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First ARM Mobile Facility (AMF1) Aerosol Observing System Instrument Handbook

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ARM

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Acronyms and Abbreviations

ACSM	aerosol chemical speciation monitor (Aerodyne Research Inc.)
AOS	Aerosol Observing System
APS	Aerodynamic Particle Sizer
ARM	Atmospheric Radiation Measurement
BNL	Brookhaven National Laboratory
CAPS	cavity attenuated phase shift extinction monitor
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.)
HTDMA	humidified tandem differential mobility analyzer (Brechtel Manufacturing Inc.)
IOP	intensive operational period
LASIC	Layered Atlantic Smoke Interactions with Clouds
MAOS-A	Mobile Aerosol Observing System − Aerosols
Neph, Amb	nephelometer, ambient (TSI Inc.)
Neph, Wet	nephelometer, varied levels of RH (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
SMPS	scanning mobility particle sizer (TSI Inc.)
SP2	single-particle soot photometer (Droplet Measurement Technologies)
UHSAS	ultra-high-sensitivity aerosol spectrometer (Droplet Measurement Technologies)
UV	ultraviolet
VAC	volts alternating current
WXT520	weather transmitter (Vaisala)

Contents

Figures

1.0 Instrument Title

New Aerosol Observing System – (AOS01)

Figure 1. AOS01 was set up at Brookhaven National Laboratory prior to its first deployment at TRACER in Houston, Texas

2.0 Mentor Contact Information

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4.0 Instrument Description

The U.S. Department of Energy Atmospheric Radiation Measurement (ARM) user facility, Mobile Aerosol Observing System designated AOS01, entered service in October of 2021 at the TRACER campaign that took place in Houston, Texas. 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 floor 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.

5.0 Measurements Taken

The instruments installed in the AOS01 and the measurements made are:

1. ACSM (aerosol chemical speciation monitor): Particle mass for non-refractory aerosols
2. Aethalometer: Black carbon loading
3. Aerodynamic Particle Sizer (APS): sizes from 550nm – 20000nm
4. CCN-200 (dual-column cloud condensation nuclei particle counter): Particle concentration as a function of supersaturation
5. CPCf (condensation particle counter): sizes from 20 nm–1000 nm
6. CPCu (ultra-fine condensation particle counter): 2.5 nm–1000 nm
7. HTDMA (humidified tandem differential mobility analyzer): Particle size distribution, growth factor
8. Neph, Dry (nephelometer, dried): Light scattering
9. PSAP (particle soot absorption photometer): Aerosol light absorption
10. SMPS (scanning mobility particle sizer): Particle concentration and size distribution, 10nm – 500nm
11. SP2 (single-particle soot photometer): Black carbon mass in individual particles
12. Trace Gases: $CO/N_2O/H_20$, Ozone, SO_2

13. UHSAS (ultra-high-sensitivity aerosol spectrometer): Particle size and number concentration from 50 nm–500 nm
14. 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 AOS01 consists of the instruments listed above and 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 2). 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 2. 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 3. 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 3. 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 upper decking and also between the hinge plate and its base.

6.2 Blower Enclosure

A stainless steel blower box houses the pumps, blowers, and air drier needed for all the systems in the AOS (Figure 4).

Figure 4. Interior view of the blower enclosure.

The air drier is a 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 SCFD (standard cubic feet per day). 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 in a small rack on sliding shelves that facilitate maintenance and replacement. 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 10" fans circulate air into and out of the enclosure to prevent the equipment overheating.

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. 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 micron and smaller to pass through; in the other state, particles of size ten microns and smaller can pass. The instruments that are downstream of the impactor are selected because of the measurements they make. The nephelometers measure light scattering, PSAP measures light absorption, and the cavity attenuated phase shift extinction monitor (CAPS), a guest instrument for the LASIC campaign, 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. Figure 5 is a diagram of the inlet flow system followed by images of the flow distributor and the bypass manifold (Figure 6).

