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Third ARM Mobile Facility (AMF3) Aerosol Observing System (AOS) Instrument Handbook

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ARM

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Acronyms and Abbreviations

ACSM	aerosol chemical speciation monitor (Aerodyne Research Inc.)
AMF3	third 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-200	dual-column cloud condensation nuclei particle counter (Droplet Measurement Technologies)
CO/N_20	carbon monoxide/nitrous oxide monitor (Los Gatos Research Inc.)
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, Amb	nephelometer, ambient (TSI Inc.)
Neph, Dry	nephelometer, dry (TSI Inc.)
O_3	ozone monitor (Thermo Scientific Inc.)
PDU	power distribution unit
PID	proportional, integral, derivative
PSAP	particle soot absorption photometer (Radiance Research)
RTD	resistance temperature detector
UHSAS	ultra-high-sensitivity aerosol spectrometer (Droplet Measurement Technologies)
UV	ultraviolet
VAC	volts alternating current
VI	virtual instrumentation
VM	virtual machine (computer)
WXT520	weather transmitter (Vaisala)

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Third Atmospheric Radiation Measurement (ARM) Mobile Facility (AMF3) Aerosol Observing System (AOS03)

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2.0 Mentor Contact Information

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

4.0 Instrument Description

The U.S. Department of Energy ARM user facility's AMF3 AOS, designated AOS03, entered service in August 2016 at the ARM Mobile Facility at Oliktok Point, Alaska. The Aerosol Observing System (pictured in Figure 2) is meant to be a standalone, completely autonomous, aerosol sampling system. It requires only power, 208VAC, 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.

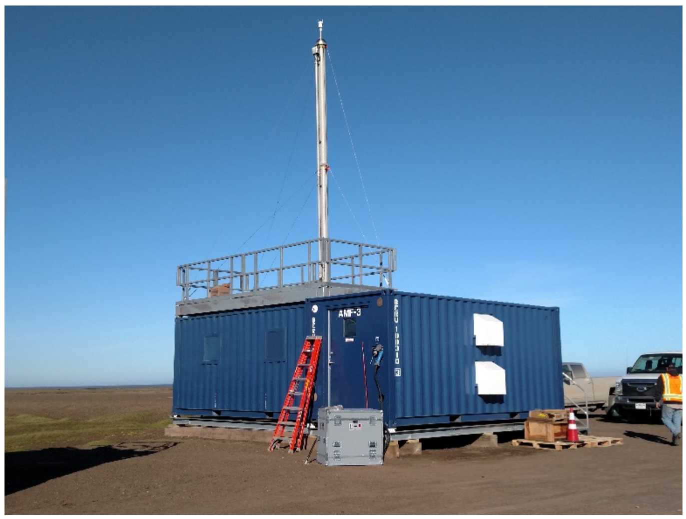


Figure 2. The AOS03 set up at Oliktok Point, Alaska.

5.0 Measurements Taken

The instruments installed in the AMF3 and the measurements made are:

1. ACSM (aerosol chemical speciation monitor): Particle mass for non-refractory aerosols
2. APS (Aerodynamic Particle Sizer) particle concentration and size distribution 550nm – 20000nm
3. CAPS (cavity attenuated phase shift monitor): Three-wavelength, extinction
4. CCN-200 (dual-column cloud condensation nuclei particle counter): Particle concentration as a function of supersaturation
5. CO/N_2O (carbon monoxide/nitrous oxide monitor): Gas concentration
6. CPCf (condensation particle counter): sizes from 20 nm–1000 nm
7. µCPC (ultra-fine condensation particle counter): sizes from 2.5 nm–1000 nm
8. HTDMA (humidified tandem differential mobility analyzer): Particle size distribution, growth factor
9. Neph, Dry (nephelometer, dry): Light scattering
10. O_3 (ozone monitor): Gas concentration

11. PSAP (particle soot absorption photometer): Three-wavelength aerosol light absorption
12. SMPS (Scanning Mobility Particle Sizer): particle concentration and size distribution 10nm – 500nm
13. SO_2 (Sulfur Dioxide) Gas concentration
14. SP2xr (Single Particle Soot Photometer, extended range) single particle incandescence and scattering
15. UHSAS (ultra-high-sensitivity aerosol spectrometer): Particle size and number concentration from 50–500 nm
16. 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 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 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.

