.

Figure 6. AOS06 blower enclosure interior and exterior.

On the left side on the enclosure is the connection panel. This is where the power cables and the hoses are connected to blower enclosure. These connections make system setup and breakdown easier. The panel is clearly labeled as well as the cables themselves. These cables exit the AOS through a “pass-through” opening in the top corner of the end wall. During shipping the cables and hoses are pulled back inside and bundled securely.

6.3 Aerosol Sample Distribution

Once the sample air enters the stack, it is pulled through a piece of 2” pipe that is polished on the inside to mitigate losses, corrosion, and dirt buildup. This 2” pipe is centered in the stack so that the sample air is taken from the center of the aerosol flow entering the stack. At the bottom of the 2” pipe is a five-port “flow distributor”. This allows sample air to be carried to different sampling systems. These different systems require unique sample conditioning before they enter the instrument. The impactor, located on port 2, is a device that has two states or positions. In one state, the impactor allows particles of size one micrometer and smaller to pass through; in the other state, 10-micrometer particles and smaller can pass.

The instruments downstream of the impactor are selected because of the measurements they make. The nephelometers measure light scattering, the PSAP measures light absorption, and the CAPS measures light extinction, which is the sum of the first two. These characteristics are used to quantify how aerosols effect visibility. These three characteristics depend on the aerosol particle size. The larger particles scatter much more light than smaller ones. The impactor helps us determine if the light is being affected by a large number of small particles or a small number of large particles. The flow distributor, as well as the conductive tubing used to transport the sample air, is insulated to prevent water from condensing in the sample lines. The main blower and bypass manifold pull the sample air to, and in some cases through, the different instruments. Each port of the flow distributor has a flow meter and a valve to control the flow through each port. They are adjusted individually to ensure that each instrument gets adequate sample flow. Guest instruments are plumbed into the sample distribution system based on the needs of the instrument. The instrument mentors coordinate the placement of their instruments with the AOS mentor to ensure the placement does not bias the standard measurements in any way. The flow rate in the modified sample line is then adjusted to compensate for the additional instrumentation. Figure 7 is a diagram of the inlet flow system followed by Figure 8 with images of the flow distributor and the bypass manifold.

