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Southern Great Plains (SGP) Aerosol Observing System (AOS) Instrument Handbook

J Uin
O Mayol-Bracero
S Smith
D De Oliveira

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J Uin, Brookhaven National Laboratory
S Smith, Brookhaven National Laboratory
O Mayol-Bracero, Brookhaven National Laboratory
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Acronyms and Abbreviations

AC	alternating current
ACSM	aerosol chemical speciation monitor (Aerodyne Research Inc.)
AOS	Aerosol Observing System
AOS07	SGP AOS
APS	aerodynamic particle sizer
ARM	Atmospheric Radiation Measurement
BNL	Brookhaven National Laboratory
CAPS	cavity attenuated phase shift monitor (Aerodyne Research Inc.)
CCN-200	dual-column cloud condensation nuclei particle counter (Droplet Measurement Technologies)
CPC	condensation particle counter (TSI Inc.)
μCPC	ultra-fine condensation particle counter (TSI Inc.)
DAQ	data acquisition board
HTDMA	humidified tandem differential mobility analyzer (Brechtel Manufacturing Inc.)
IOP	intensive operational period
Neph, Dry	nephelometer, ambient RH (TSI Inc.)
Neph, Wet	nephelometer, controlled RH (TSI Inc.)
n-SMPS	nano scanning mobility particle sizer (TSI Inc.)
PDU	power distribution unit
PID	proportional, integral, derivative
PSAP	particle soot absorption photometer (Radiance Research)
RH	relative humidity
RTD	resistance temperature detector
SCFD	standard cubic feet per day
SGP	Southern Great Plains
SMPS	scanning mobility particle sizer (TSI Inc.)
SO_2	sulfur dioxide analyzer (Thermo Environmental Instruments)
TAP	tricolor absorption photometer (Brechtel Manufacturing Inc.)
UHSAS	ultra-high-sensitivity aerosol spectrometer (Droplet Measurement Technologies)
UPS	uninterruptible power supply
UV	ultraviolet
VAC	volts alternating current
VI	virtual instrumentation
VM	virtual machine (computer)
WXT520	weather transmitter (Vaisala Inc.)

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Southern Great Plains (SGP) Aerosol Observing System (AOS07)

Figure 1. AOS07 on site at ARM's Southern Great Plains Central Facility in Oklahoma.

2.0 Mentor Contact Information

Olga Mayol-Bracero
Brookhaven National Laboratory
Upton, New York 11973
Ph: 631-344-2871
Email: omayolbra@bnl.gov

Janek Uin
Brookhaven National Laboratory
Upton, New York 11973
Ph: 631-344-3612
Email: juin@bnl.gov

Scott Smith
Brookhaven National Laboratory
Upton, New York 11973
Ph: 631-344-7197
Email: ssmith@bnl.gov

3.0 Vendor/Developer Contact Information

Structure: Berg Manufacturing Inc. Ph: 509-624-8921

System: Brookhaven National Laboratory. Ph: 631-344-7197

4.0 Instrument Description

The U.S. Department of Energy Atmospheric Radiation Measurement (ARM) user facility's new Southern Great Plains (SGP) Aerosol Observing System (AOS) (pictured in Figure 2), designated AOS07, entered service in November of 2016 at the Central Facility of the ARM SGP observatory. The AOS is meant to be a standalone, completely autonomous aerosol sampling system. It requires only power, 240VAC, 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 and ceiling are lined with 2.5" insulated panels and are coated with epoxy paint for durability. The floor is also insulated, lined with ¾" marine-grade plywood, and coated with epoxy paint for durability.

Figure 2. Another view of AOS07 at the SGP observatory.

5.0 Measurements Taken

The instruments installed in the SGP AOS and the measurements made are:

1. ACSM (aerosol chemical speciation monitor): Particle mass for non-refractory aerosols
2. APS (aerodynamic particle sizer): Particle number and sizes .5−20 µm
3. CAPS (cavity attenuated phase shift monitor): Three-wavelength, aerosol extinction

4. CCN-200 (dual-column cloud condensation nuclei particle counter): Aerosol concentration as a function of supersaturation
5. CPCf (condensation particle counter): Sizes 20 nm−1000 nm
6. CPCu (ultra-fine condensation particle counter): sizes 2 nm–1000 nm
7. Neph, Dry (nephelometer, dried): Three-wavelength aerosol light scattering
8. n-SMPS (nano scanning mobility particle sizer): Particle number concentration and sizes 2.5−60 nm
9. PSAP (particle soot absorption photometer): Three-wavelength aerosol light absorption
10. SMPS (scanning mobility particle sizer): Particle number concentration and sizes 10−500 nm
11. SO_2(sulfur dioxide analyzer): sulfur dioxide concentration
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 precipitation.

