

HOUSEHOLD AIR POLLUTION EXPOSURE HAPEX SENSOR V4 USER MANUAL

HAPEX SENSOR SPECIFICATIONS

- **Size:** 6.5cm*2.3cm*3.5cm
- **Weight:** 40g (1.4 oz)
- **Measurement rate:** 1 minute
- **Log rate:** 1-30 minutes
- **Compliance monitoring:** internal accelerometer.
- **Measurement range:** from 10ug/m³ to 50mg/m³
- **Battery life:** 5 years of usage (10 years of shelf life)
- **Maximum number of samples recorded:** 10,368
- **Easy start/download in the field:** no computer needed with the wireless touchscreen launcher

INTRODUCTION

The HAPEx v4 is a real time passive Particulate Matter (PM) logger. It uses a light scattering sensor to measure the amount of light scattered by the particulate matter. This logger also senses tiny vibrations which allows it to track when the device is being worn.

The HAPEx Nano was designed specifically to study PM exposure such as that seen in household air pollution linked to the use of dirty fuel for cooking. It is meant to be used along with constant flow pumps and impactors (gravimetric method). Its small size and weight and its long run time allows for work with large sample sizes during long periods of time.



When the data is being downloaded in the household, a summary of up to 20 sensors is displayed. This quantitative data is instantly available as one enters the household. This allow the surveyor to build upon it and to collect more qualitative data and explanations from the cook about the different usage patterns. All the meta-data is input in the field (stove type, household number, study arm) during deployment.

LAUNCHER DESCRIPTION



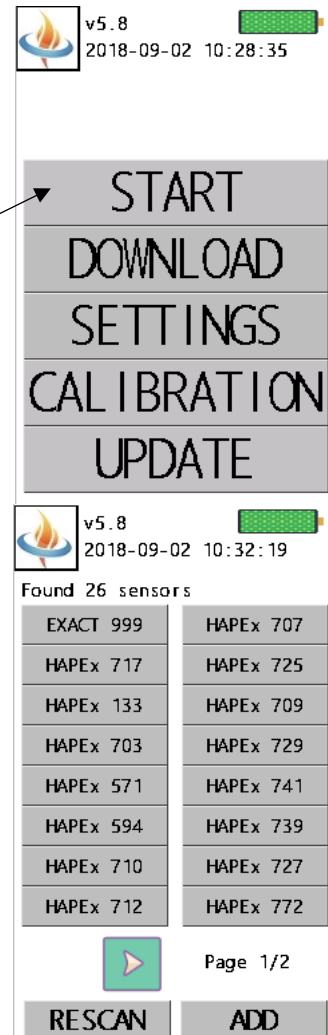
SENSOR DESCRIPTION



LAUNCHING THE SENSORS IN A NEW HOUSEHOLD

- Press the START button on the launcher. This will scan for all the sensors in the surroundings.

Press "START"



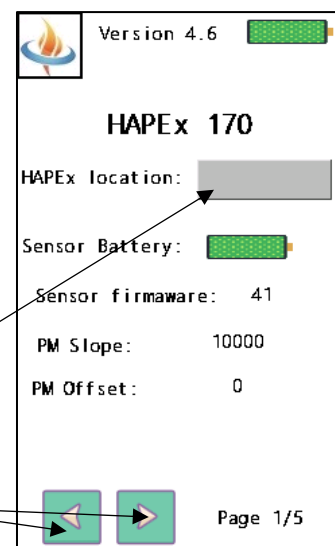
- Select then the sensors you want to add to this household. And then press "ADD"

N.B: the launcher can list up to 64 sensors. If there are more than 64 sensors around, they will not be all listed. Keep the sensors you don't want to launch far away from the launcher.

- For each sensor selected, select the location on which they will be placed. A predefined list of 14 locations is available (this list is customizable, see below).

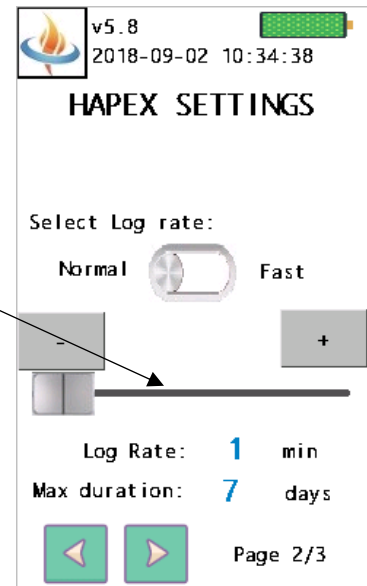
Press here to select location where the HAPEx is deployed

Press here to navigate between sensors



- Select then the log rate, this will determine how long the mission can last before the memory is full, make sure to leave some room here.

