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# Second ARM Mobile Facility (AMF2) Aerosol Observing System (AOS) Instrument Handbook

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April 2025

ARM

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# Acronyms and Abbreviations

| | |
|---|---|
| AMF2 | second ARM Mobile Facility |
| AOS | Aerosol Observing System |
| ARM | Atmospheric Radiation Measurement |
| BNL | Brookhaven National Laboratory |
| CCN-100 | cloud condensation nuclei particle counter (Droplet Measurement Technologies) |
| $CO/N_2O$ | carbon monoxide/nitrous oxide monitor (Los Gator Research Inc.) |
| CPC | 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.) |
| $O_3$ | ozone monitor (Thermo Scientific Inc.) |
| PDUs | power distribution units |
| PID | Proportional, Integral, Derivative |
| PSAP | particle soot absorp0tion photometer (Radiance Research) |
| RH | relative humidity |
| RTD | resistance temperature detector |
| STORMVEx | Storm Peak Laboratory Cloud Property Validation Experiment |
| UHSAS | ultra-high-sensitivity aerosol spectrometer (Droplet Measurement Technologies) |
| UV | ultraviolet |
| VI | virtual instrumentation |
| VM | virtual machine (computer) |
| WXT520 | weather transmitter (Vaisala) |

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# 1.0 Instrument Title

Second Atmospheric Radiation Measurement (ARM) Mobile Facility (AMF2) Aerosol Observing System (AOS02)

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**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 second mobile facility (AMF2) Aerosol Observing System, designated AOS02, entered service in October of 2010 at Steamboat Springs, Colorado, for the Storm Peak Laboratory Cloud Property Validation Experiment (StormVEx). The Aerosol Observing System (pictured in Figure 1) is meant to be a standalone, autonomous, aerosol sampling system. It requires only power, 208 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 1**. The AMF2 AOS deployed at Crested Butte, Colorado, during the winter of 2024

# 5.0 Measurements Taken

The instruments installed in the AMF2 and the measurements made are:

1. ACSM (aerosol chemical speciation monitor): Particle mass for non-refractory aerosols
2. CCN-100 (cloud condensation nuclei particle counter): Particle concentration as a function of supersaturation
3. $CO/N_2O/H_2O$ (carbon monoxide/nitrous oxide/water vapor monitor): Gas concentration
4. CPCf (condensation particle counter): sizes from 20 nm–1000 nm
5. CPCu (condensation particle counter): 2.5nm – 1000nm
6. APS (Aerodynamic Particle Sizer) particle concentration and size distribution 550nm – 20000nm
7. SMPS (Scanning Mobility Particle Sizer): particle concentration and size distribution 10nm – 500nm
8. HTDMA (humidified tandem differential mobility analyzer) Particle size distribution, growth factor
9. Neph, Amb (nephelometer, ambient): Three-wavelength 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 nm–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 AMF2 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 and minimize radiative heating. The inlet can be used for ship-based deployments, and other needs, with only one 10-foot section. Modified solid reinforcements as an alternative to guy wires have also been constructed and can be used when operationally required.

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 a weatherproof roof flange.

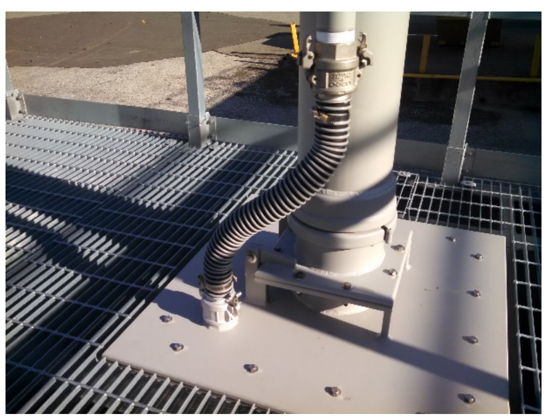


**Figure 3**. The base of the aerosol inlet, where it mates to the roof of the mobile laboratory.

The roof flange, custom-made to Brookhaven National Laboratory’s (BNL) specifications, hinges on one side to allow for lowering the stack using only two to three technicians without a crane. 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 and blowers for all the systems in the AOS. This blower box is mounted on the outside of the back wall of the AOS. Mounted next to the blower box is the Altec air drier. The air drier supplies dry air, <10%RH, to the required instruments.