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 AMF3 AOS 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" (Figure 3). 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 (to 5°C) 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 (as shown in Figure 4). 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's (BNL) specifications, hinges on one side to allow for lowering the stack by personnel without a crane. Polyurethane gaskets seal between the roof flange, the upper decking, and the hinge plate and its base. On top of the AOS is a 13"-tall main deck that rests on the corner posts of the AOS. These four corners support the weight of the upper deck and all of the equipment placed on it. The main deck is made of 12"x ¼" galvanized steel I-beams with sectional galvanized steel decking and a brushed aluminum handrail system. The deck meets the roof of the AOS and is sealed by a 3-inch-thick, vinyl-covered, polyurethane "donut." This seals the opening in the roof from the environment. The platform is attached to the top of the AOS using "Tandemloc Double Vertical Clamp Connectors."

6.2 Blower Enclosure

A stainless steel blower box houses the pumps, blowers, and air drier needed for systems in the AOS.

The air drier is a Puregas P4200pm designed to intake wet ambient air and remove 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 2600 standard cubic feet per day (SCFD), with a maximum capability of 4200 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 bypass or 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 Figure 5.)

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 instruments requiring vacuum, and the Nafion driers that dry sample air. The other vacuum pump and the compressor are specific to the HTDMA instrument. These pumps are mounted in a small rack on sliding shelves to facilitate maintenance and replacement. A quad receptacle box to plug in the pumps is in the back, left-hand corner of the blower enclosure. 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 pump and near the top of the air drier. These readings are part of the “housekeeping” measurements that monitor the instruments and support equipment. Four 10” fans circulate air into and out of the enclosure to prevent the equipment from overheating.

Figure 5. AOS07 blower enclosure interior and connection panel.

On the left side of the enclosure is the weatherproof connection panel. This is where the power cables and the hoses connect to the 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. (See Figure 6.)

Figure 6. AOS07 cable pass-through opening and interior view of the cable bundle.

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 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 conditioning of samples before they enter the instrument. The impactor, located on port 1, 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 and TAP measure light absorption, and the CAPS measures light extinction, which is the sum of the first two. These parameters are used to quantify how aerosols effect visibility and radiation transfer in the atmosphere. These three radiative parameters 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, reduce the transit time through the inlet tubing, AND maintain a constant flow through the main inlet. 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.

