Test Plan

CR/ER

CR1-Easy to carry, compact and lightweight
The overall unit is small and portable. Can be easily carried outdoors

CR2-Easy to operate
Fewer steps for the operator to run the unit

CR3-High resolution
Capture clear images

CR4-durable
A durable design can greatly extend the life and working duration of the device

CR5-Stable
The equipment should work as steadily as possible to ensure a clear shot.

CR6-Fast collection
Much more efficient than traditional passive sampler

CR7-Can be used in different environments
Can be used in a wide range of environments

ER1-Decrease weight and volume of body
ER2-increase flow rate and speed
ER3-Increase control system automaticity
ER4-Decrease exposure time for shooting
ER5-Increase camera sharpness
ER6-Increase strength of material
ER7-Increase working duration

Table 1: Test summary table

Experiment/Test	Relevant DRs
EX1-Flow Rate and Speed Test	ER2,CR6,CR7
EX2-Control System Test	ER3,CR2,CR4,CR5,CR7
EX3-Shooting Resolution Test	ER5,CR3,CR7
EX4-Capture Speed Test	ER4,CR3,CR7
EX5-Working Duration Test	ER7,CR4,CR7

1.Flow Rate and Speed Test

Objective

The purpose of calculating the flow rate in the central channel with a vacuum pump is to optimize the system for effectively suspending and capturing soil dust particles. Ensuring a suitable flow rate is crucial for the high-resolution imaging sensor to accurately capture and characterize 2µm-sized dust particles in real time. To effectively optimize the system, considerations such as adjusting the fan speed, fine-tuning the channel dimensions, and selecting an appropriate filter can be made. These adjustments ensure consistent and efficient dust agitation and collection, thereby enhancing the quality and reliability of data collected for Valley Fever research.

Procedure

Steps:

- Measure and calculate the cross-sectional area, A, at the vacuum pump inlet and outlet, respectively.
- Set up the flow meter with Hot Wire for flow speed measurement mode.
- Measure the flow speed at the vacuum pump inlet and outlet, respectively.
- Calculate the flow rate at inlet and outlet.
- Calculate the cross-sectional area in the middle of the channel.
- The two flow rate values in the middle of the channel are calculated and then average to get the final result.

Results

Cross sectional area of inlet:

$A_i = length \times width = 0.01748m \times 0.00794m = 1.387 \times 10^{-4} m^2$

Cross sectional area of outlet:

$A_o = \pi r^2 = \pi 0.003625^2 = 0.00004128m^2$

Flow speed at inlet:

$v_i = 12.1\frac{m}{s}$

Flow speed at outlet:

$v_o = 37.6\frac{m}{s}$

Flow rate at inlet:

$Q_i = A_i \times V_i = 1.387 \times 10^{-4} m^2 \times 12.1\frac{m}{s} = 0.001678\frac{m^3}{s}$

Flow rate at outlet:

$Q_o = A_o \times V_o = 0.00004128m^2 \times 37.6\frac{m}{s} = 0.001552\frac{m^3}{s}$

Cross sectional area of middle of the channel:

$A_m = length_m \times width_m = 0.013m \times 0.0013m = 0.000169m^2$

Calculate the flow speed at the middle of the channel:

$$v_1 = \frac{Q_i}{A_m} = \frac{0.001678\frac{m^3}{s}}{0.000169m^2} = 9.93\frac{m}{s}$$

$$v_2 = \frac{Q_o}{A_m} = \frac{0.001552\frac{m^3}{s}}{0.000169m^2} = 9.18\frac{m}{s}$$

Average to get the final result:

$$v = \frac{v_1+v_2}{2} = \frac{9.93\frac{m}{s}+9.18\frac{m}{s}}{2} = 9.555\frac{m}{s}$$

2.Control System Test

Objective

The objective of this test is to ensure the correct connection of the entire system and the stable operation of the control system, as well as to check if the code still runs properly after changing the power source. This includes the signal control of the Raspberry Pi, the correct operation of the relay, the normal operation of the fan, and the photo shooting of the camera. During the experiment, the only parameter that needs to be measured is the fan's rotation speed, to check whether it aligns with the expected operation of PWM. Based on the measurement results, adjustments might be required in the control code for the fan speed and the high-level duration of the relay.