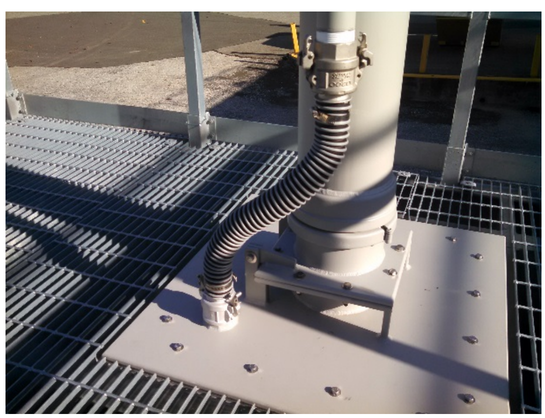


Figure 4. The base of the aerosol inlet, where it mates to the roof of the mobile laboratory.

The roof flange, custom-made to Brookhaven National Laboratory's (BNL) specifications, hinges on one side to allow for lowering the stack. Polyurethane gaskets seal between the roof flange and the upper decking and also between 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 on it. The main deck is made of 12"x ¼" galvanized steel I-beams with sectional galvanized steel decking and a galvanized steel handrail system. The deck meets the roof of the AOS and is sealed by a 3"-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

The blower box houses the pumps, blowers, and the air drier needed for all the systems in the AOS.

The air drier is an Altec 5000pm 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 5000 standard cubic feet per day. The HTDMA, the inlet drying system, and the PSAP dilution system require the dry air supplied by the air dryer.

There are two blowers: a manifold blower and a bypass 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 Figures 5 and 6.)

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, 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 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 10" fans circulate air into and out of the enclosure to prevent the equipment from overheating.

Figure 5. AOS03 blower enclosure interior and connection panel.

On the left side of the enclosure is the 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.

Figure 6. AOS03 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, 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 conditioning of samples 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.

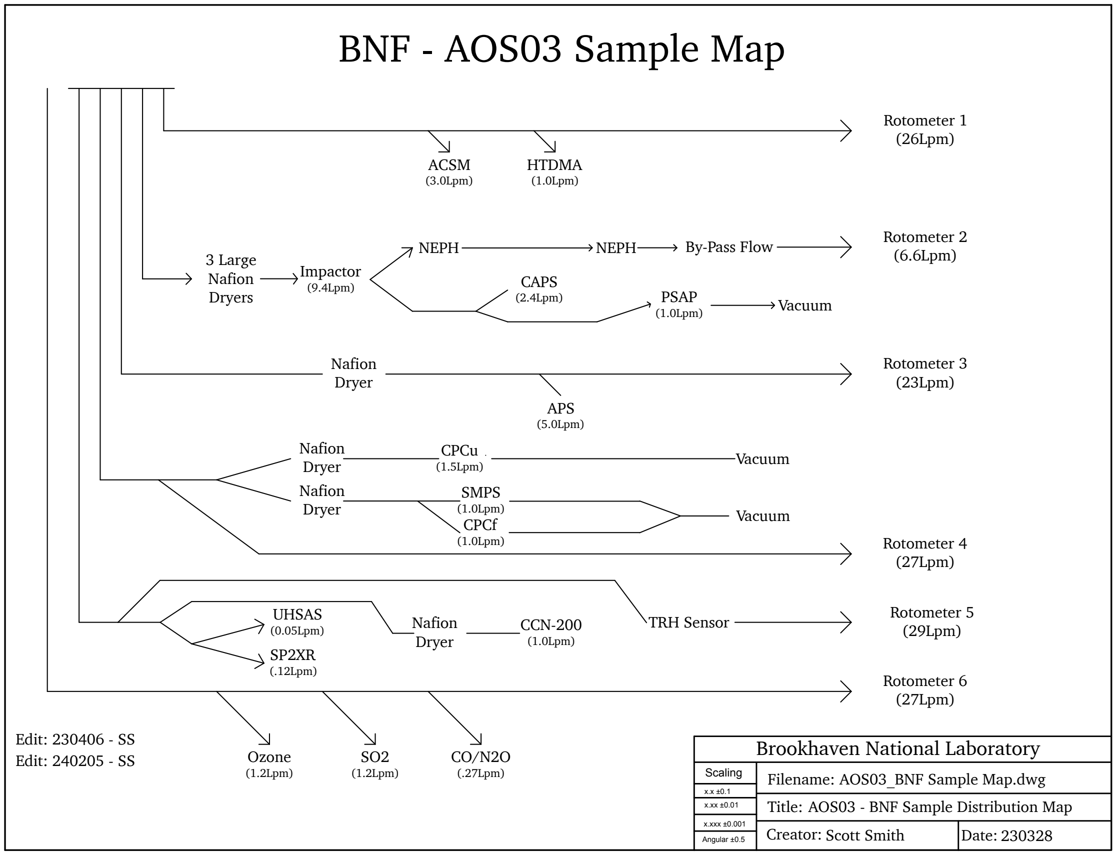


Figure 7. Diagram of the AOS3 inlet flow system.

