1 Basic Operation

1.1 Fluid Connections

Fluid ports on the front and the rear of the AD60 are the end points of 2 internal flow paths shown in Figure 1.

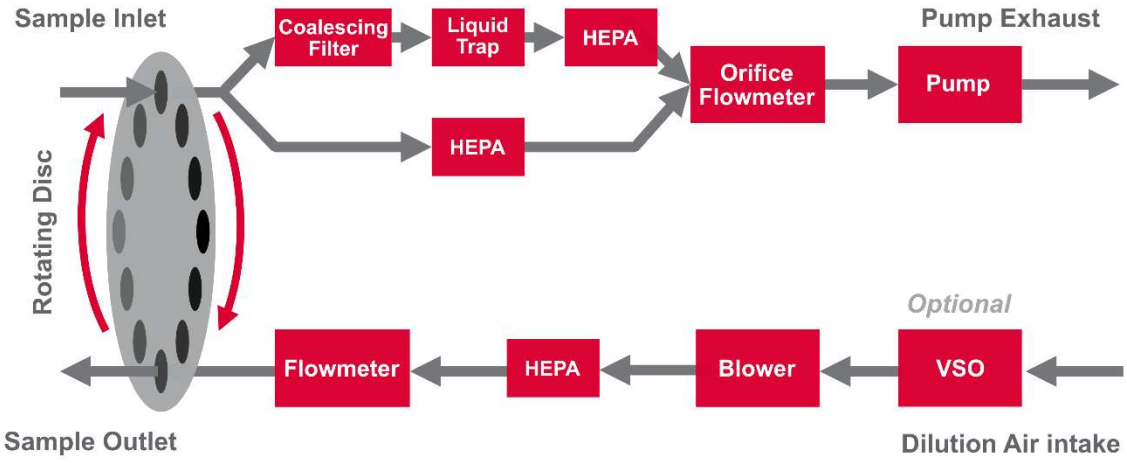

Figure 1 AD60 Fluid Schematic

1.1.1 Pump Exhaust port

The exhaust of the AD60 contains the carrier gas of the sample being diluted. If the aerosol contains potentially hazardous gases, it must be connected to an extract by pushing a well fitting tube over the barb on the rear panel. Tubes with internal diameter between 10 and 12 mm are recommended. The exhaust must not be connected to a vacuum.

1.1.2 Dilution air intake port

AD60 operates by transporting a portion of the sample inlet flow into a particle free gas flow, which becomes the sample outlet flow. This particle free gas flow consists of the gas supplied at the dilution air intake port, which passes through an internal HEPA filter. If nothing is connected to the dilution air intake port, carrier gas of the sample outlet flow is the ambient air.

To use a different carrier gas for the diluted aerosol, it must be supplied to the dilution intake port at near **ambient pressure, 0 – 50 mb gauge,** by pushing a well fitting tube over the barb on the rear panel. Tubes with internal diameter between 10 and 12 mm are recommended.

1.1.3 Sample Inlet

The sample inlet (high concentration) connection is the left tube on the front of the diluter. Electrically conductive sample tubing is recommended to avoid electrophoretic particle losses. Suitable electrically conductive silicone tubing is available from Cambustion. Push the tube over the sample inlet tube, which has outer diameter of 6.35 mm (1/4 inch).

AD60 can either passively measure the sample inlet flow that is being blown into it by an external aerosol source or actively control it via the integrated pump. In controlled mode inlet flow rate is user adjustable between 1 and 3 slpm (as measured by AD60), see section 2.1.2 for definition of slpm.

While the sample inlet flow is actively controlled and the sample inlet flow is blocked, restricted (for example, by a tube or device upstream of the diluter) or too overpressurised, the error “Setpoints not achievable” appears. To allow the diluter to achieve the user input setpoint, reduce the restriction or stop the excessive overpressure.

