Manawa Ora

Technical Note after Agorize submission

Manawa Ora Team

2020-04-03

Contents

Summary

This note is a collection of documents that were part of the submission in the Agorize Competition: "Code Life Ventilator Challenge". The team name for that competition was *Manawa Ora*, and that name is also used herein for the team and the design.

Our design goals were to make and design a simple ventilator that:

- could be made anywhere in the world
- used parts with supply chains outside the medical industry

Our main constraint was that we started the design only a couple of days before New Zealand went into lock-down, and therefore only had the parts we'd bought the day before stores closed.

The current version has the following "features":

- 1" (25mm) BSP irrigation fittings provide gas conveyance, structural integrity, and sensor housing. These can be purchased from local suppliers in (plastic or stainless steel) or 3D-printed.
- Air and oxygen flow are sensed using automotive Mass Air Flow Sensors. The ratio of these flows provides measurement of FiO2.
- An expiration valve closes during inspiration and when expiration pressure falls below PEEP. High PEEP pressures can be provided by introducing small amounts of air via the inspriation valves.
- The valving logic removes the need for a flap valve at the Y-piece.
- Wireless communication of measured data and control commands. This allows for multiple viewers (e.g. tablet, PC, centralised PC, decentralised).
- Filters and humidifier are separate units.

The design relies on the supply of clean compressed air and oxygen. This choice has been made to a) keep the machine simple, and b) because we think large gas banks and/or compressors are a more efficient way to supply several or many ventilators.

Status

The prototype is built and satisfies most of the Agorize competition goals. It is, however, not ready for production. The big picture of outstanding work follows:

Missing/incomplete feature	Difficulty
Add alarms to code and GUI	Simple
Sort required security for wireless communication and control	Depends on reuirements
Add correct fittings for hospital air/O2 supply	Simple
Improve flutter in valve control	Medium
Improve/test PEEP control when there is vacuum connected to expiration exhaust	Medium
Add a 230 v plug and main switch	Simple

Many of these aspects could be improved by having technical support from appropriately trained and experienced medical personnel.

Design

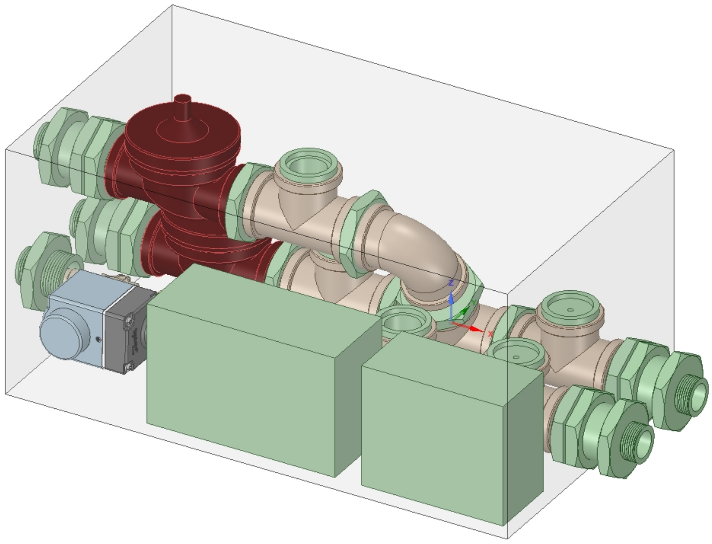


Figure 1: Isometric depiction of ventilator. The cabinet is semi-transparent, and the two ports on the front of the machine are the patient-side inspiration (right) and expiration (left) ports