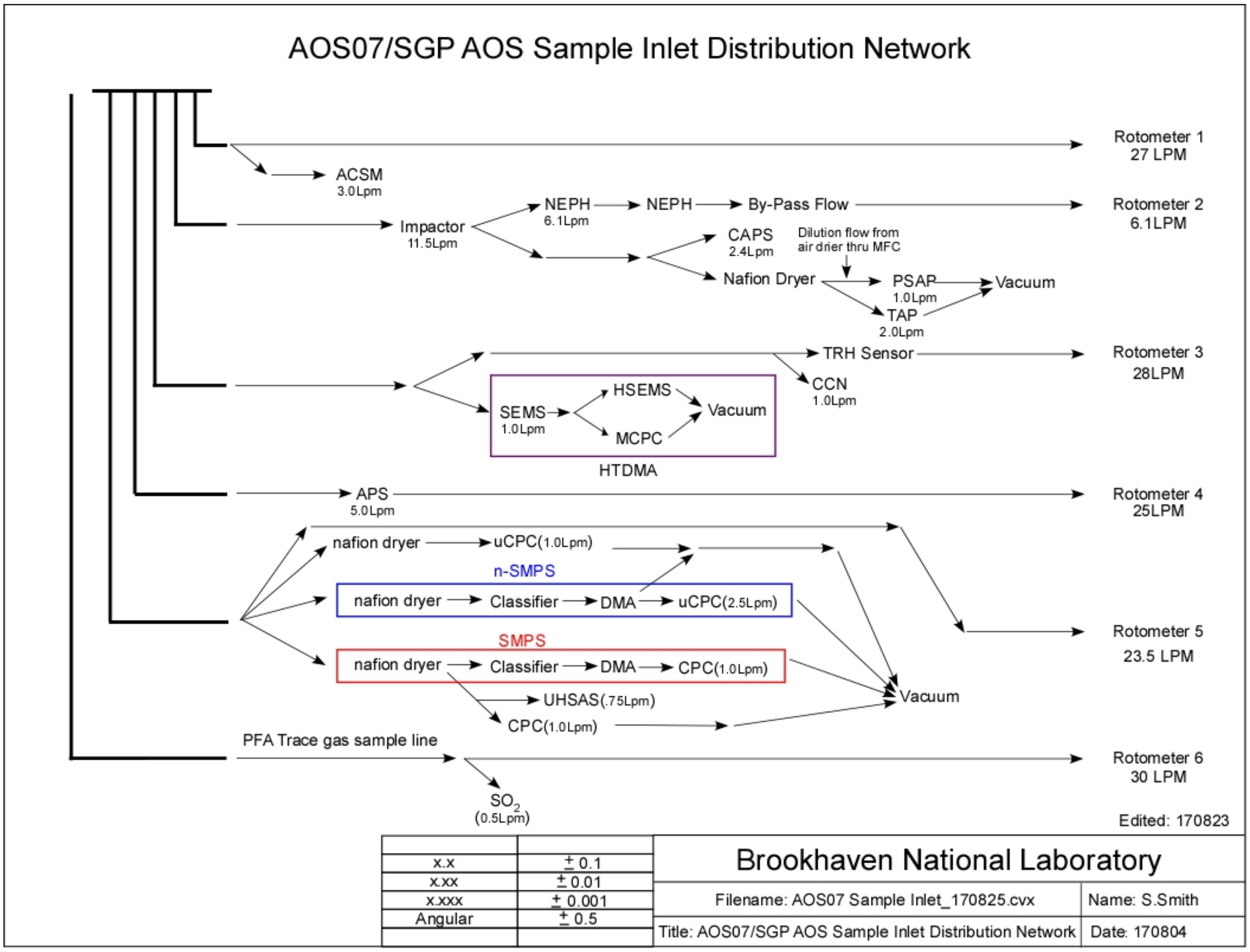


Figure 7. Diagram of the AOS7 inlet flow system.