1.1.4 Sample Outlet

The sample outlet connection is the right tube on the front of the diluter. Electrically conductive sample tubing is recommended to avoid electrophoretic particle losses. Suitable electrically conductive silicone tubing is available from Cambustion. Push the tube over the sample inlet tube, which has outer diameter of 6.35 mm (1/4 inch).

AD60 can either passively measure the outlet flow that is being sucked through it or actively control it via the integrated blower. The outlet flow rate is user adjustable between 1 and 15 slpm (as measured by the diluter).

While the out flow is actively controlled and the sample outlet flow is blocked, restricted (for example, by a tube or device downstream of the diluter), or too underpressurised, the error “Setpoint not achievable” appears. To allow the diluter to achieve the user input setpoint, reduce the restriction or stop the excessive underpressure.

1.2 Turning On

Connect the supplied mains cable to the AC power inlet on the rear panel of the diluter and to the mains supply. After this change the power switch on the rear panel to the *on* position. This will cause the diluter to turn on and you will be presented with the main screen, as shown below:

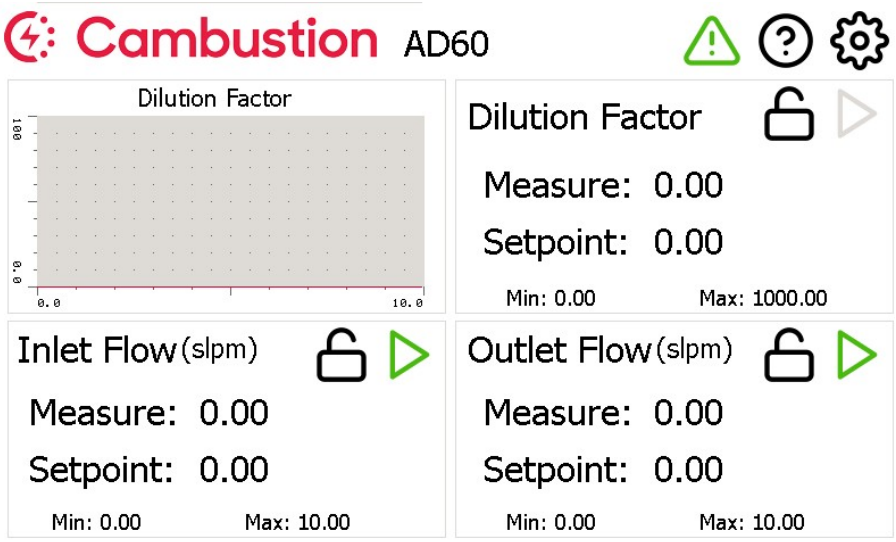

Figure 2 Main Screen

Input the desired inlet flow, outlet flow and dilution factor by tapping on the associated setpoint value. This will bring up an input screen. Confirm your selection by pressing ✓, which will return to the main screen and cause the variable to become locked, indicated by 🔒. A variable can also be toggled between locked and unlocked by pressing 🔓 and 🔒, respectively. For more information regarding locked variables see section 2.2.3

To turn on the respective variable tap the *on* button ▷. Dilution factor can only be turned on if at least two of three variables are locked. To turn off a variable tap the *off* button ☐.

When turned on inlet and outlet flows are actively controlled to the user setpoints, but if they are turned off AD60 measures the flows and uses that information to achieve the desired dilution factor. This means inlet flow can be blown into and outlet flow sucked through the AD60 without being controlled by it.

The order of operations can matter. This is because the allowed dilution factors are based on the measured values of the inlet and outlet flows. Consequently, the flows should be turned on, or blown into/sucked through, before adjusting the dilution factor setpoint.

1.3 Achievable Dilution Factors

The range of possible dilution factors depends on the flowrates, rotational speed, geometry of the disc and the ambient conditions, for more details see Appendix **Error! Reference source not found.**.