Procedure

Step 1: Circuit Connection

- Properly connect the circuits between the devices, linking the Raspberry Pi's ground interface to the negative terminal of the power supply.
- Use heat shrink tubing to reinforce the connections at each circuit junction.

Step 2: Power and Video Output Activation

- Turn on the power switch and connect the video output.
- Check if the relay and Raspberry Pi indicator lights are correctly lit.
- Launch the command window and execute the file with python3.

Step 3: Program Monitoring

- Wait for the program to run and use auditory cues to determine if the relay is functioning properly.
- Record the operation time of the fan and compare it with the time set in the control code.

Step 4: Camera Check

- Verify that the camera is operational and saving the captured images locally.

Step 5: Fan Speed Verification

- Compare the fan speed returned by the program with the set speed percentage.

Results

This test will record the fan's rotation speed and operation time. The fan is controlled by a PWM signal. The principle of this control is to adjust the frequency and duty cycle of the PWM signal to achieve percentage control of the fan's rotation speed. Assuming the fan's maximum speed is 5500rpm, setting a 50% rotation speed in the control code will result in a maximum fan speed of 2750 rpm. The control code can also set the relay conduction time, which determines the time the fan will be powered. Compare the fan's maximum speed with the set speed, as well as its operation time. Since the fan undergoes an acceleration process and lasts no less than 5 seconds, its expected speed should be between 30-50% of the maximum speed.

3.Shooting Resolution Test

Objective

The purpose of this test is to measure the equivalent resolution of the Raspberry Pi under a fixed magnification lens, so as to roughly estimate the size of dust particles in the captured field of view and the expected image blurriness after shooting. The equipment required for this test includes a Raspberry Pi and a Raspberry Pi camera lens. Variables that need to be controlled in this test are the magnification of the lens, the size of a single pixel of the Raspberry Pi sensor, the focusing distance, and the size of the shooting range. Based on the test results, adjustments may need to be made to the lens magnification and focusing distance.

Procedure

Step 1: Camera and Raspberry Pi Connection

- Connect the camera to the Raspberry Pi, power on the Raspberry Pi, and ensure the power supply is functioning properly.

Step 2: Camera Preview Setup

- Enter the camera preview code into the Raspberry Pi's console, set it for 300 seconds, and adjust the lens magnification for focusing. The Raspberry Pi's output image should be visible on the display screen.

Step 3: Focus on Shooting Area

- Focus the Raspberry Pi's camera on a section of the desktop and use a marker to delineate the shooting area.

Step 4: Sensor Parameters and Resolution Calculation

- Using the Raspberry Pi's sensor parameters, focus distance, and the marked shooting area, calculate the equivalent resolution.

Step 5: Dust Particle Size Comparison

- Compare the calculated resolution with the size of dust particles. If necessary, adjust the lens magnification to ensure the particles are clearly visible.

Results

The field of view (FoV) can be calculated using the lens's focal length and the sensor size. The formula for the horizontal FoV is:

$$FoV_{horizontal} = 2 \times arctan(\frac{sensor\ width}{2 \times focal\ length})$$

The sensor width can be calculated from the sensor diagonal and pixel size. With the diagonal and aspect ratio, you can calculate the sensor's width and height.

Calculate the size of the area that the camera will capture at a particular distance using the following formula:

$$Width\ of\ area = 2 \times distance\ to\ subject \times tan(\frac{FoV_{horizontal}}{2})$$

$$Height\ of\ area = 2 \times distance\ to\ subject \times tan(\frac{FoV_{vertical}}{2})$$

knowing the actual width and height of the area captured, equivalent resolution can be calculated as follows:

$$Equivalent\ resolution\ width\ = \frac{Width\ of\ area}{Pixel\ size\ width}$$

$$Equivalent\ resolution\ height\ = \frac{Height\ of\ area}{Pixel\ size\ width}$$

Under ideal circumstances, the calculated equivalent pixel size should be smaller than the size of the dust particles. This means that each dust particle will occupy several pixel grids, making it observable.

