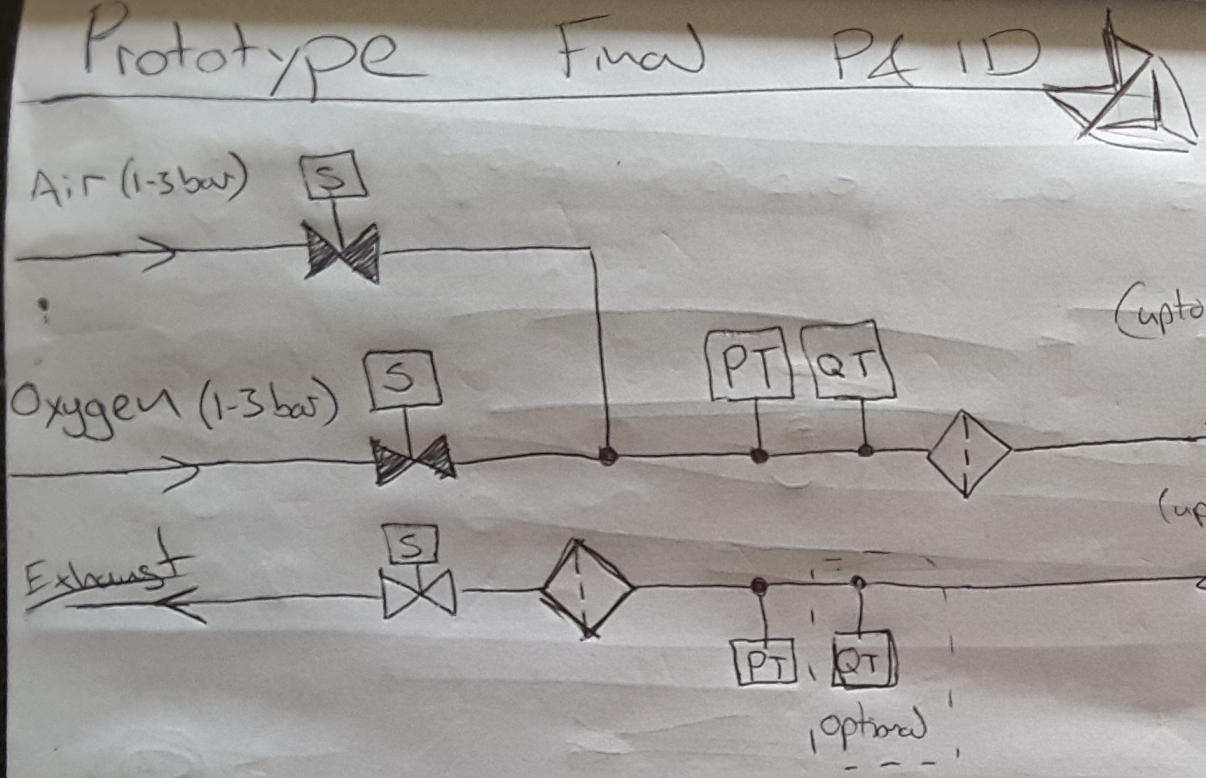
Prototype Final P&ID



Control Functions

- IP
- PEEP
- B.P.M
- ~~Fi~~ O_2 (not really)

Measurement Functions

- TV
  - Flow
  - Pressure curve
  - B.P.M & total breaths
  - Minute ventillation
- RH (if humidifier used)
- Air temp