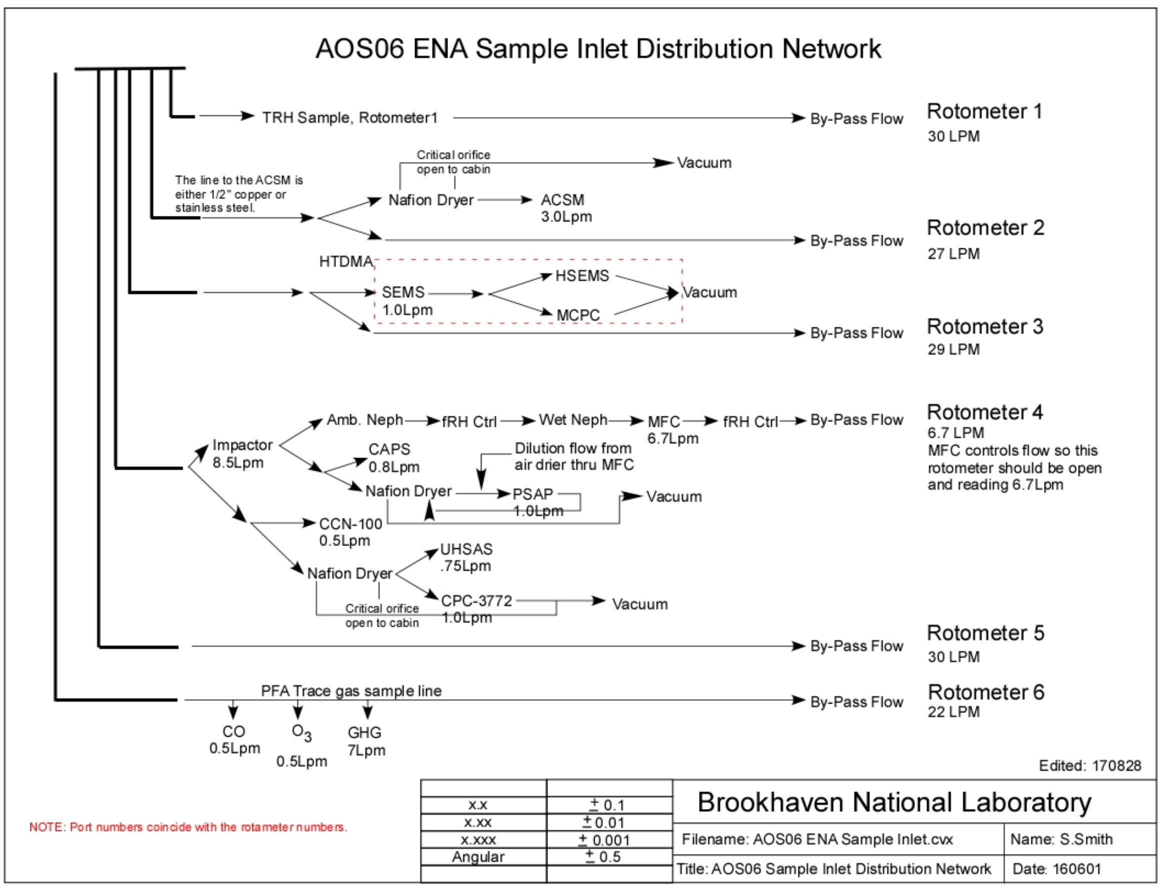


Figure 7. Diagram of AOS06 inlet flow system.

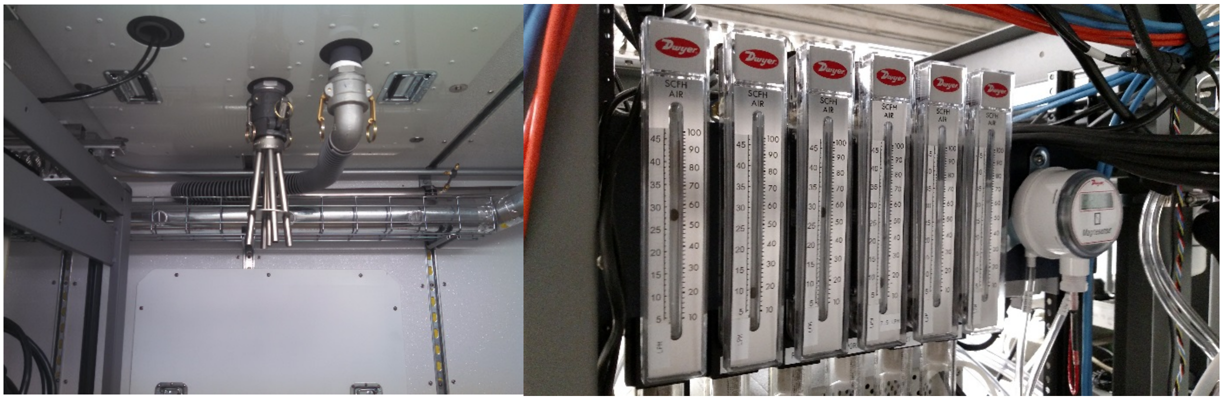


Figure 8. AOS06 flow distributor and bypass manifold.

6.4 System Monitoring

One of the ports from the flow distributor is dedicated to measuring the temperature and relative humidity of the incoming sample air. This is done using an Omega temperature/relative humidity sensor and a PID to both display and log this data. A PID is a proportional-integral-derivative controller commonly used as a control loop feedback mechanism in industrial control systems. There is a 3-wire resistance temperature detector (RTD) and a heater around the edge of the inlet cover referred to as the “Hat Heater”. This is also controlled by a PID and is used to prevent the buildup of ice around the edge of the inlet.