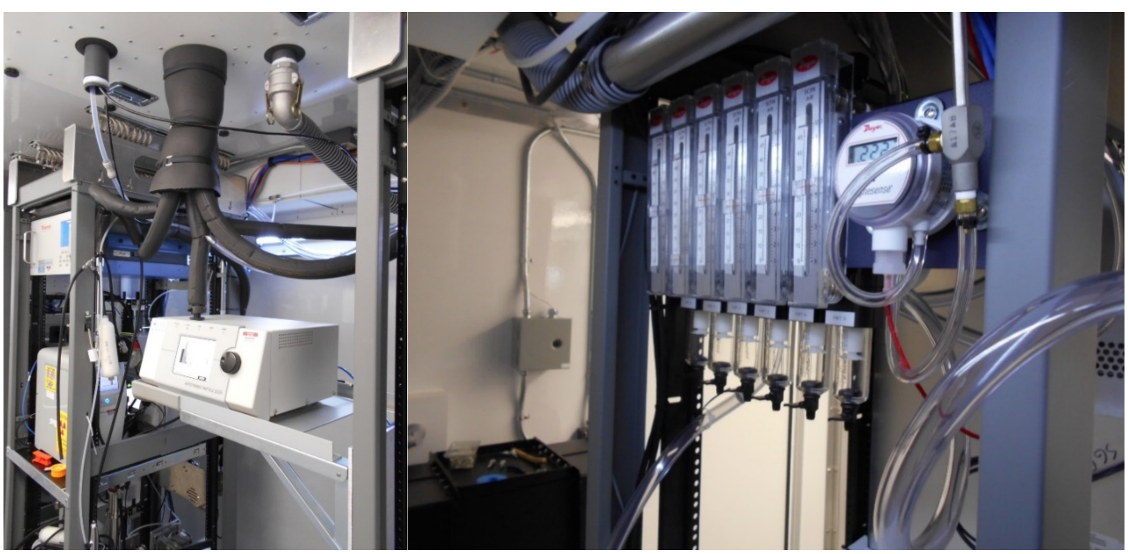


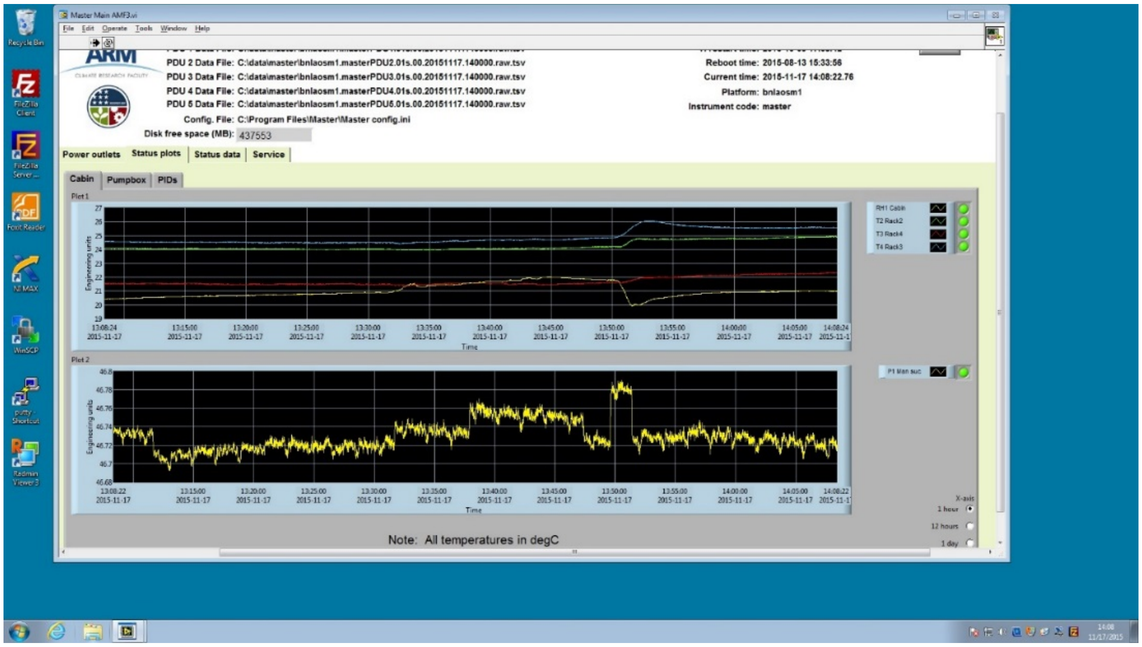
Figure 8. AOS07 flow distributor and bypass manifold.

6.4 System Monitoring

One of the ports from the flow distributor is dedicated to measuring the ambient temperature and relative humidity of the incoming sample air. Some change in temperature and thus RH is inevitable even though the lines are insulated. T/RH is monitored 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" (Figure 9). This is also controlled by a PID and is used to prevent the buildup of ice around the edge of the inlet.

Figure 9. AOS07 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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File Edit Operate Tools Window Help
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PDU 3 Data File: C:\data\master\bnlaosm1.masterPDU3.01s.00.20151117.140000.raw.tsv
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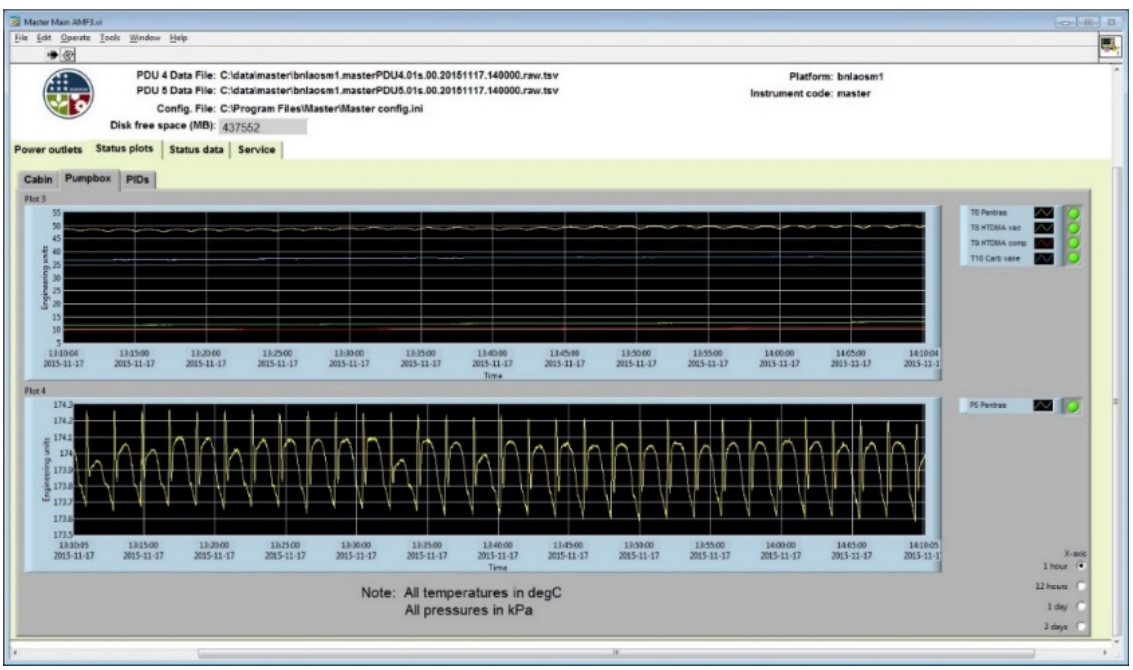
Reboot time: 2015-08-13 15:33:56
Current time: 2015-11-17 14:08:22.76
Platform: bnlaosm1
Instrument code: master
Power outlets
Status plots
Status data
Service
Cabin
Pumpbox
PIDs
Plot 1
Plot 2
Engineering units
Time
Note: All temperatures in degC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File Edit Operate Tools Window Help
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Platform: bnlaosm1
Instrument code: master
Power outlets
Status plots
Status data
Service
Cabin
Pumpbox
PIDs
Plot 3
Plot 4
Engineering units
Time
Note: All temperatures in degC
All pressures in kPa

