



SACRAMENTO STATE

Reciprocating Air Compressor Test

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Abstract

The purpose of this experiment is to provide further experience with electronic data acquisition hardware and software by evaluating a Reciprocating Air Compressor Test System. The use of electronic data acquisition systems allow for the measurement of steady-state along with time-dependent (transient) properties to be recorded, which would be otherwise difficult to record manually. Temperature and Pressure properties were recorded at pre-determined locations in the system; these locations were defined by certain pressure values. The measurements were taken at five different receiver tank pressures (160 psig, 200 psig, 240 psig, 280 psig, 320 psig) and then compared against each other to see how the varying pressures affect the behavior of the system. As a result of the steady-state experiment, it was found that the low-pressure and high-pressure cylinders followed a polytropic process when the results were graphed and the curves were very close to identical for the varying low-cylinder pressures and the variance was more in the high-pressure cylinder. As the receiver tank pressures increased, so did the energy consumption, most notably in the high-pressure cylinder.

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Introduction

The objective of the experiment was to provide further experience with electronic data acquisition hardware and software along with real world experience. This provides a further understanding of the operation and operating characteristics of a two-stage reciprocating compressor. Pressure and Temperature values were recorded over a range of receiver tank pressures (160-320 psig or 1130.8-2240.9 kPa) and were then evaluated to show how the ideal cycle analysis can be applied for the piston-cylinder cycle.

The analysis of this experiment requires some assumptions to be made. The first assumption is the system properties are taken at equilibrium at each receiver pressure increase. The second assumption is that the specific heats of the gas are constant. The third assumption made to calculate the power delivered by compressor into the air is that it is an ideal gas. The final assumption is the compression process is polytropic. These assumptions make it possible to find the total work and power done in a 2-stage, double-acting compressor.

Apparatus and Procedure

Equipment:

- Ingersoll-Rand two-stage, double-acting, reciprocating piston compressor
- 7.5 horsepower GE Induction motor
- Thermometer (Celsius)
- Barometer
- Computer with LABTECH Notebook software
- Floppy disk
- Input Power Gage
- Annubar Flowrate (Standard Cubic Feet Per Minute)
- Tank Pressure Gauge
- Receiver Tank