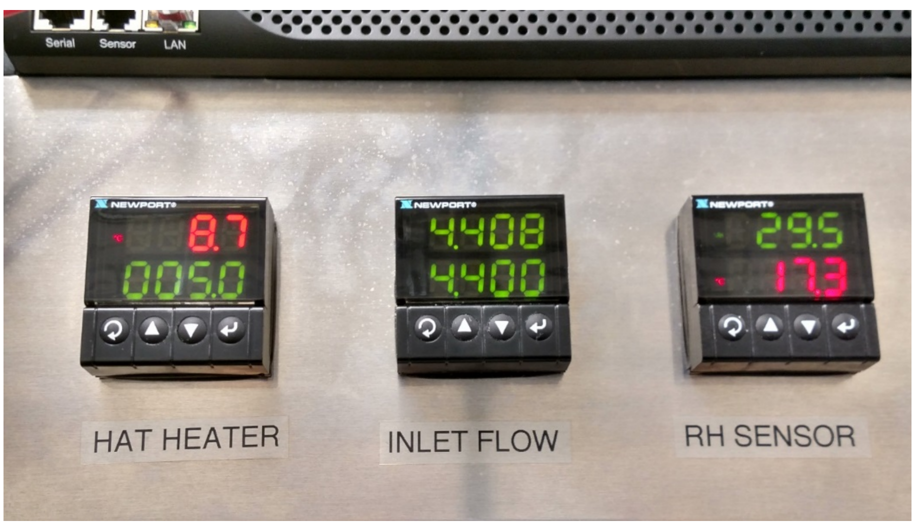
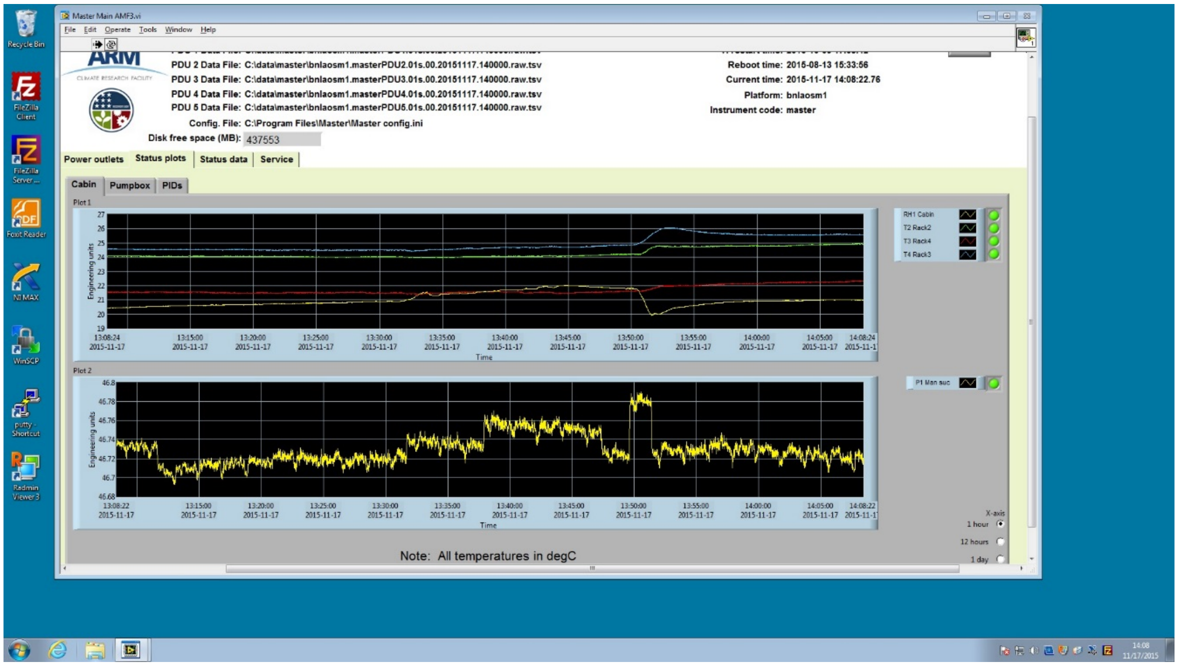


Figure 9. AOS06 monitoring console.