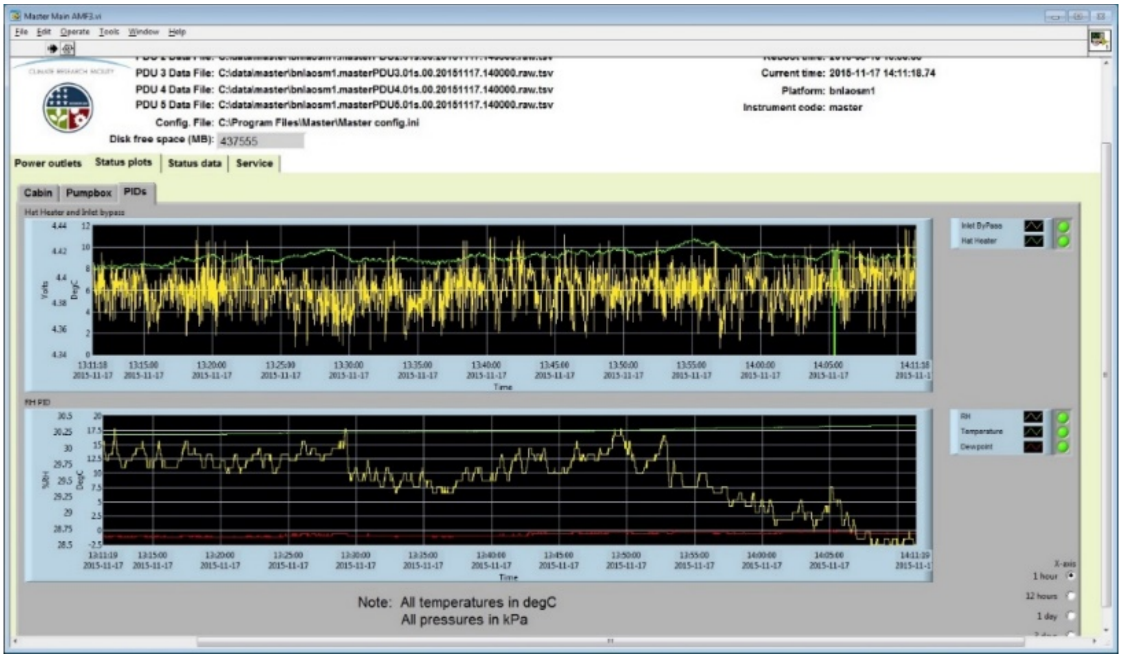

Figure 10. Three views of typical housekeeping plots for the AOS07.

Housekeeping measurements made inside the instrument shelter are:

Relative humidity – back of rack 5
Temperature – front of rack 1
Temperature – back of rack 2
Temperature – front of rack 3
Temperature – back of rack 4
Temperature – front of rack 5
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 SGP3 AOS07 is the second AOS to use the new “virtual computing system”; the virtual computers are referred to as virtual machines (VMs). There are also two physical computers located in the AOS. One is the “Infrastructure Computer” and the other is called the “AOS Master”. While working inside the AOS, the infrastructure computer is the system used to connect to the other systems running instrument software. These are the virtual machines (VMs; computers). The hardware units for these VMs are located at the same site, but not necessarily in the same structure. They will be located where they can be more easily maintained, backed up, and serviced both remotely and physically. The software that is used to collect the data from and control the instruments run on these VMs. The AOS master is a physical computer that collects and displays all of the housekeeping data. The National Instruments DAQ (data acquisition board) is connected to the AOS master and the Labview vi that collects the data also runs on this computer.

