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DOE/SC-ARM-TR-268

Mobile Aerosol Observing System – Chemistry (MAOS-C) Instrument Handbook

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ARM

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Acronyms and Abbreviations

AC	alternating current
AOS	Aerosol Observing System
ARM	Atmospheric Radiation Measurement
BNL	Brookhaven National Laboratory
DAB	data acquisition board
IOP	intensive operational period
IS	instrument shelter
LASIC	Layered Atlantic Smoke Interactions with Clouds
MAOS-C	Mobile Aerosol Observing System – Aerosols
OD	outside diameter
PACE	Pajarito Aerosol Coupling to Ecosystems
PDU	power distribution units
PFA	perfluoroalkoxy
PID	proportional, integral, derivative
PILS	particle into liquid sampler
PTRMS	proton transfer mass spectrometer
RH	relative humidity
RTD	resistance temperature detector
SCFD	standard cubic feet per day
UV	ultraviolet
VAC	volts alternating current
VI	virtual instrumentation
WXT520	weather transmitter (Vaisala)

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1.0 Instrument Title

Mobile Aerosol Observing System – Chemistry (MAOS-C)

Figure 1. MAOS-A (right) and MAOS-C (left) deployed on Ascension Island in the South Atlantic Ocean for the Layered Atlantic Smoke Interactions with Clouds (LASIC) campaign.

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 – chemistry (MAOS-C), designated AOS08, entered service in March of 2012 at the Los Alamos National Laboratory for the Pajarito Aerosol Coupling to Ecosystems (PACE) field campaign. 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.

Figure 2. Multiple Aerosol Observing Systems side by side during an intercomparison at BNL, summer of 2010: (left) MAOS-A; (right) MAOS-C; (left rear) AOS06.

5.0 Measurements Taken

The instruments installed in the MAOS-C and the measurements made are:

1. $CO/N_2O/H_2O$ (carbon monoxide/nitrous oxide/water vapor monitor): Gas concentration
2. $NO/NO_2/NO_y$ (nitrogen oxides monitor): Gas concentration
3. O_3 (ozone monitor): Gas concentration
4. PTRMS (proton transfer mass spectrometer): Concentration of gas-phase organic compounds
5. SO_2 (sulfur dioxide monitor): Gas concentration.

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 MAOS-C 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.

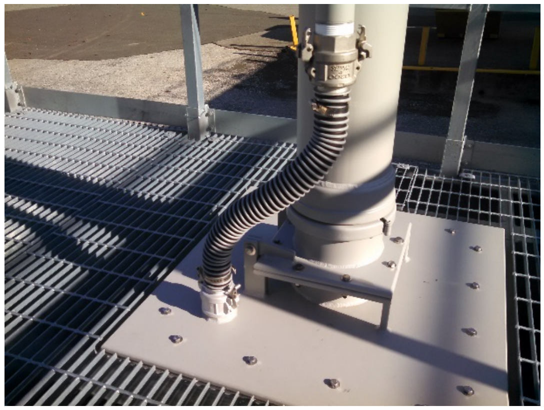

Figure 4. The base of the aerosol inlet, where it mates to the roof of the mobile laboratory.

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 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 needed for all the systems in the AOS.

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 are located in the blower box. These are special Teflon-coated diaphragm pumps for the oxides of nitrogen detector. A carbon vane pump was installed for the original particle into liquid sampler (PILS) instrument, but this is no longer used. To monitor heat in the enclosure, temperature sensors are mounted on each of the pumps as well as near the top of the enclosure. 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.