The AOS, as a system, is monitored using custom-made voltage, temperature, relative humidity, and pressure sensors. The blower enclosure has a cabinet temperature sensor as well as temperature sensors on all of the pumps in the cabinet. The outlet pressure from the Puregas drier is also monitored. Inside the AOS are three temperature sensors and an RH sensor to monitor conditions around the instruments. Bypass flow velocity is monitored using a pitot tube in conjunction with another PID to maintain a controlled sample flow rate to all of the instruments. All of these parameters are recorded and displayed on a virtual instrumentation (VI) display that runs on the AOS personal computer. Figure 10 shows three images of typical housekeeping plots.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Config. File: C:\Program Files\Master\Master config.ini
Disk free space (MB): 437553
Reboot time: 2015-08-13 15:33:56
Current time: 2015-11-17 14:08:22.76
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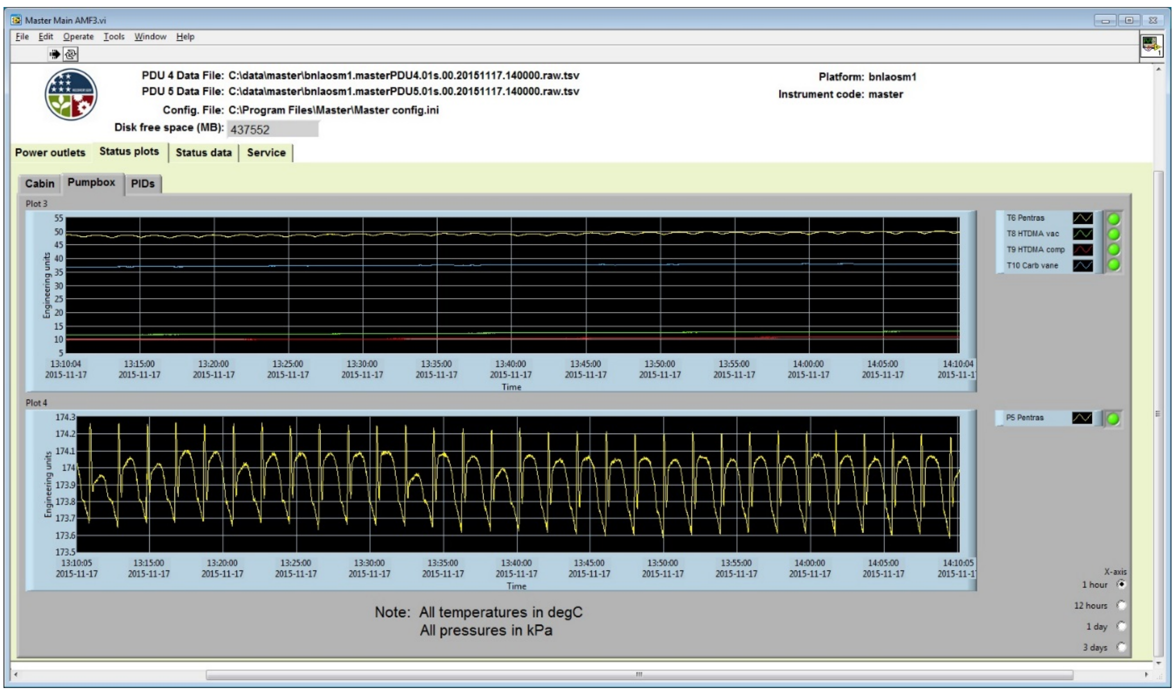
Instrument code: master
Power outlets
Status plots
Status data
Service
Cabin
Pumpbox
PIDs
Plot 1
Plot 2
Note: All temperatures in degC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Instrument code: master
Power outlets
Status plots
Status data
Service
Cabin
Pumpbox
PIDs
Plot 3
T6 Pentras
T8 HTDMA vac
T9 HTDMA comp
T10 Carb vane
Plot 4
P5 Pentras
Engineering units
Time
X-axis
1 hour
12 hours
1 day
3 days
Note: All temperatures in degC
All pressures in kPa