Figure 3 shows an approximate operating map for air at ambient conditions, which can be used to estimate the operating range. AD60 displays the exact limits in the variable fields as the minimum and maximum values achievable at current conditions. For a larger format graph see Appendix **Error! Reference source not found.**.

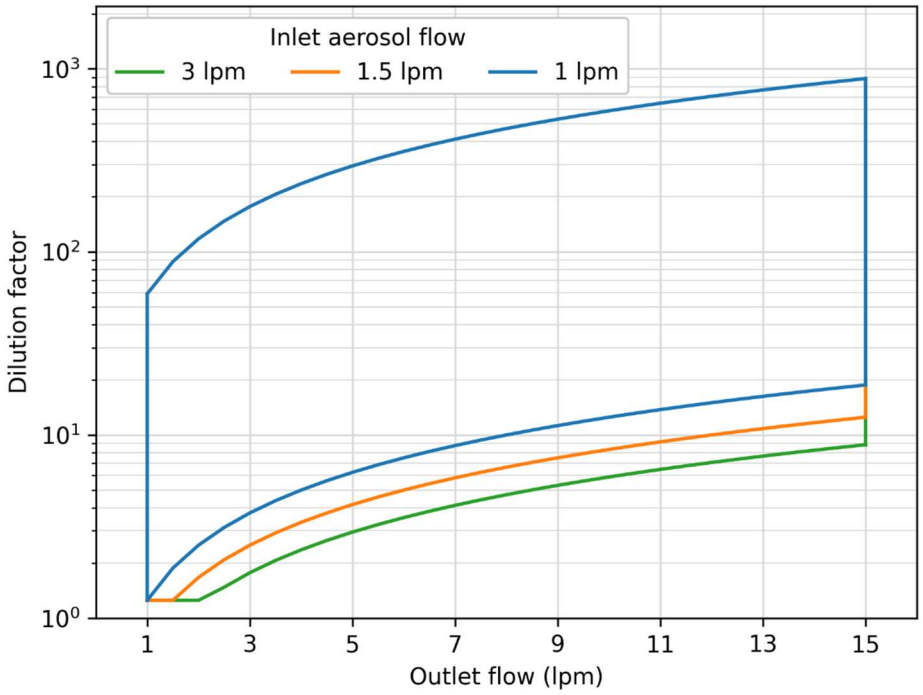

Figure 3 Achievable dilution factors

1.4 Exporting a log

The diluter records an ongoing 'black box' log at ~1Hz, this frequency can be changed with a command (see Appendix **Error! Reference source not found.** in Full Manual), but returns to ~1Hz on startup.

1.5 Shutting Down

Change the power switch on the rear panel to the *off* position to shut down the instrument. All settings will be saved, except for on/off statuses, which will be set to off on startup. However, please wait 2 seconds after changing any setting before turning AD60 off to allow them to be saved.

If settings are changed or data inputted at the moment of shut down, they might not get saved. Similarly, log entry might not get saved at the moment of shut down. Please take that into account when operating the AD60.

2 User Interface

2.1 Conventions

2.1.1 Temperature and Pressure

Quantity	Temperature	Pressure
Unit	Degrees Celsius / °C	Pascals / Pa

Standard conditions are user adjustable – see section 2.3.2.

2.1.2 Standard flow (slpm)

Either inlet or outlet sample flow at the selected reference standard conditions (temperature, pressure). In standard litres per minute.

By default reference standard conditions are 20 °C at 101325 Pa.

2.1.3 Dilution Factor

The dilution factor achieved by the diluter. Defined as the ratio of standard concentration in the sample inlet flow to the standard concentration in the sample outlet flow assuming zero losses of particles within the diluter. Since particle losses are size dependent, the effective dilution factor will have a dependency on particle size.

2.1.4 Motor Speed (RPM)

The rotational speed of the motor and hence the diluting disc. Expressed in revolutions per minute.

2.2 Main Screen

Upon powering on the diluter, after a short delay you are presented with the main screen.