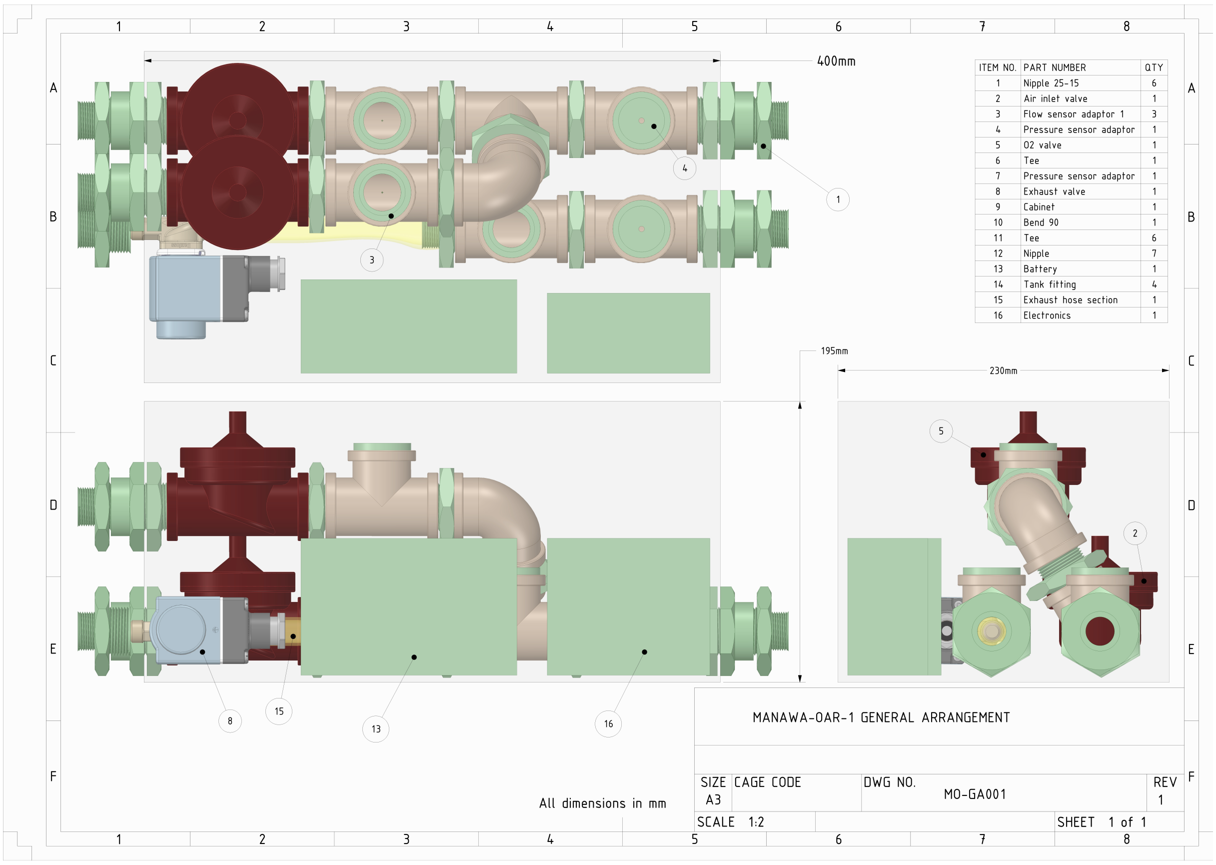


Figure 2: Layout of the proposed ventilator

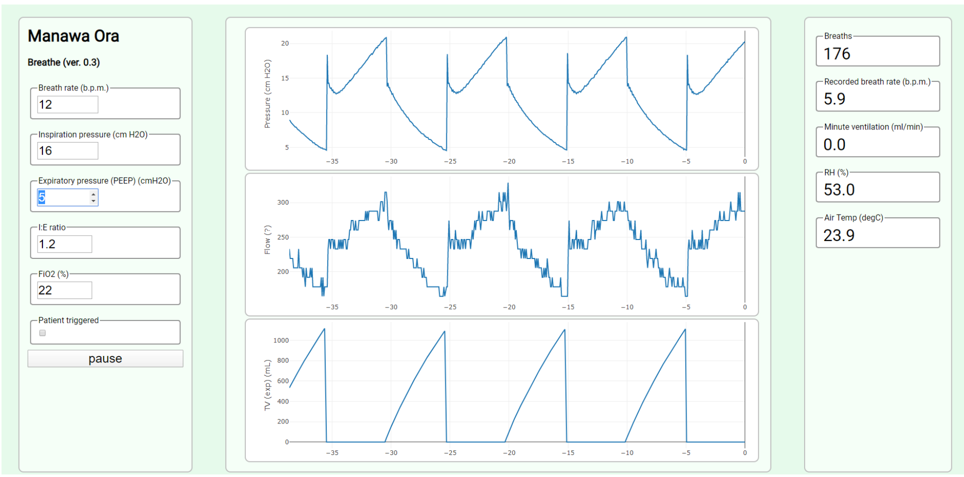


Figure 3: Operator user interface. The unit does not have any screen of it's own: it relies on wireless communication to other computers and devices.

Prototype

The following two photos show the prototype that was made.