6.6 Power and Power Distribution

Main power is supplied from the “Prairie Entry”, to which two instrument shelters can be mated. In the entry way is a multi-tap transformer that can support multiple voltage inputs and convert them to the 208V single-phase power needed for the AOS. After power enters the AOS main panel, a 60amp breaker feeds a single uninterruptible power supply (UPS) that supplies power to all of the instrument racks and some wall-mounted outlets (Figure 11). The UPS absorbs the expected power “bumps” that are common at the SGP site. The UPS should keep all of the instruments on for about 30 minutes.

Figure 11. AOS07 power main panel and UPS.

A map of the power distribution units (PDUs) and the instruments they control is shown in Figure 12.

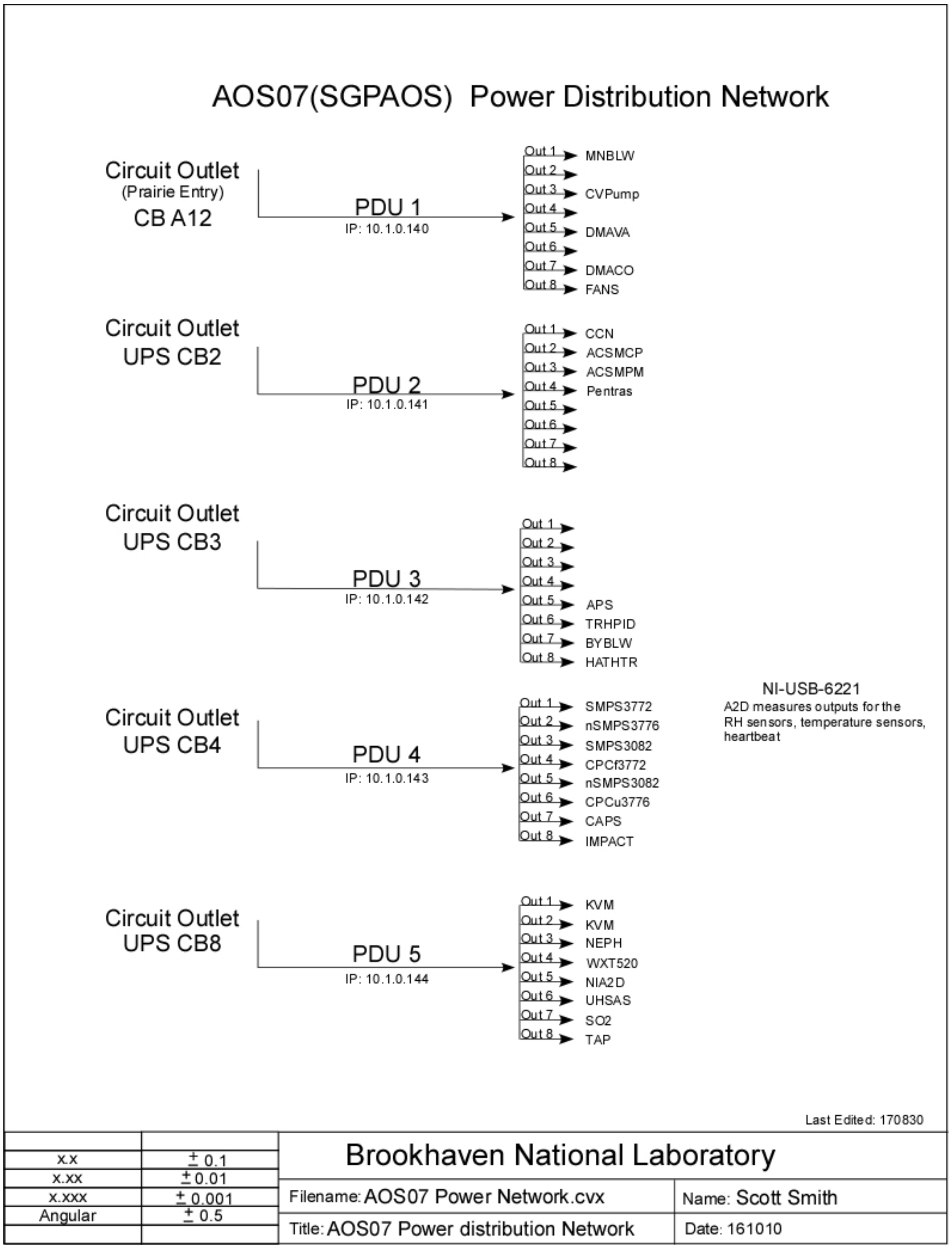

Figure 12. Diagram of AOS07 power distribution network.

