rTPCflowmeter_v4

October 30, 2020

[1]:
```
import numpy as np
from scipy import interpolate
```

[2]:
```
import matplotlib.pyplot as plt
%matplotlib inline
plt.rcParams["figure.figsize"] = (15,8)
x=np.linspace(5.0,150.0,300)
```

1 Summary

The input gas flow rate calculated from the flow rate of the two indivual rotameter agrees within a sigma with the one calculated from gas mixture flow rate. This value is between 650 and 680 sccm. The return fraction after the two detectors in series is about 40%. The quencher fraction is 2% below the target.

2 Calibration

2.1 Setup for atmosphere Argon and Stainless Steel ball

https://www.mathesongas.com/pdfs/flowchart/602%20(E300)/ARGON%20602(E300)%20SS%200%20PSIG.pdf

$\phi_{\mathrm{Ar}}(z)$

[3]:
```
ro,cal=np.loadtxt('ARGON_602(E300)_SS_0_PSIG.dat',unpack=True) # sccm
arflow=interpolate.interp1d(ro, cal)
```

2.2 Setup for atmosphere Carbon Dioxide and Glass ball

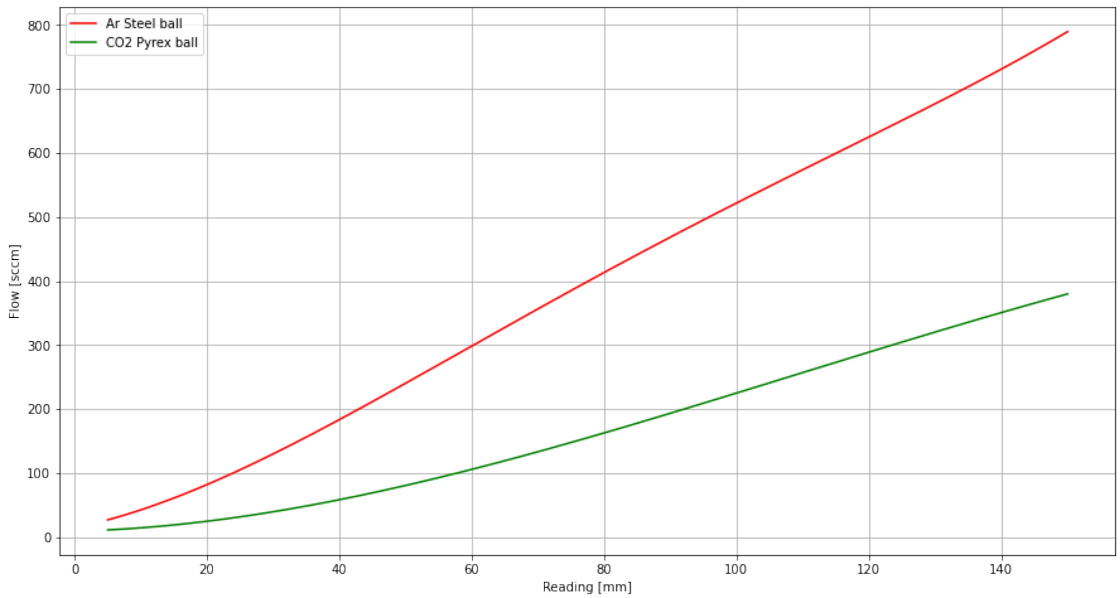
https://www.mathesongas.com/pdfs/flowchart/602%20(E300)/CARBON%20DIOXIDE%20602(E300)%20GLASS

$\phi_{\mathrm{CO_2}}(z)$

[4]:
```
ro,cal=np.loadtxt('CARBON_DIOXIDE_602(E300)_GLASS_0_PSIG.dat',unpack=True) #␣
↪sccm
co2flow=interpolate.interp1d(ro, cal)
```