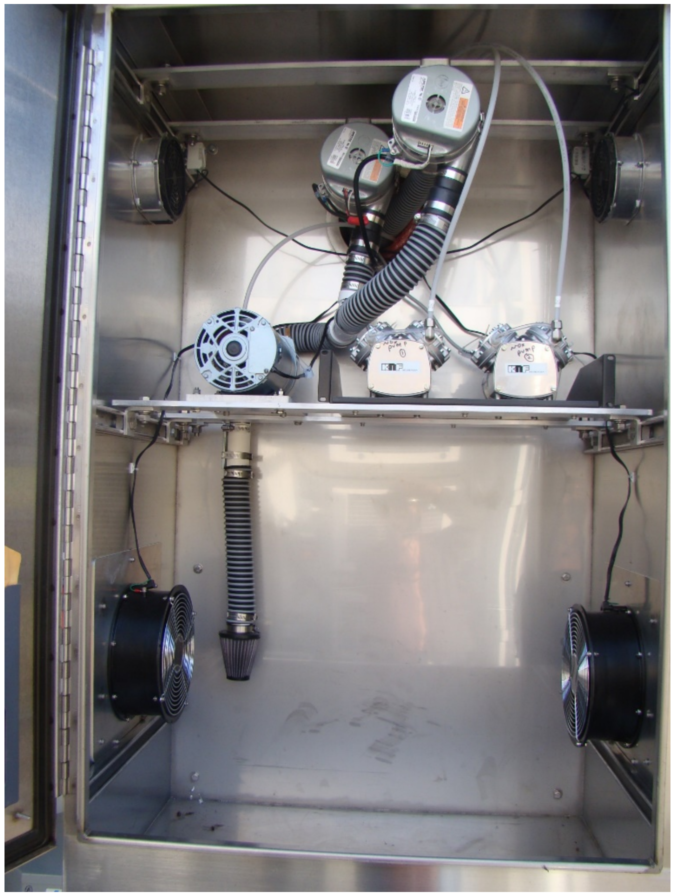

Figure 5. Interior of the blower enclosure showing the blowers and vacuum pumps.

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 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. The image below is a diagram of the inlet flow system followed by images of the flow distributor and the bypass manifold. As presently configured, MAOS-C instruments sample from the ½” OD perfluoroalkoxy (PFA) inlet. The oxides of nitrogen instrument has its own separate inlet with a temperature-controlled converter box 10 m above ground level.

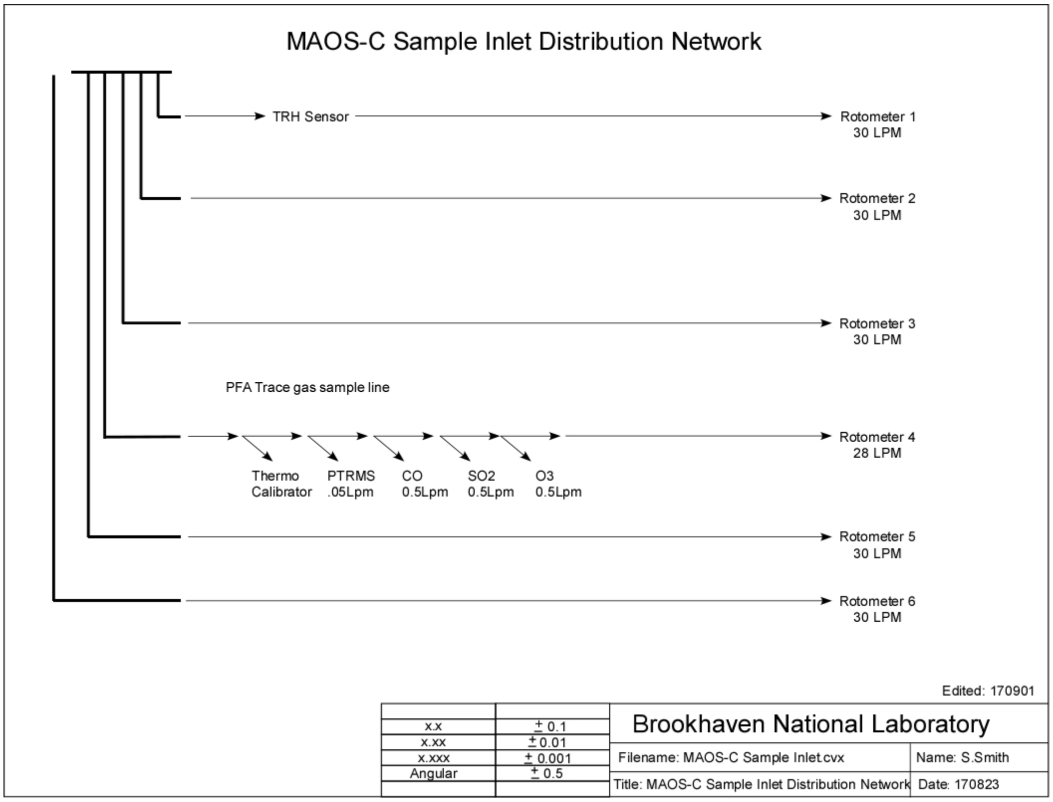

Figure 6. Diagram of the MAOS-C inlet flow system.