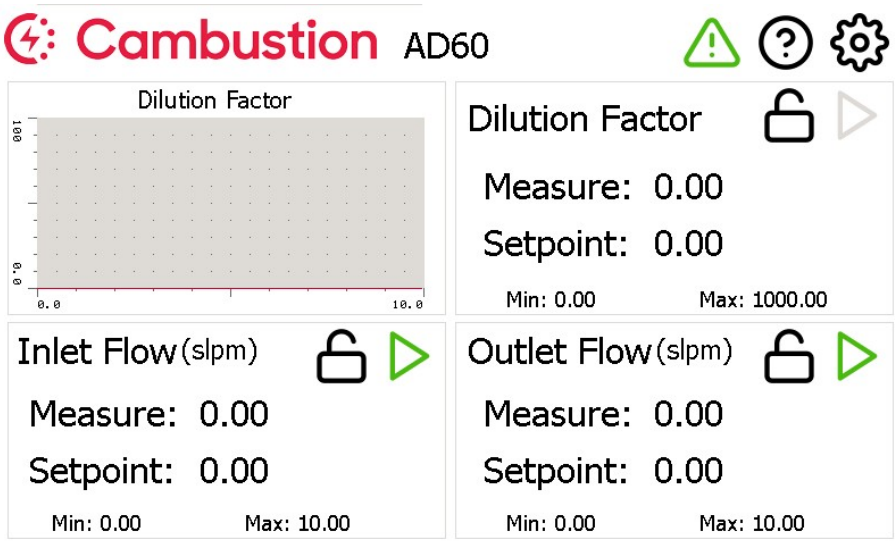

Figure 4 Main screen

The AD60 saves most settings between sessions with the exception of *on/off* statuses, such that all variables are off after startup.

2.2.1 Scope

Scope is located on the upper left quadrant of the main screen. It shows a graph of one of the variables over time. Tapping the graph opens up scope settings, where the user can select which variable is being shown and adjust the timescale and range of the plot.

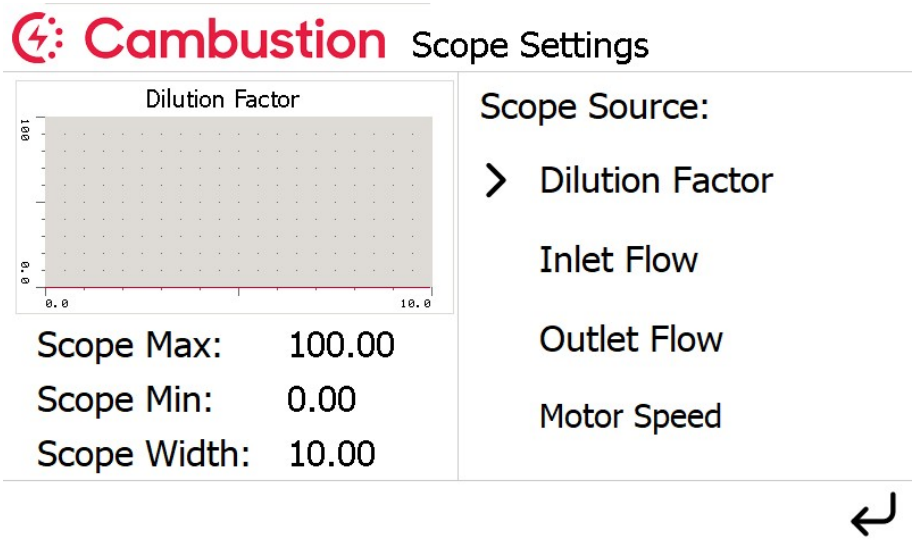

Figure 5 Scope settings selection

2.2.2 Variable fields

On the main screen there are variable fields, which display information regarding respective variables and are used to adjust them. In open loop mode there are 3 for inlet flow, outlet flow and dilution factor, or motor speed in direct speed mode. Outlet flow field is shown below:

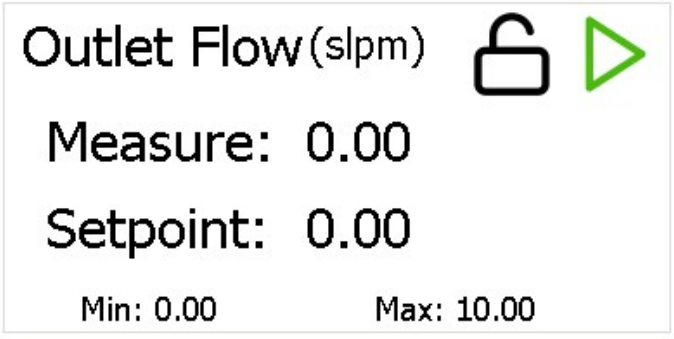

Figure 6 Outlet flow field

Each variable field shows the measured value, setpoint value, locked status, for unlocked and for locked, *on*/*off* status, for off and for on, and allowed limits of the respective variable. The , , and icons are both status indicators, showing the current state, and toggles used to switch between the states.

On startup all variable fields are off, showing ▷. To turn a variable on tap the ▷ icon, which will change to ▢ signifying the variable is currently running. Similarly, to lock a variable tap 🔓, which will change to 🔒 indicating the variable is locked.

To adjust the setpoint tap the displayed setpoint value, this will bring up a selection screen with limits still present at the bottom. Notably the setpoints can be adjusted while a variable is active, but the respective variable needs to be unlocked.

Variable fields also show the minimum and maximum value possible for the respective variable. They can either be the absolute limits or dynamic limits, described in the following section, depending on the number of locked variables. Furthermore, while in the main screen clicking on the limits will display a message box describing what they are caused by and potentially how to extend them, like shown in Figure 7.

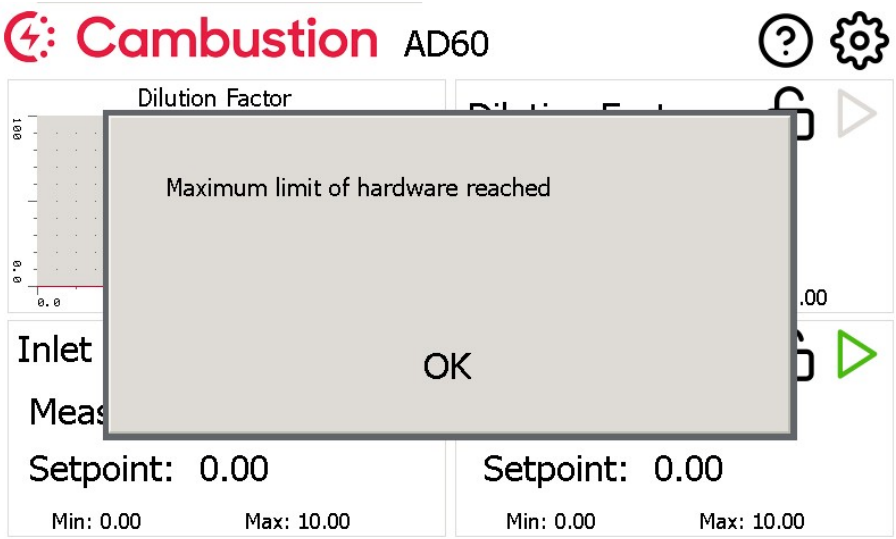

Figure 7 Limit Message

A variable must be unlocked to adjust it. After inputting a setpoint it locks automatically if less than 2 variables are locked.

Uniquely, dilution factor can only be turned on if at least 2 variables are locked, if that is not the case dilution factor's on/off status is greyed out ▷. This is not the case for other variables and crucially a variable can be turned on while left unlocked.