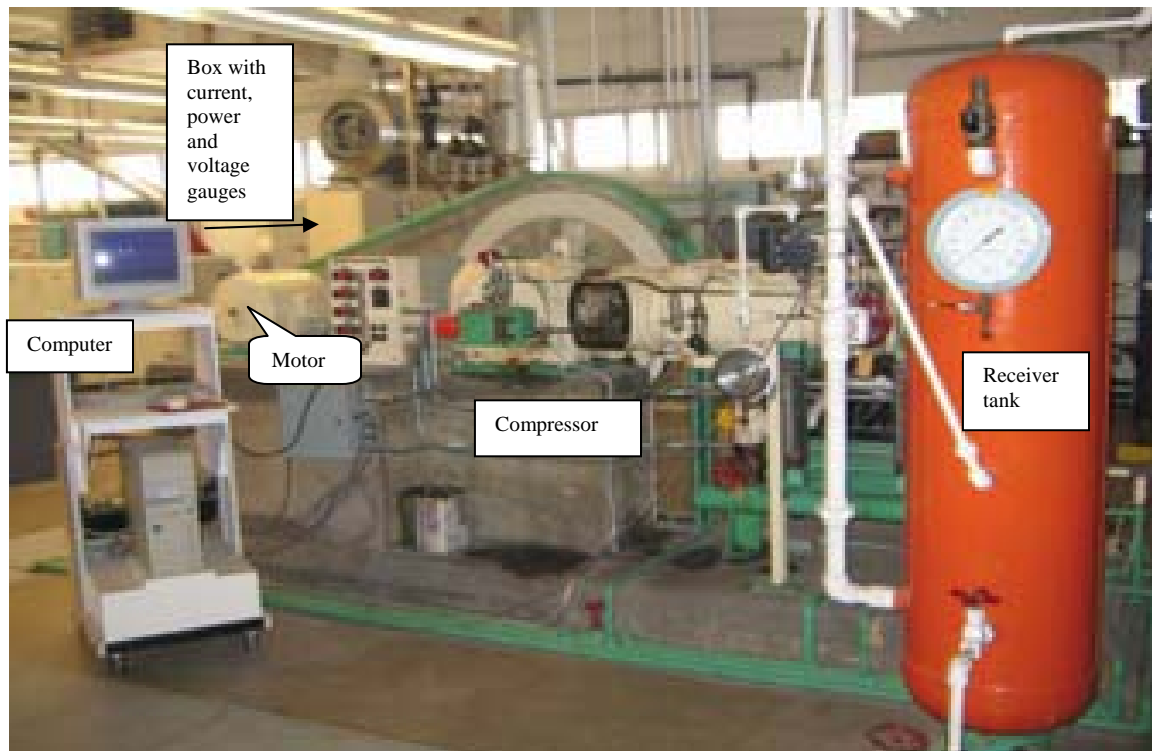


Figure #1 Reciprocating Air Compressor Test System



Figure #2 Annubar Flowrate (SCFM)

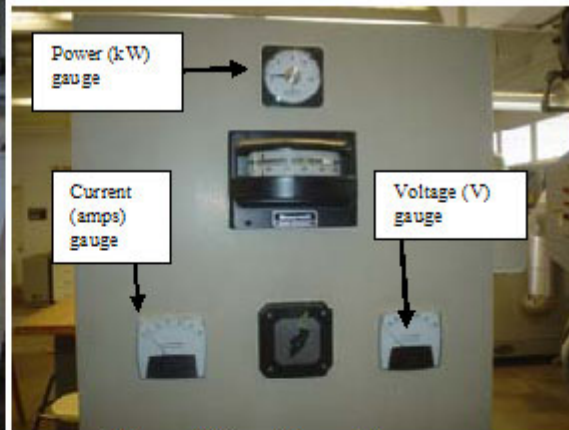


Figure #3 Input Power Gauge

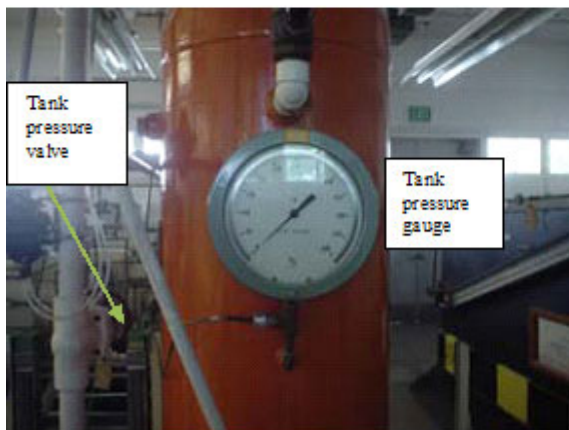


Figure #4 Tank Pressure Gauge

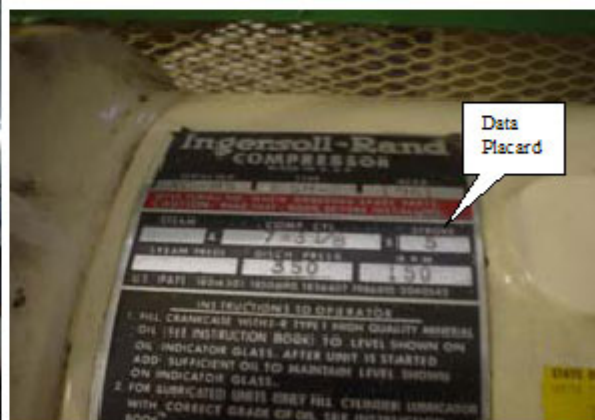


Figure #5 Data Placard

Procedures:

1. We manually recorded the stroke (L in inches), the high pressure cylinder and low pressure cylinder diameters (d_{HP} and d_{LP} , in inches), and the Rotational Speed (N) in Revolutions per Minute (RPM). The Stroke and Rotational Speed were found on the placard mounted on the compressor (shown in Figure #5). The diameters of the high pressure and low pressure cylinders were given by the professor.
2. We manually recorded the atmospheric conditions:
 - a. Room Temperature (T_{atm}) was found using a thermometer and measured in degrees Celsius.