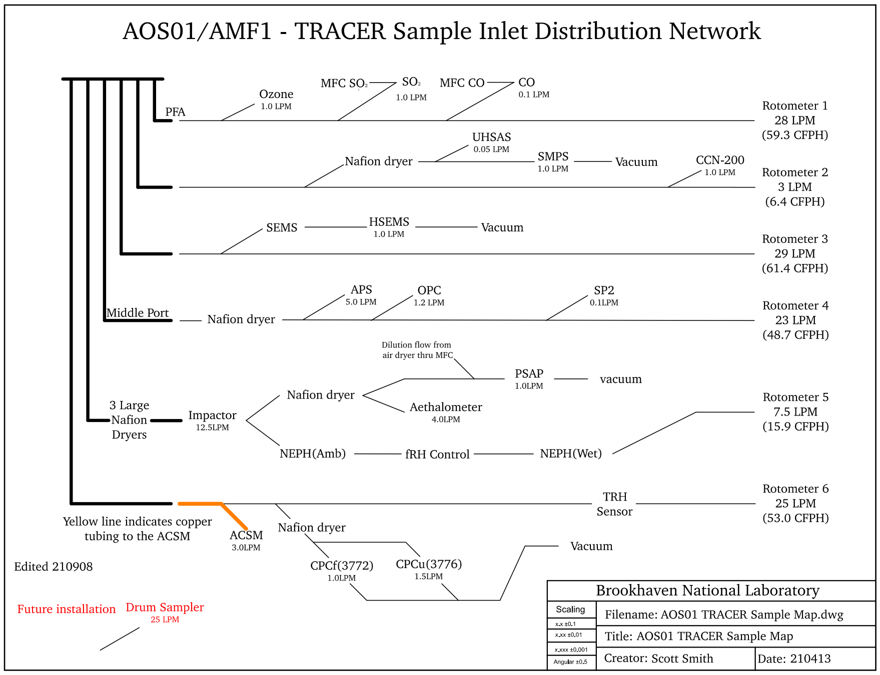

Figure 5. Diagram of the AOS01 inlet flow system.

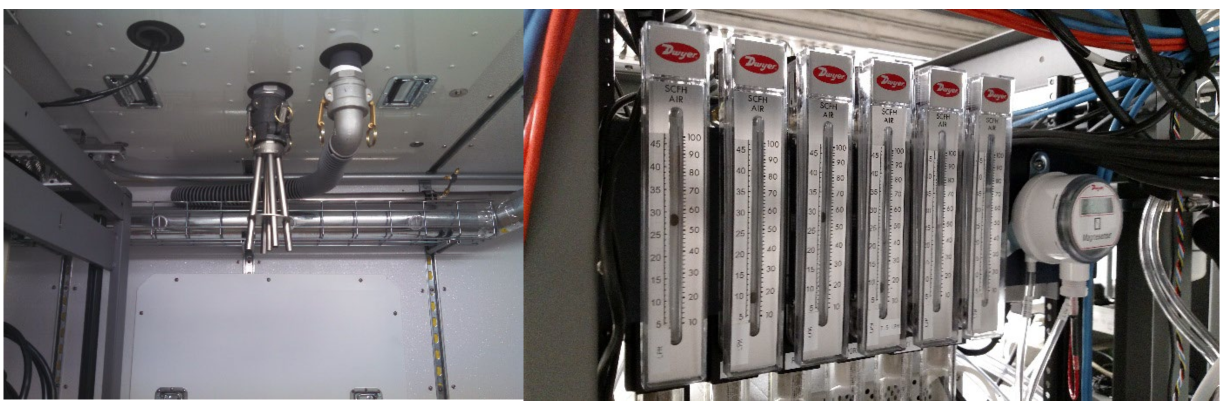

Figure 6. AOS01 flow distributor and bypass manifold.