2.2.3 Dynamic limits and locking

AD60 dilutes an aerosol by transferring a certain volume flowrate through the disc from the inlet sample into the outlet sample, which starts as a particle free flow. This results in a 3 degree of freedom nonlinear system, which presents a challenge to intuitively explain to the user. To learn more, see Appendix **Error! Reference source not found.**.

To help remedy that AD60 uses dynamic limits for the 3 variables of interest that become active when at least 2 variables are locked. Any combination of any 2 out of the 3 variables restricts the operating range for the remaining one to a subset of the

full range, referred to in the operating map, Figure 3, and the specification, Appendix **Error! Reference source not found.**.

This means, for example, when starting with all 3 variables unlocked and entering the desired setpoints one by one the allowable range for the 3rd one will be restricted (if less than 2 variables are locked, entering a setpoint will lock the respective variable). This feature allows the user to easily gauge the operating range at any given conditions, whenever 2 variables are locked.

Crucially, the dynamic limits do depend on the inlet and outlet conditions, which means they can change if, for example, the inlet temperature or pressure changes. Because of that the dynamic limits can shift invaliding a previously entered setpoint. What AD60 does in such a situation depends on how many variables are locked.

When all 3 variables are locked, AD60 **will temporarily adjust** the last locked variable setpoint to keep it within the operating range and return to its initial value if it becomes possible. This is most likely to happen when the last locked variable setpoint is near its limits. In practice the least 'important' variable should be locked last. If AD60 adjusts a locked setpoint, a "**Setpoints not achievable**" warning will appear.

When 2 variables are locked, AD60 will adjust the setpoint of the unlocked variable to keep it within the operating range. It **will not** return to its initial value even if it becomes possible.

When only 1 variable is locked, AD60 will not adjust any setpoints, as the dynamic limits only apply when at least 2 variables are locked. This, however, is not very useful, because dilution can only be turned on when at least 2 variables are locked.

Importantly, AD60 only adjusts a setpoint if the respective variable is turned on.

2.2.4 Errors and Warnings Icon

This icon is located in the upper right of the main screen. When no errors or warnings are present it is green and if any appear it turns red. Tapping it brings up the Errors and Warnings screen, as shown in Figure 8 below:

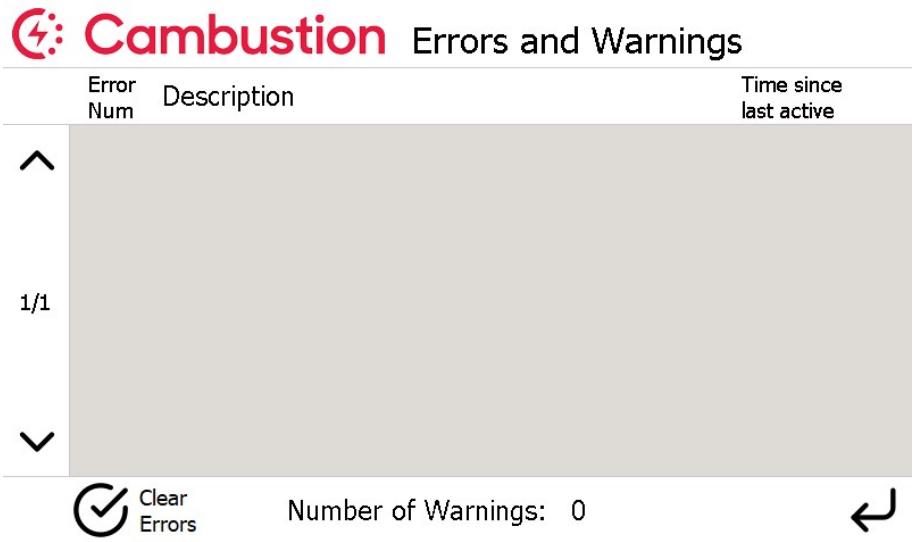

Figure 8 Errors and Warnings screen

This screen shows any active or past errors, which have not been cleared. It displays the error identification number, its description, time since it was last active and overall number of errors. To clear errors, tap the clear errors button .