6.7 Instrument Racks

The instrument racks are BUD Industries racks mounted on cable isolators to help mitigate vibration and damage during shipping. Five of these are mounted side by side in the AOS. All instruments and computing equipment are mounted in these racks, as shown in Figures 13 and 14.

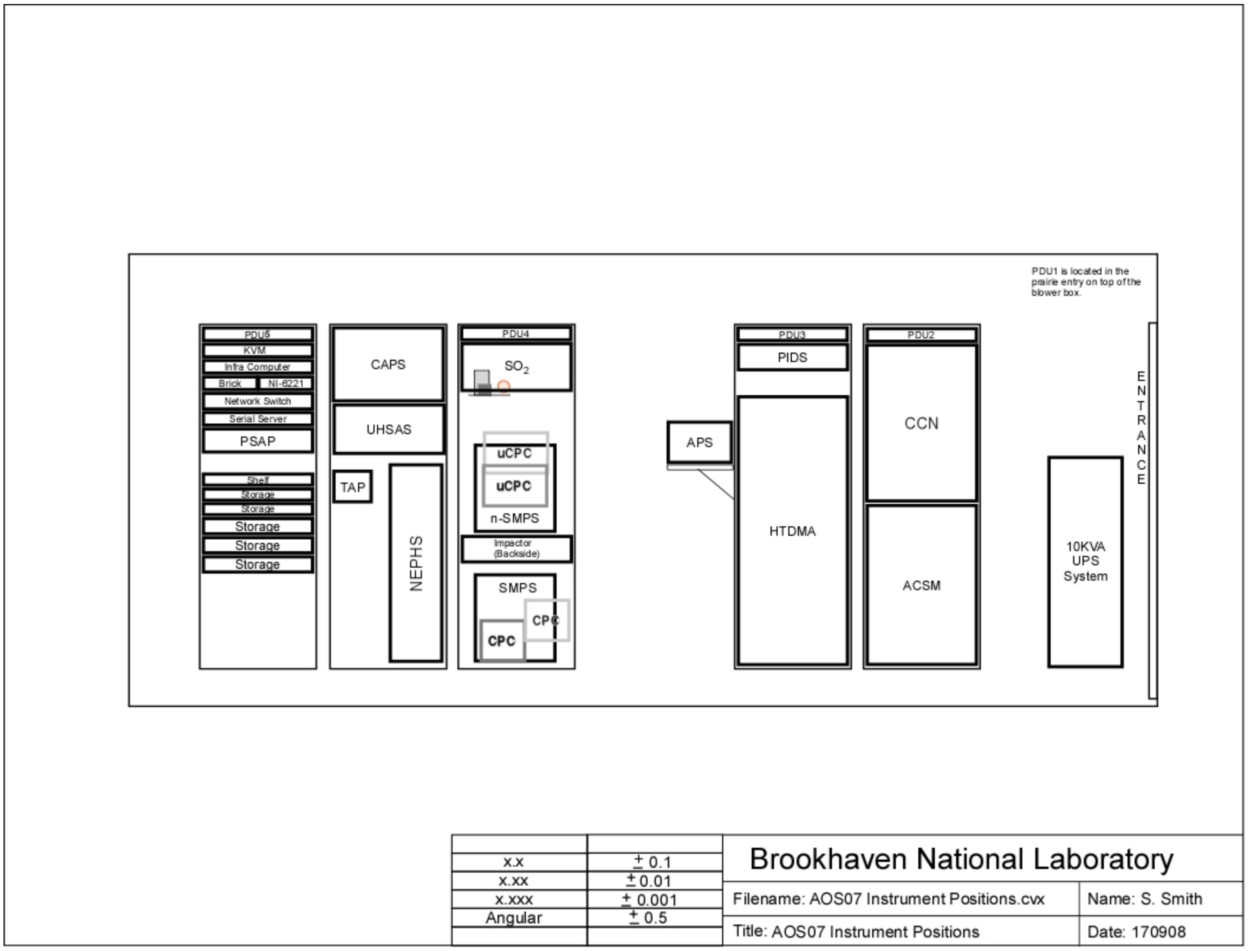

Figure 13. AOS07 instrument layout.

