Bubble CPAP testing & validation summary

Date: 30-04-2018

Objective:
To observe and understand the relationships between different parameters of the Bubble CPAP system.

Parameters to alter, observe & correlate:

- Flow rate **(1lpm to 10 lpm)**
- Humidifier water level **(1cm to 3cm)**
- Humidifier water surface area
- **(9.5cm x 15.5mm; 0% to 100%;** to control evaporation rate)
- Pressure level (**1cm to 11cm of H_2O**)
- Temperature (**ambient & compressed Air**)
- Humidity (**ambient & compressed Air**)

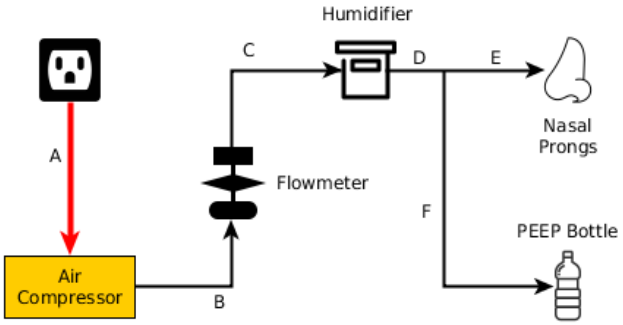


Fig. 1: System overview

Experimental setup:
There are four major parts of this experimental setup.

i) Sensors Selection.
ii) Data acquisition.
iii) Data logging
iv) Plots, graphs & data analysis.

Sensors & measuring devices:
A number of sensors are deployed along the breathing circuit for measuring different parameters.

Gas Sensors: (For detecting level of concentration of the gases)
MQ-2: useful for detecting H_2, LPG, CH_4, CO, Alcohol, Propane.
MQ-5: useful for detecting LPG, Natural gas, Town gas.
MQ-135: useful for detecting NH_3, C_6H_6, smoke, CO_2.

Temperature & Humidity Sensors: (For collecting both ambient & relative data)
DHT11: 16 bit resolution temperature & relative humidity sensor.

Pressure Measurement: (For detecting leakage & measuring pressure)
PM-6205: HTC Instrument Digital Manometer.

Flow Measurement:
Dwyer Rate-master flow-meter.

Data Acquisition:
Data is collected using an embedded microcontroller attached to the sensors. The interval between each data point is 3 seconds.

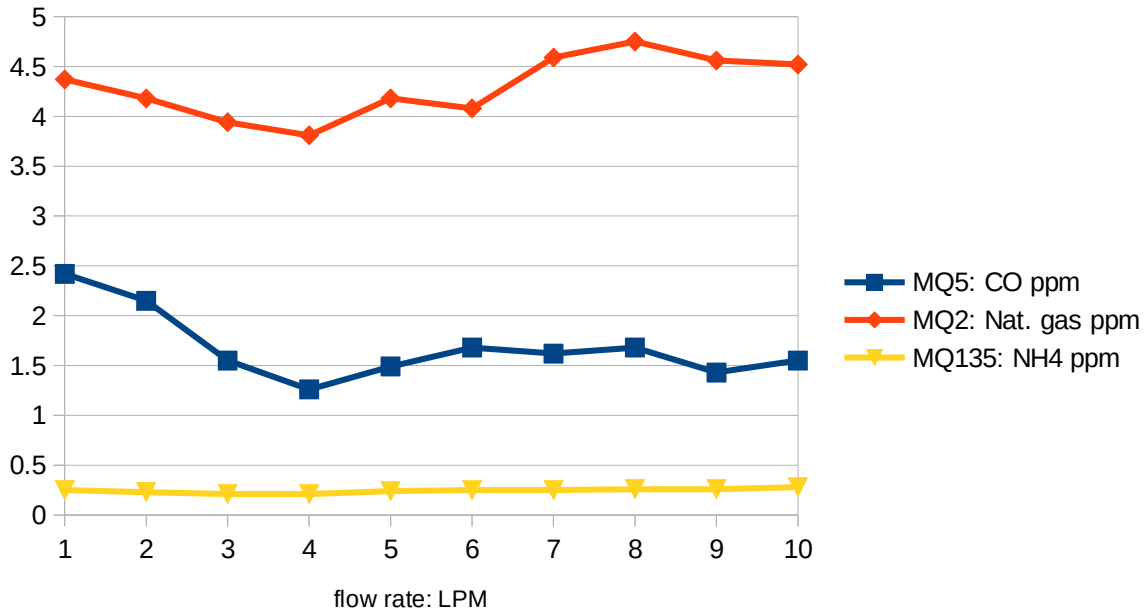
Data logging:
Since the space provided in the internal EEPROM of the controller is very small, we have logged the data into spreadsheet using serial programming & python.

