PROJECT REPORT

SCHEMATIC PROPOSAL DRAFT-I

SCHEMATIC OF LOW COST VENTILATION SYSTEM

REPORT BY
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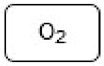
DIAGRAM LEGEND



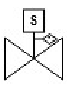
Medical Oxygen source

Medical Air Source

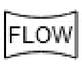
CO_2 concentration sensor

O_2 concentration sensor

Pressure sensor



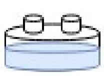
Solenoid Valve



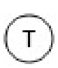
Flowrate Sensor

Medical Filter

Check Valve/ Regulator



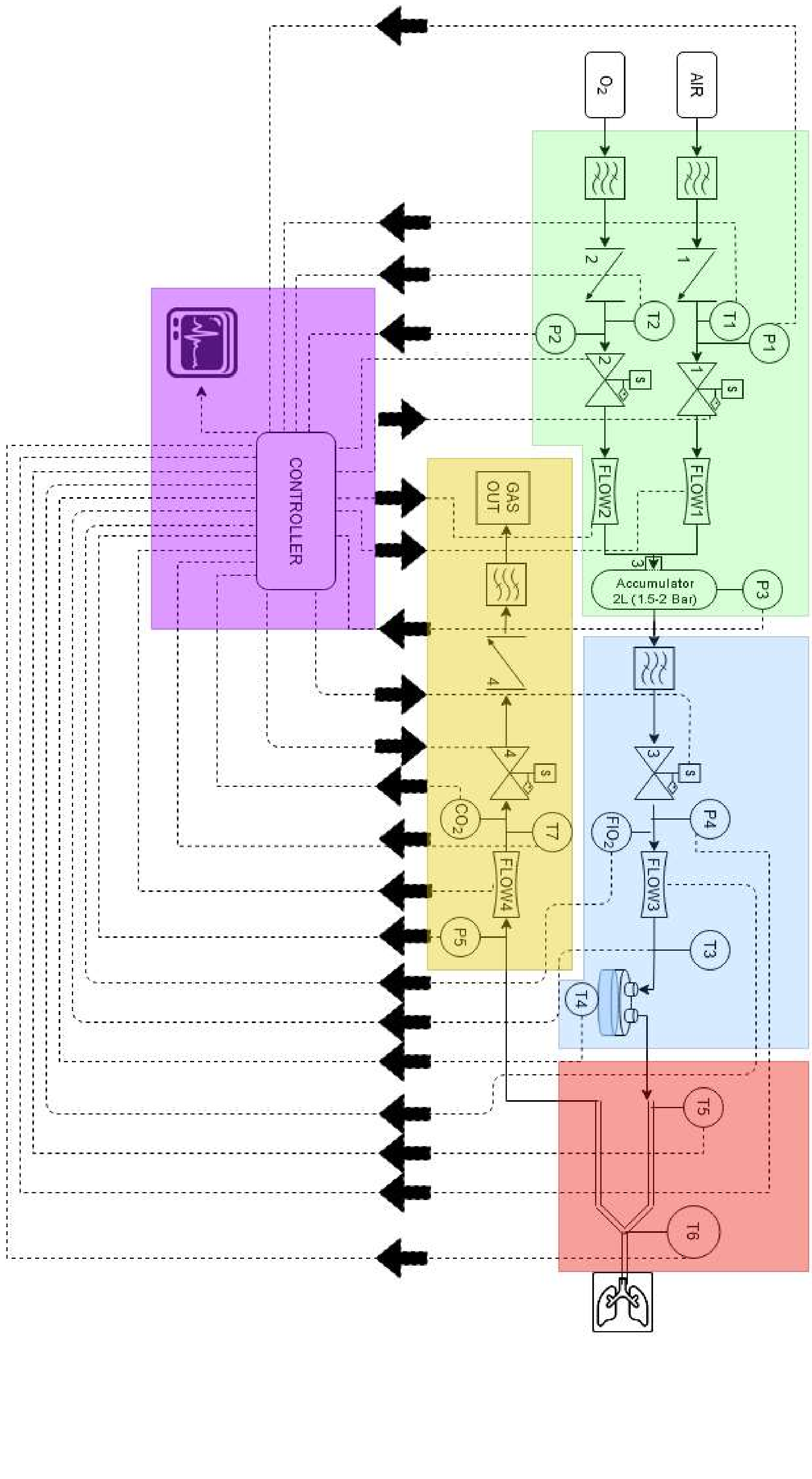
Humidifier



Temperature Sensor

Display

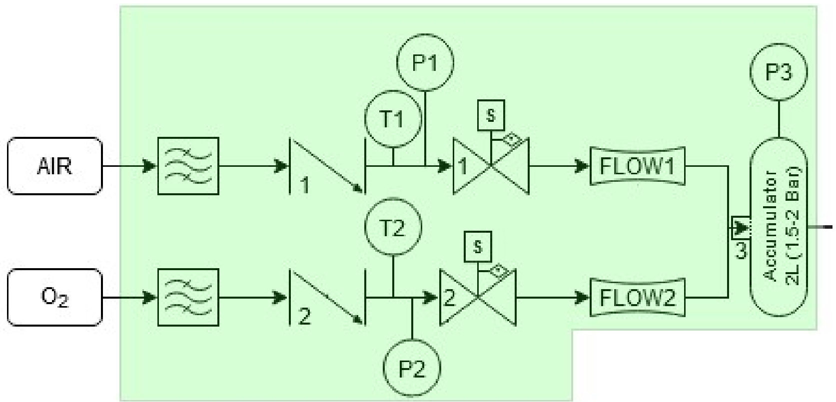
FULL SCHEMATIC



SCHEMATIC DESCRIPTION

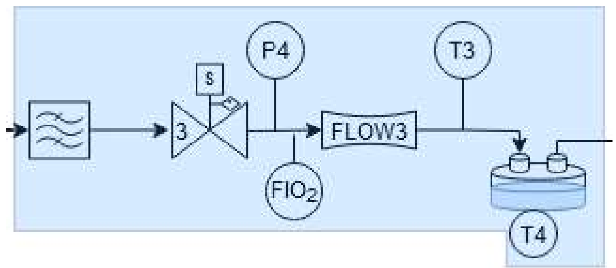
For convenience, the whole device may be sub divided into the following 5 categories:

- GAS METERING ASSEMBLY: Following diagram represents the gas metering assembly section from the whole schematic.



The gas metering assembly shall control the gas input to the ventilator and pre-mix the gases to obtain the FIO_2 level required. The design proposed allows for intake from both a central gas facility or individual gas cylinders. The gas inlet may be at varying pressures and shall be passed through medical gas filters to minimize gas contamination and also prevent damage (choking) to the other expensive components of the ventilator. The gas shall then be passed through a check valve/regulator. This would avoid the back flow of the gas from the device to the source and also normalize the pressure of the