There are two blowers: a main blower and a bypass blower. The main 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 4 and 5.)

**Figure 4**. The rear vestibule of the AMF2 AOS (AOS02): (left) air dryer; (right) pump enclosure; (bottom middle) power transformers.

**Figure 5**. The AMF2 AOS blower enclosure interior and exterior.

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, to 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 cabinet. 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.

On the left side on the enclosure is the connection panel. This is where the power cables and the hoses are connected to the blower enclosure. These connections make system setup and breakdown easier. The panel is clearly labeled as are 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 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, and the PSAP measures light absorption, which can be summed for light extinction. 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 AND to reduce the transit time to the instrument. 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 6 is a diagram of the inlet flow system followed by Figure 7 with images of the flow distributor and the bypass manifold.

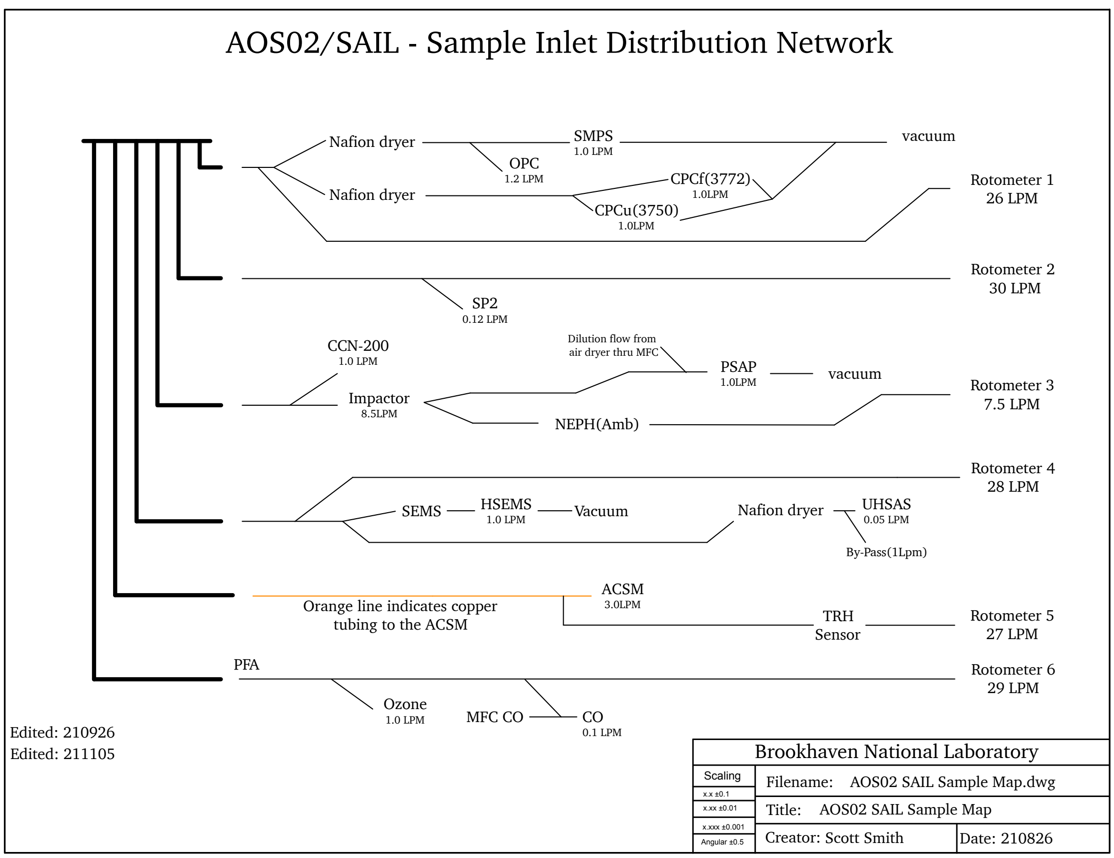



**Figure 6**. Diagram of the AOS2 inlet flow system.

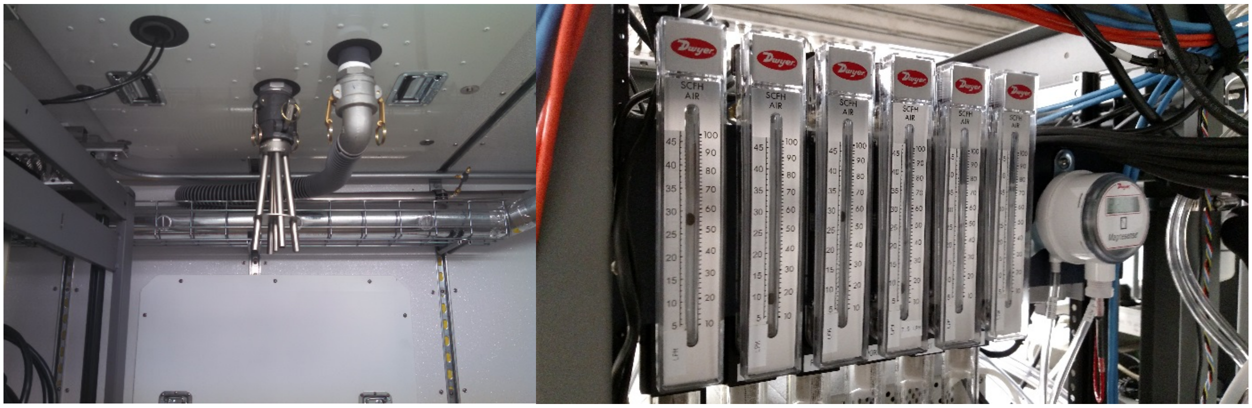



**Figure 7**. AOS02 flow distributor and bypass manifold.

## 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. No active heating of the incoming sample is done. 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 8). This is also controlled by a PID and is used to prevent the buildup of ice around the edge of the inlet.