Select the logging rate by sliding the bar. The mission time is automatically adjusted.

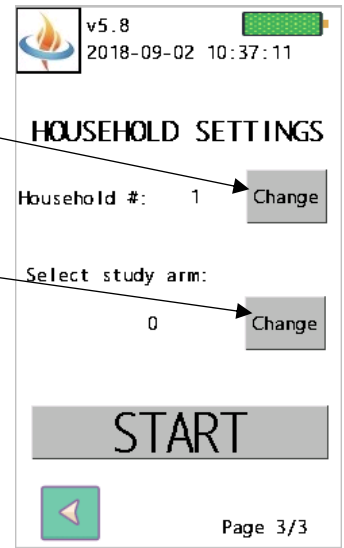


N.B: The "fast" mode is a special mode that is useful to do sensor placement testing. In this mode, the sensor will log data every 4 seconds. In this mode though, the internal memory will be full in 6 hours, so it is not very useful for long term deployment.

- Provide then the information for the household: household #, study arm (control/intervention).

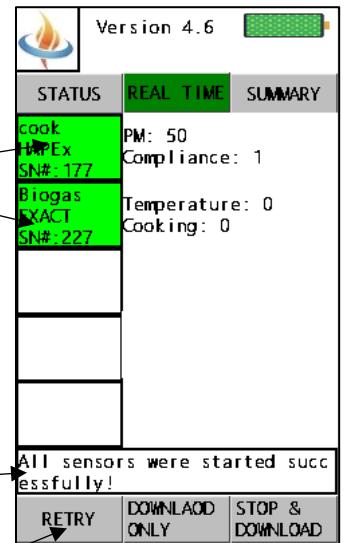
Select the household #.

Select the study arm in which the household is.



- Then press "START". You will receive a confirmation that each sensor has been started successfully (they turn green).

The name of the sensor turns green when it is successfully launched



If for some reason some sensors have not been started successfully, press the retry button until they have all succeeded.

A summary of the action taken is displayed here

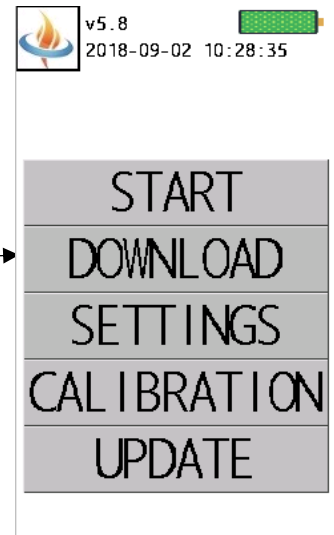
Press the "RETRY" button to execute again the latest action

N.B: when you start a new mission, the sensor reset them-self and all the data from the previous mission is erased. So be sure to download the data you need from the sensor before you start a new mission.

DOWNLOAD THE DATA FORM RUNNING SENSOR

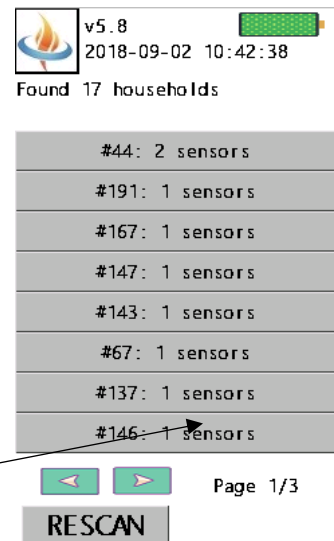
- Make sure a SD card is inserted into the launcher
- Press the OPEN HOUSE button

Press "DOWNLOAD"



- After a 20 second scan the household numbers and number of sensors in each household will be displayed.
- If you don't find the household you are looking for or if the number of sensor inside the household is lower than it should be then make sure you are within range of the sensors and press "RESCAN"
- Choose the household number you want to OPEN.