Figure 14. AOS07 instruments in the mounting racks.

7.0 Setup and Operation 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 AOS Procedures Manual. Operators fill out daily log sheets covering each instrument and AOS systems as provided by mentors.

8.0 Sample Line Integrity Checks

This process ensures the integrity of sample lines by identifying and correcting any leaks.

8.1 Procedure

Remove the sample line from the stack and place a HEPA filter on the stack end. Each instrument connected to the sample line should read zero. If not, further investigation is required. Every connection on the sample line is treated as a potential single point of failure.

8.2 When to Perform?

Before deployment, prior to the AOS leaving the facility. On-site, before any disruptions or modifications to the sample lines (Figure 15). On-site after field activities, once all work is completed. As needed, whenever a significant change occurs, such as replacing a tube or adding/removing a component.

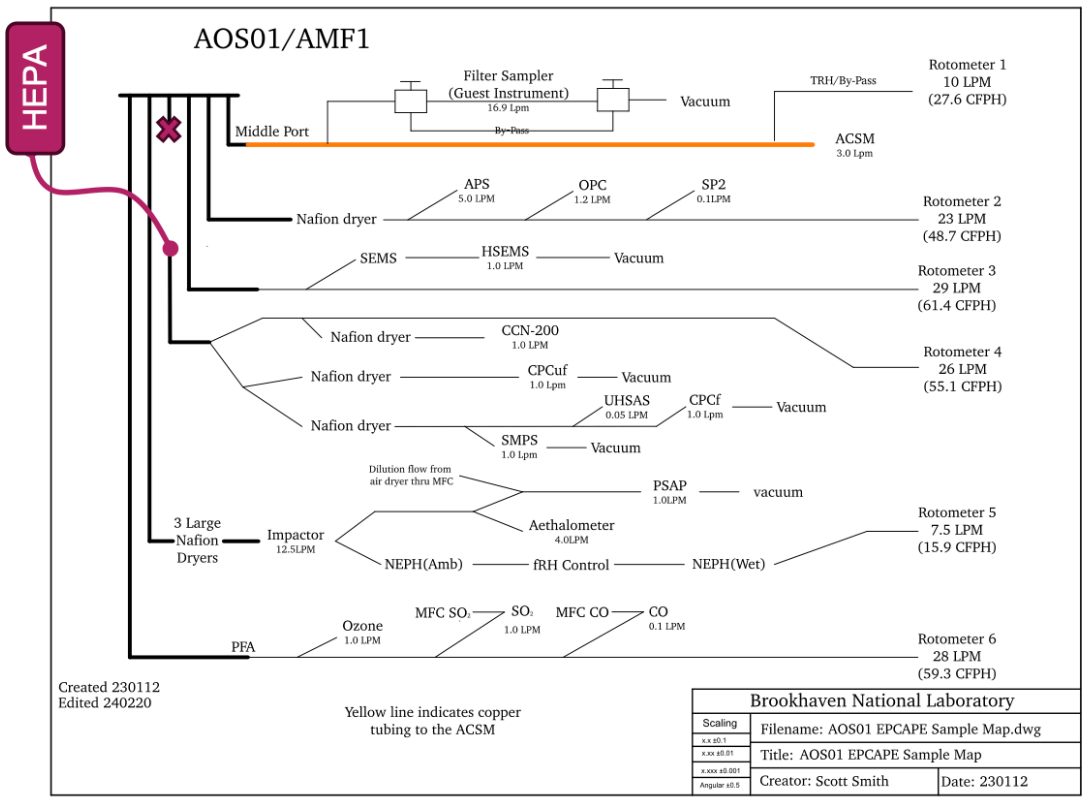

Figure 15. Sample line distribution network for AMF1 with integrity check for the microphysics line.

8.3 Future

Automate using the zero-air purge system that was used during MOSAIC (fills the AOS sampling system with particle free-air).

9.0 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 railing gate to ensure the gate swings freely and make sure the latch works properly and engages fully. Lastly, check the guy wires. 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.

10.0 Safety

As with all ARM operations safety is extremely important. All installations must have a site safety plan written by the operator's institution in place. All working with the AOS 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. Additional safety information is provided in the AOS procedures document available on the infrastructure computer.

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