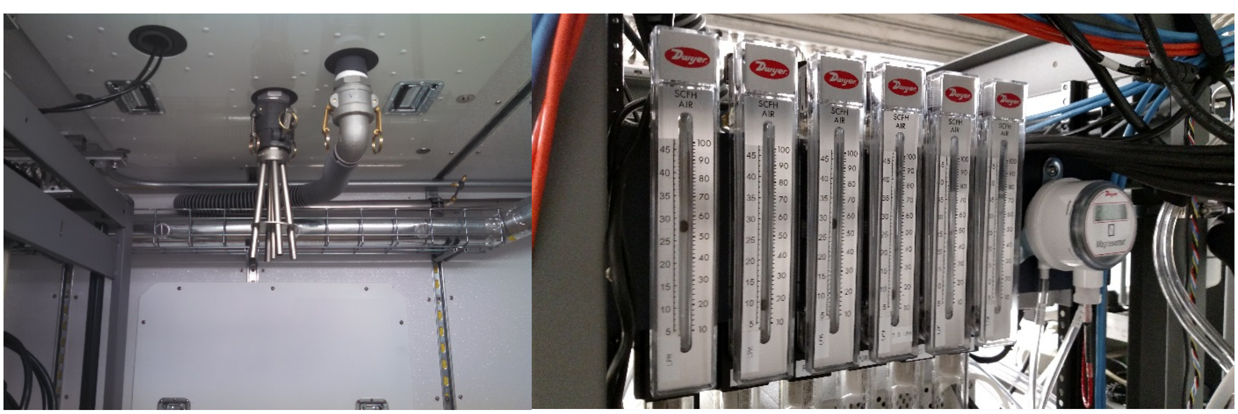


Figure 8. AOS03 flow distributor and bypass manifold.

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" (Figure 9). This is also controlled by a PID and is used to prevent the buildup of ice around the edge of the inlet.

