Calibration of Bourdon Gauge

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Abstract:

This laboratory experiment was performed in order to learn the function of devices that measure pressure. The primary objective of this lab was to calibrate a Bourdon Gauge by using a Dead-Weight Testing method. The results were uniform between the two trials conducted. Linear relationships were obtained between gauge pressure and the pressure exerted by the piston and weights on the system. The relative percent error for this experiment displayed power equations that were downward sloping, showing that values with smaller applications of pressure in the cylinder yielded a higher figure of % relative error. Data for the increasing and decreasing procedures of adding weight to the system were plotted, and the results showed figures that were so similar that the points on the plot were indistinguishable due to overlapping. Based on the figures similarity, the experiment is repeatable with precise results. Overall, the average values of gauge pressure were linearly proportional to the cylinder pressure that acted as the independent variable in the experiment. There were two standard deviations calculated between the increasing and decreasing sets of data, one for each trial of the experiment. The standard deviations of *61.970255* kPa in Trail One and 63. 234089 kPa in Trial Two shows the distance between the data points collected during the calibration of the Bourdon Gauge. By plotting the average data, an equation of **y = 0.009x** could be used for both trials of the experiment to accurately calculate values of gauge pressure ***y*** for a specified cylinder pressure of ***x***.

By looking at the relationship between the trials conducted in the experiment and the relationship between the experimental results analyzed on the manometer and the actual results being measured by adding weight to the cylinder, a calibration of the system can be conducted.

Introduction:

This laboratory experiment introduces the concept of using deadweight pressure calibration system in order to properly calibrate a Bourdon Gauge. Dead weight testing methods are one of the most reliable ways to measure data of pressure in order to collect accurate data and be able to calibrate other devices for use. An experiment performed in order to help uniformly distribute anhydrous ammonia highlights the importance of being able to calibrate instruments using reliable methods. Anhydrous ammonia is difficult to control and distribute evenly. Using instruments that focus on the hydraulics of the substance, the anhydrous ammonia can be controlled and evenly distributed in soil in order to yield optimal crop results (Major et. al 2003). Similarly, in the experiment performed, the data collected was used with the intention of successfully calibrating a Bourdon Gauge.

The importance of the experimentation that Major conducted is supported by research that H. Richard Jarboe reported in 1983. According to important observations, the study and cultivation of fluid mechanics has solved some of the world's greatest work-intensive projects. Properly using fluid mechanics lessens the amount of work that humans have to conduct in practice–especially within agriculture (Jarboe 1983).

Balascio et. al conducted research for a rainfall estimation of hydraulic modeling on large basins. By using different methods of collecting data, they were able to calibrate data in order to predict very specific, important information that could not be accurately collected and predicted in the field without carefully calibrating their instruments to their experimental values (Basascio et. al 2001).

Through the proper use of a dead weight pressure calibration system and reading the manometer connected to the hydraulics system, it will be possible to learn how to effectively calibrate a Bourdon Gauge and obtain necessary skills to calibrate other pressure systems in the future.

Objectives:

1. One of the objectives of the lab preformed is to become familiarized with operating devices that measure pressure.
2. Calibrating a Bourdon Gauge is also an objective of this lab activity.

Materials

- Edibon Hydrostatics System
- Dead weight Pressure Calibration System
- Electronic balance
- 329 gram piston
- Four weights of differing masses
    - 498.5 gram weight
    - 169.62 gram weight
    - 478.75 gram weight
    - 995.49 gram weight
    - 2495.32 gram weight
- Vaseline
- Gloves
- Kimtech Lab Kimwipes
- Water

Methods:

1. The mass of the weights was measured by using an electronic balance to assess the value of each weight used in the procedure. The value of the mass of the piston used was given by the instructor before the experiment commenced.
2. The cylinder was filed with water making sure that air was eliminated from the system as much as possible in order to avoid miscalculating the values obtained during the trials.
3. The piston was added to the cylinder. A reading on the manometer was obtained (in bars) and recorded by one team member and recorded by the other members on Team Six.
4. A 498.5-gram weight was added to the piston. The value of pressure on the manometer was recorded.
5. A 169.62-gram weight was added to the piston without removing the other weight. The value of pressure on the manometer was recorded.
6. A 995.49-gram weight was added to the piston without removing the other weights. The value of pressure on the manometer was recorded.
    a. As weights were added to the manometer, water would escape the system. Vaseline was used around the piston in order to insulate water into

the system and keep it from leaking and distorting the readings on the manometer.