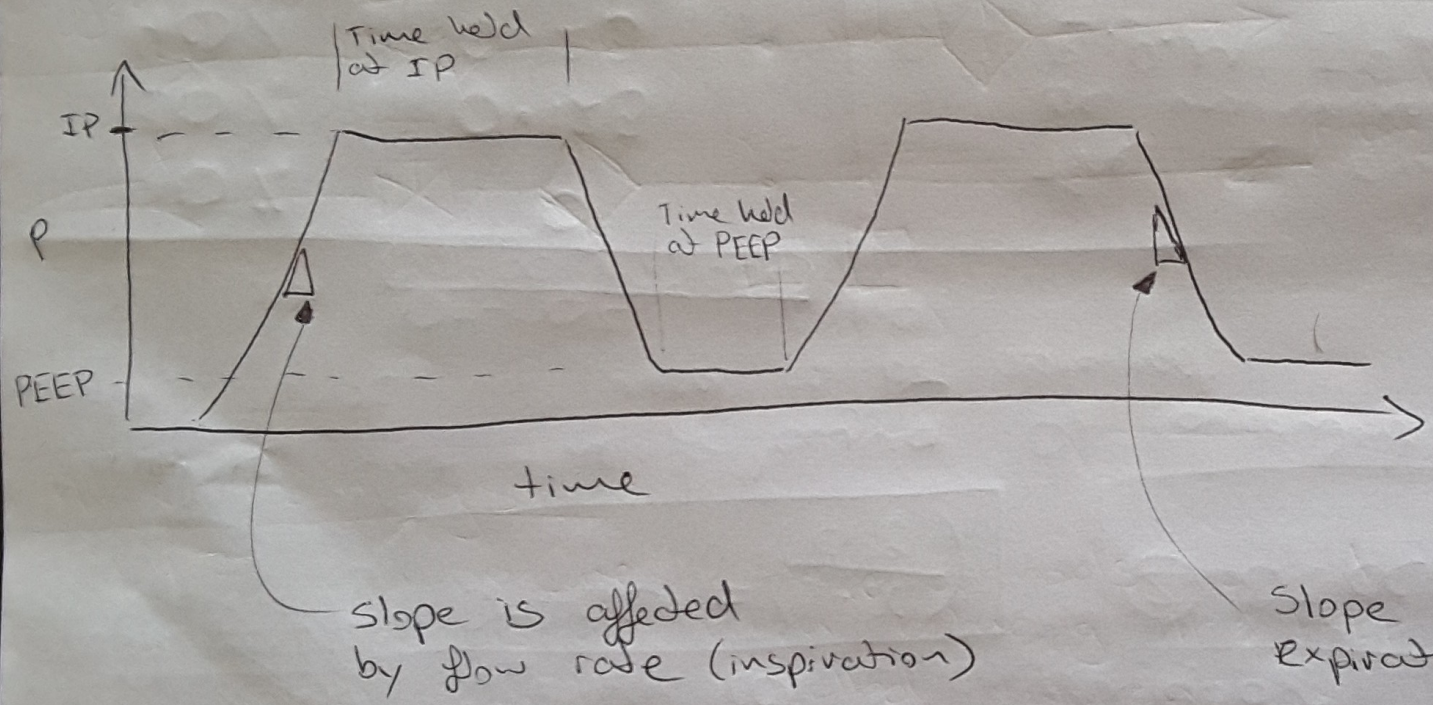
Main learnings

- Control w high pressure & on/off solenoids is hard to make smooth & consistent when balancing IP, PEEP & B.P.M
- Flow & FiO_2 can be controlled through 2 x Flow meters on the air & Oxygen lines
- System needs to be sealed well so it can control IP & PEEP better
- System would operate much smoother w variable flow control over a wide range, rather than pulsating on/off valves.
- Flow rate w 1-3 bar & irrigation solenoids is too high. need better flow control to reduce flow and make smooth control more manageable.

B.P.M: controlled using ~~either~~ flow rate & or time held at IP & PEEP.

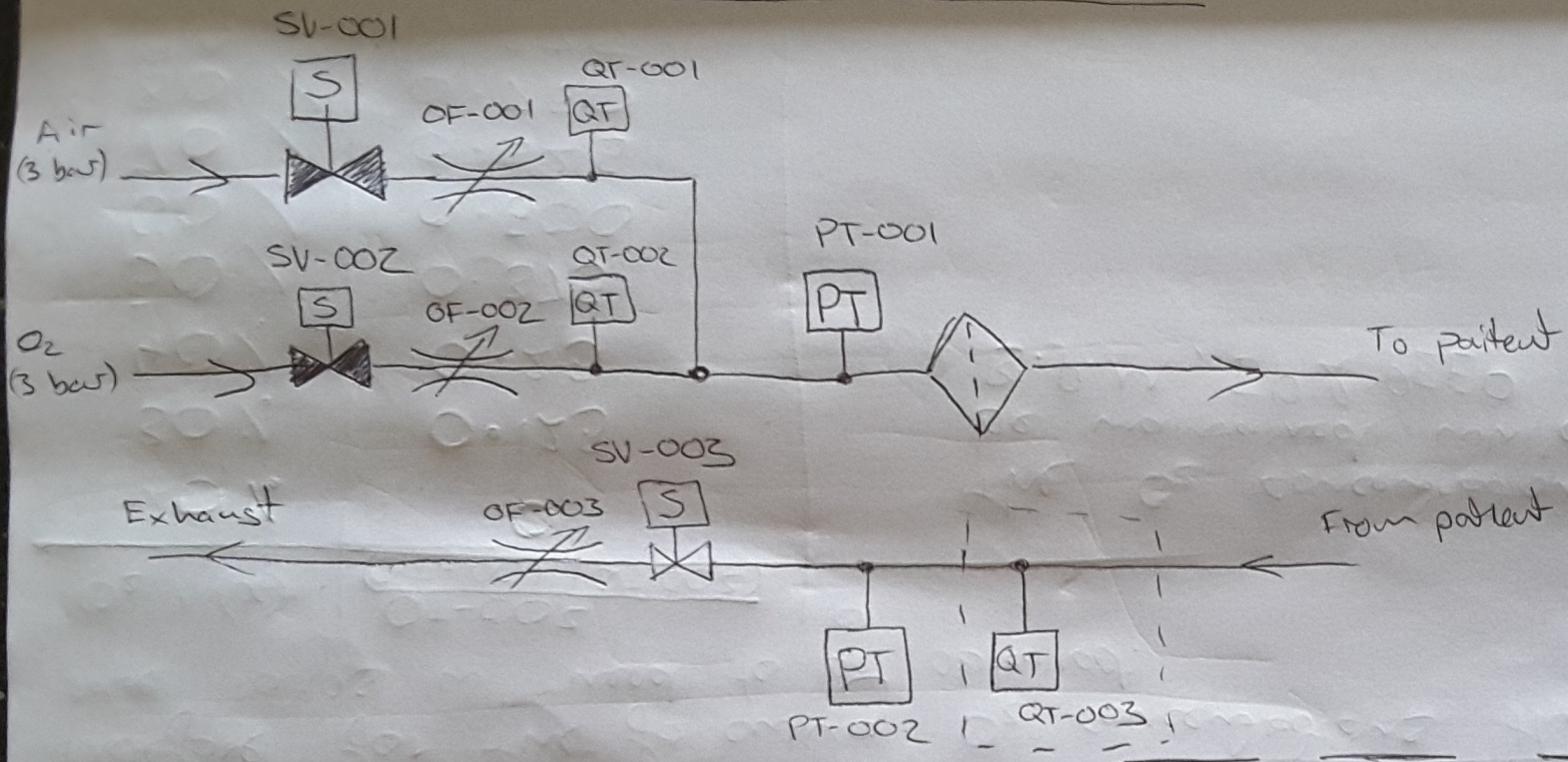
IP: controlled using on/off valve or variable flow rate

