Iowa State University

M:2:I MAKE TO INNOVATE

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Pressure Method
The Accurate Filling of High Altitude Balloons

Theory

An important aspect of high altitude ballooning is accuracy regarding the calculation of helium inflation in the balloon. If the balloon is over-filled it will increase rapidly in velocity and burst too quickly to record data. If the balloon is under-filled the rate of ascension will be too slow or not at all. This poster highlights the importance of accuracy in helium inflation by examining a method that uses pressure to control the inflation of a high altitude balloon. On every helium tank there is a pressure gauge, which can be used to monitor the change in pressure inside the tank. Using that pressure change and a non-ideal gas equation, the number of moles transferred between vessels can be calculated. The number of moles can then be used to calculate the overall volume of the balloon which then can be used to calculate the lift force. Since the tank and the balloon represent a closed system, the moles remain constant, insuring the accuracy of (this method) using the pressure method to inflate a high altitude balloon.

Method/Equations

The method for calculating the lift of helium in terms of pressure is done in three parts. The first part is calculating how many moles of helium are in the tank by using the initial pressure. This can be done using the non-ideal gas equation.

$$PV = ZnRT$$

Where Z is the compressibility factor given by Smith:**

The second part is calculating how many moles are required for the desired lift of the balloon. That can be calculated by the basic lift equation:

$$L = V(\rho_A - \rho_H)$$

The volume is first solved and then plugged into the ideal gas equation to find the moles used. The final calculation is subtracting the moles needed for lift from the initial moles in the helium tank the result is the moles that are left over in the helium tank. The non-ideal gas equation is then used once more to calculate the final pressure.

$$X = (10.2297 * 10^{-5} - 19.2998 * 10^{-8} T + 1.1836 * 10^{-10} T^2)$$

$$**Z = 1 + X * P - 2.217 * 10^{-10} P^2$$

Conclusions and Problems

This method when integrated into high altitude ballooning can be highly accurate. According to Smith the accuracy can be up to 0.5%. However our team is currently having difficulties with model prediction. We believe that this is due to the extremely low temperatures inside the helium tank that we deem impossible. We are currently calculating the temperatures with a back calculation after the experiment is done. The temperature can be calculated with heat transfer equations but in order to do that the air velocity has to be known. The only way to do that is if we bought a flow meter; however, this would allow us to use a more direct method instead and is prohibitively expensive. We believe the reason the temperatures are so low is that during our theory we neglected something that was not supposed to be neglected. We are currently experimenting with different variables such as changing our compressibility equation.

Experiment Data

	Tank temperture *F			Pressure in tank Kpa				Density lbm/ft^3			
Test	Initial	Final	Internal	Initial	Final	Temperture outside *F	Overall Lift lbf	Air	Helium	Could it be checked by weighing method	Date
1	17.6	-9.4	-170	14000	2000	22	11.8	0.08217	0.01114	Yes (Good)	Feb ? 2015
2a	22	19.4		600 psi	400 psi	64	9.18	0.07568765	0.01039	No (underfilled) Fixed with 8 lbf	Apr 2 2015
2b	20.2	18.2		400 psi	100 psi	64	9.18	0.07568765	0.01039	No (underfilled) Fixed with 8 lbf	Apr 2 2015
2c	20.4	10.2	-251	2150 psi	600 psi	64	9.18	0.07568765	0.01039	No (underfilled) Fixed with 8 lbf	Apr 2 2015
3a	40.5	31.5		625 psi	100	31	10.06	0.08104	0.011143	Yes (Good)	Apr 11 2015
3b	39	33.5		400	100	31	10.06	0.08104	0.011143	Yes(Good)	Apr 11 2015
3c	38	NA	-225	2225	700	31	10.06	0.08104	0.011143	Yes(Good) Sorta predicted	Apr 11 2015
4	42.5	27	-378	800	100	37	10.14 (sorta)	0.07942	0.011143	Yes (10.8)	Apr 26 2015
4b	42	16	-108	1900	400	37	10.14 (sorta)	0.07942	0.011143	Yes (10.8)	Apr 26 2016

References: Smith, Michael. "Review and Assessment of Helium Inflation Calculation Methods." AIAA Balloon Systems Conference, March (2013).

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