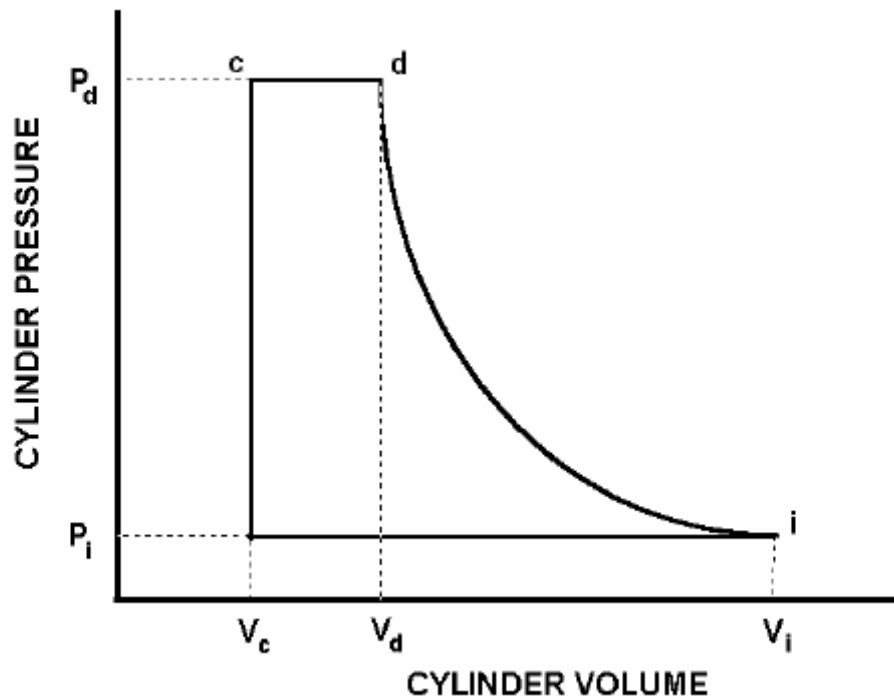
- b. Atmospheric Pressure head (h_{atm}) was found using a barometer and measured in unit of inch mercury (inch Hg).
3. We conducted a series of steady-state performance tests at receiver tank pressures of 160, 200, 240, 280 and 320 psig by the steps below:
 - a. We inserted the floppy disk into the PC, and ran LABTECH software by going to file, open, clicked on 'comp_lab' and then clicked the 'Run' button on the window.
 - b. We turned on the power to start the motor and then we adjusted the flow control valve to our desired receiver tank pressure of 160 pounds per square inch gage (psig).
 - c. We allowed the whole system to stabilize for 5 minutes. We knew stability occurred when the pressure (and temperature) values shown on the monitor board (T-P Readout Panel) stopped changing.
 - d. We manually recorded the power (kilowatts), voltage (Volts) and current (Amperes) consumed by the compressor for at the receiver tank pressure by reading the appropriate gauges (shown in figure 3);
 - e. We used the computer to record data for T1, T4, T7, T9, P1, P2, P3 and P5.
 - f. We then raised the receiver tank pressure to the next value by turning the tank pressure valve clockwise. The tank pressure valve was located to the left of the tank pressure gauge
 - g. We repeated steps c-f until all the data points were taken.
4. After conducting these tests, we saved the data file (in spreadsheet format) on the computer by going exiting out of the run-time box and then going to file and exiting out of the build time box.
5. We then opened up Excel, opened up drive (C:), opened up the Temp folder and clicked on 'comp_lab'.
6. We then saved 'comp_lab' to our floppy disk after re-naming it.
7. We then ran a transient test at receiver tank pressure 318psig.
 - a. We opened LABTECH Notebook, opened the file 'comp_PV' and pushed the *Run* button in the window.
 - b. We then had the program record data for a few seconds.

- c. We saved the data in the same manner as we saved the data for the steady-state performance tests, except we clicked on 'comp_PV,' and saved it to our floppy disk after renaming it.
8. We then copied the data from the floppy disk on to our USB storage devices.

Results and Discussion

Throughout this experiment there are 12 variables being measured periodically: Power, Voltage, Current, T1, T4, T7, T9, P1, P2, P3, P5, and Ch15. Nine of these variables will be used to calculate the power put into the air at each of the five receiver tank pressures. Once this calculated power is found it will be compared with the actual power supplied to the compressor.

For the step-by-step computation of the power input and graphs, please see the MATLAB file located in the appendix.



For the calculation of the power input, a number of assumptions had to be made. First, the process dc and ci are adiabatic. Second, the process cd is done under constant volume. Third, the motor converts the electrical energy it receives, to the motion of the two pistons with 100%

efficiency. Fourth, the value V_c/V_i is usually between 3% and 10%, the assumption was made that the value was 5%. Fifth, there is no entropy generation taking place.

Polytropic Processes

The following two graphs show the polytropic processes (process id) both pumps take. These graphs clearly show that the processes are dependent on the receiver tank pressures.