4.Capture Speed Test

Objective

The capture speed test is also a test taken to ensure that clear images are captured. When equipment is used to capture high-speed particles, the combination of shutter speed and light source is especially critical, as it directly affects the ability to clearly capture these fast-moving objects. If the shutter time is long it will result in the motion of the particles being captured. In order to freeze the motion of high-speed particles, it is necessary to use an extremely fast shutter speed, such as 1 μs second or faster. This reduces motion blur and captures the instantaneous position of the particles. Since fast shutter speeds greatly reduce the amount of light coming in, the shutter speed allows the option of adding varying degrees of light sources to supplement the shutter speed to achieve the best results.

Procedure

Step 1 : Shooting particles with the shutter time set to 1 μs.
Step 2 : Shooting particles with the shutter time set to 0.1 μs.
Step 3 : Shooting particles with the shutter time set to 0.01 μs.
Step 4 : Set up different light sources at different shutter times to see which one is the sharpest.

Results

Compare the three sets of pictures to see which is the clearest (with clear outlines)
The length of the target in the image (m)=length of the target (m)+speed (m/s)*shutter time (s)

5.Working Duration Test

Objective

The purpose of this test is to measure the endurance time of the device. As the device uses a 10000mAh lithium battery for power supply and needs to be tested externally, and it will experience a significant instantaneous power consumption in a single operation cycle, it is necessary to test the number of cycles the device can run stably. The equipment needed for this test is the entire device, and an additional multimeter is used to measure the current and voltage during the operation process. Variables to control during the test include a constant power source, changes in current during operation, and instantaneous power at each moment. Since the power source can be removed and replaced at any time, there are no parameters or equipment that need to be adjusted. The test results will serve as a reference for the number of batteries we carry.

Procedure

Step 1: Voltage and Current Measurement Setup

- Connect a voltmeter and ammeter to both ends of the power supply to prepare for recording the voltage and current during operation. If possible, use sensors to record data over time.

Step 2: Power Supply Activation

- Turn on the power switch, which will boot up the Raspberry Pi. Record the voltage and current at this moment.

Step 3: Fan Activation and Monitoring

- Execute the code to start the fan and observe the changes in voltage and current. Theoretically, the current should resemble an inverted parabola, similar to a downward-opening quadratic function.

Step 4: Energy Consumption Calculation

- Calculate the electrical energy consumed during a working cycle. This can be done by integrating the product of voltage and current over time to calculate the total energy. The theoretical number of operation cycles can be determined by dividing the battery capacity by this energy consumption value.

Results

Record the initial voltage (V_0) and current (I_0) when the Raspberry Pi is turned on. The power (P) can be calculated as:

$P = V \times I$

To calculate the energy (E) consumed over a working cycle, integrating the power over time. If P(t) is the power as a function of time, then energy is:

$E = \int P(t)dt$

To calculate the theoretical number of operation cycles (N) that a battery can support, use the battery's capacity (C) , in watt-hours or milliampere-hours) and the energy consumed per cycle (E):

$N = \frac{C}{E}$

Table 2: CR summary table

Customer Requirement	CR met? (Yes or No)	Client Acceptable (Yes or No)
CR1-Easy to carry, compact and lightweight		
CR2-Easy to operate		
CR3-High resolution		
CR4-durable		
CR5-Stable		
CR6-Fast collection		
CR7-Can be used in different environments		

Table 3: ER summary table

Engineering Requirement	Target	Tolerance	Measured/Calculated Value	ER met? (Yes or No)	Client Acceptable (Yes or No)
ER1-Decrease weight and volume of body	1600 cm^3 5 kg	5%			
ER2-increase flow rate and speed	9 m/s	2%			
ER3-Increase control system automaticity	Most parts in the device can be controlled by Raspberry Pi				
ER4-Decrease exposure time for shooting	1µs	5%			
ER5-Increase camera sharpness	1.8 * 1.8 µm	5%			
ER6-Increase strength of material	350 Mpa	5%			
ER7-Increase working duration	1 h	10%			