7. A 2495.32-gram weight was added to the piston without removing the other weights. The value of pressure on the manometer was recorded.
8. The order in which the weights were added was recorded. In the reverse order, the weights added were removed. As each weight was removed, the reading on the manometer was recorded again in an order referred to as "decreasing order" of the weights.
9. The procedures above were repeated in order to have two trial sets of data. At the end of the second trial, two sets of data for the values of pressure with increasing weight on the piston were recorded. Two sets of data for the values of pressure while detracting from the weight on the piston were also recorded.
10. The values of the data collected and were processed. The manometer measurements obtained in bars were converted to kPa. The mass of the piston and its area were used in order to obtain the cylinder pressure for each reading in order process and analyze the data obtained in the lab experiment.

Results & Discussion:

The results of this experiment are analyzed by assessing values such as the gauge reading of the manometer as well as the pressure in the cylinder. The pressure it the cylinder is obtained by taking the area of the piston used in the Dead Weight Pressure Calibration System and the mass of the piston and using the equation F = M÷A in order to find the pressure in kPa that the piston exerted on the system.

The first data obtained was the gauge pressure versus the pressure in the cylinder when the pressure is increasing and decreasing as the values were plotted on the same graph. Two trials of the data (increasing and decreasing) were collected.

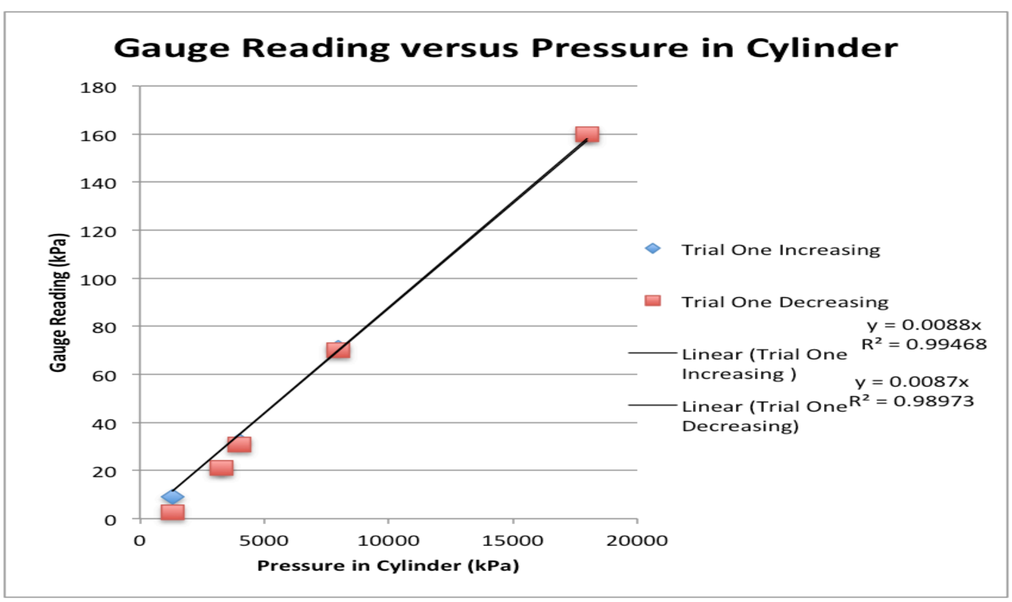

Figure One: illustrates a plot demonstrating the relationship between the pressure of the cylinder when weight is being added to the system and detracted from the system.

Figure One is a graph demonstrating the relationship between the pressure in the piston and the gauge reading on the manometer. There is a linear relationship between the values plotted on the x and y chart. Because the values were so similar in numbers, many of the data points over lap and it is difficult to see the increasing pressure in the cylinder plotted due to the decreasing data points covering them.