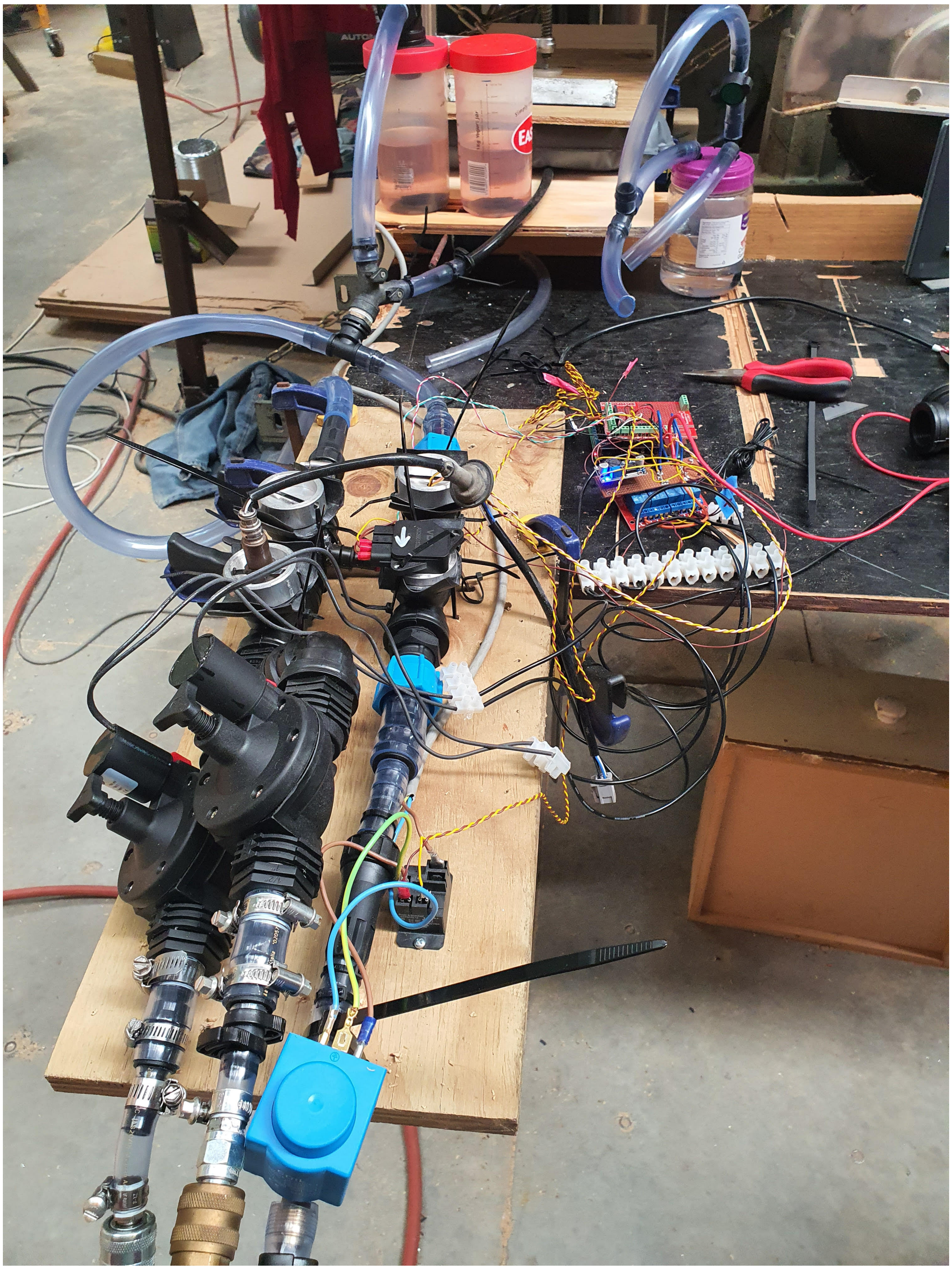


Figure 4: Ventilator prototype. The rear of the machine is in the foreground: air inlet, oxygen inlet, expriation exhaust. The middle ground shows the inspiration and expiration conveyances, sensors, and electronics. In the background is the tidal volume calibration (EasyYo) containers, the patient, and the bubble humidifier. The patient is simulated by a dry bag restrained by a weighted and sprung plywood hinge. Patient compliance is reduced by increasing the spring stiffness.