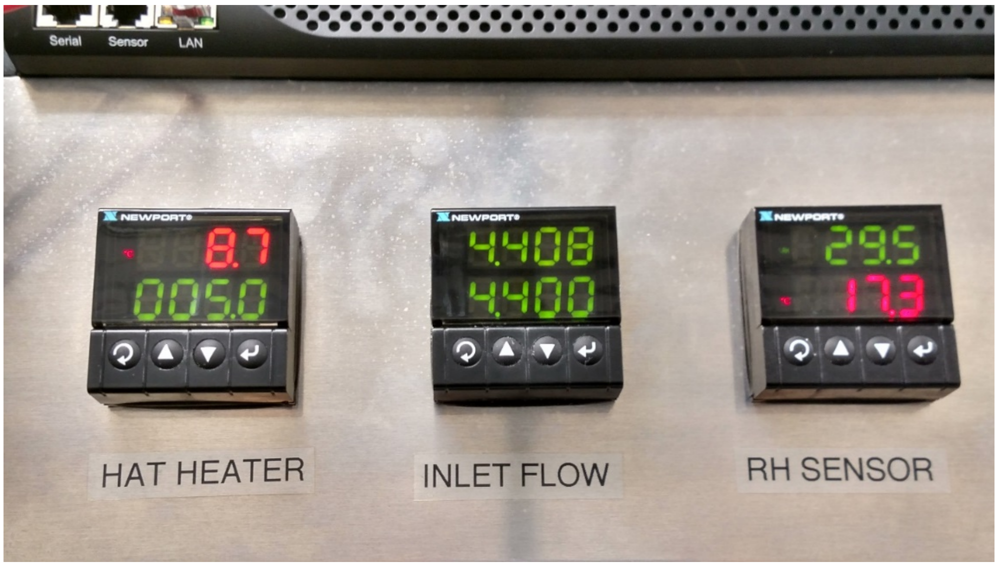
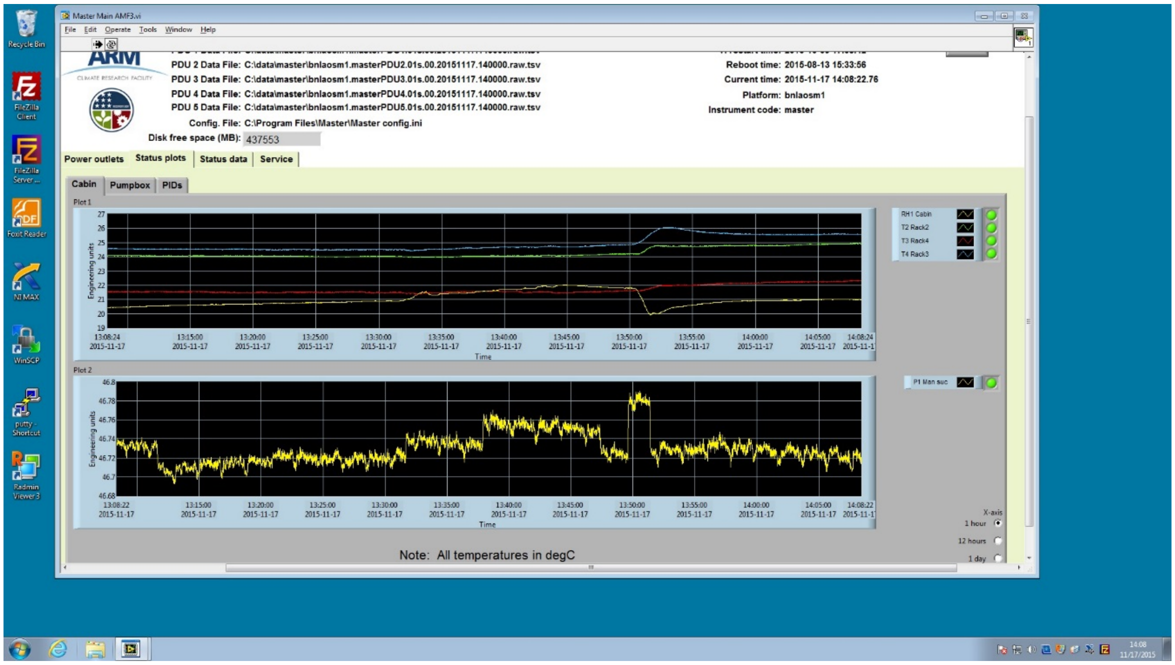


Figure 9. AOS03 monitoring console.

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.