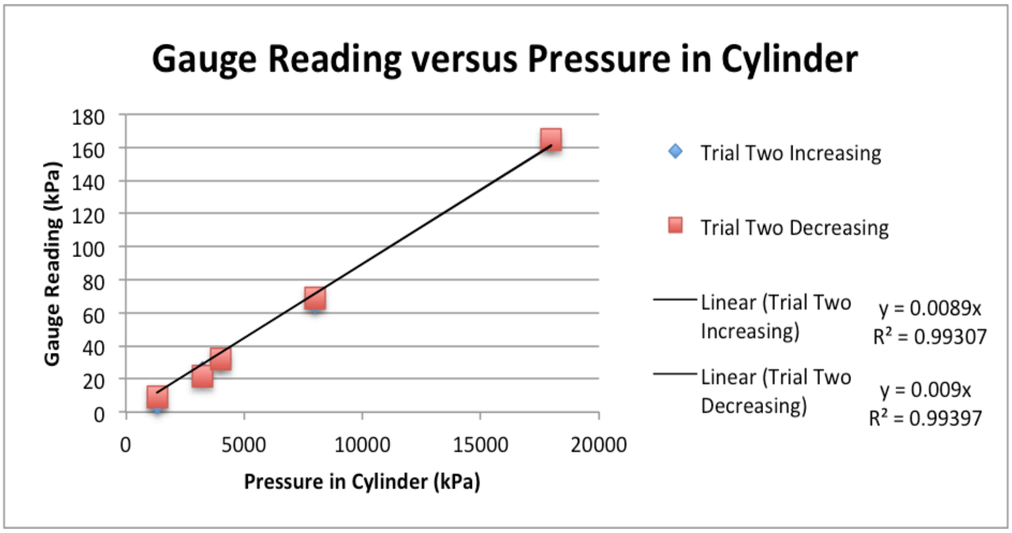

Figure Two: illustrates a plot demonstrating the relationship between the pressure of the cylinder when weight is being added to he system and detracted from the system during the second trial of the experiment

Figure Two demonstrates the similarity of the results obtained in the first trial of the experiment. Like the values in **Figure One**, the linear representation of the data points are so similar for the plots of increasing and decreasing weight that the values overlap. The data in Figures One and Two are so similar that the equation of the line of best fit for both graphs would be identical if the figures were rounded one more decimal point.

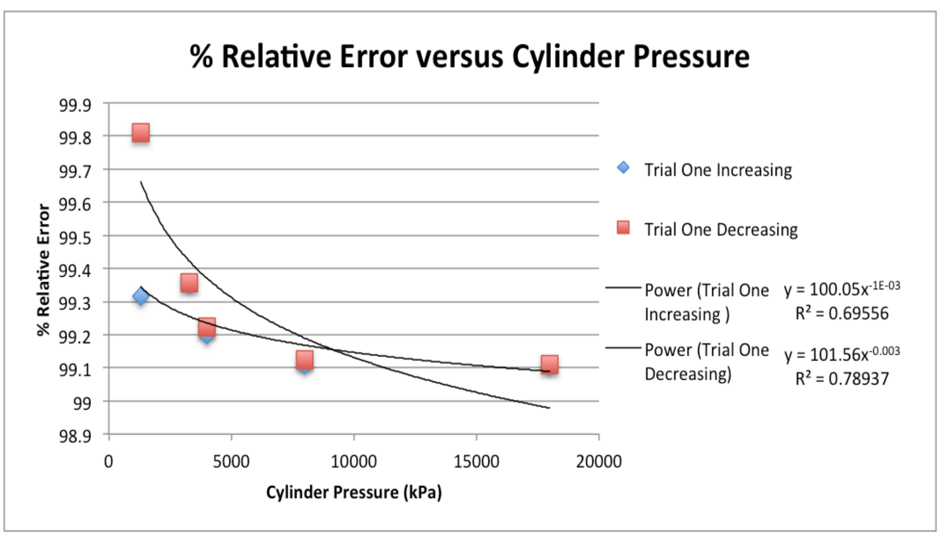

Figure Three: a graph illustrating the relationship between % relative error and the cylinder pressure of the piston and weights on the system.

The absolute error in this experiment juxtaposes the value of the data that should be obtained and the value of the data that is being measured by the system being used. The pressure in the cylinder is known due to adding the weights and calculating how much force is actually being put on the system. The number displayed by the manometer is the value that the system is collecting. The relative % error values of the data collected shows, by percent, how close or far away the values obtained by the instrument were close the actual value that was measured.

Figure Three demonstrates a downward-sloping power equation. The relative error was highest when the cylinder pressure was at its lowest and decreases a cylinder pressure increases. The values of these plots follow a traceable trend, however, they are not as similar as the data displayed in the gauge reading versus pressure in cylinder graphs. Because the values vary a bit more, the individual data plots for the increasing and decreasing trial data are discernable.