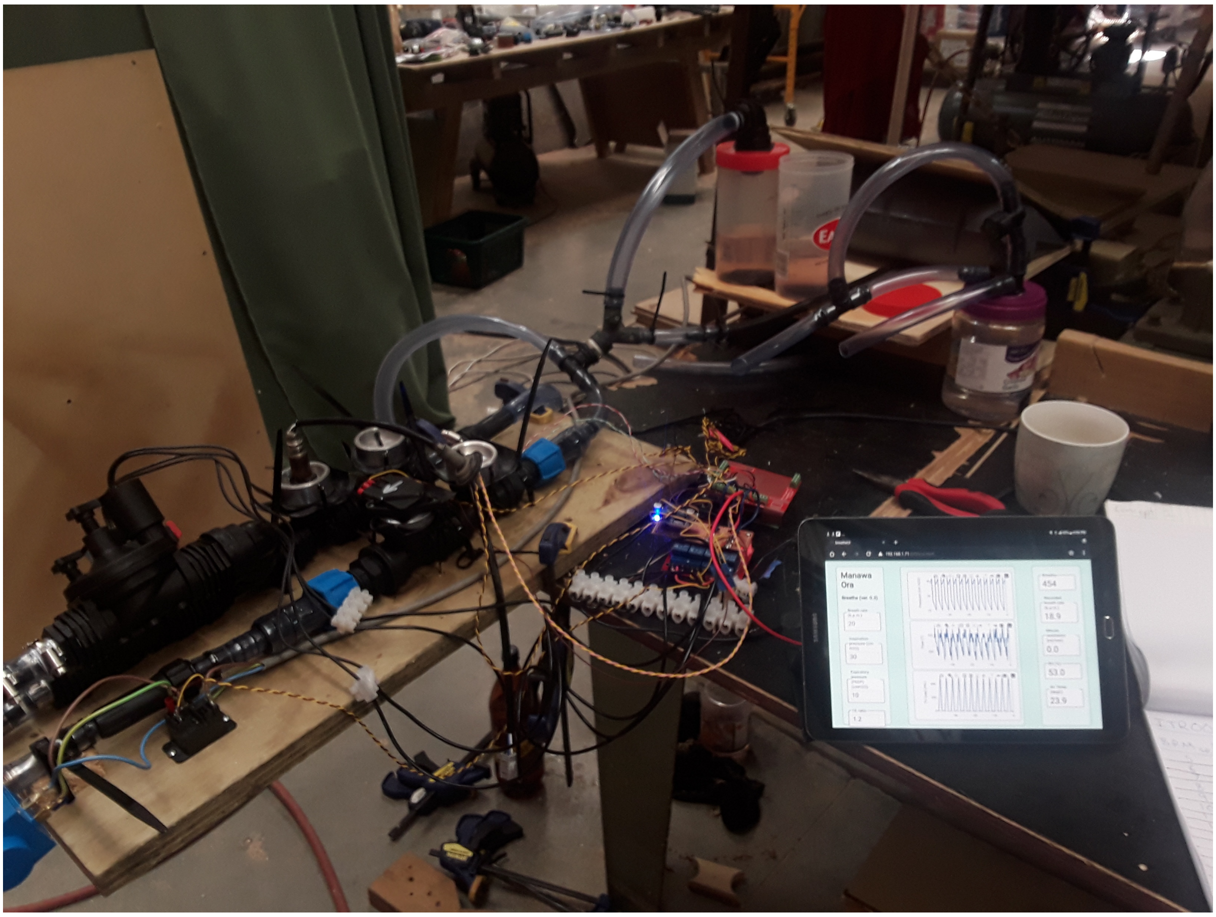


Figure 5: Operator interface on a tablet

Appendices

Assembly instructions

1. Assemble pipe fittings and solenoid valves for inspiratory line as per MO-GA001. Take care to ensure thread tape is used on all male threads. Tighten fittings hand tight and then a further 3/4 turn or more using a spanner.
2. Assemble pipe fittings and solenoid valve for expiratory line as per MO-GA001. Take care to ensure thread tape is used on all male threads. Tighten fittings hand tight and then a further 3/4 turn or more using a spanner.
3. Lower expiratory line into housing. Mount tank fittings onto housing and expiratory line as per MO-GA001.
4. Lower inspiratory line into housing. Mount Tank fittings onto housing and inspiratory line as per MO-GA001.
5. Mount all sensors in T-junctions as per MO-GA001 & MO-PID-001. Ensure sensors are mounted using correctly modified 1" BSP blanking plugs.
6. Mount “raspberry pi controller”, “12V Relay Board”, “12-5V DC-DC” converter and “230V AC 12V DC UPS” as per MO-E-001
7. Mount the above electrical controls into ventilator housing as per MO-GA001
8. Connect solenoid valves and flow sensors to 12V Relay Board as per MO-E-001 & MO-PID-001
9. Connect humidity and pressure sensors to 5V rail on Raspberry Pi Controller as per MO-E-002 & MO-PID-001
10. Once device has been fully assembled. Consult MO-ITP-001 for Factory acceptance testing