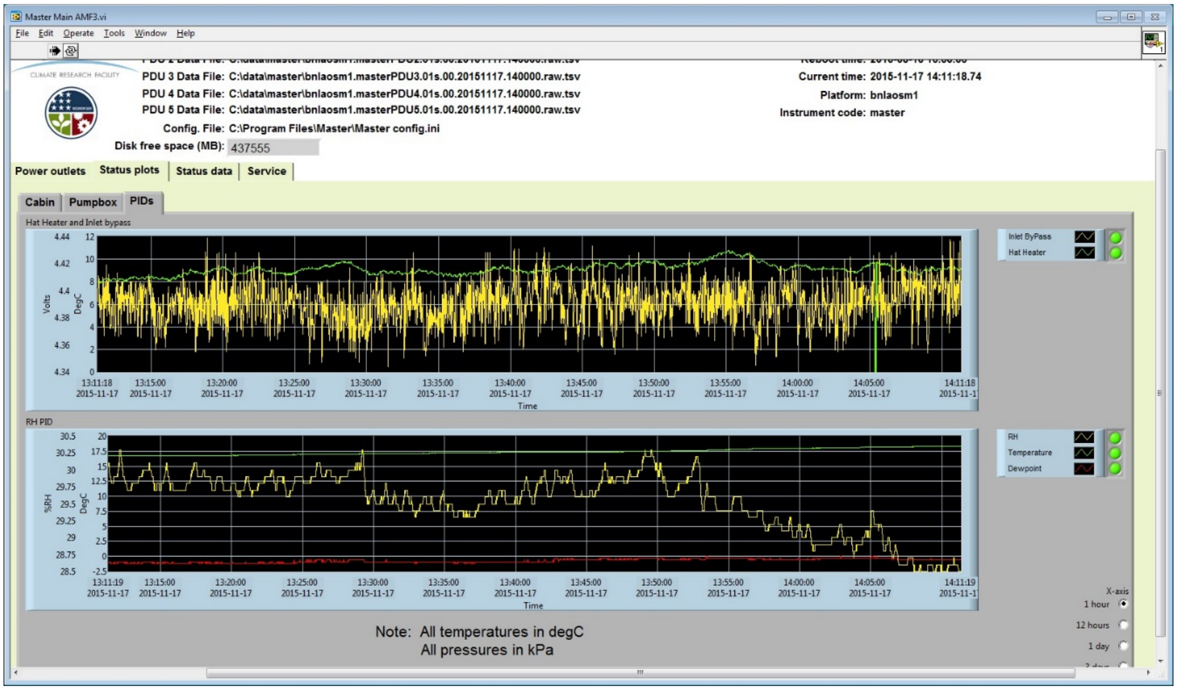

Figure 10. Three views of typical housekeeping plots for the AOS06.

Housekeeping measurements made inside the instrument shelter (IS) are:

- Relative humidity – back of rack 2
- Temperature – back of rack 2
- Temperature – back of rack 4
- Temperature – front of rack 3
- Vacuum – incoming vacuum line
- Pressure – air drier outlet pressure
- Voltage – Instrument AC receptacle voltage.

Housekeeping measurements made inside the pump box are:

- Temperature – near the top of the air drier
- Temperature – air drier compressor
- Temperature – HTDMA vacuum pump
- Temperature – HTDMA compressor
- Temperature – Carbon vane vacuum pump.

PID measurements include:

- Temperature – hat RTD, controls hat heater
- Inlet air flow – bypass air flow, controls variable-speed blower to maintain flow rate
- RH – measures the relative humidity of the inlet sample air
- Temperature – measures the temperature of the inlet sample air
- Dewpoint – calculates the dewpoint of the inlet sample air.

6.5 Data Collection and Computing

The AOS06 uses one rack-mounted computer, the infrastructure computer, and four “brick”-style computers. The “brick” computers are Ampro Adlink fanless computers running the Windows 7 operating system. The infrastructure computer is a Superlogics 1U rack-mounted computer. While working inside the AOS, the infrastructure computer is used to connect to the internet, for the daily check sheets, and for reference materials such as the handbook. The software to collect and display Webcam views is also on this computer. The “brick” computers run the instrument software, which collects the data from, and controls, the instruments. The AOS master is a another physical “brick” computer that collects and displays all of the housekeeping data. The National Instruments DAQ (data acquisition board) that inputs the temperature, RH, and pressure sensors is connected to the master. The Labview vi that collects the housekeeping data includes the DAQ data.

6.6 Instrument Racks

The instrument racks are BUD Industries racks mounted on cable isolators to help mitigate vibration and damage during shipping. Four of these are mounted side by side in the AOS. All instruments and computing equipment are mounted in these racks, as shown in Figures 11 and 12.