2.3 Plots

[5]:
```
plt.plot(x, arflow(x), 'r', label='Ar Steel ball')
plt.plot(x, co2flow(x),'g', label='CO2 Pyrex ball')
plt.xlabel('Reading [mm]')
plt.ylabel('Flow [sccm]')
plt.grid()
plt.legend(loc='upper left')
plt.show()
```



3 Determination of the flow prior to mixing

Carbon Dioxide flow $\phi_{\mathrm{CO}_2}(z_1)$ for reading z_1

pic goes here

[6]:
```
z1=85 # reading of glass ball
inCO2Flow=co2flow(z1)
print(f'CO2 inflow {inCO2Flow:.0f} sccm')
```

```
CO2 inflow 178 sccm
```

Argon flow $\phi_{\mathrm{Ar}}(z_2)$ for reading z_2

pic goes here

[7]:
```
z2=90 # reading of stainless stell ball
inArFlow=arflow(z2)
print(f'Ar inflow {inArFlow:.0f} sccm')
```

```
Ar inflow 469 sccm
```

Total flow prior to mixing $\phi_{\mathrm{sum}} = \phi_{\mathrm{CO_2}}(z_1) + \phi_{\mathrm{Ar}}(z_2)$

[8]:
```
totFlow=inCO2Flow+inArFlow
print(f'Total input Flow {totFlow:.0f} sccm')
```

```
Total input Flow 647 sccm
```

Calculate CO_2 fraction $f_{\mathrm{CO_2}} = \frac{\phi_{\mathrm{CO_2}}(z_1)}{\phi_{\mathrm{sum}}}$

[9]:
```
co2frac=inCO2Flow/totFlow
print(f'CO2 fraction {co2frac*100:.0f}%')
```

```
CO2 fraction 28%
```

3.1 Error Estimation

This document

https://www.mathesongas.com/sites/default/files/inline-files/Model-FM-1050-High-Accuracy-Flowmeters.pdf

reports that the accuracy of the tube is ±5% of full scale flow rate.

The full scale rate for Argon using the calibration above is 790 sccm

[10]:
```
Arerr=790.*0.05
print(f'Argon flow rate measurement accuracy: {Arerr:.1f}sccm')
```

```
Argon flow rate measurement accuracy: 39.5sccm
```

The full scale rate for Argon using the calibration above is 380 sccm

[11]:
```
CO2err=380.*0.05
print(f'Carbon Dioxide flow rate measurement accuracy: {CO2err:.1f}sccm')
```

```
Carbon Dioxide flow rate measurement accuracy: 19.0sccm
```

Therefore the total flow rate is

[12]:
```
totErr=Arerr+CO2err
print(f'({totFlow:.0f} +/- {totErr:.0f}) sccm')
```

```
(647 +/- 58) sccm
```

4 Determination of the flow of a gas mixture

Calculate correction for different gas mixture

https://www.mathesongas.com/pdfs/flowchart/RotameterGasFactorChart.pdf

[13]:
```
Ar_factor=0.851
CO2_factor=0.808
```

Mixture fraction $f_{\mathrm{Ar}} = 1 - f_{\mathrm{CO_2}}$

[14]:
```
q_frac=co2frac
```

[15]:
```
mix_factor=((1.0-q_frac)*Ar_factor)+(q_frac*CO2_factor)
print(f'mix factor: {mix_factor:.5f}')
```