inflow gas. By doing so the sensors and valves further down the assembly shall function accurately as the risk of sudden pressure spikes shall be nullified. Once the stream flows through the check valve (at a constant pressure of about 50 psig), the pressure and temperature of the inflowing gas is measured via sensors T1 and P1 for air supply and T2 and P2 for oxygen gas supply. The temperature of the gas is essential as it allows for precise calculation of the gas density necessary for accurate gas metering, while the pressure sensor enables the clinician to be alerted about low level of medical air and oxygen from the source (the case when the pressure decreases below the previously stated range). The gas then passes through the mass flow meter assembly, consisting of the solenoid valve and gas flow sensor operating in a feedback loop. The flowrate here shall be determined by several ventilation parameters such as FIO_2, mode of ventilation, total tidal volume, peak inspiratory pressure and plateau inspiratory pressure. This whole MFM (mass flow meter) assembly shall also work with the pressure sensor P3 on the accumulator in a feedback control loop so as to maintain a constant accumulator pressure of 2.5-3 Bar. After being metered by the MFM, the gas mixture is then stored in the accumulator. The accumulator has an inbuilt check valve to avoid flow in backward direction. The accumulator allows for effective gas mixing. The accumulator shall also have a pressure sensor which would allow the system to maintain a constant pressure even with a variable gas removal.