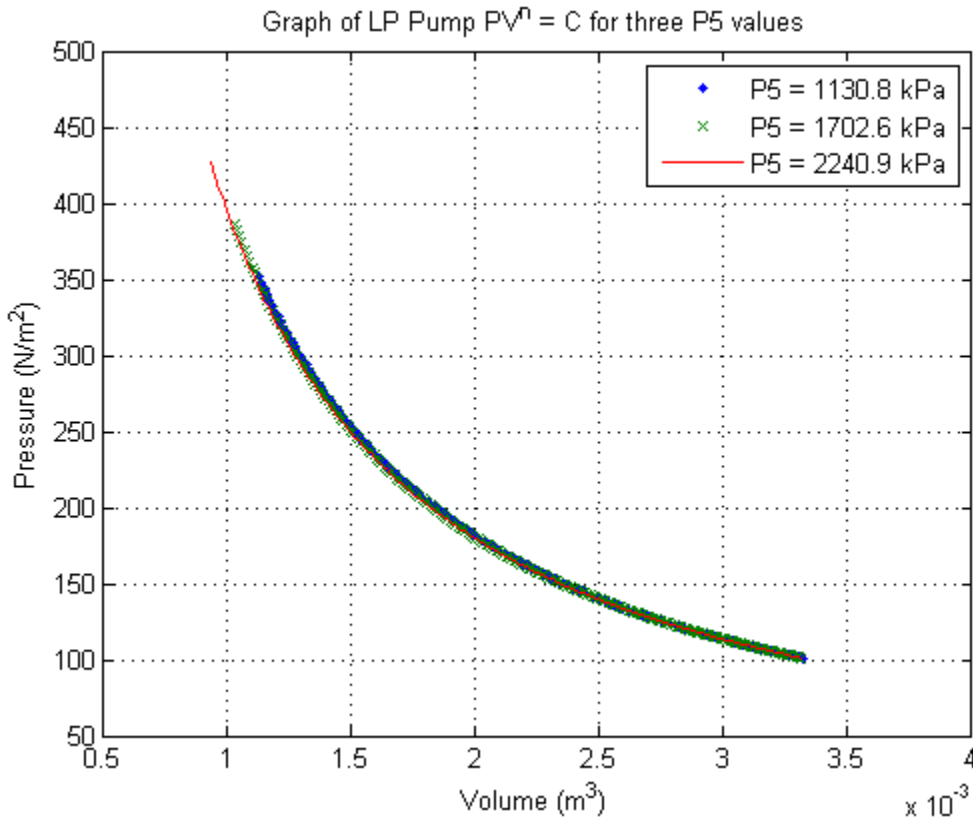


Figure #6 Graph of 3 Polytropic Processes for the Low Pressure Pump

The figure above shows how the polytropic processes change as the receiver tank pressure changes. As the receiver tank increases in pressure it requires that the air entering it be at a higher pressure. This is shown in the graph as the polytropic processes increase with increasing receiver tank pressure values. As the polytropic processes increase then the total area under the

curve also increases, which makes sense because as the pressure builds in the receiver tank it requires more energy to force air into it.