PEEP: controlled using on/off valve or variable flow rate



- Graph above shows a possible way to smoothly control IP, PEEP & B.P.M with on/off solenoid valves and some manual flow control. (see P&ID on next page).

P&ID w Manual Flow Control



Control logic

IP: SV-001 & 002 are opened if pressure is below IP. SV-001 & 002 close when IP is reached. SV-003 is closed throughout.

PEEP: SV001 & 002 are closed. SV-003 is open if pressure is above PEEP. SV-003 is closed when pressure reaches PEEP.

B.P.M: ~~This~~ This is ~~affected by~~ equal to 60/((time taken to reach IP) + (time held at IP) + (time taken to reach PEEP) + (time held at PEEP)). The time ~~held~~ held at IP & time held at PEEP can be controlled by the timing of SV-001, 002 & 003. The time to reach IP & PEEP can be manually set using OF-001, 002 & 003. Therefore B.P.M can be controlled unless (time held at IP)+(time held at PEEP) needs to be negative.

I:E ratio: This ~~can be~~ is equal to (time taken to reach IP)+(time held at IP): (time taken to reach PEEP)+(time held at PEEP). This ratio can be adjusted by changing (time held at IP):(time held at PEEP) while maintaining B.P.M.

F_iO_2: The oxygen concentration can be adjusted by altering the opening times of SV-001 & SV-002 to ensure that the flow rate ratio ensures the correct O_2 concentration. see table below:
(assuming air has 20% O_2 & Oxygen is 100% O_2)

x = required O_2 concentration

① $$QT\text{-}001 = \left(\frac{1-x}{0.8}\right)$$

② $$QT\text{-}002 = \left(1-\left(\frac{1-x}{0.8}\right)\right)$$

Therefore for the following O_2 concentrations the corresponding flow rate ratios will need to be obtained:

O_2 % (x)	$\frac{QT\text{-}002}{(QT\text{-}001 + QT\text{-}002)}$
20%	0
30%	0.125
40%	0.25
50%	0.375
60%	0.500
70%	0.625
80%	0.750
90%	0.875
100%	1

The O_2 concentration would need to be maintained while ensuring that B.P.M, IP & PEEP are maintained.

Interlocks

1. When SV-001 or SV-002 are open, SV-003 must be closed.
2. When SV-003 is open, SV-001 & SV-002 must be closed.
3. When SV-001 is open, SV-002 must be closed
4. When SV-002 is open, SV-001 must be closed.
5. ~~QT001 + QT002 = QT-003 & (calculations)~~
   IP & PEEP take presedence over B.P.M. ie. B.P.M can be automatically increased to ensure IP & PEEP are met. (Alarm should be raised)

Alarms

SP alarms: If any items such as IP, PEEP, B.P.M & FiO_2 deviate from thier set point values by more than specified amounts over a specified time frame then an Alarm for that specific item should be raised.

Over pressure: If pressure in either PT-001 or PT-002 is recorded above a specified value (ie: 60cm H_2O) then an alarm should be raised and ventilator shut down.

High B.P.M: If B.P.M goes above a set High value then an alarm should be raised.

Low B.P.M: If B.P.M goes below a set low value then an alarm should be raised.

TV asymetric: Volume inhaled is different to volume exhaled (outside a certain margin). This can only be implemented if QT-003 is used.

TV + or - : Tidal Volume increases or decreases (outside a certain margin) without any changes in other parameters.

Patient triggered breathing

- If PT-001 (or PT-002) see a pressure a set amount lower than that of the PEEP set point. ~~(with a margin~~ This should trigger an inspiration. ~~The~~ During patient triggered breathing ~~the~~ a set minimum B.P.M should still be met and an alarm raised if ~~the~~ a maximum B.P.M is exceeded. ~~A~~ A minimum B.P.M will be ensured by having an underlying cycle running which will breath for the patient if they take too long to trigger.