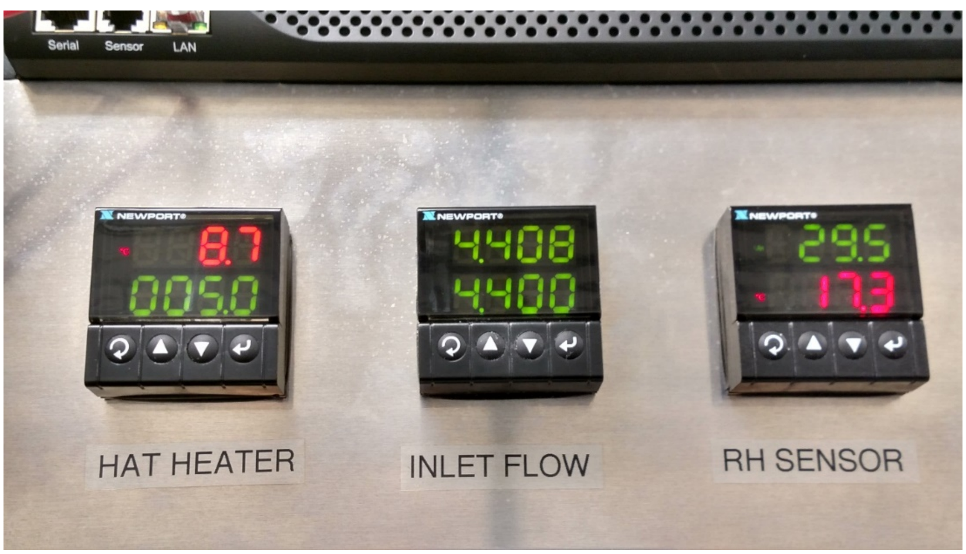
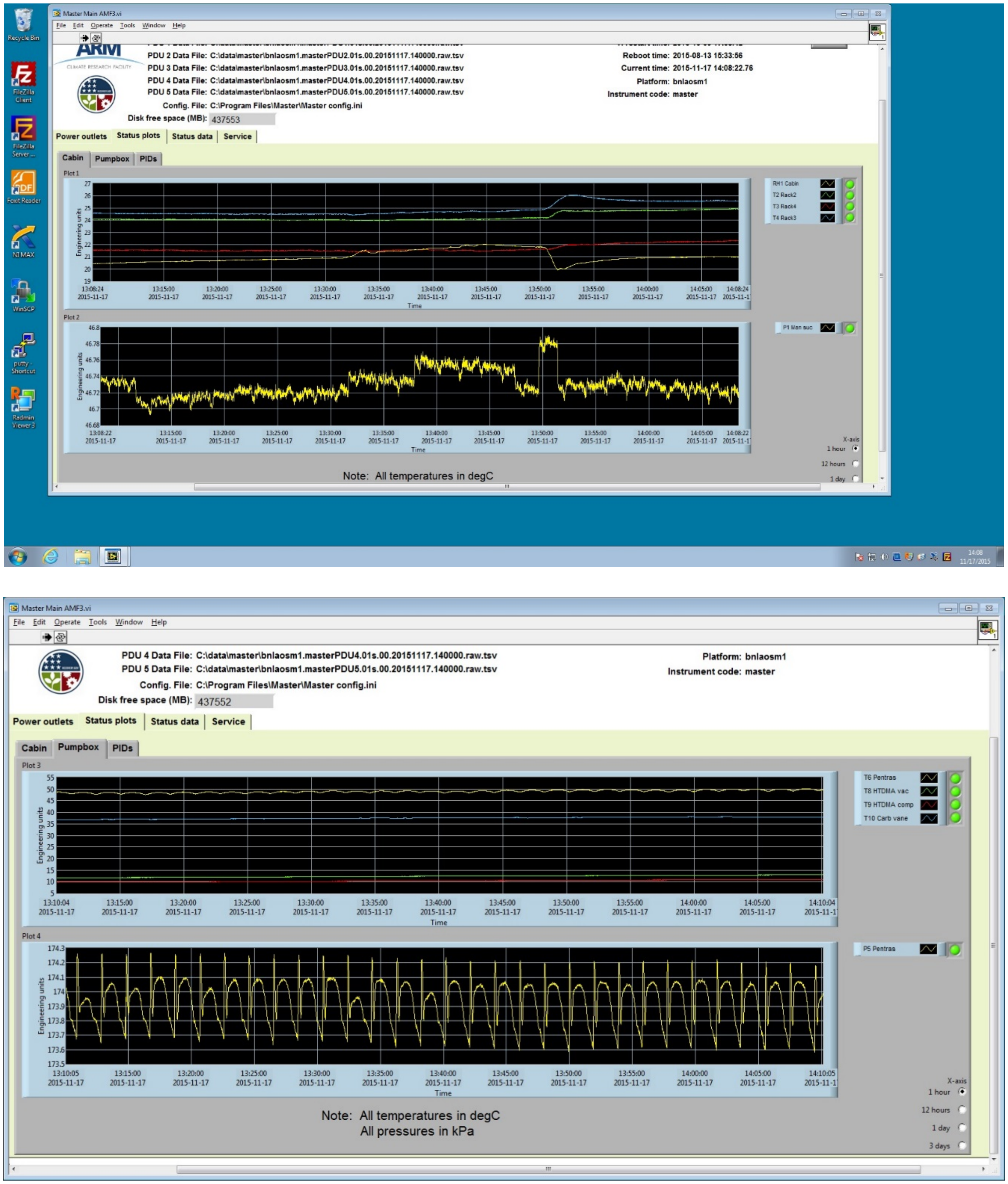



**Figure 8**. AOS02 monitoring console.

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 9 shows three images of typical housekeeping plots.