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

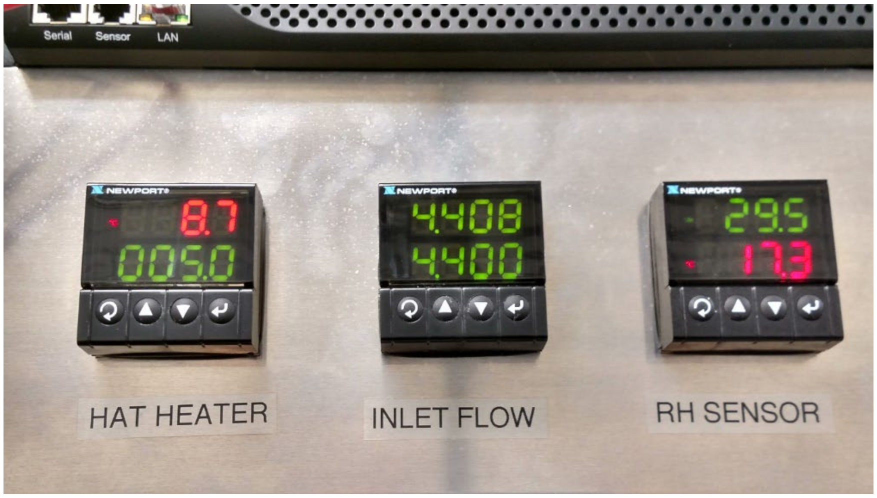

Figure 7. AOS01 monitoring console.

The AOS, as a system, is monitored using custom-made 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 Altec 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. These parameters are recorded and displayed on a virtual instrumentation display that runs on the AOS personal computer. Figure 8 shows an image of a typical housekeeping plot.

Housekeeping measurements made inside the instrument shelter are:

- Relative humidity – front and back of all 4 racks
- Temperature – front and back of all 4 racks
- Atmospheric Pressure – front and back of all 4 racks
- 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.

Instrument sample line temperature, pressure and relative humidity measurements include:

CPCf, CPCu, SMPS, PSAP, impactor drying system, aethalometer, HTDMA, SP2, APS, UHSAS, and before and after Nafion dryers.

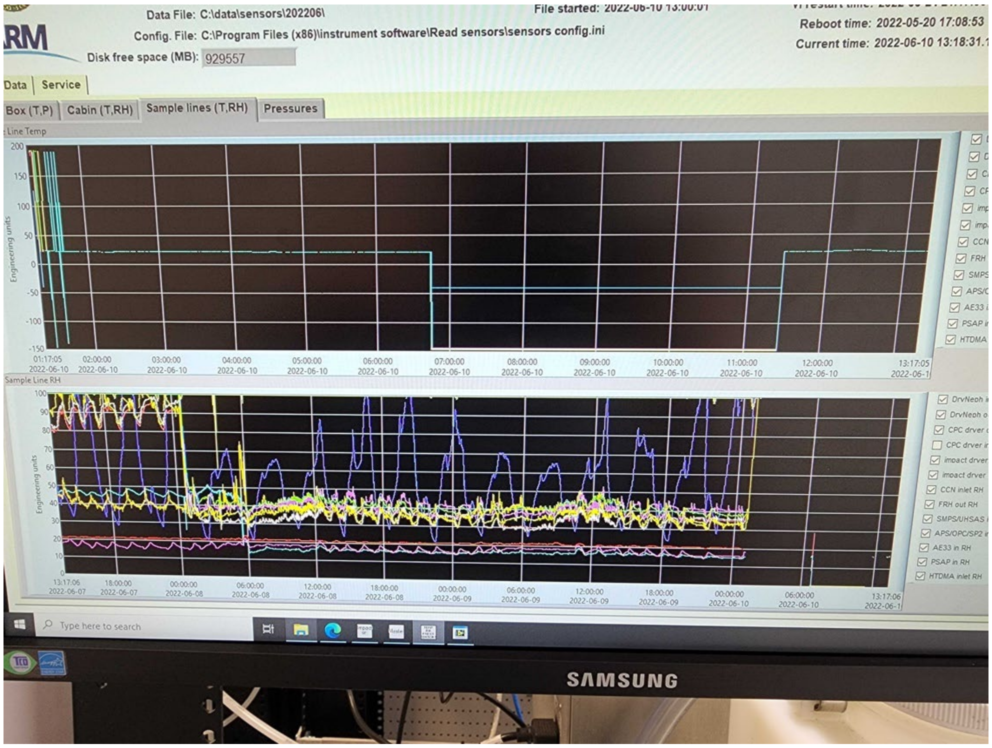

Figure 8. Three views of typical housekeeping plots for the MAOS-A.