Maintenance and cleaning instructions

Cleaning

Exterior

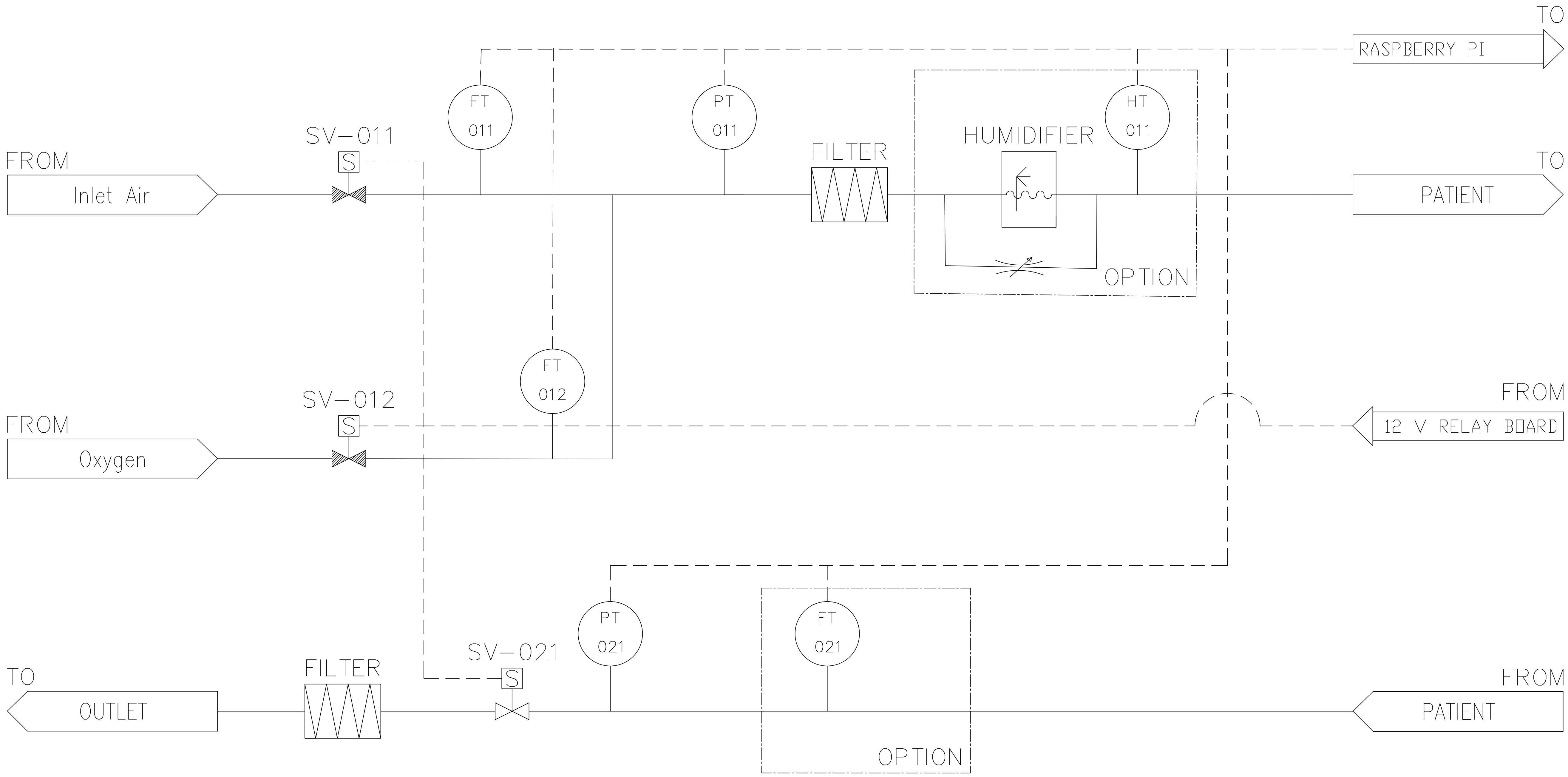
1. Disconnect hoses and filters
2. Wipe the outside of the cabinet with a damp clean cloth. Light solvents and detergents may be used

Interior

1. Clean the exterior, do not connect hoses until interior cleaning is complete
2. Connect a 22mm hose to the expiration connector on the front of the unit
3. Connect the expiration connector at the rear of the unit to a watertight receptacle
4. If a flow sensor is fitted to the expiration channel (this is an optional extra), then this sensor must be removed prior to the following step. Also prior to the following step, screw the supplied blind fitting in place of the flow sensor.
5. Flush ten (10) litres of water-disinfectant solution through, from the front to the rear, of the expiration channel
6. NEVER FLUSH LIQUIDS THROUGH THE INSPIRATION SIDE OF THE MACHINE.

Maintenance

1. The filters and humidifier are external to the unit and should be maintained/replaced as required by the manufacturer
2. The 12v solenoids should be replaced every 4000 hours.

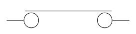


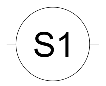
			SCALE	NTS		Project CODE LIFE VENTILATOR CHALLENGE MANAWA ORA	Description VENTILATOR DESIGN PROCESS AND INSTRUMENT DIAGRAM	DRAWING No. MO-PID-001
			DESIGNED	Joseph Jury	03/20			
			DRAWN	Miriam Odlin	03/20			
No.	AMENDMENTS	DATE	CHECKED	Ra Cleave	03/20			SHEET No 001 OF 001

