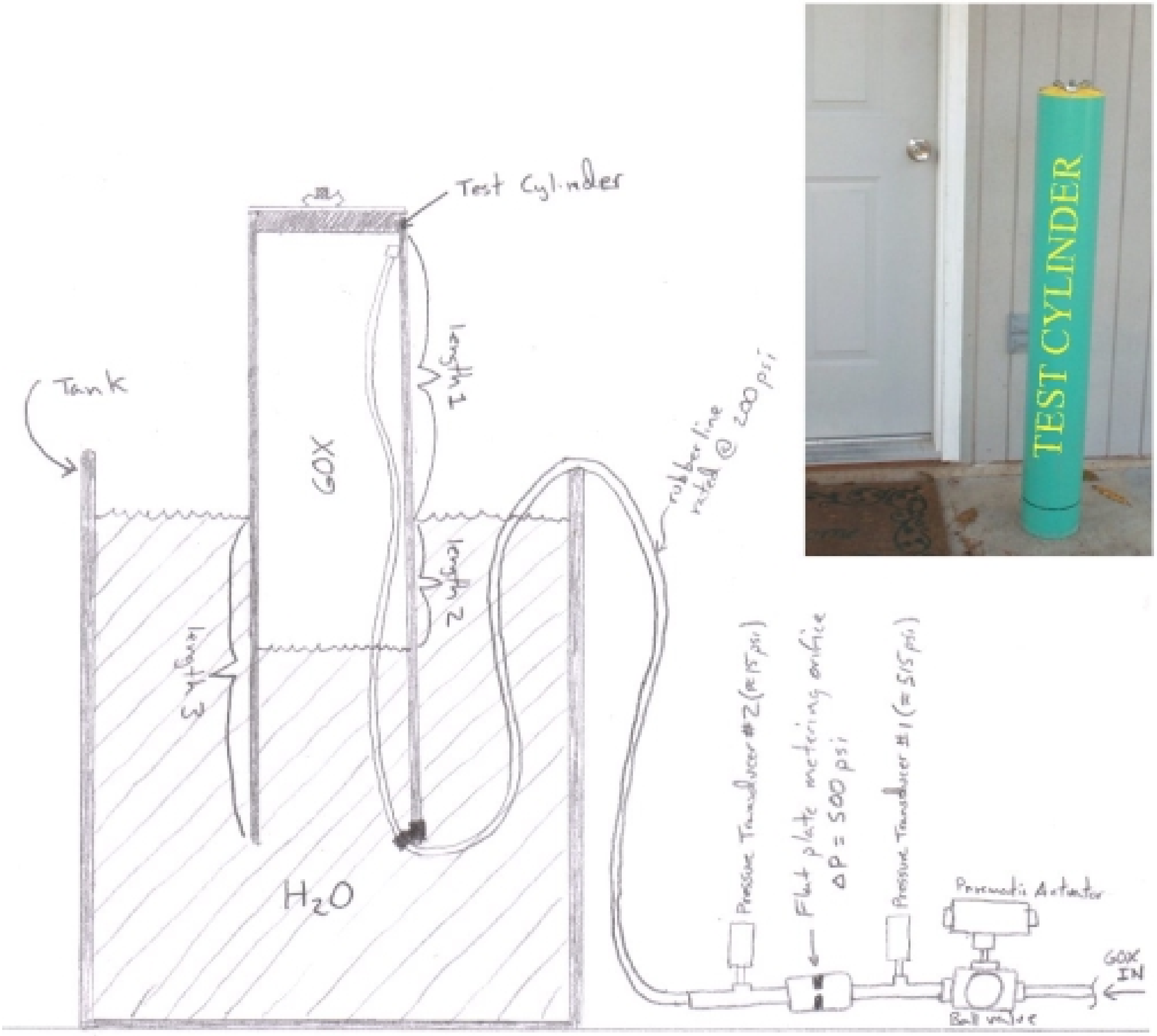
Validation of Metering Orifice - Flow Rate Test

Test Set Up



Feasibility calculations:

Test cylinder Volume:

$$lengthtotal := 43.625 \cdot in$$
$$OD := 6.3125 \cdot in$$
$$ID := 5.875 \cdot in$$
$$Volume := \frac{\pi ID^2}{4} \cdot lengthtotal$$
$$Volume = 0.684 ft^3$$

Calculated Oxygen flow rate (from metering orifice design calculations):

$$Vdot := 35\frac{ft^3}{min}$$

$$Vdot = 0.583\frac{ft^3}{s}$$

Time to completely fill submerged test cylinder:

$$Tfill := \frac{Volume}{Vdot}$$

$$Tfill = 1.173s$$

For this geometry a 1 second GOX flow test is about the best we can do.