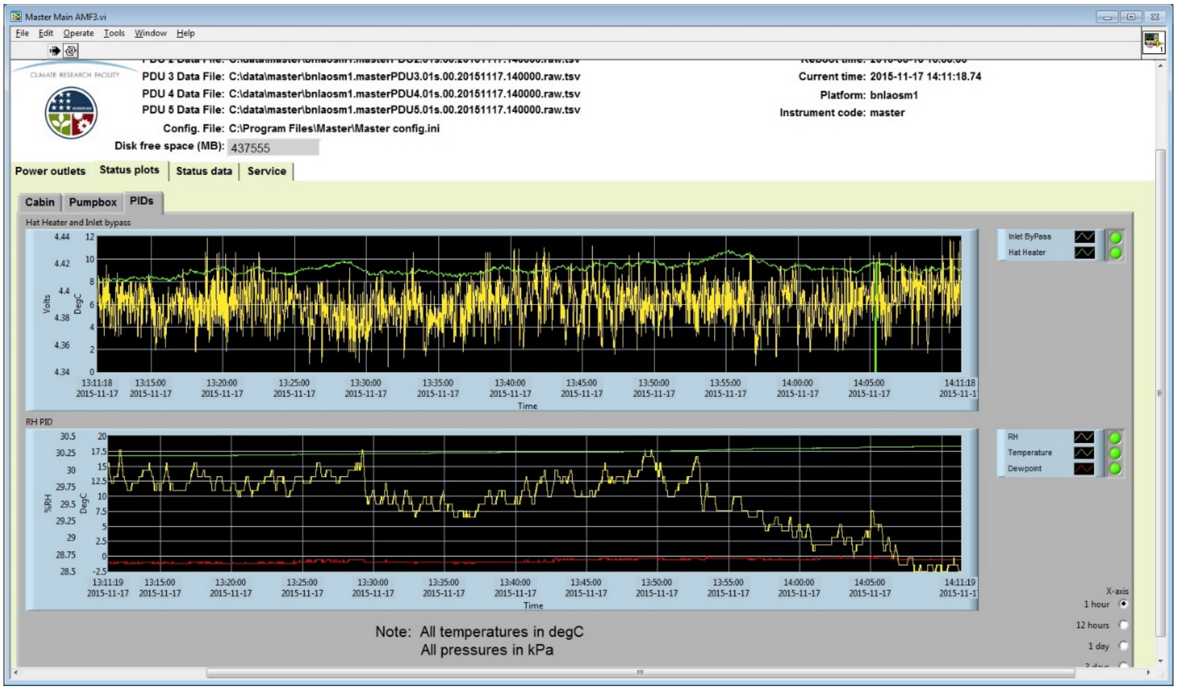



**Figure 9**. Three views of typical housekeeping plots for the AOS02.

Housekeeping measurements made inside the instrument shelter are:

- Relative humidity – back of rack
- Temperature – various positions on the racks about 2 meters from the floor
- Vacuum – incoming vacuum line pressure
- 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 AMF2 AOS uses the new virtual machine (VM) computing system starting in 2017. It also 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 VMs. 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. In tests, the VM hardware can even be located in another state if connectivity is sufficient. The software that is used to collect the data from and control the instruments runs 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. Three of these are mounted side by side in the AOS. All instruments and computing equipment are mounted in these racks, as shown in Figures 10 and 11.