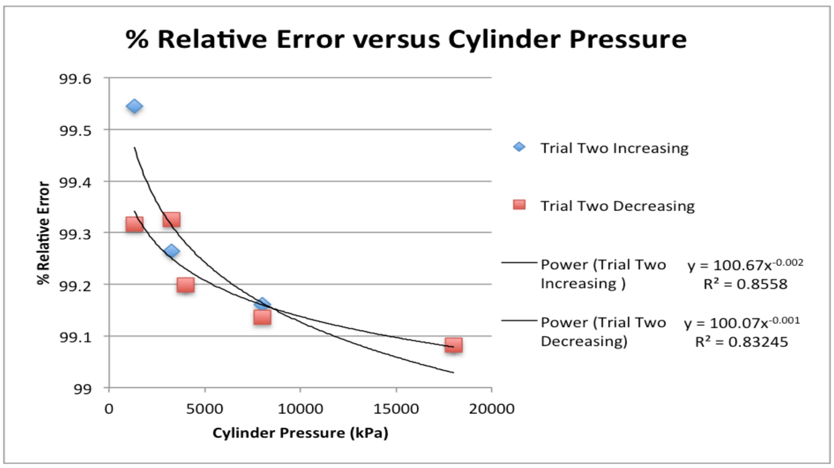

Figure Four: a graph illustrating the relationship between % relative error and the cylinder pressure of the piston and weights on the system for the second trial of data obtained.

The second trials of data for relative error in **Figure Four** also demonstrate a power equation with an inverse relationship between % relative error and the value of cylinder pressure. The data between increasing and decreasing values of the cylinder pressure vary enough to display the variation in the data points on the graph. The trendline highlights data that follows a fairly uniform set of data for both sets of the trials.

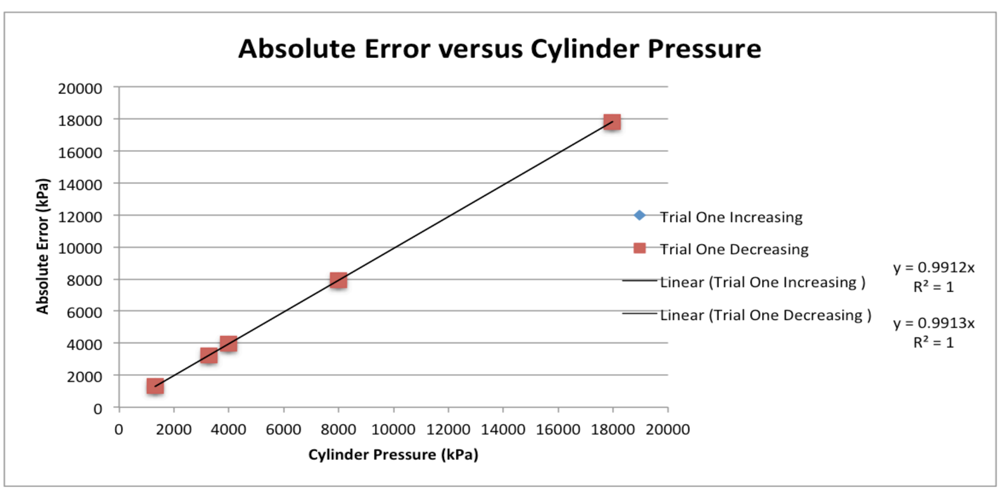

Figure Five: this plot illustrates the relationship between absolute error and cylinder pressure in the first trial set of increasing and decreasing data.

The data in **Figure Five** demonstrates the relationship between absolute error and cylinder pressure for the first trial round in data. The values are very close in value, so some of the points for the graph are not visible within the data set. The relationship between absolute error and cylinder pressure is linear, with a trendline that shows that the data follow a very predictable trend for the results recorded.

The second trial, as demonstrated below in **Figure Six** shows very similar results to the data is **Figure Five**. There is a linear relationship between the data points and a trendline that demonstrates that the data plotted yields a very predictable projection of data points. The data points in both the increasing and decreasing in data is so similar that the points overlap.

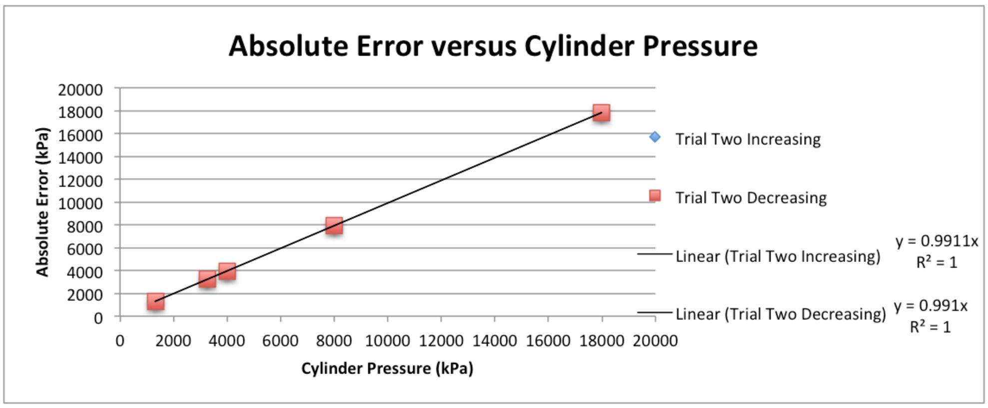

Figure Six: this plot illustrates the relationship between absolute error and cylinder pressure in the second trial set of increasing and decreasing data.