LEGEND OF SYMBOLS

ELECTRICAL

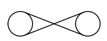

NORMALLY OPEN CONTACT

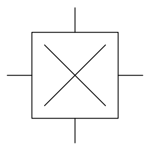

NORMALLY OPEN CONTACT



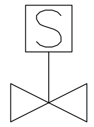
SOLENOID

5A

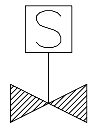

FUSE


SENSOR

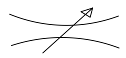
PIPING

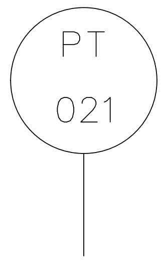


SOLENOID VALVE
NORMALLY OPEN

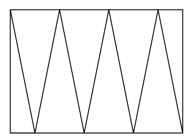


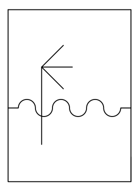
SOLENOID VALVE
NORMALLY CLOSED


MANUALLY VARIABLE
FLOW RESTRICTOR



TRANSDUCER


FILTER


HUMIDIFIER

– – – – – SIGNAL

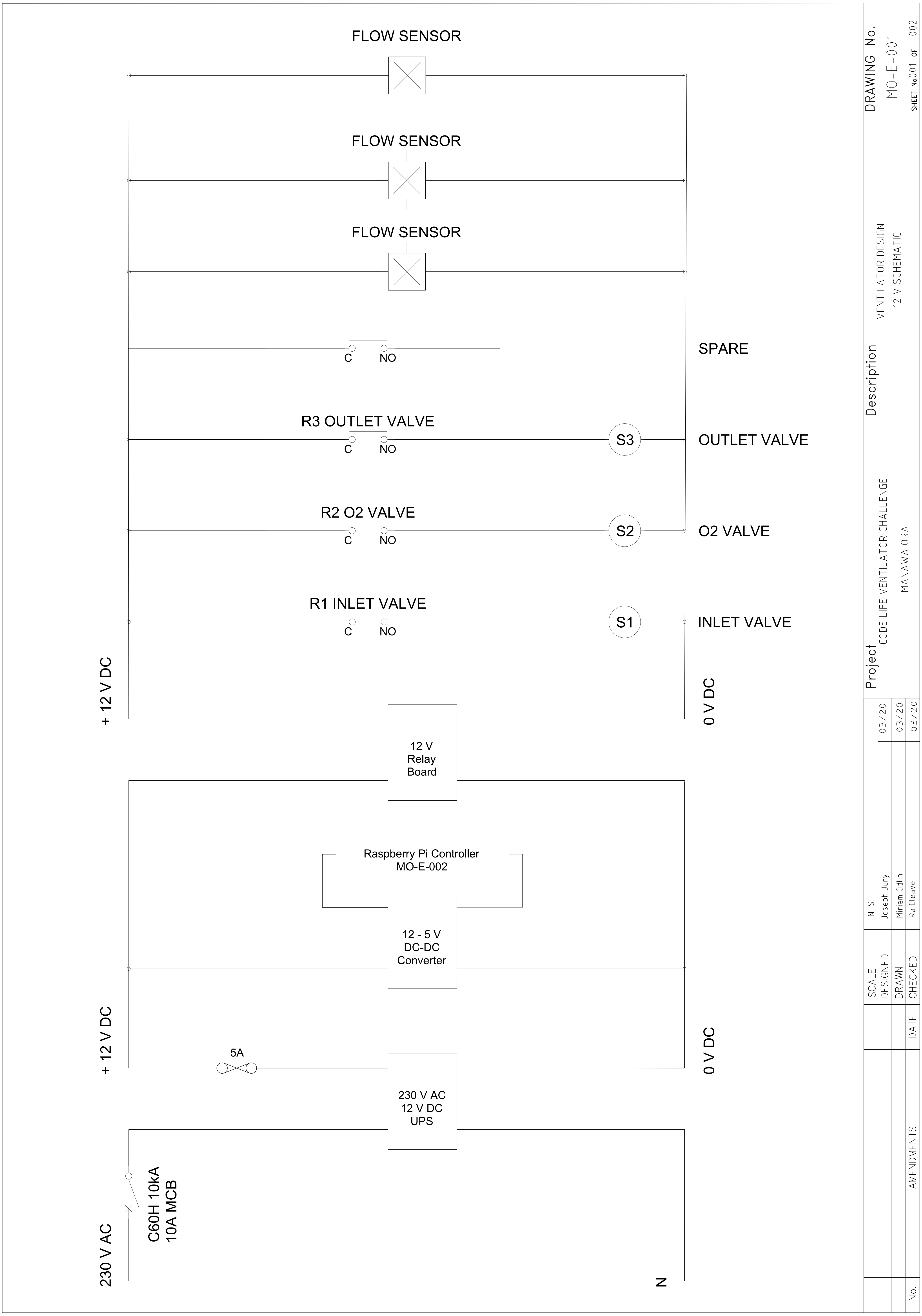
———— PIPING

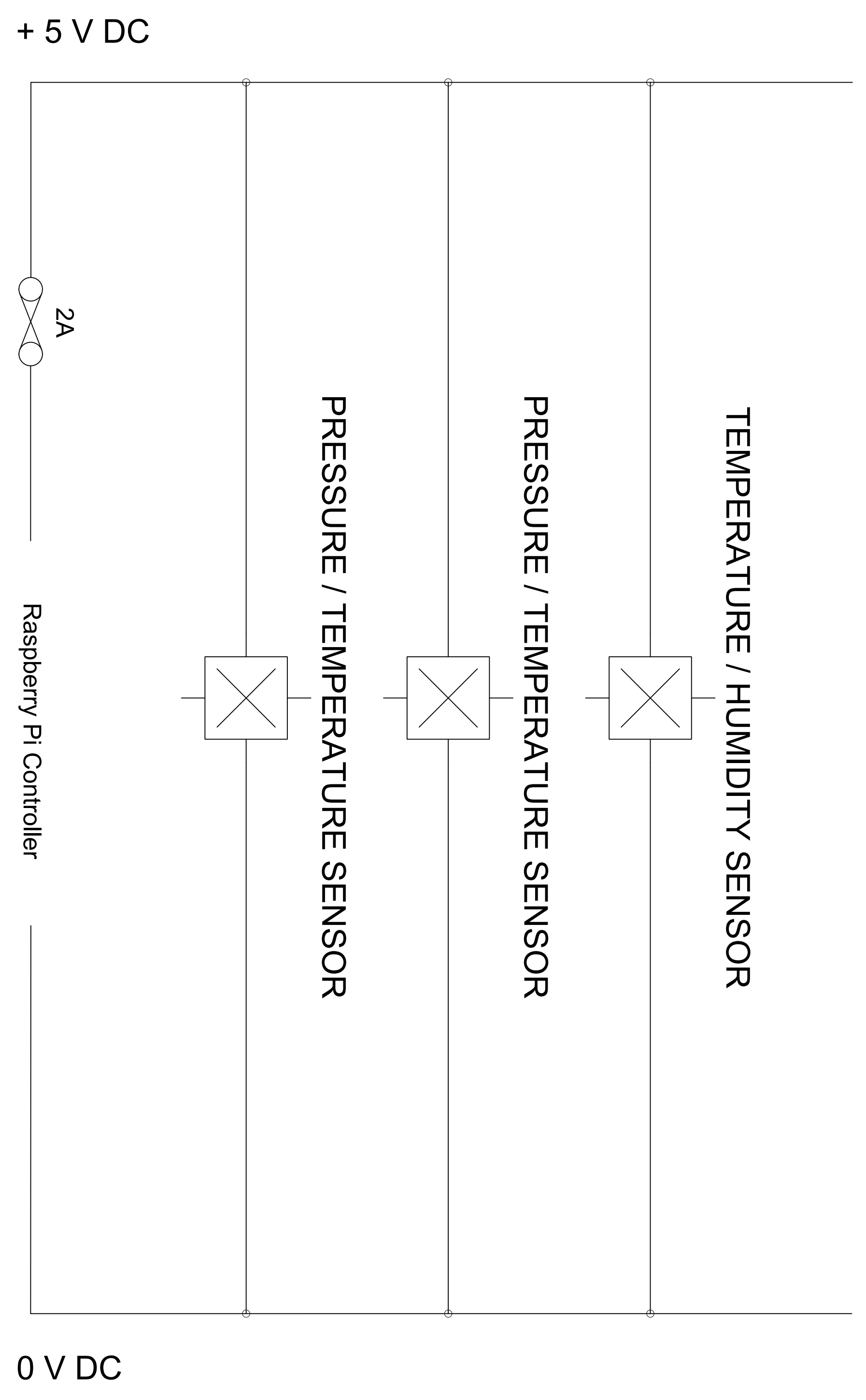
			SCALE	NTS	
			DESIGNED	Joseph Jury	03/20
			DRAWN	Miriam Odlin	03/20
No.	AMENDMENTS	DATE	CHECKED	Ra Cleave	03/20

Project
CODE LIFE VENTILATOR CHALLENGE
MANAWA ORA

Description
VENTILATOR DESIGN
LEGEND OF SYMBOLS

DRAWING No.
MO-LS-001
SHEET No 001 OF 001


FLOW SENSOR
FLOW SENSOR
FLOW SENSOR
C
NO
SPARE
R3 OUTLET VALVE
C
NO
S3
OUTLET VALVE
R2 O2 VALVE
C
NO
S2
O2 VALVE
R1 INLET VALVE
C
NO
S1
INLET VALVE
+ 12 V DC
0 V DC
12 V Relay Board
Raspberry Pi Controller MO-E-002