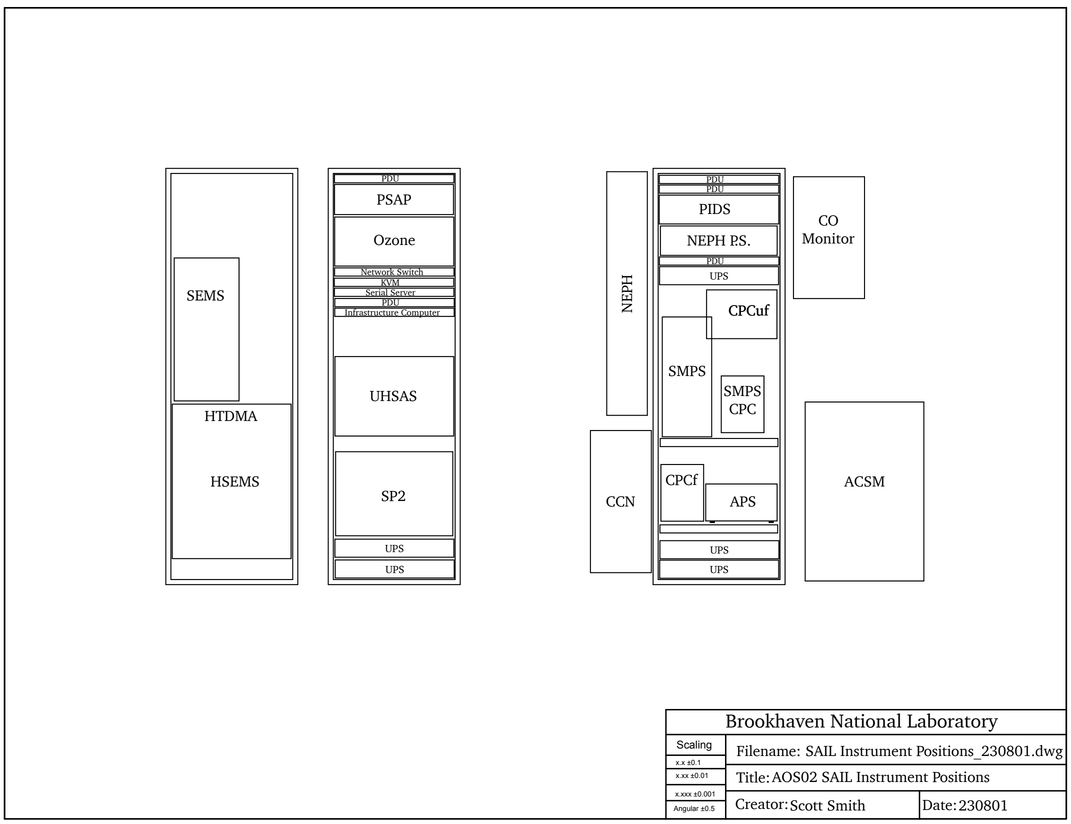



**Figure 10**. AMF2 AOS02 instrument layout.

**Figure 11**. AOS02 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 12 is a diagram that maps the power distribution system in the AOS.