2.3 Settings

Tapping the button in the upper right corner of the main screen brings up the settings menu, as shown below. Some of the settings are described in the following sections.

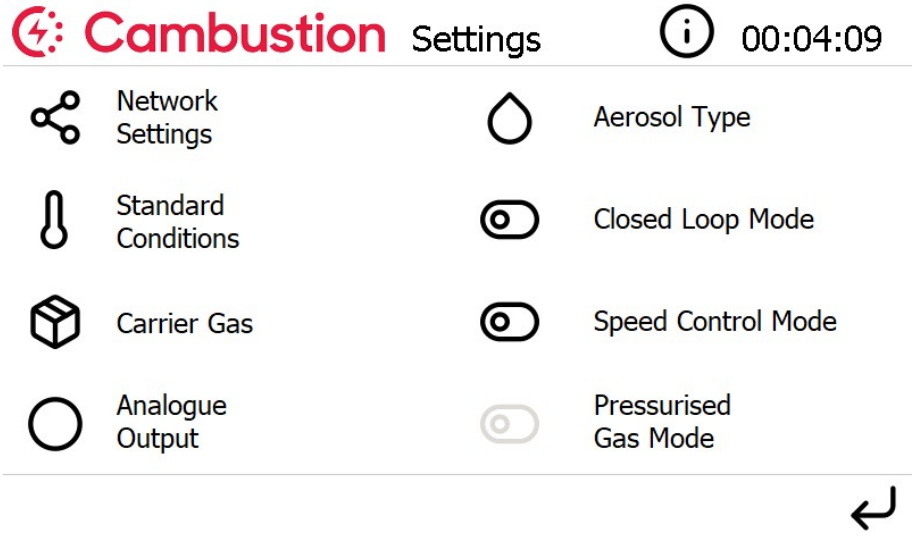

Figure 9 Settings screen

2.3.1 Network Settings

This menu can be used to view the MAC address and adjust the IP, by default it's set to 192.168.1.12. To change it, touch IP Address field and type the address, using period (.) as a separator.

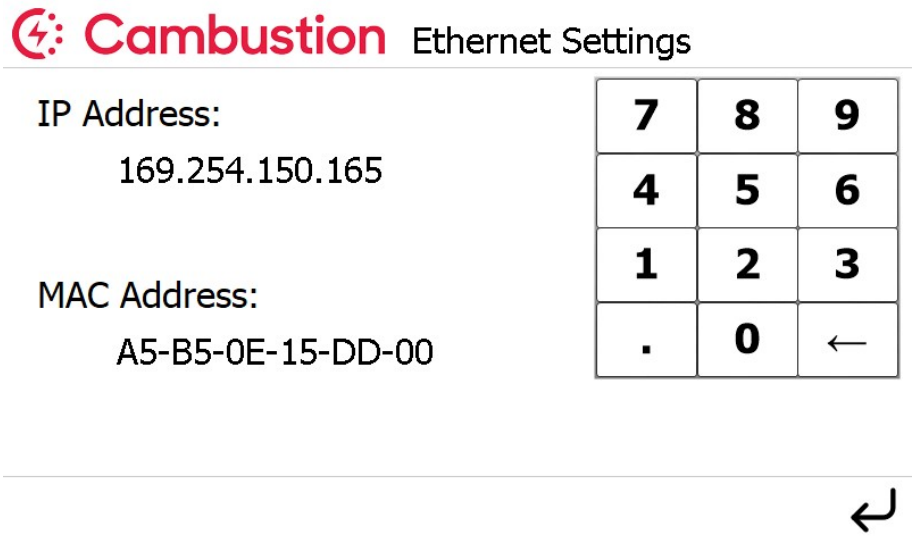

Figure 10 Ethernet Configuration

2.3.2 Reference Standard Conditions

Reference standard conditions can be changed by tapping on temperature and pressure, which will bring up a numerical input pad, where the desired conditions can be entered.