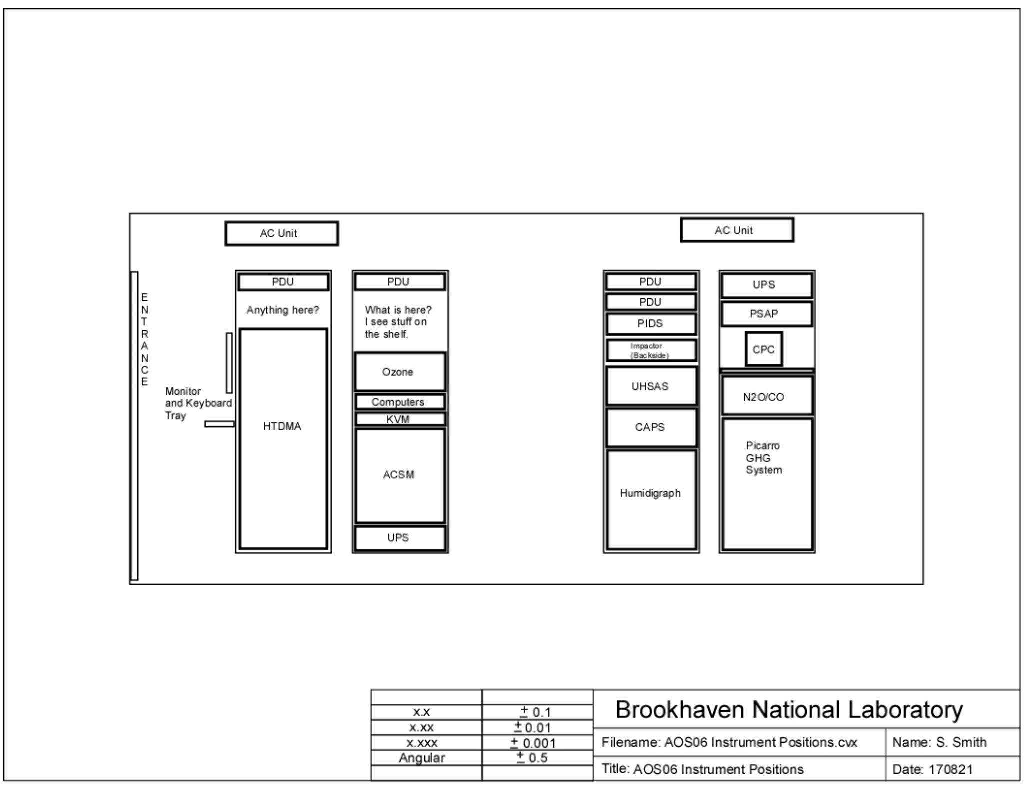

Figure 11. AOS06 instrument layout.

Figure 12. AOS06 instruments in the mounting racks.

In addition to the instrument systems there are power distribution units (PDUs) located in the racks. These PDUs give operators, both local and remote, the ability to turn equipment on and off without physically using a switch. This is useful for mentor troubleshooting when the mentors are not on site. Figure 13 is a diagram that maps the power distribution system in the AOS.