6.5 Data Collection and Computing

The AOS01 uses one rack-mounted computer, the infrastructure computer, and 1“brick”-style computers. The “brick” computers are Intel NUC fanless computers running Microsoft Windows 10 OS. 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 "brick" computers run the main AOS infrastructure software, which collects the data from all of the housekeeping sensors. The instrument data collection software runs on virtual machines, VMs, so no physical computers are needed.

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 9 and 10.

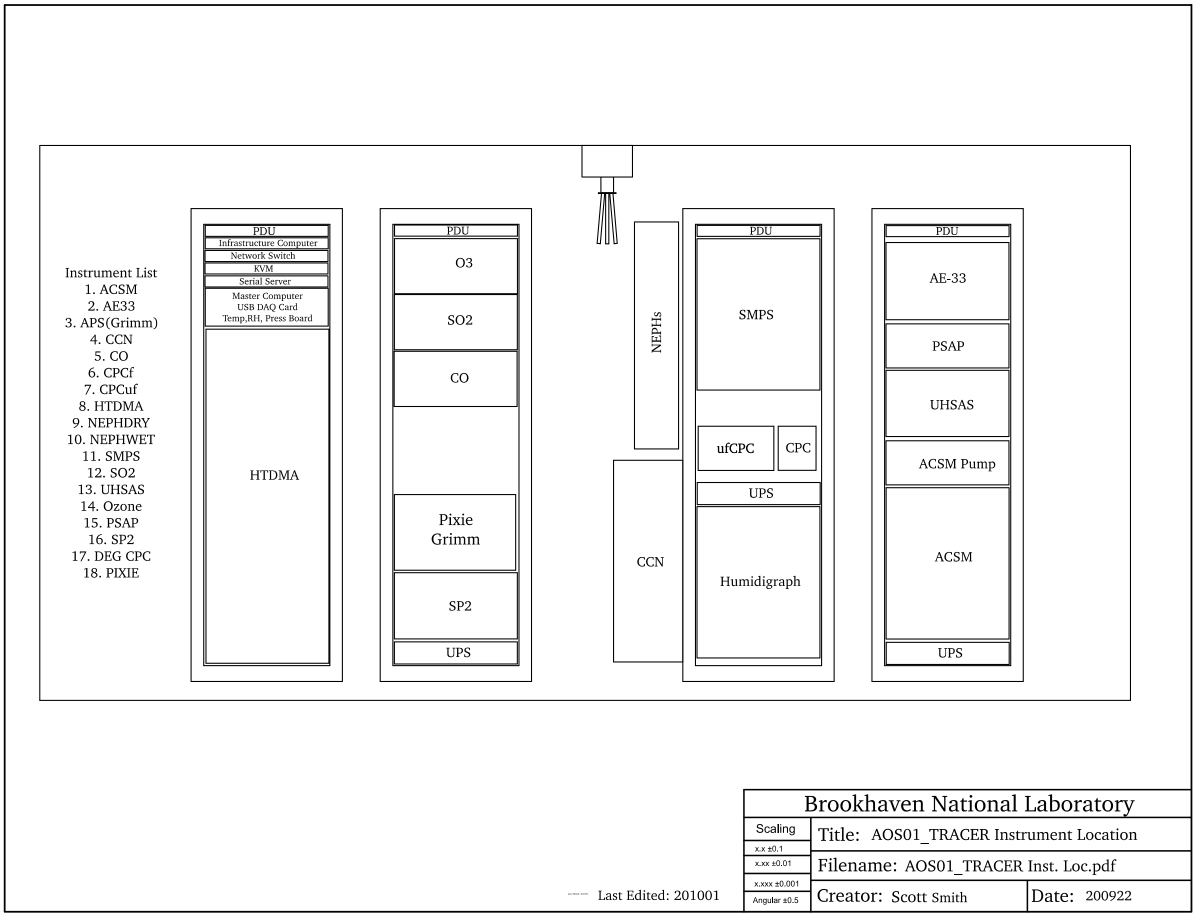

Figure 9. AOS01 instrument positions.