Press on the household number you want to OPEN



- You will see a summary of up to 20 sensors present in this household. At the top you have three options:

- STATUS: shows if the sensors are active or not and display their battery level and their memory level (a sensor automatically stops when its memory is full)

STATUS	REAL TIME	SUMMARY
cook HAPEX SN#: 177		State: running Battery: 100% Memory: 0%
Biogas EXACT SN#: 227		State: running Battery: 100% Memory: 0%
All sensors were started successfully!		
RETRY	DOWNLOAD ONLY	STOP & DOWNLOAD

- REAL TIME: shows the current PM value and whether the sensors detect compliance or not.

STATUS	REAL TIME	SUMMARY
cook HAPEX SN#: 177		PM: 50 Compliance: 1
Biogas EXACT SN#: 227		Temperature: 0 Cooking: 0
All sensors were started successfully!		
RETRY	DOWNLOAD ONLY	STOP & DOWNLOAD

○ SUMMARY: shows a summary of the average PM2.5 and of the average compliance value. For personal exposure, compliance value of 100% are not expected since the sensor is not worn at night, but if the compliance is below 50% that probably means that the subject has not worn the sensors throughout the day.

Version 4.6		
STATUS	REAL TIME	SUMMARY
cook HAPEX SN#: 177		Average PM: 67 Avg Comp: 96 %
Biogas EXACT SN#: 227		Cooking events: 0 Cooking time: 0 Last used: 0d ago
All sensors were started successfully!		
RETRY	DOWNLOAD ONLY	STOP & DOWNLOAD

At the bottom, you have two options:

- **DOWNLOAD ONLY** if you want download the data but keep the sensors to running.
- **STOP & DOWNLOAD** if you want to download the data and stop the sensors as well.
- When the box turns green that means that the sensor data has been downloaded successfully.
- If some of the download have not been successful then press the RETRY button
- Once the data from all the sensor have been downloaded, the launcher combine all the data into one file, please don't turn off the launcher during this operation.

N.B: To make sure the data is written to the SD Card correctly, never remove the SD Card when the Launcher is powered ON. Turn OFF the launcher first then remove the SD Card.

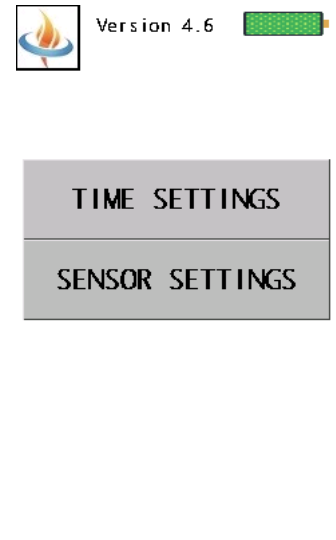
When you insert the SD Card back into the launcher, make sure it powered OFF first, insert the SD Card, then power ON the launcher.

Those simple steps will insure that the data is written reliably to the SD Card.

SETTINGS

You change the settings by pressing the “SETTINGS” button on the home screen.

You can then, choose between the “time settings” and the “sensor settings”



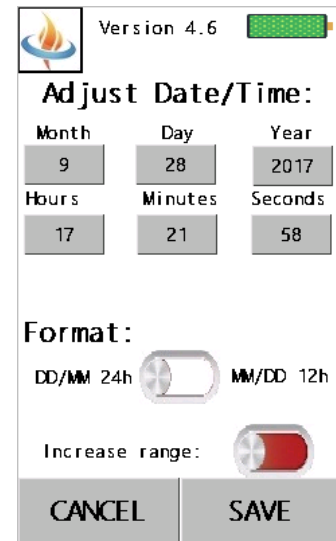
Time Settings:

Before using the launcher in a time zone, make sure that the local time has been set on the launchers. This will assure that the time stamps are accurate. The clock inside the launcher may drift so make sure to check it from time to time.

The timestamp may be displayed in MM/DD/YYYY 12H AM/PM or DD/MM/YYYY 24H format. Please choose the most convenient format for your needs.

N.B: Once the starting time has been sent to the sensor, it keeps a very accurate track of time. The time drift of the sensor should be less than 10 minutes per year.