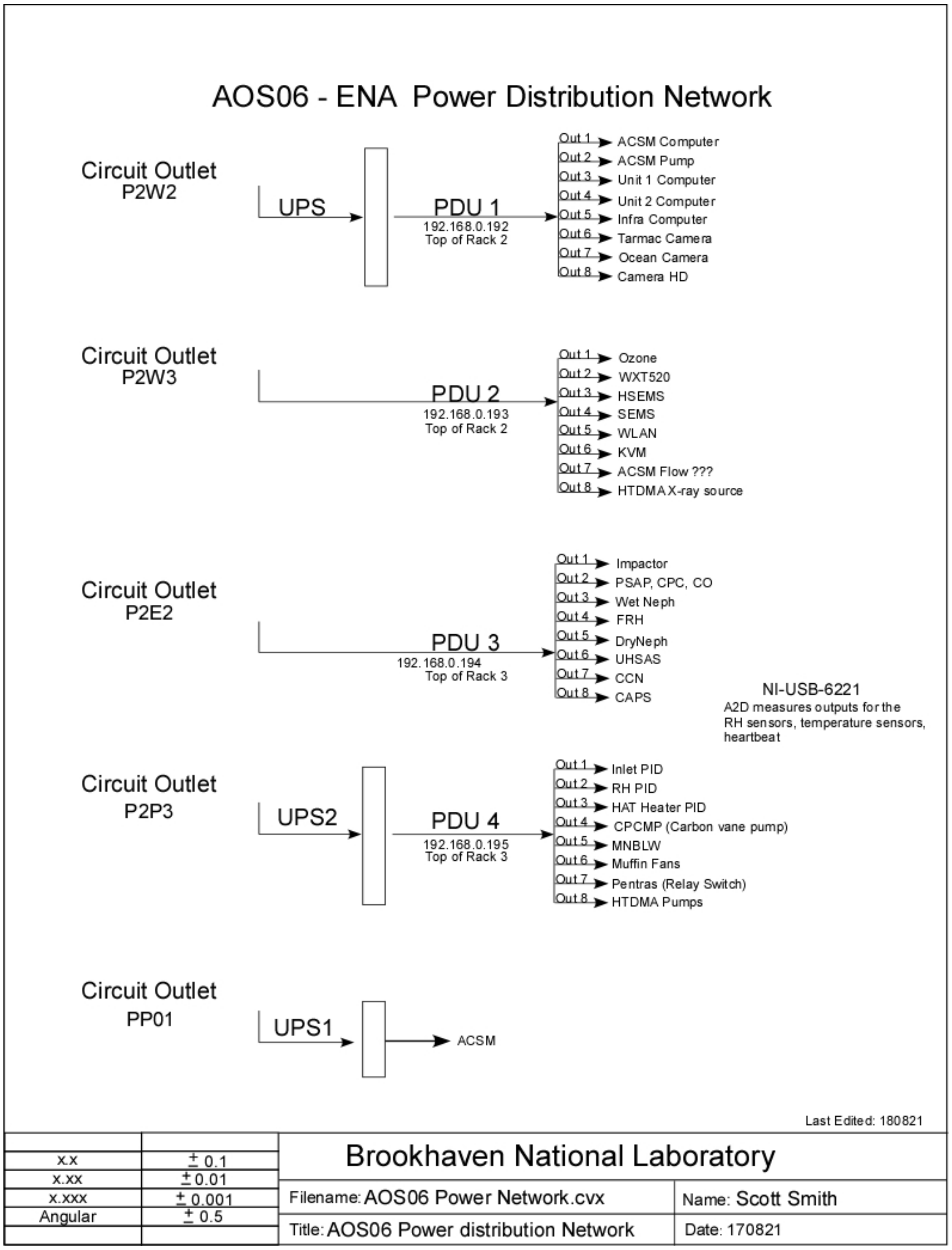

Figure 13. Diagram of AOS06 power distribution network.

7.0 Setup and Operations of Instruments

Information about individual instruments is found in separate handbooks and is not part of this document. The setup and operation information can be found in the operations manual.

8.0 Maintenance

Maintenance for these AOS structures is straightforward and minimal. On a monthly basis check the outside of the structure for signs of rust. If found, scrape, clean, and apply touch-up paint as needed. Check the door hinges for wear and rust. Grease or oil the hinges every three months or as needed. Inspect the door knob mechanism for signs of wear, rust, dust, and overall functionality. Clean, oil, and tighten the mechanism as needed. Inspect the roof railing bolts and pins for tightness and wear. Check the safety chain for wear and rust. Change the chain if necessary. Lastly, check the guy wires or alternative supports. Check the cables for rubbing and frayed wires. Confirm they have similar tension (the cables will stretch over time). If any feel loose compared to the others, adjust the tension as needed.

9.0 Safety

As with all ARM operations safety is extremely important. All installations should have a site safety plan in place. All must adhere to the safety procedures documented in the plan. Special care should be taken while installing the roof railings and installing the aerosol inlet (stack). Safety shoes, gloves, and hardhats should be worn while the AOS is being set up.

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