The last data to be plotted is a graph of the average gauge reading versus the cylinder pressure in **Figure Seven** below. By taking the average of the increasing and decreasing values in trial one and the respective increasing and decreasing values of pressure in trial two, the values were compared on the same plot. The error bars notating standard deviation were added to the graph as well. Standard deviation is a value that denotes how spread apart the values in a data set are.

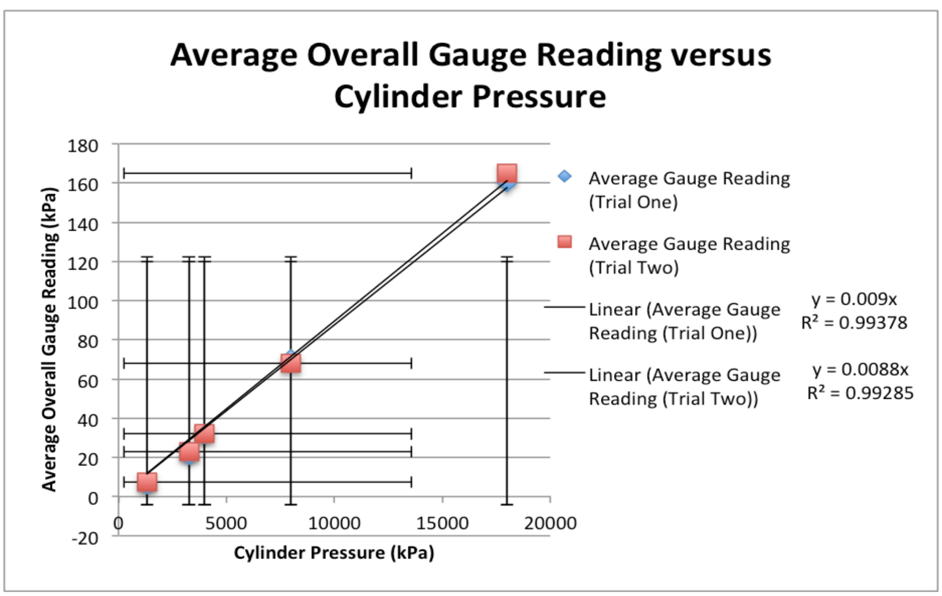

Figure Seven: is a data plot comparing the average overall gauge reading and the cylinder pressure of the two trials of data. Expressed on the graph are the error bars for standard deviation

The value of standard deviation (σ) is 61.970255 kPa for Trial One in the data of **Figure Seven.** The value of σ for the second trial of data points is 63.234089 kPa. The numbers on this data set are fairly spread apart, especially as the data points grow larger along the x and y axes.

In creating an equation that appropriately relates the average overall gauge reading and the cylinder pressure, the linear equation computed by excel would accurately predict future values of the average overall gauge pressure when supplying a cylinder pressure and vice versa. Both linear equations have R^2 values close to 1 meaning that the equation of the values for future values should be close to the experimental value.

Due to this observation, by setting the y-intercept to 0, an equation that would relate the average overall gauge reading and the cylinder pressure would be **y = 0.009x** where y is equal to the average overall gauge pressure and x is equal to the cylinder pressure. For both Trial One and Trail Two in the average overall gauge readings because the equation computed in Trial Two can be rounded to less significant figure, Trial Two can have the same predictive equation as Trial One.

Conclusion:

Overall, the data gathered in this lab demonstrate mostly linear relationships between cylinder pressure and different variables of measuring the data within the lab. As the cylinder pressure increased in all of the trial types run, the gauge reading linearly increased. The numbers gathered for absolute error and the percent of relative error were all high numbers, indicating that some type of random or systematic error occurred. In observing the leaking of water from the dead weight system, it can be inferred that that may have contributed the error in the experiment conducted. The standard deviation of the data collected as obtained by using the standard deviation function within excel in order to determine how spaced out the data collected was. By plotting the average overall gauge pressure, a mean equation for the data was computed linearly in excel. **y = 0.009x** where plugging in a cylinder pressure value of **x** will predict a future mean value of absolute pressure in **y** works for both trials conducted in the lab. Due to the similarities in predicting the values and their tendencies to overlap, it can be concluded that the exercise has a relatively high instance of repeatability in the pressure gauge.

In conclusion, the objectives outlined were achieved. By computing and calculating data, the familiarization of measuring devices and the calibration of a Bourdon Gauge were accomplished.

References

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