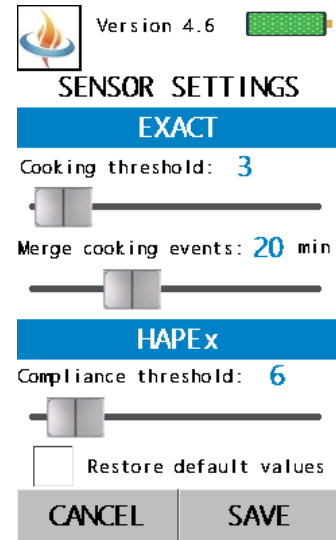
Increase Wireless Range: if you need to be able to access the sensors from far away (if for example the respondent is not home and you cannot come closer to the stoves), you can check this box. This option will increase the radio power of the antenna and allows to detect sensor from further away.



Sensor Settings

You can change the threshold above which movement is detected. With low threshold, smaller movement will be detected while with a higher threshold it will take large movement before the HAPEx detect movement.

You can restore default value by checking the box at the bottom of the screen.

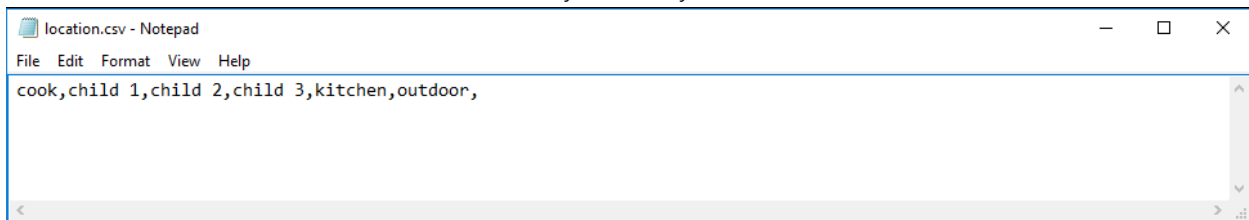


CHARGING THE LAUNCHER BATTERY.

The battery is recharged via the micro USB port. In two hours the battery will be fully charged. The battery level is displayed on the top right corner of the screen when the device is powered. When the charger is plugged in, a lightning symbol is displayed nearby the battery gauge. A fully charged battery should last a couple of days of intensive use.

CHANGING THE HAPEx LOCATION LIST

A list of 14 different location is stored into the launcher. This list should be customized to your specific project area. The locations allow to easily know where the HAPEx were deployed. It also allows afterward to run interhousehold analysis and to automatically group data by location. It is important that the location names are consistent across your study.



The locations are stored in a file on the SD card called "location.csv". You can open this file in a text editor (like notepad, it is better to not use MS Word or Excel for that) and change the name of the stove. Each name is separated by a coma, don't add any space or carriage return (no need to press "enter"). The best way of assure consistent names is to edit one file and then to paste it onto the SD cards of all the launchers used in your study.

N.B: The location are limited to 9 characters.

N.B: It is important that you don't change the name of the file itself (location.csv) so that the launcher will know to look in this file for the list of location.

ZEROING AND CALIBRATING THE HAPEX

Two parameters allow correction of the sensitivity of the devices: the offset and the slope parameters. They are used in the following equation:

$$PM_{calibrated} = (PM_{raw} + Offset) * Slope$$

The “zero” procedure allow to adjust the Offset parameter while the “calibration” procedure allows to change the Slope parameter (sensitivity).

All the HAPEX are factory calibrated against a reference device. But to maintain the best accuracy, we recommend that you **zero the HAPEX before each new sampling session** and that you **recalibrate them at least once per year**.

We designed the HAPEX so that those two operations may be performed very easily by the user with a limited set of equipment. We provide calibration services.

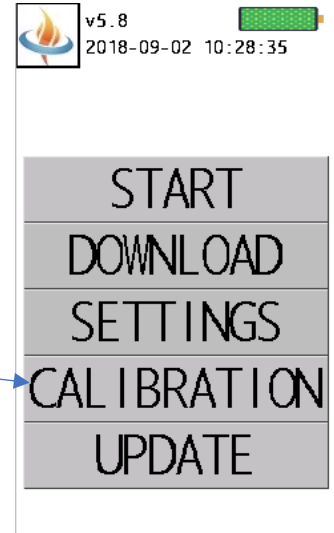
ZERO

We recommend to zero your device before each field session.

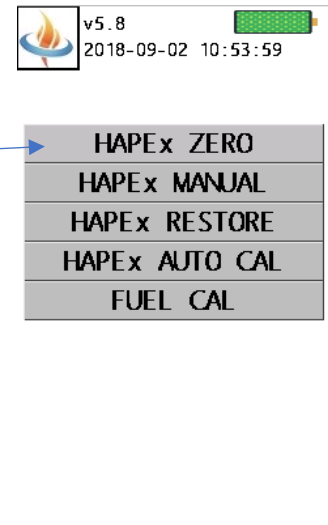
- Place first the HAPEX into the Zero Box.
- Start the air purifier and close the box.
- Wait for at least 2 minutes for the air purifier to clean the air inside the box.