Figure 10. AOS01 instruments in the mounting racks.

In addition to the instrument systems, power distribution units (PDUs) are 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 11 is a diagram that maps the power distribution system in the AOS.

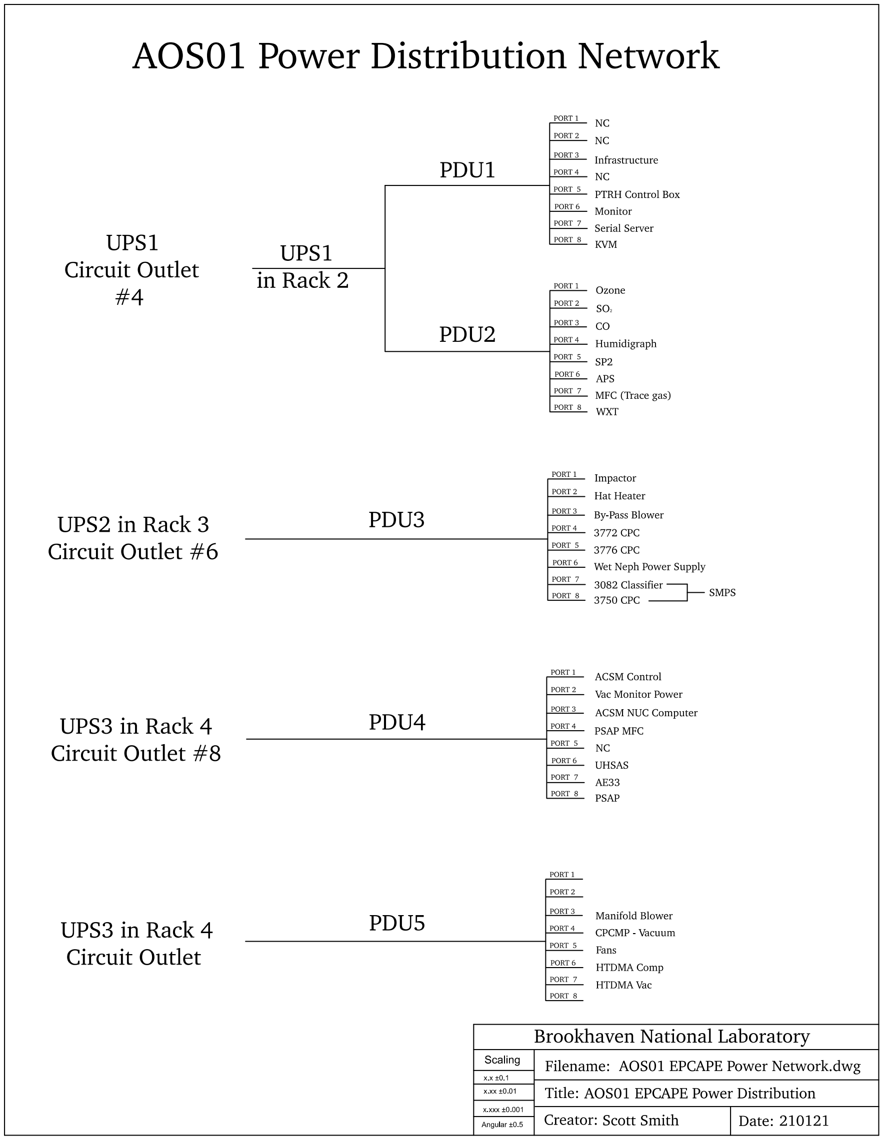

Figure 11. Diagram of AOS01 power distribution network.