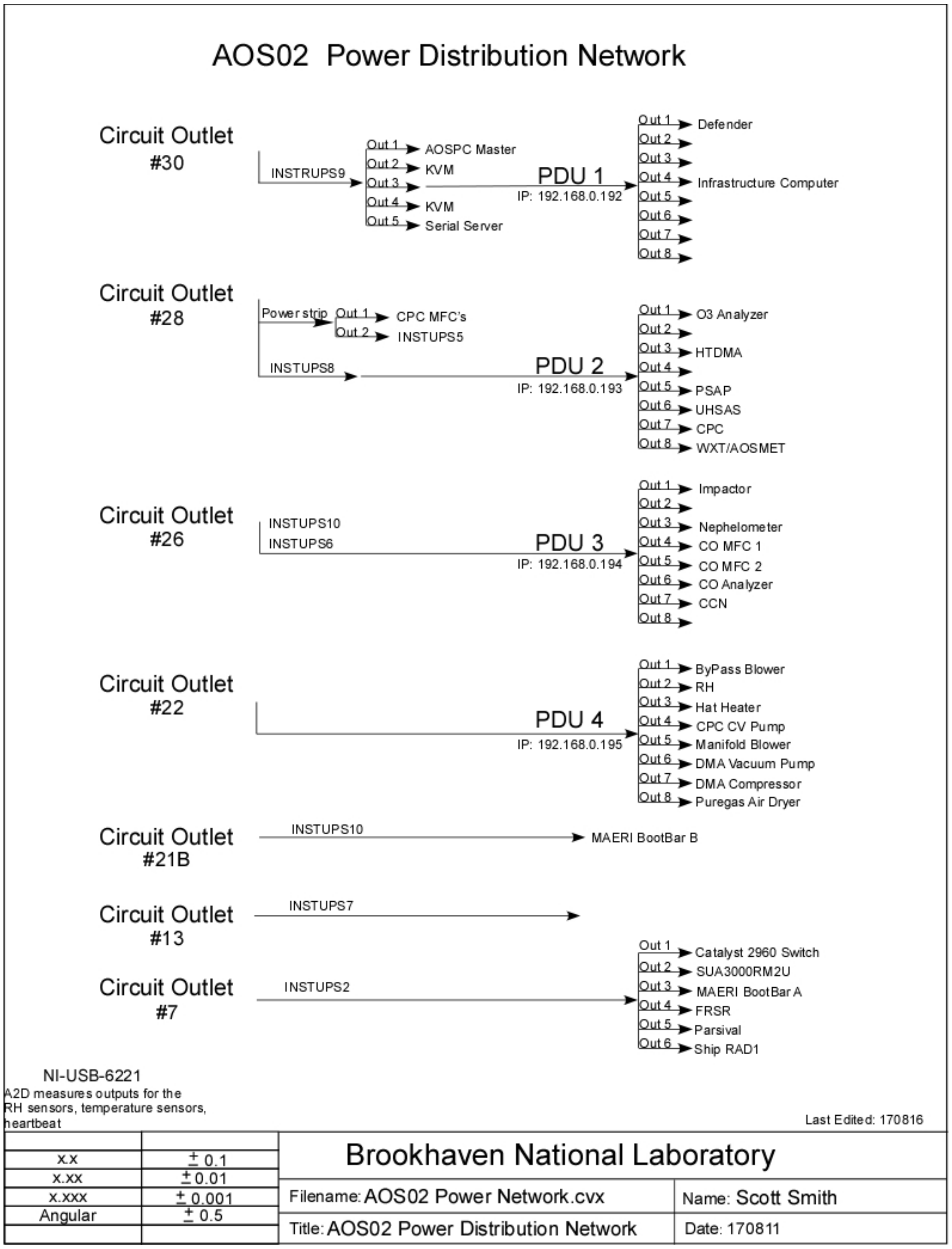



**Figure 12**. Example of AOS02 power distribution network.

# 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 13). 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.

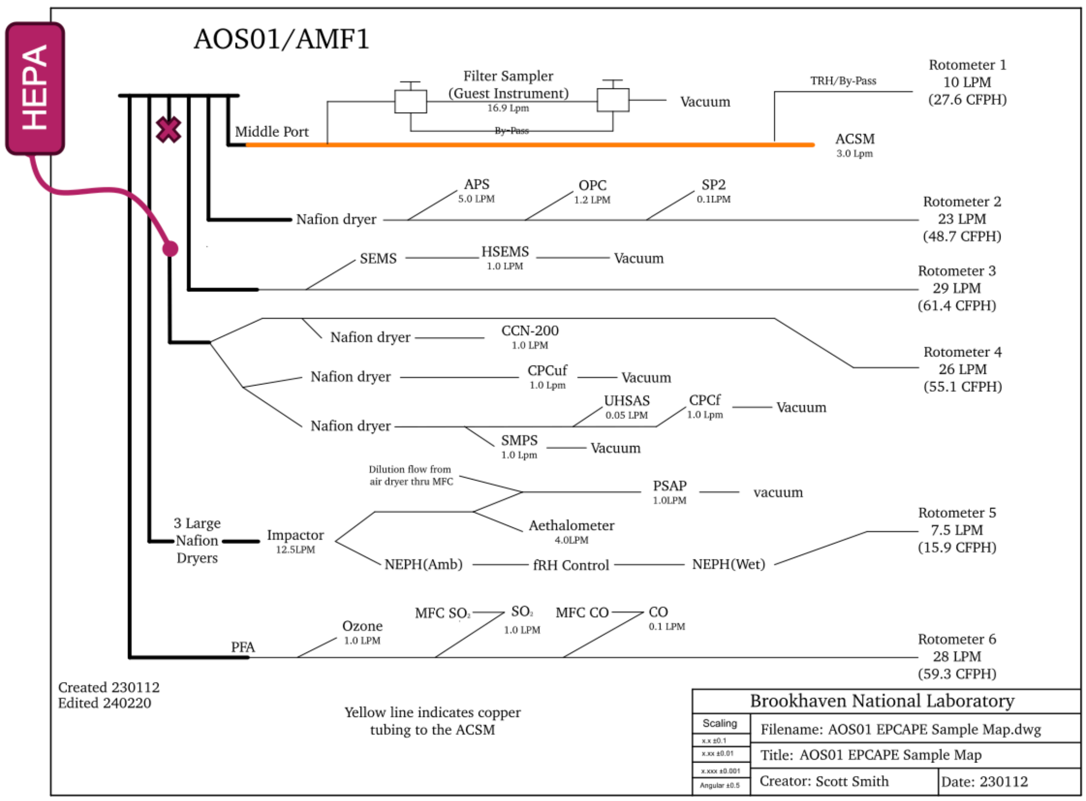



**Figure 13**. Sample line distribution network for AMF1 with integrity check for the microphysics line.

## 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. Operator and technician safety is prescribed by the operator’s home institution. Mentor safety when on site is prescribed by the mentor’s home institution. In case of conflicts, the more conservative rule must be followed.

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