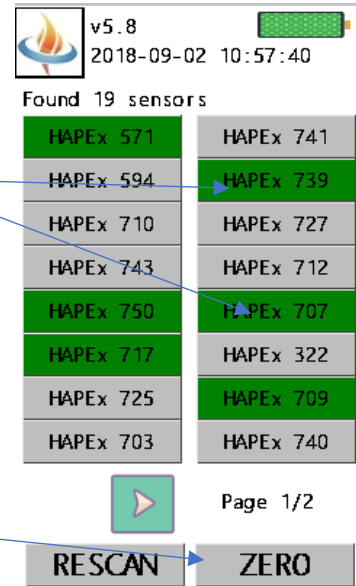
- Then, start the launcher and press CALIBRATION



- Press HAPEX Zero

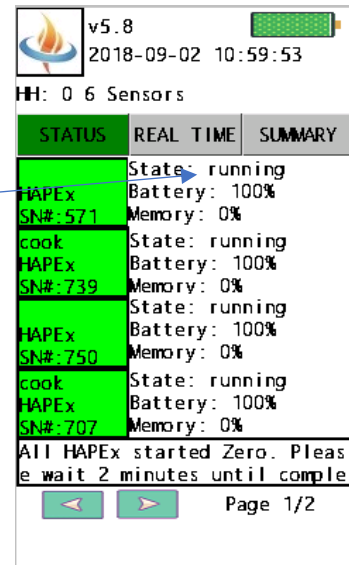


- After the 15 seconds scan up to 64 HAPEX will be listed. You can select up to 20 HAPEX you want to zero



- press "ZERO"

- You will then see this page indicating the zero process is on-going, the process will last 2 minutes.



- When the process is completed, the screen will display COMPLETED

v5.8
2018-09-02 11:06:39
HH: 0 6 Sensors

STATUS	REAL TIME	SUMMARY
HAPEX SN#: 571		State: stopped Battery: 100% Memory: 0%
cook HAPEX SN#: 739		State: stopped Battery: 100% Memory: 0%
HAPEX SN#: 750		State: stopped Battery: 100% Memory: 0%
cook HAPEX SN#: 707		State: stopped Battery: 100% Memory: 0%

All HAPEX started Zero. Please wait 2 minutes until complete

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- You can then open the box, the HAPEX have been zeroed successfully.

This method allows you to easily zero up to 20 devices in a few minutes.

CALIBRATION

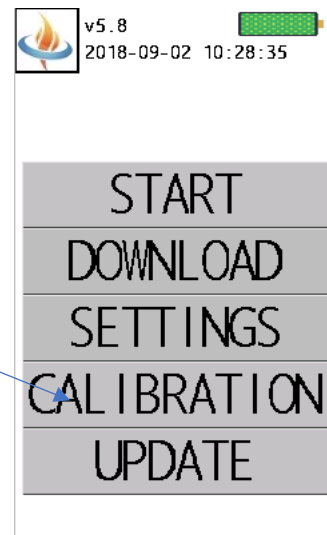
The “calibration” procedure allows to change the calibration parameter to ensure that each device has the same sensitivity.

A yearly recalibration of the devices is recommended to make sure they have the same sensitivity. Calibrating the HAPEx is not trivial, we provide this service for a small fee.

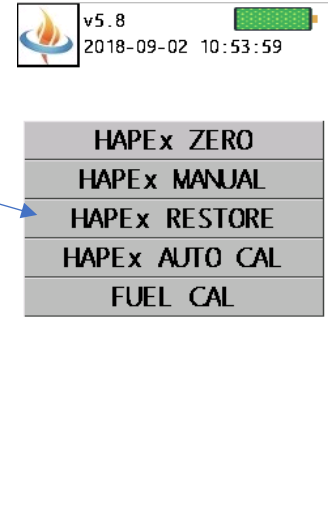
If you made a mistake during the calibration, you can restore the factory calibration of your device using the following procedure.