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 12). 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.

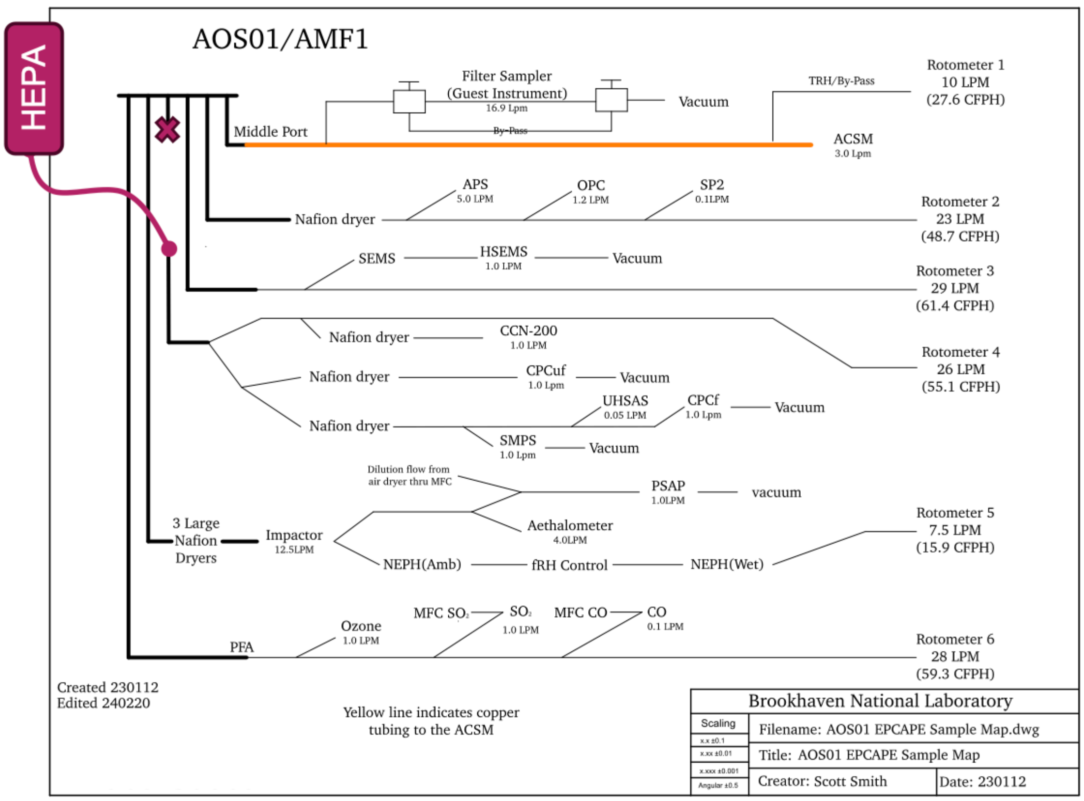

Figure 12. Sample line distribution network for AMF1 with integrity check for the microphysics line.

8.3 Future

Automate using the zero-air purge system (Figure 13) that was used during MOSAIC (fills the AOS sampling system with particle free-air).

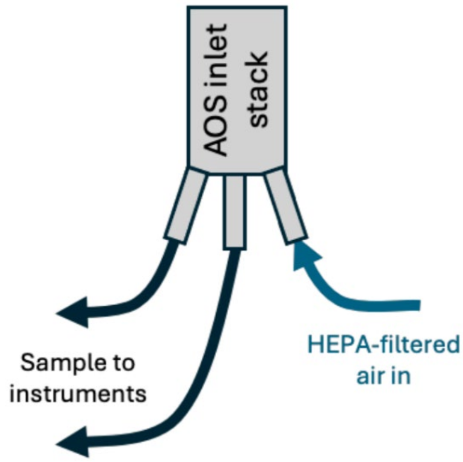

Figure 13. Zero-air purge system example.

9.0 Maintenance

Maintenance for these AOS structures are 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. 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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