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

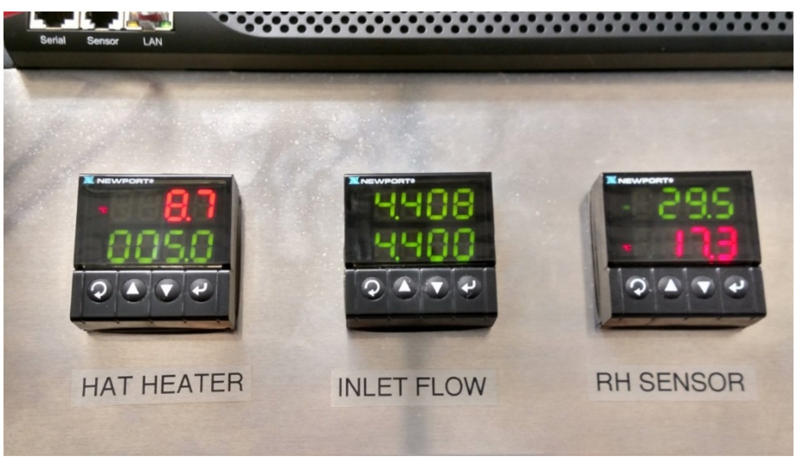

Figure 7. MAOS-C monitoring console.

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. 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.