Plots, Graphs & data analysis:
Visualizing the data trend, cross-correlation between different parameters such as flow-rate vs humidity or flow-rate vs pressure.

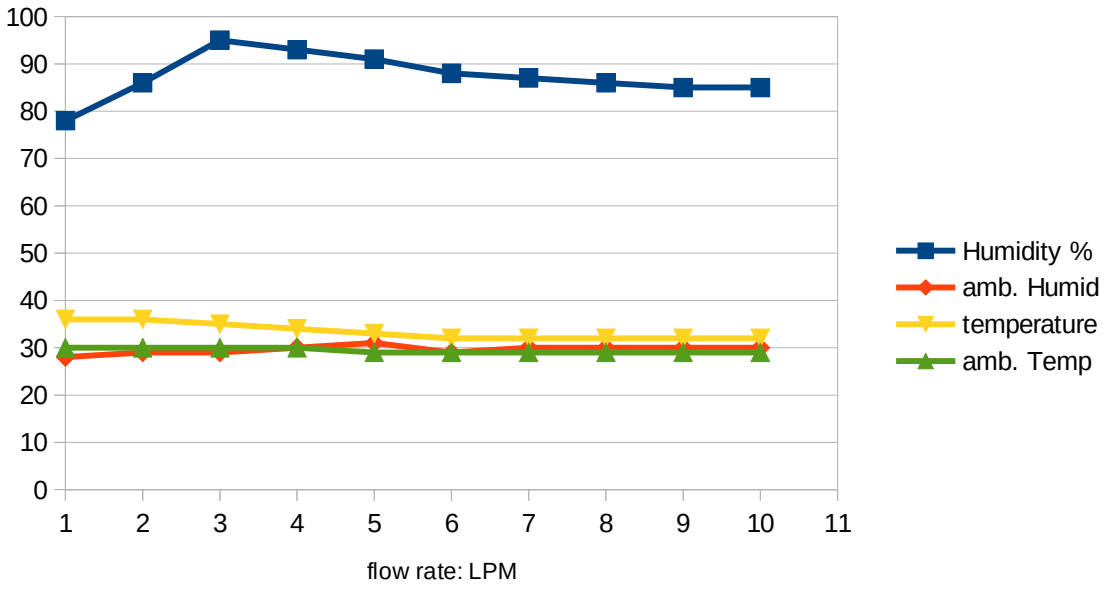
Test results:

	MQ5: CO ppm	MQ2: Nat. gas ppm	MQ135: NH4 ppm	Humidity %	amb. Humid	temperature	amb. Temp
Flow = 1 Lpm	2.42	4.37	0.25	78	28	36	30
Flow = 2 Lpm	2.15	4.18	0.23	86	29	36	30
Flow = 3 Lpm	1.55	3.94	0.21	95	29	35	30
Flow = 4 Lpm	1.26	3.81	0.21	93	30	34	30
Flow = 5 Lpm	1.49	4.18	0.24	91	31	33	29
Flow = 6 Lpm	1.68	4.08	0.25	88	29	32	29
Flow = 7 Lpm	1.62	4.59	0.25	87	30	32	29
Flow = 8 Lpm	1.68	4.75	0.26	86	30	32	29
Flow = 9 Lpm	1.43	4.56	0.26	85	30	32	29
Flow = 10 Lpm	1.55	4.52	0.28	85	30	32	29

Humidifier: open water surface, PEEP: 3cm H_2O



Plot 1: Gas concentration vs Flow rate



Plot 2: Gas concentration vs Flow rate

Test setup:

In this experiment we have considered three major parameters i.e. Pressure, Volume/ rate of flow & Humidity level & tried to find out the correlation between them. Ambient temperature & humidity measurement has also been done in order to calibrate the gas sensor.

The CPAP device is set up as shown in Fig 1. Air compressor is connected to a 220 V wall socket. The Flow meter is directly connected to the compressor outlet.

Air flow through the breathing circuit is controlled by a pin valve provided in the flow meter that can deliver flow rates ranging from 1LPM to 10 LPM.

The next component in the breathing circuit is the Humidifier. Since evaporation occurs only on the surface of a liquid, small templates are created using PP sheets that covers certain areas of the water surface. Internal area of the humidifier is approx 9.5cm X 15.5 cm. We have found that the rate of change of humidity is directly proportional to the open surface of the water.

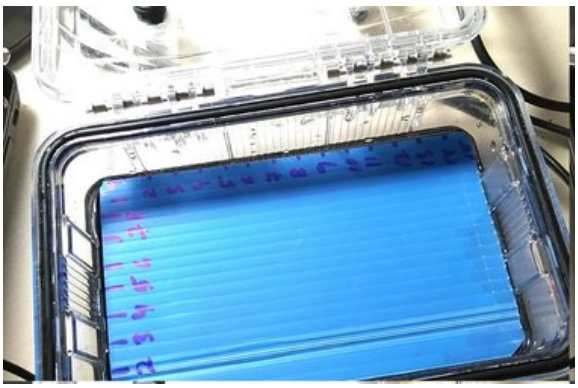


Fig. 2: Humidifier

3 pairs of humidity, temperature and gas sensors are deployed at the opening of the nasal prongs to detect the level of heat, moisture & gas concentration at both the ambient & test conditions. Ambient levels are required to calibrate the sensitivity of the sensors.