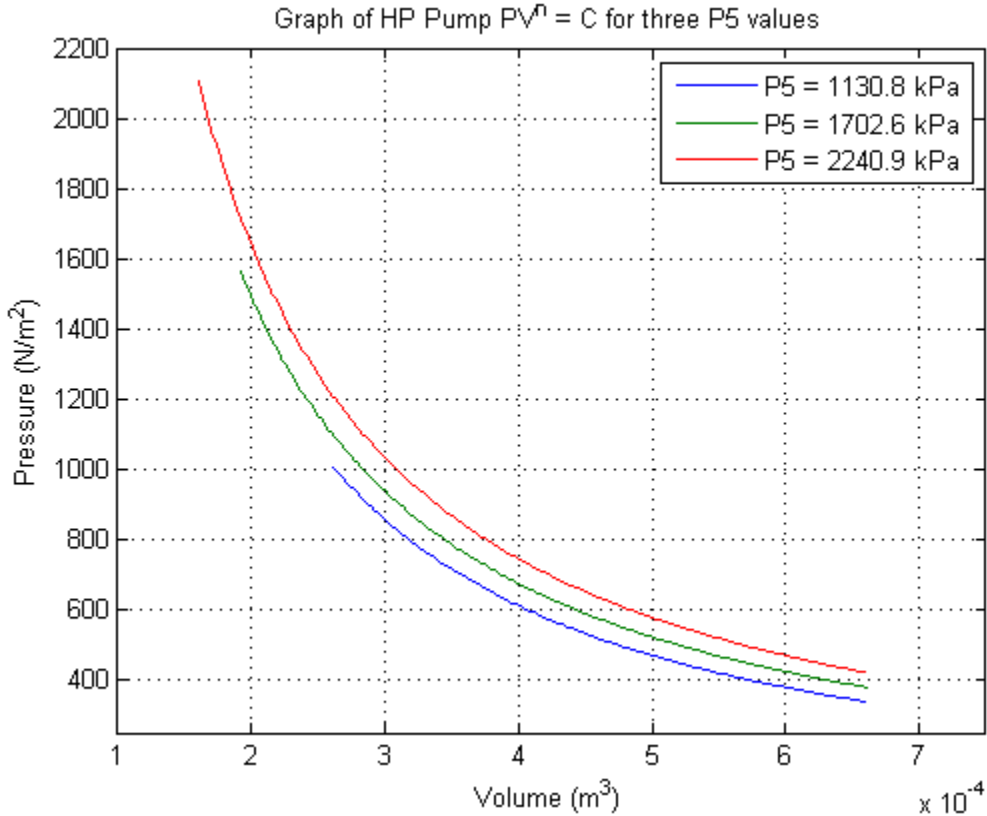


Figure #7 Graph of 3 Polytropic Processes for the High Pressure Pump

The figure above shows how the polytropic processes changes as the receiver tank pressure changes. The analysis of the last graph also applies to this one as well. In addition, note that the initial conditions of figure #6 are the same, that is $P = P_{atm}$ and $V = V_{atm}$ which are both constants. However, for figure #7 the initial pressure increases with increasing receiver tank pressures. This is because the low pressure pump increases the final pressure with increasing receiver tank pressures as seen in figure #6.

Power Consumption

Table #1 shows the calculated and actual power supplied to the motor at each receiver tank pressure.

Table #1 Power Consumption at each Receiver Tank Pressures

Receiver Tank Pressure	Power Calculated (kW)	Power Supplied (kW)
1130.8 kPa or 160 psig	3.2800	5.25
1435.3 kPa or 200 psig	3.6387	6
1702.6 kPa or 240 psig	3.9648	6.5
1964.4 kPa or 280 psig	4.2682	6.75
2240.9 kPa or 320 psig	4.5600	7.25

The calculated power is clearly different than the actual power supplied to the motor. This difference is expected because the motor does not work with 100% efficiency. In fact this motor converts about 80% of the electrical energy supplied to it to mechanical work. The rest of this difference is due to the ideal assumptions being made. For example: no thermal energy transfers, a closed-system (no leaks in or out), and no entropy generation.