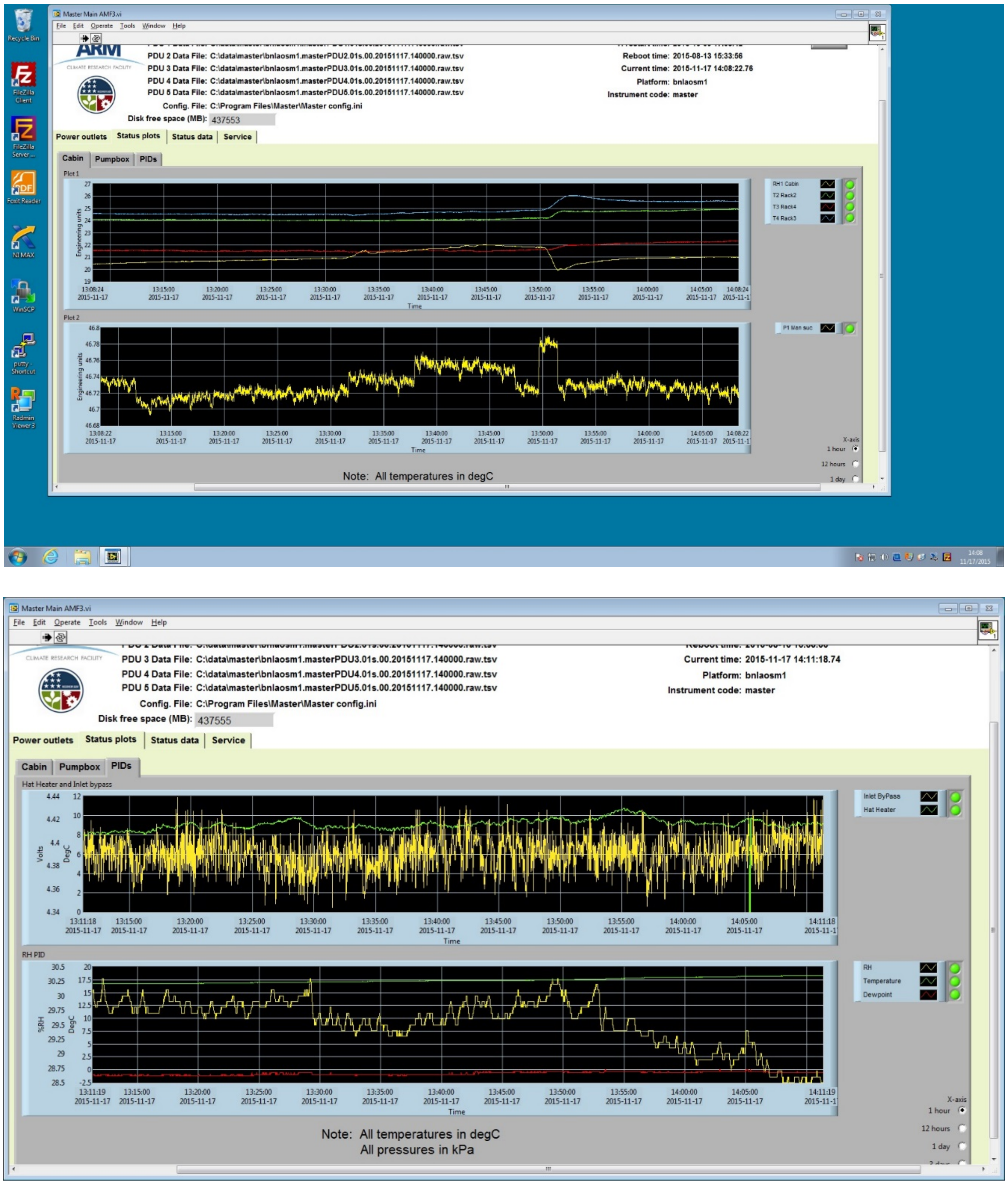

Figure 8. Three views of typical housekeeping plots for the MAOS-C.

Housekeeping measurements made in side of 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.

PID measurements include:

Temperature – hat RTD, controls hat heater
Inlet air flow – by-pass 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 MAOS-C uses one rack-mounted computer, the infrastructure computer, and two “brick”-style computers. The “brick” computers are Ampro Adlink fanless computers running Microsoft 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 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. 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 10 and 11.

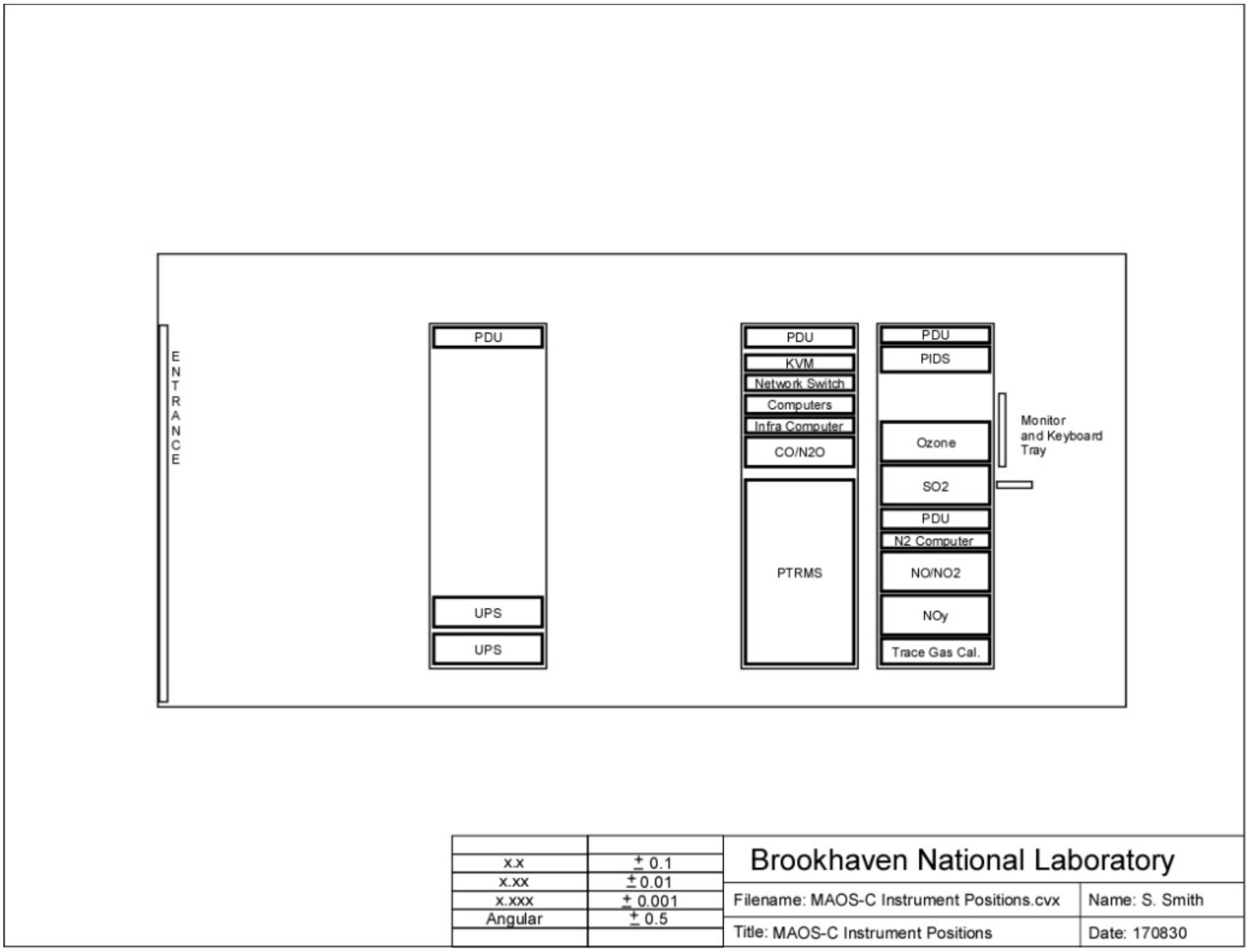

Figure 9. MAOS-C instrument positions.