RESTORING FACTORY CALIBRATION VALUE

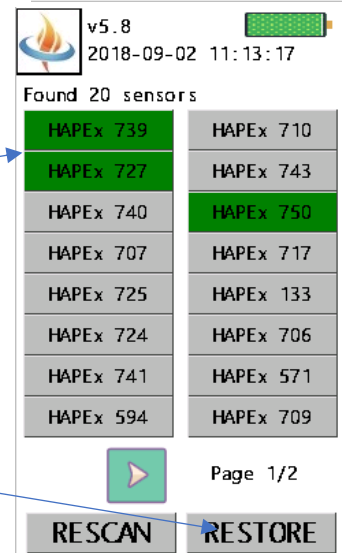
- Press the CALIBRATION button on the home screen



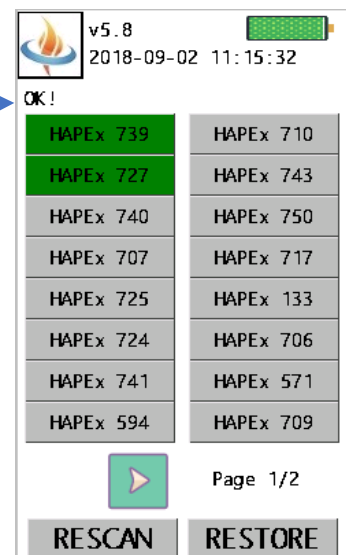
- Choose "HAPEx Restore"



- Select up to 20 HAPEx you want to restore to factory settings
- Press "RESTORE" and all the calibration value will be reset to factory state.



-
-
-
- Once all the calibration values have been restored, "OK!" will be displayed



MANUAL CALIBRATION

You will need at least two units to perform a recalibration: a reference unit and one or more units that need to be recalibrated. The reference unit should be a unit that you do not deploy in the field and that you store in clean, dry air while not being used. This will ensure that its sensitivity will remain the same and that you can use it as a reference to recalibrate your other units.

Before you perform the calibration, you should zero both your reference unit and the units you want to calibrate.

You should then start both your reference units and the units you want to calibrate. Select a “Fast” sampling rate (ie: log rate every 4 seconds).

Then, place them inside a sealed chamber containing a mixing fan. Introduce a source of smoke in the chamber through a small orifice (an incense stick is perfect for that).

Wait until the level reached about 10,000 raw units then remove the source of smoke from the small orifice.

Wait a few minutes

Open the calibration chamber to let the smoke escape (do this outside or in a well-ventilated room). Alternatively, a vacuum pump and a HEPA filter can effectively lower the PM level inside the chamber down to zero.

Wait a few minutes for the PM level to go down.

Stop the mission and download the data.

The new Slope value of the device number y is as follow:

$$Slope_{new} = Slope_{old} * \frac{PM_{average_{ref}}}{PM_{average_y}}$$

With:

$Slope_{new}$: new slope of the device

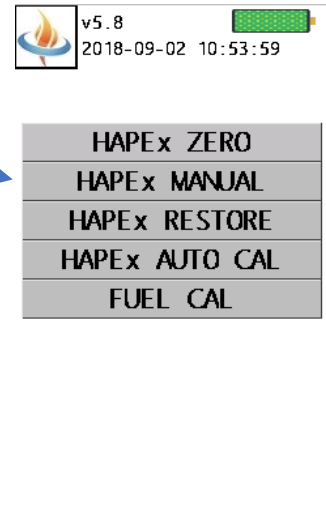
$Slope_{old}$: previous slope of the device

$PM_{average_{ref}}$: Average PM value recorded by the reference device during the calibration.

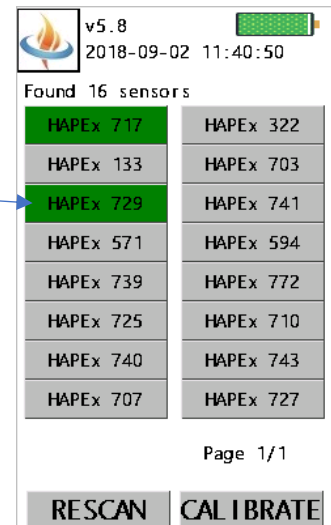
$PM_{average_y}$: Average PM value recorded by the HAPEx Serial Number y device during the calibration.

Once you have calculated the $Slope_{new}$ for each device you want to calibrate, follow the procedure below to input the new value into each device memory.