12 - 5 V DC-DC Converter
+ 12 V DC
5A
0 V DC
230 V AC 12 V DC UPS
230 V AC
C60H 10kA 10A MCB
N
DRAWING No.
MO-E-001
SHEET No 001 of 002
Description
VENTILATOR DESIGN
12 V SCHEMATIC
Project
CODE LIFE VENTILATOR CHALLENGE
MANAWA ORA
SCALE
NTS
DESIGNED
Joseph Jury
03/20
DRAWN
Miriam Odlin
03/20
CHECKED
Ra Cleave
03/20
DATE
AMENDMENTS
No.



			SCALE	NTS	
			DESIGNED	Joseph Jury	03/20
			DRAWN	Miriam Odlin	03/20
No.	AMENDMENTS	DATE	CHECKED	Ra Cleave	03/20

Project: CODE LIFE VENTILATOR CHALLENGE

MANAWA ORA

Description: VENTILATOR DESIGN

5 V SCHEMATIC

DRAWING No. MO-E-002

SHEET No 002 OF 002

Function	**Tag**	**Instrument**	**I/O**	**PI address**	**Bus**	**PI Terminal**
Inspiration pressure / temperature sensor	PT-011				I2C-1	3, 5
Temp / humidity sensor	HT-011					4
Expiration pressure / temperature sensor	PT-021				I2C-4	24,25
Air flow sensor	FT-011		analogue in		A-D card	3, 5
Oxygen flow sensor	FT-012		analogue in		A-D card	3, 5
Expiration flow sensor	FT-021		analogue in		A-D card	3, 5
Air inlet valve	SV-011	R1 relay board	digital out			17
Oxygen inlet valve	SV-012	R2 relay board	digital out			18
Expiration valve	SV-021	R3 relay board	digital out			25