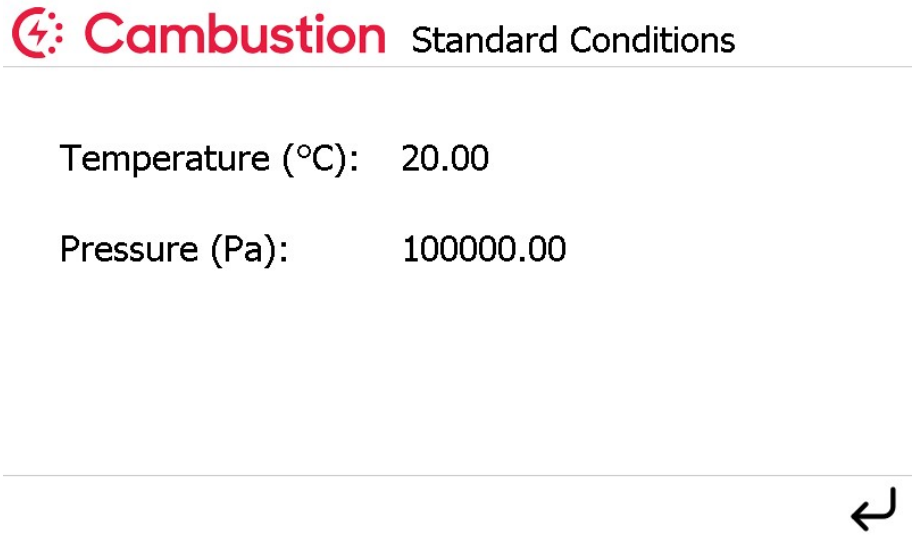

Figure 11 Conditions screen

These conditions are used for the slpm as reference for the inlet and outlet flows.

2.3.3 Info

Tapping this button bring up an information screen. It lists all the sensor readings, including temperatures and pressures, and information about the AD60: Firmware version, screen software version and serial number.

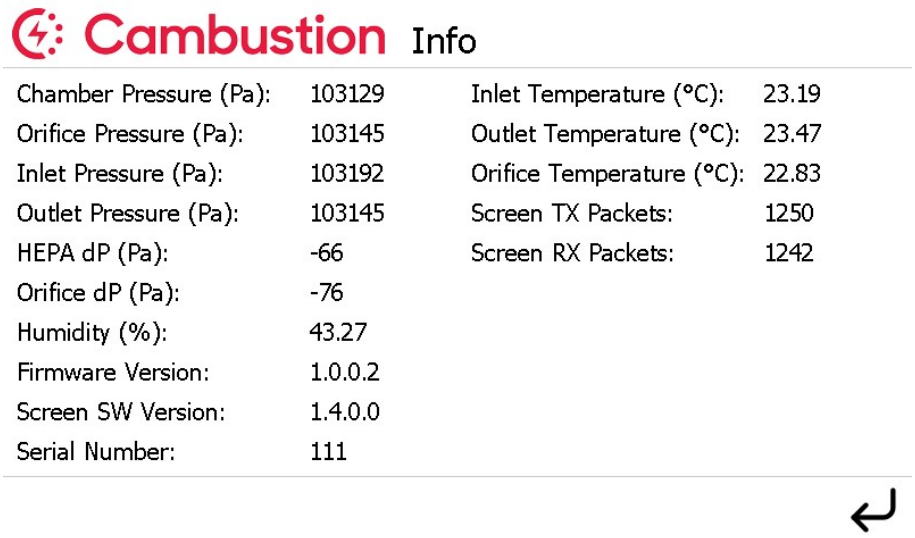

Figure 12 Information screen