Master Main AMF3.vi
File Edit Operate Tools Window Help
ARM
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PDU 3 Data File: C:\data\master\bnlaosm1.masterPDU3.01s.00.20151117.140000.raw.tsv
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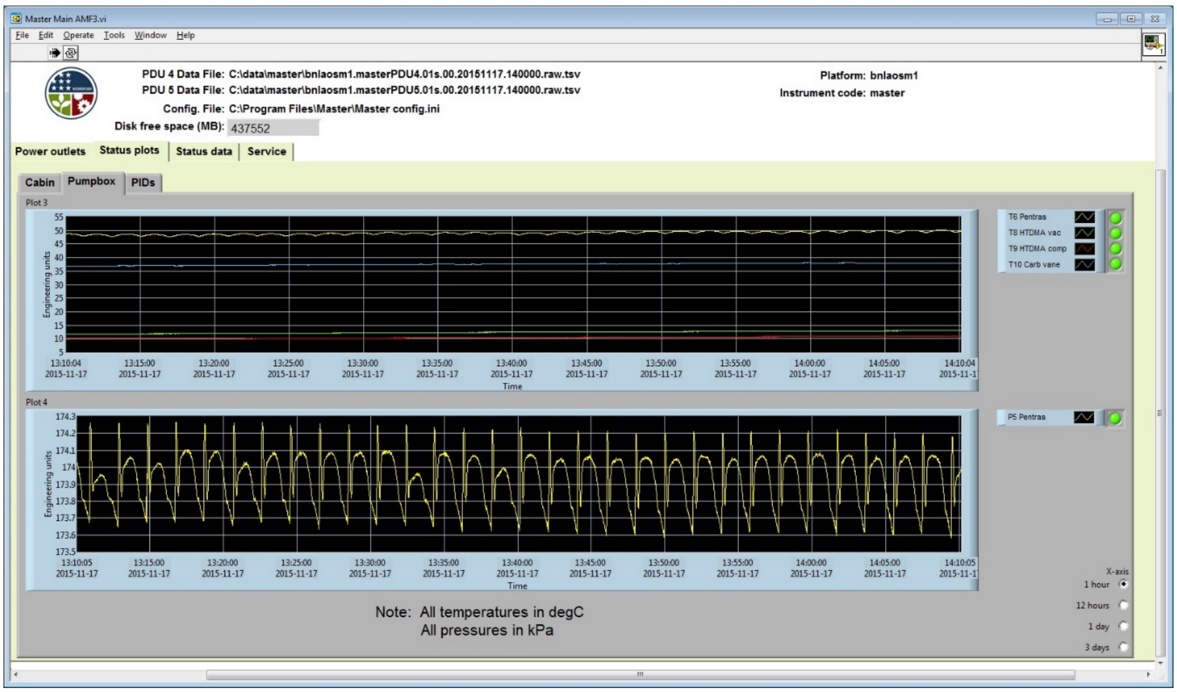
PDU 5 Data File: C:\data\master\bnlaosm1.masterPDU5.01s.00.20151117.140000.raw.tsv
Config. File: C:\Program Files\Master\Master config.ini
Disk free space (MB): 437553
Reboot time: 2015-08-13 15:33:56
Current time: 2015-11-17 14:08:22.76
Platform: bnlaosm1
Instrument code: master
Power outlets
Status 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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PDU 5 Data File: C:\data\master\bnlaosm1.masterPDU5.01s.00.20151117.140000.raw.tsv
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Disk free space (MB): 437552
Platform: bnlaosm1
Instrument code: master
Power outlets
Status plots
Status data
Service
Cabin
Pumpbox
PIDs
Plot 3
Plot 4
Engineering units
Time
T6 Pentras
T8 HTDMA vac
T9 HTDMA comp
T10 Carb vane
P5 Pentras
X-axis
1 hour
12 hours
1 day
3 days
Note: All temperatures in degC
All pressures in kPa

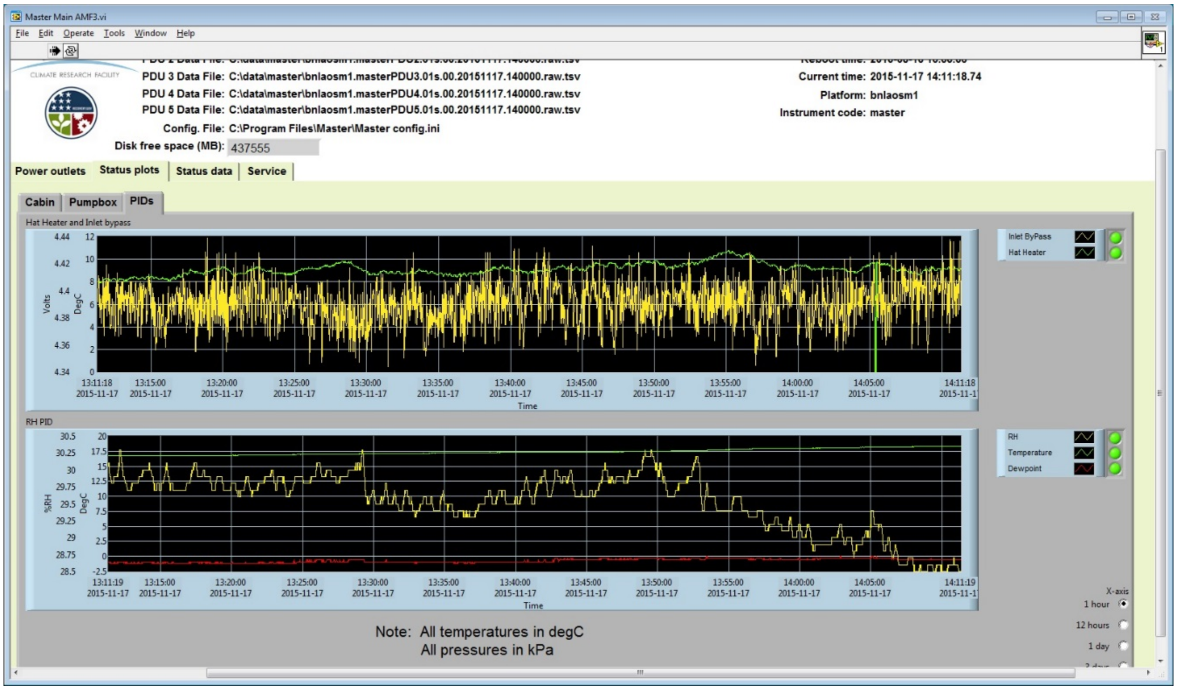

Figure 10. Three views of typical housekeeping plots for the AOS03.