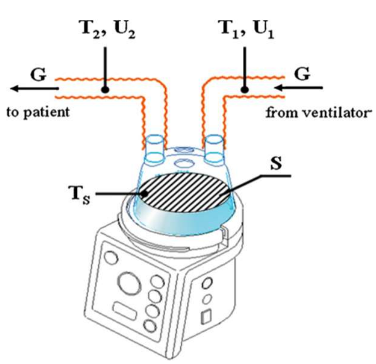
- <u>INSPIRATORY ASSEMBLY</u>: Following diagram represents the inspiratory assembly section from the whole schematic.



The inspiratory assembly shall control the gas mixture flow to the patient and continually monitors for P_{airway} drops for modes of ventilation that require a trigger variable. Additionally, the inspiratory assembly is also for humidifying and heating the inflowing gas into the patient circuit. Once the gas mixture is homogenous and at an elevated pressure, upon requirement by the patient, the gas passes through another filter. This medical filter is installed to avoid any internal debris from the accumulator tank to flow into the inspiratory assembly. The airway is monitored for pressure drops by the pressure sensor P4 for triggering the metering process. Once triggered, the gas is metered by another MFM assembly consisting of solenoid valve 3 and flow sensor 3. Within this line, as a precautionary measure, the concentration of oxygen in the inflowing gas is also recorded and compared with the set FIO_2 valve to ensure proper working of the gas metering assembly. Once metered in accordance with the mode of ventilation and other pre-determined ventilation parameters, the gas is then humidified in the humidifier. According to the model previously proposed, the humidity of the exit gas from the humidifier can be calculated as follows:

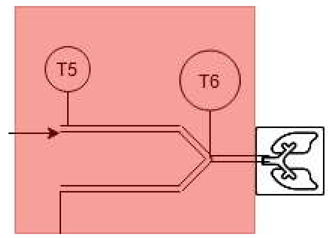
$$U_2 = \frac{\{-G[C^U_{P,2}(T_2 - T_o) - C^U_{P,1}(T_1 - T_o)] + G\lambda U_1 + K_Y U_s S[\lambda + C_{P,w}(T_s - T_o)] + S[h(T_s - T_2)]\}}{\{G\lambda + K_Y S[\lambda + C_{P,w}(T_s - T_o)]\}}$$

For further detail on the model prepared refer to the document titled “Modelling Humidifier”. As mentioned above, the outlet humidity is a function of the inherent properties of the inflowing gas (which may be calculated by the constitutive relations proposed in the same document) and the physical conditions. These have been illustrated in the diagram below:



Since the inflow gas velocity (from the MFM assembly in the inspiratory section), outflow gas velocity (approximately the same in case of a pass over humidifier), and the inflow temperature (monitored by the temperature sensor T3 in the above schematic) shall be known, by fixing outflow temperature, the level of humidity may be controlled by changing base plate temperature. The baseplate temperature shall be monitored by the temperature sensor T4 in this section of the ventilator.

- PATIENT CIRCUIT ASSEMBLY: Following diagram represents the patient circuit assembly section from the whole schematic.



The patient circuit shall deliver the humidified, heated and metered gas to the patient via the ETT (endo-tracheal tube) and remove the exhaled gas from the patient lungs and supply it back into the ventilator for filtering before exhausted from the device. An actual patient circuit has two temperature probe insertions (as shown in the diagram below).

The temperature probe insertions shall allow for monitoring the temperature through the entirety of the circuit. The circuit also comes with inbuilt heated wires so as to avoid (i). temperature decrement (as the circuit ranges from 1-2 meters in length, significant enough to allow for temperature drops whilst transit) and (ii). Avoid rainout as a result of the mentioned decrement. In the schematic, these temperature sensors have been represented by T5 and T6.