MANUFACTURING BOM – Basic model

ITEM	DESCRIPTION	PART NUMBER	QTY	UNIT COST	NZ SUPPLIER	PRICE (NZD)	Price (USD)	Supply industry
1	25mm BSP Female Tee	(T25F)	3	2.97	The Water Sprinkler Shop	8.91	5.35	Irrigation/plumbing
2	25mm BSP Female Elbow	(7208/25)	2	2.25	The Water Sprinkler Shop	4.50	2.70	Irrigation/plumbing
3	25mm BSP Male Nipple	(NP-25)	6	0.91	The Water Sprinkler Shop	5.46	3.28	Irrigation/plumbing
4	12V 25mm normally closed solenoid valves	(SV25-12)	2	30.36	The Water Sprinkler Shop	60.72	36.43	Irrigation/plumbing
5	25x15mm Reducing Bush	HRB2515	4	1.77	Irrigation Express	7.08	4.25	Irrigation/plumbing
6	Tank fittings	HTFFT25	4	7.41	Irrigation Express	29.64	17.78	Irrigation/plumbing
7	Solenoid valve, EVR 6 - normally open	032L8085	1	72.5	Philip Smith	72.50	43.50	Electrical supplies
8	Solenoid coil, BE230AS	018F6701	1	72.5	Philip Smith	72.50	43.50	Electrical supplies
9	Large particle filter	8-16/9W4P	1	1.9	Irrigation Express	1.90	1.14	Irrigation/plumbing
10	Temp/Humidity sensor	DHT12	1	14.9	Jaycar	14.90	8.94	Electronic supplies
11	Digital barometric pressure sensor	BMP180	2	22.9	Jaycar	45.80	27.48	Electronic supplies
12	Raspberry Pi 3B+	3B+	1	65	Jaycar	65.00	39.00	Electronic supplies
13	Raspberry Pi shield and ADC	XC9050	1	17.9	Jaycar	17.90	10.74	Electronic supplies
14	Raspberry Pi GPIO expansion	XC9040	1	16.9	Jaycar	16.90	10.14	Electronic supplies
15	Relay board 4 ch 12v	XC4419	1	17.9	Jaycar	17.90	10.74	Electronic supplies
16	PS with battery SLA 12v 6Ah	SB2485	1	36.9	Jaycar	36.90	22.14	Electronic supplies
17	DC-DC voltage regulator (variable)	XC4514	1	10.9	Jaycar	10.90	6.54	Electronic supplies
18	Fuelmiser Air Flow Sensor	VDO - CAF034	2	40	Repco	80.00	48.00	Automotive parts warehouse
19	Cabinet	22” toolbox	1	30	Bunnings	40.00	24.00	
				Total cost		**609.41**	**365.65**	

Validation Test

This test should be conducted on a minimum of a monthly basis. This test ensures that the machine is running consistently and accurately.

1. Setup

   a) Connect the machine to pressurised oxygen and air supplies. Leave outlet of expiratory unconnected.
   b) Connect auxiliary pressure gauges to the inspiratory outlet (patient end) and expiratory inlet (patient end).
   c) Connect inspiratory and expiratory lines to y connection and then to a dummy set of lungs that can provide compliance.

2. Pressure Set Point Testing

   a) Run the system at the IP and PEEP set points outlined in the table below. Fill in the table recording the results of the tests. Record IP and PEEP both from the output graphs and from the auxiliary gauges.

IP Set-Point (cmH20)	PEEP Set-Point (cmH20)	IP from aux gauge (cmH20)	Percentage differ-ence from set point (%)	PEEP fro-maux gauge (cmH20)	Percentage differ-ence from set point (%)	IP from graph (cmH20)	Percentage differ-ence from aux gauge (%)	PEEP from graph (cmH20)	Percentage differ-ence from aux gauge (%)	Tidal Vol-ume from graph (ml)	Notes
40	20										
35	15										
30	10										
25	5										
20	0										

1. FiO2 Set Point Testing

   a) Run the system at the FiO2 set points outlined in the table below. Fill in the table recording the results of the tests.

IP Set Point (cmH20)	PEEP Set Point (cmH2O)	FiO2 Set Point (% O2)	FiO2 Recorded from graph (% O2)	TV recorded from graph (ml)	Notes
40	20	20			
40	20	30			
40	20	40			
40	20	50			
40	20	60			
40	20	70			
40	20	80			
40	20	90			
40	20	100			

1. B.P.M Set Point Testing

    a) Run the system at the B.P.M set points outlined in the table below. Fill in the table recording the results of the tests.

IP Set Point (cmH20)	PEEP Set Point (cmH2O)	B.P.M Set Point	B.P.M Recorde d from graph	Percent age differe nce from set point to recorde d B.P.M (%)	TV recorde d from graph (ml)	Notes
40	20	5				
40	20	10				
40	20	15				
40	20	20				
40	0	5				
40	0	10				
40	0	15				

40	0	20