Housekeeping measurements made inside the instrument shelter are:

Temperature, pressure and relative humidity are measured at about 5 feet above the floor on the front and back of each rack.

Housekeeping measurements made inside the pump box are:

Temperature ,pressure and relative humidity are measured near the top of the inside of the pump box.

Sample line measurements are temperature, pressure and relative humidity in front of these instuments:

CCN, Neph, APS, CAPS, PSAP, SP2xr, UHSAS,CPCf, CPCu, SMPS, and the HTDMA

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 AMF3 AOS is the first AOS to use the new virtual computing system. It has 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 master and the Labview VI that collects the data also runs on this computer.

6.6 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 11 and 12.

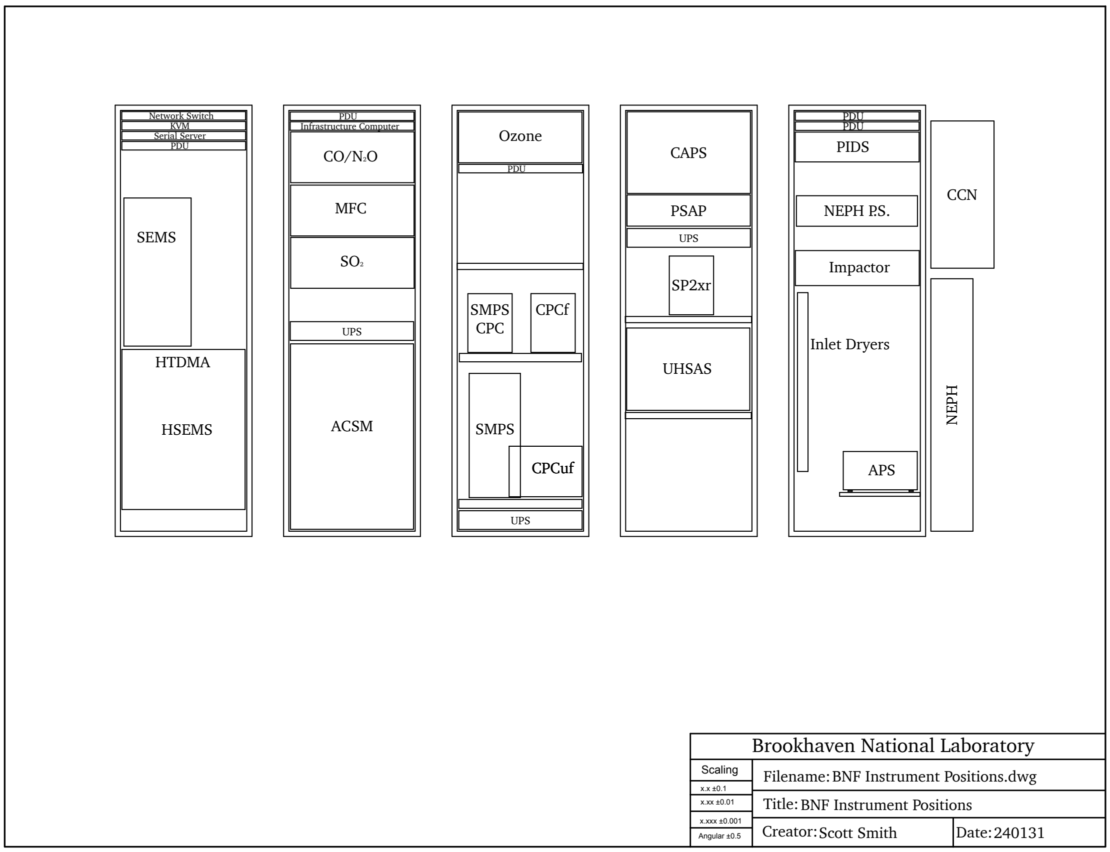

Figure 11. AMF3 AOS03 instrument layout.