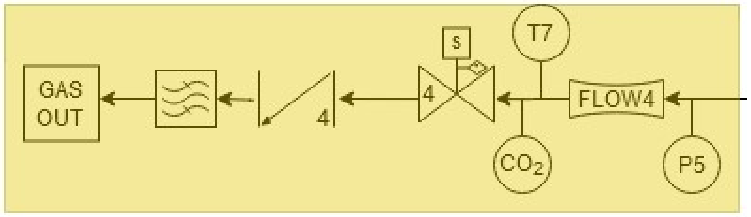
Patient circuit tubes:

Patient Height	IBW (Kg)	Trach. tube ID (mm)	Breathing circuit tube OD (mm)
30 to 150 cm	3 to 48	3 to 7	15
>130 cm	>30	>=5	22

The IBW, based on Pennsylvania Medical Center (adults) and Traub SL. Am J Hosp Pharm 1980 (pediatric patients), is calculated as follows:
IBW: Ideal Body Weight [kg]
BH: Body Height [cm]
BH <=70 cm
IBW = 0.125 x BH – 0.75
70 < BH <= 128
IBW = 0.0037 x BH2 – 0.4018 x BH + 18.62
BH >=129
Male IBW = 0.9079 x BH – 88.022
Female IBW = 0.9049 x BH – 92.006

MOC –FLEXI TUBES

- <u>EXPIRATORY ASSEMBLY</u>: Following diagram represents the expiratory assembly section from the whole schematic.



The expiratory assembly section extracts the expired gas from the patient circuit and filters is before exhausting it into the atmosphere to avoid pathogenic infection to the clinician. The flow of exhaled gas from the patient is also controlled in order to maintain a pre-set positive end expiratory pressure (PEEP, by the clinician). The outflow gas pressure is measured by the pressure sensor P5 before it flows into the MFM assembly. This is done as it shall work in communication with the MFM to maintain a minimum pressure in the patient lung. In the case of diseases such as COVID-19, the surfactant secretion in the alveoli of the patient is inhibited leading to acute respiratory distress syndrome (ARDS). Hence in order to avoid alveoli collapse, and to maintain maximum number of employed alveoli, a PEEP is always maintained. The flow sensor FLOW4 is shall also work in communication with the solenoid valve forming the MFM assembly in this section. The temperature of the exit gas is also measured to prevent rainout in the exhaust of the ventilator. As the temperature of the exhaust gases decreases to the dew point temperature of the exhaled gas, the moisture starts to rain out in form of liquid. In order to avoid that, the heated patient circuit also comes equipped with a heating wire in the expiratory end of the tube (double heated wire). This keeps them temperature of the exit gas above dew point.

As a precautionary measure, the CO_2 is also monitored to determine lung functionality. The gas flow is then controlled by the solenoid valve in the MFM assembly. To avoid back flow, the gas passes through a check valve and then through the exhaust filter.

COMPONENT SPECIFICATIONS REQUIRED

The component specifications are listed below:

COMPONENT TYPE	COMP. NAME	RANGE REQUIRED	FURTHER SPECIFICATIONS
Pressure Sensors	P1	0-60PSI	Temperature – 0 to 50˚C RH- 0 to 50%
	P2		
	P3		
	P4	0-120cmH_2O	Temperature – 0 to 50˚C RH- 0 to 100%
	P5		
Temperature Sensors	T1	0-50°C	RH – 0 to 100%
	T2		
	T3		
	T4		
	T5	20-45°C	Comes with the patient Circuit
	T6		
	T7	0-50°C	RH – 0 to 100%
Flow Sensors	FLOW 1	0-300 LPM	Withstand upto 50psi Temperature – 0 to 50˚C RH- 0 to 50%
	FLOW 2		
	FLOW 3	0-180 LPM	Withstand upto 120cmH20 Temperature – 0 to 50˚C RH- 0 to 100%
	FLOW 4		
Proportional Solenoid Valve	S 1	0 – 300 LPM	Resolution – 0.5 LPM Withstand upto 50psi Temperature – 0 to 50˚C RH- 0 to 50%
	S 2		
	S 3	0-180 LPM	Resolution – 0.5 LPM Withstand upto 120cmH20 Temperature – 0 to 50˚C RH- 0 to 50%
	S 4		
Variable Check Valve	1	0-2200 PSI Inlet	
	2		
	3	0-75 PSI Inlet	
	4	120 cmH_2O Inlet	
Oxygen Sensor	FIO_2	120 cmH_2O	Withstand upto 120cmH20 Temperature – 0 to 50˚C
CO_2 Sensor	CO_2	120 cmH_2O	Withstand upto 120cmH20 Temperature – 0 to 50˚C RH- 0 to 100%