PEEP bottle has been marked with 0cm to 11cm H_2O pressure levels. In this experimental setup the PEEP level is also variable & at each level, the same experiment to be carried out to understand the relation between humidity & gas concentration at different pressure levels.

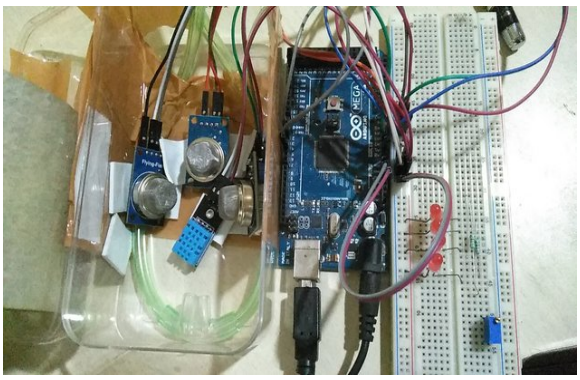


Fig. 3: Gas, temperature & humidity sensor

The data has been collected using a microcontroller platform & sent to the PC using USB communication. A simple python script is written to automatically log it into a spreadsheet.

Analogue to Digital conversion values are used to calculate the PPM concentration of the gases.

The following parameters are measured during the testing process.

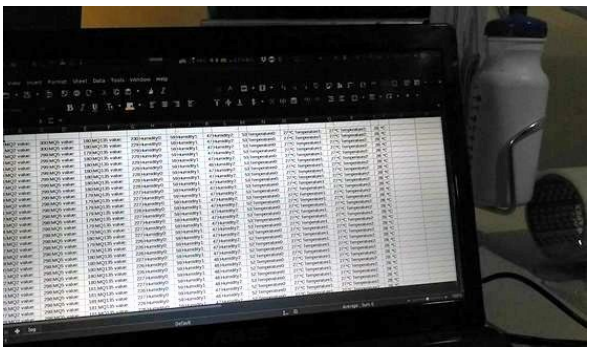


Fig. 4: Data logging using python

Flow = 7lpm
Duration: 25 min Humidifier water height = 1cm
Humidifier surface covered area = 9.5x15.5 sq.cm
PEEP = 2cm

sl. no.																								
0	MQ2 value:	363	MQ5 value:	197	MQ135 value:	316	Humidity0:	44	Humidity1:	42	Humidity2:	52	Temperature0:	30	*C Temperature1:	30	*C Temperature2:	34	*C
1	MQ2 value:	365	MQ5 value:	197	MQ135 value:	316	Humidity0:	44	Humidity1:	42	Humidity2:	52	Temperature0:	30	*C Temperature1:	30	*C Temperature2:	34	*C
2	MQ2 value:	364	MQ5 value:	197	MQ135 value:	316	Humidity0:	44	Humidity1:	42	Humidity2:	52	Temperature0:	30	*C Temperature1:	30	*C Temperature2:	34	*C
3	MQ2 value:	364	MQ5 value:	197	MQ135 value:	317	Humidity0:	44	Humidity1:	42	Humidity2:	52	Temperature0:	30	*C Temperature1:	30	*C Temperature2:	34	*C

Observations:

sl. no.	Observations	Remarks	
1.	Electrical Properties of the compressor is in line with the specifications provided by the manufacturer. It has an issue of making excessive vibration during the run.	Rubber pads are provided at the base of the motor to absorb the vibration. Mounting screws and internal assembly is not affected by continuous 8 hours run for 5 days. The Noise and vibration is not affecting the working of the CPAP device.	
		No significant level of harmful gases are found during the run.	
2.	Water column height & area is altered to understand the relation between evaporation & humidification levels.	Humidification is directly proportional to the area exposed to air inside the humidifier.	
		Ambient humidity is also taken under consideration & the value is measured using separate humidity sensor during the test run.	
3.	Air compressor dissipates heat during the run. 3 temperature sensors are deployed; 2 for ambient & 1 at the outlet of the nasal prong to understand the rise of air temperature through the breathing circuit	A maximum difference of 6 degree is observed during the testing. (Ambient: 30*C, Breathing Ckt: 36*C)	

Scope:

Leakage detection in the breathing circuit, pressure difference at different points of the circuit etc. to be verified.

A more robust & calibrated gas sensing technique can be adopted to identify the exact gases that are causing the mild foul smell in the breathing circuit.