To eliminate transient effects in the system and other difficulties such as the volumetric flow rate of GOX as the ball valve is in the process of opening. We can perform a 0.5 sec test and measure GOX volume then perform a 1.0 sec test and measure GOX volume.

By subtracting the 0.5 second test volume from the 1.0 second test volume we should be able to isolate the volumetric flow rate for a 0.5 second period at steady state. This steady state condition can be verified by looking at the pressure data for the inlet and outlet of the metering orifice and checking to see if the pressure levels are constant and similar between the two runs for all times other than the time at which the ball valve is opening and closing.

Procedure:

1) Fill the test cylinder with water.

2) Invert test cylinder and submerge in tank of water.

3) Securely connect oxygen line base of test cylinder with outlet as near as possible to top.

4) Set second stage (outlet) of oxygen regulator to approximately 515 psi.

5) Open pneumatically actuated ball valve with computer for exactly 0.50 seconds. (Capture data)

6) Stabilize test cylinder as it emerges from the tank.

7) Measure length1 directly.

8) Calculate total volume of released oxygen.

9) Dispose of captured oxygen in test cylinder.

10) Reset test cylinder by performing steps 1-3 again.

11) Open pneumatically actuated ball valve with computer for exactly 1.00 seconds. (Capture data)

12) Measure length1 directly.

13) Calculate total volume of released oxygen.

14) Verify data from both the 0.50 and 1.00 second runs looks similar.

15) Subtract oxygen volume from 0.50 second trial from the oxygen volume in the 1.00 second trial. This will be equivalent to the oxygen volume generated in a 0.50 second 'steady state' trial.

16) Divide the results in step 15 by 0.50 seconds to get the volumetric flow rate.

17) Compare this with the calculated volumetric flow rate.

Calculations:

Note: *the red colored values mean that they are undefined in MathCAD, the program from which they were imported. Ignore the color.*

Calculating oxygen volume in test cylinder from distance the test cylinder rises out of the water

Given:

$\rho h2o := 1000\frac{kg}{m^3}$	density of water
$masstc := 7kg$	mass of test cylinder
$g = 9.807\frac{m}{s^2}$	acceleration due to gravity
$Area1 := \frac{\pi ID^2}{4}$	Cross section area inside test cylinder
$Area2 := \left(\frac{\pi \cdot OD^2}{4} - \frac{\pi \cdot ID^2}{4}\right)$	Cross section area of test cylinder
length1	Distance test cylinder rises out of water (Directly measured)
length2	The length of the column of oxygen that is below the tank water surface. (calculated below)
$length3 := lengthtotal - length1$	The length of the test cylinder still submerged under the water after test.
$Volumeh2oinside := Area1 \cdot length2$	volume of displaced water inside test cylinder
$Volumeh2otc := (Area2) \cdot length3$	volume of displaced water of the test cylinder

Archimedes principle states that the force of buoyancy on an object is equal to the weight of the volume of fluid that the object displaces.

$$Fb := (Volumeh2oinside + Volumeh2otc) \cdot \rho h2o \cdot g$$

At the termination of oxygen flow into the test cylinder a force balance will exists. The upward buoyant force will be equal to the downward force of the weight of the test cylinder.

$$Fb := masstc \cdot g$$

Rewriting and solving for length2:

$$(Volumeh2oinside + Volumeh2otc) \cdot \rho h2o \cdot g := masstc \cdot g$$

$$(Volumeh2oinside + Volumeh2otc) \cdot \rho h2o := masstc$$

$$(Area1 \cdot length2 + Area2 \cdot length3) \cdot \rho h2o := masstc$$

$$length2 := \frac{\frac{masstc}{\rho h2o} - Area2 \cdot length3}{Area1}$$

$$length2 := \frac{\frac{masstc}{\rho h2o} - Area2 \cdot (lengthtotal - length1)}{Area1}$$

Therefore if we know length1 (the distance the test cylinder rises out of tank) we can calculate length2 (the length of the coulomb of oxygen below the water line) from this we can calculate the total volume of oxygen in the test cylinder.

$$Volumeoxygen := (length1 + length2) \cdot Area1$$

Performing two tests (0.50 seconds and 1.00 seconds) will give us the required data to calculate the volumetric flow rate:

Volume1	Volumeoxygen from 0.50 second run
Volume 2	Volumeoxygen from 1.00 second run

$$Vdot := \frac{Volume2 - Volume1}{deltaT}$$