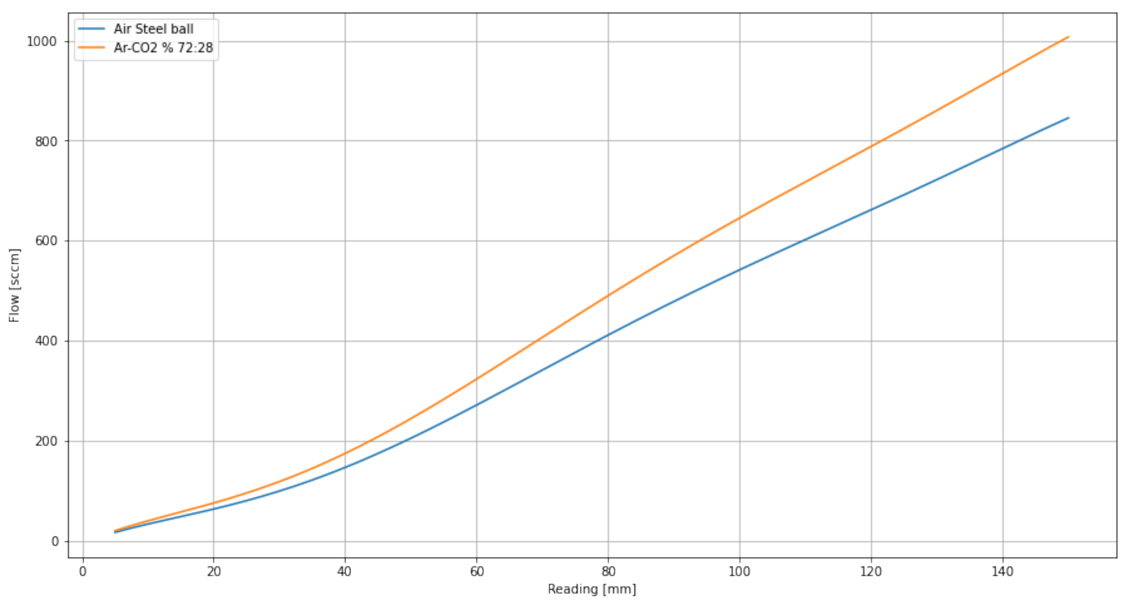
```
mix factor: 0.83916
```

Setup for atmosphere Air and Stainless Steel ball

https://www.mathesongas.com/pdfs/flowchart/602%20(E300)/AIR%20602(E300)%20SS%200%20PSIG.pdf

[16]:
```
ro,cal=np.loadtxt('AIR_602(E300)_SS_0_PSIG.dat',unpack=True) # sccm
airflow = interpolate.interp1d(ro, cal)
```

[17]:
```
plt.plot(x, airflow(x), label='Air Steel ball')
plt.plot(x, airflow(x)/mix_factor, label=f'Ar-CO2 % {(1.-q_frac)*100:1.0f}:
↪{q_frac*100:1.0f}')
plt.xlabel('Reading [mm]')
plt.ylabel('Flow [sccm]')
plt.grid()
plt.legend(loc='upper left')
plt.show()
```



Readout of the SS ball

[18]:
```
inSS=105
outSS=55
```

Determine input flow post mixing

[19]:
```
inFlow=airflow(inSS)/mix_factor
print(f'Gas Mixture inflow {inFlow:.0f} sccm')
```

```
Gas Mixture inflow 682 sccm
```

Determine output flow

[20]:
```
outFlow=airflow(outSS)/mix_factor
print(f'Gas Mixture outflow {outFlow:.0f} sccm')
```

```
Gas Mixture outflow 282 sccm
```

Determine return fraction

[21]:
```
print(f'Return fraction {outFlow/inFlow*100.0:.1f}%')
```

```
Return fraction 41.4%
```

4.1 Error Estimation

The full scale rate for the gas mixture using the calibration above is the following:

[22]:
```
mix_maxrate=airflow(150.)/mix_factor
print(f'Max flow rate for mixture {mix_maxrate:.0f} sccm')
```

```
Max flow rate for mixture 1007 sccm
```

Therefore the input and output flow rate of the mixture are

[23]:
```
mixerr=mix_maxrate*0.05
print(f'Input: ({inFlow:.0f} +/- {mixerr:.0f}) sccm')
print(f'Output: ({outFlow:.0f} +/- {mixerr:.0f}) sccm')
```

```
Input: (682 +/- 50) sccm
Output: (282 +/- 50) sccm
```

[ ]:
```

```