Figure 10. MAOS-C 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.

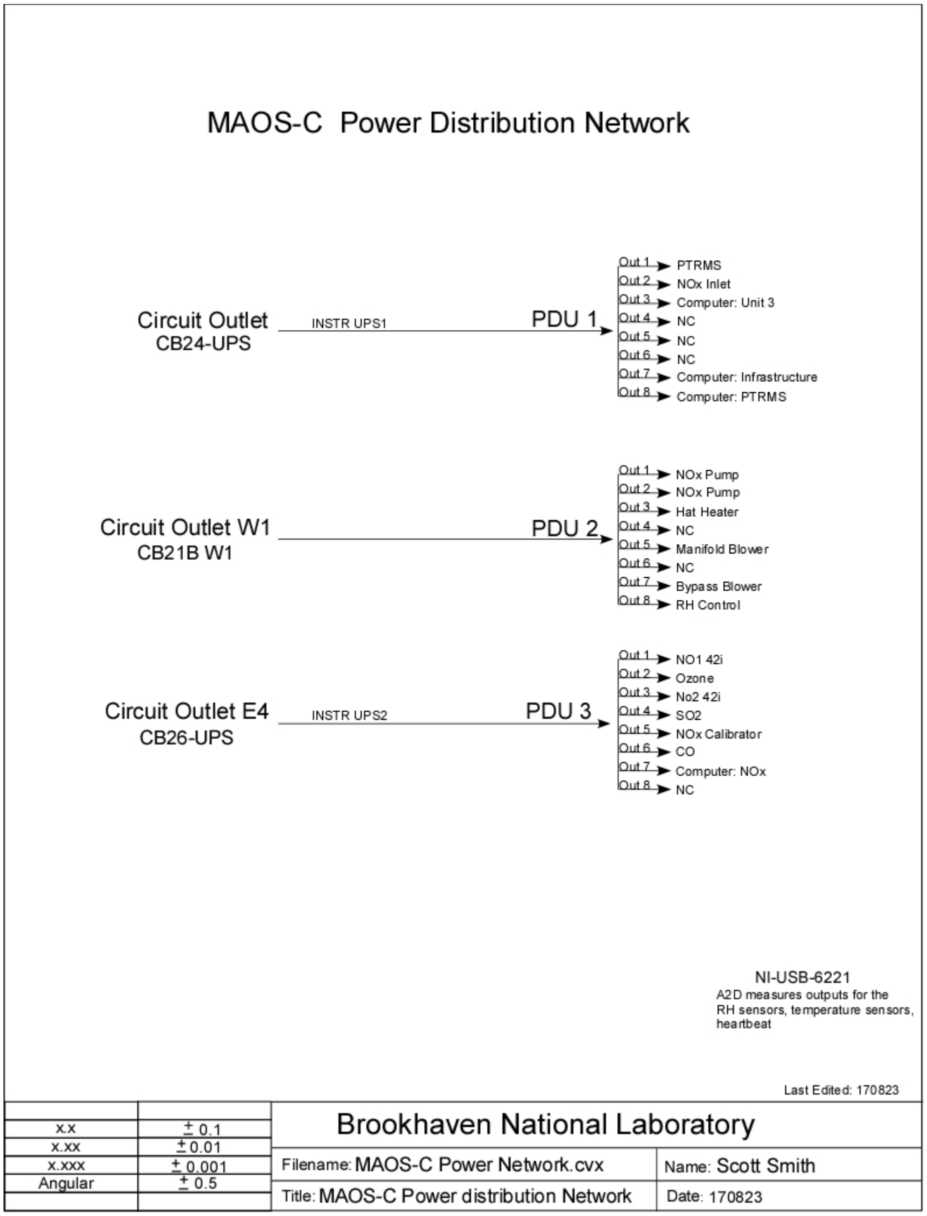

Figure 11. Diagram of MAOS-C power distribution network.

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 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. 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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