- You can adjust manually the calibration value by selecting the manual calibration option



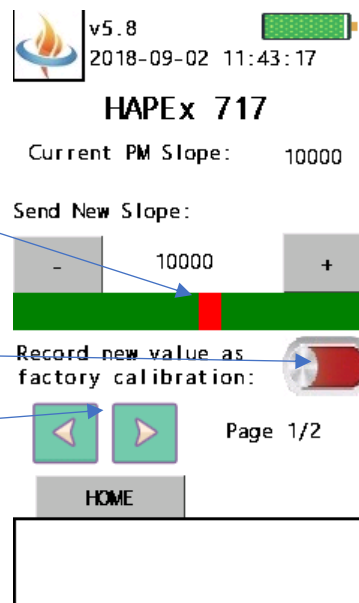
- Select the up to 20 HAPEX for which you want to update the calibration value.
- Then press "CALIBRATE"



- You then land on this page which will allow you to change the PM slope (sensitivity) of the device.

NB: we recommend that you don't record the new value as a factory calibration (ie: leave this red) so that you may restore it if needed.

- Use the arrow to navigate between sensors
- Once you reach the last sensor, press SEND to send the new value to the device



INTERPRETING THE DATA

The file produced by the device is fairly straightforward. It looks like this:

	A	B	C	D
1	Household ID:	888		
2	Total number of stove:	2		
3	Total number of PM measurement location:	1		
4	Start time:	9/28/2017 10:40		
5	Stop time:	9/28/2017 10:54		
6	Total number of logs:	209		
7	Study arm:	intervention		
8	Type of stove data logged:	usage and temperature		
9				
10	Stove Name:			
11	Cooking Events per day:			
12	Cooking Time (min/day):			
13	Number of days since last use:			
14				
15	PM measurement location:	kitchen		
16	PM average:	129		
17	Compliance average:	0%		
18	PM slope:	11241		
19	PM offset:	52		
20				
21	Timestamp	kitchen Compliance (HAPEX)	kitchen PM (HAPEX 8)	
22	9/28/2017 10:40	0	11	
23	9/28/2017 10:40	0	0	
24	9/28/2017 10:41	0	-5	
25	9/28/2017 10:41	0	2	
26	9/28/2017 10:41	0	1	
27	9/28/2017 10:41	0	3	
28	9/28/2017 10:41	0	3	
29	9/28/2017 10:41	0	2	
30	9/28/2017 10:41	0	-3	
31	9/28/2017 10:41	0	-5	
32	9/28/2017 10:41	0	-2	
33	9/28/2017 10:41	0	0	

For each time stamps two values are displayed: the concentration of PM2.5 and the “compliance”.

Compliance

If compliance = 0 that means that the device was not worn. If compliance = 1 then the device was worn during the corresponding time period. When the average of multiple samples is logged then compliance is set to 1 only when 50% or more of samples measured showed some active movement.

N.B: the compliance measurement is a little bit noisy. To get cleaner data, so can simply post process the data by calculating a running average of 10 compliance value, if the average is above 0.5, the device is worn, if it is below 0.5 the device was not worn.

Particulate Matter

The value of PM are **unitless**. To get a value of PM in mg/m³ you need to multiply the raw signal by the Particulate Coefficient. This coefficient depends on the type of aerosol sampled. To measure the particulate coefficient, you need to use a gravimetric system co-located with the HAPEx.

The following equation may be used to measure PC:

$$PC = \frac{[\text{mean PM2.5 concentration from gravimetric } (\frac{mg}{m^3})]}{[\text{mean PM concentration measured by HAPEx (unitless)}]} \text{ in (mg/m}^3\text{)/(raw HAPEx unit)}$$

It is best if you can establish this coefficient for each household that is part of the study. For example, the gravimetric system may be used during 24 hours along with the HAPEx while the HAPEx alone will sample for longer time period.

Alternatively, this coefficient may be determined on only a sub-sample of the household and then extrapolated for the other households. We recommend that at least 20% of the households have both the gravimetric and HAPEx measurement. In this case it is important to stratify the household per type of fuel used and to establish the particulate coefficient individually for each strata since the aerosol properties will change between different fuels/stove combination.

Once the field PC has been established, real time reading in mg/m³ may then be calculated with the following formula:

$$\text{HAPEx PM reading (mg/m}^3\text{)} = \text{HAPEx raw readings (unitless)} * \text{PC}$$