Figure 12. AOS3 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. The PDUs report current draw for each outlet. 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.

BNF - AOS03 PDU Map

	Out-1	Out-2	Out-3	Out-4	Out-5	Out-6	Out-7	Out-8
PDU-1	Unused	Nephelometer	CAPS	Unused	Unused	Impactor	Hat Heater PID	Inlet Flow PID
PDU-2	DMACO	DMAVA	Pentras	ByPass Blower	Manifold Blower	Blower Box Fans	Carbon Vane Vacuum Pump	AIr Dryer
PDU-3	CO Analyzer	SO2 Analyzer	UHSAS	Infrastructure Computer	Calibration MFCs	Unused	Unused	WXT520
PDU-4	Serial Server	Unused	Unused	Unused	Unused	Unused	HTDMA Power Strip	Unused
PDU-5	PSAP	Master Nuc	Ozone Monitor	CPCf	SMPS (CPC)	SMPS Classifier	CPCu	Unused

Brookhaven National Laboratory		
Scaling	Filename: AOS03_BNF PDU Map.dwg	
x.x ±0.1 x.xx ±0.01	Title: AOS03 - BNF PDU Map	
x.xxx ±0.001 Angular ±0.5	Creator: Scott Smith	Date: 240201

Figure 13. Diagram of AOS03 power distribution network.

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 operations manual.

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 14). 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.

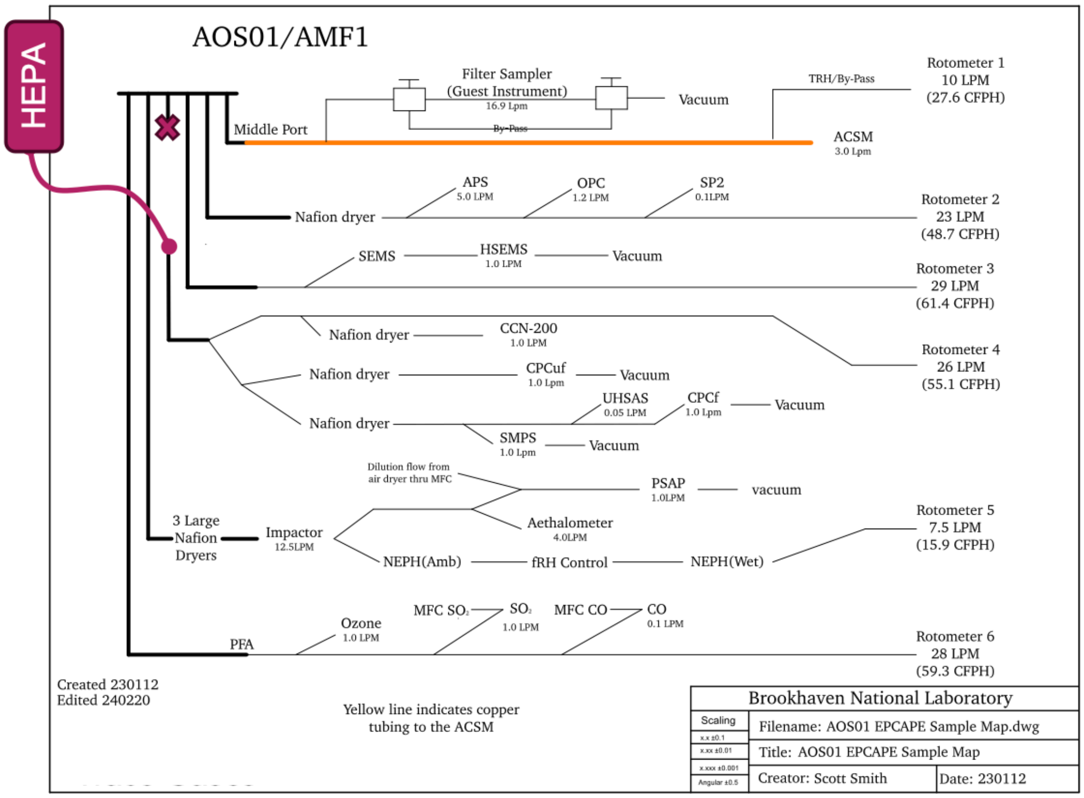

Figure 14. Sample line distribution network for AMF1 with integrity check for the microphysics line.

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 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.

10.0 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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