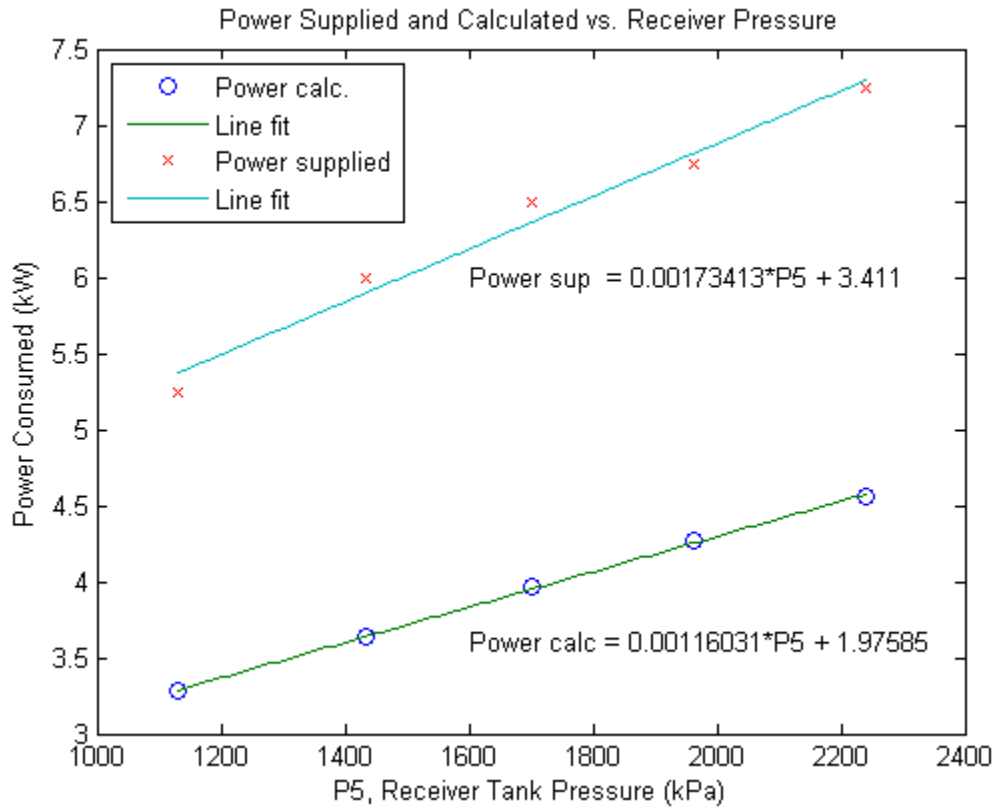


Figure # 8 Graph of Power Consumed against Receiver Pressure

The figure above shows that the calculated power and the actual power are nearly parallel. Although there is a relatively large off-set between them (3.41 vs. 1.98), the fact that their slopes are nearly identical indicates that the calculated power values are fairly precise although inaccurate. The actual power supplied to the motor increases faster than the calculated power with increasing P5 values. This makes sense because as the pump works harder and harder its efficiency will decrease slightly, a factor not included in our calculations.

Conclusion

In conclusion, the experiment gave us further experience with electronic data acquisition hardware and software along with real world experience of evaluating a two-stage reciprocating air compressor. The polytropic process was used to interpret the data obtained from the experiment. The results showed that as tank pressures were increased, so did the work needed to compress the air to those higher pressures. The n and C values were calculated and used to graph the volume and pressure properties, which clearly showed the polytropic processes of the various tank pressures. The power calculated was less than the actual power supplied because the motor cannot convert 100% of the electrical energy into mechanical work; its efficiency is around 80%.

As with any experiment conducted, there are changes that can be made to help improve the experiment. One change would be a more precise valve to control the receiver tank pressures. The current valve would not hold the pressure constant in the tank and would slowly either increase or decrease a little over the course of taking values. Another change would be to have a digital readout for the power, current, and voltage that is being supplied to the system instead of the standard analog gages. These changes would allow for more stability in the properties to be analyzed. The increase in stability would lead to an increase in the accuracy of the final results.

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Team KAB's Analysis of Lab 4

Programmer: Aaron Klapheck

```
% Lab #4 The Reciprocating Air Compressor 26-Sep-08
clear, clc, home
fprintf('The date and time: %s \n', datestr(now))
```

The date and time: 30-Sep-2008 13:29:59

Data

```
% This section consists of data either recorded by hand or by the computer
% used in this experiment.
```

```
% Recorded data came from the excel file Data.xls.
```

```
% Computer generated data came from the excel file KAB_COMP_LAB.xls.
```

```
% The following data is constant throughout the experiment (from Data.xls).
```

```
P_atm = 30; % Atmospheric Pressure in Inches of Hg (inHg).
```

```
T_room = 23; % Room temperature in degrees Celsius (C).
```

```
N = 150; % Angular acceleration in revolutions per minute (rpm).
```

```
d_low = 7; % Diameter of low pressure piston in inches (in).
```

```
d_high = 3.125; % Diameter of high pressure piston in inches (in).
```

L = 5; % Distance the piston travels in one direction measured
 % in inches (in) aka stroke.

% The following data changes with time.

% There are a total of 13 variables being measured. Of those 13, 3 are
 % being measured by hand (Voltage, Current, and Power), the 10 others are
 % being measured by the computer. For the variables being measured by hand
 % there is only one measurement being taken for each "steady-state" reached.
 % Whereas the computer takes multiple measurements at each steady state so
 % the values being measured are then averaged at each of the five
 % steady-states. The data can be distinguished from each other according to
 % the different receiver pressure values which are P5. In other words each
 % P5 value corresponds to one steady state.

%

% Units:

% Power in kilowatts (kW)

% Voltage in Volts (V)

% Current in Amps (A)

% Temperature in degrees Celcius (C)

% Pressure in pounds per square inch (psi)

% Ch15 refers to inches of water (in H2O)

%

% T's and P's:

% T1 is the Temperature out of the low pressure Cylinder

% T4 is the Temperature out of the high pressure Cylinder

% T7 is the Temperature into the low pressure Cylinder

% T9 is the Temperature into the high pressure Cylinder

% P1 is the Pressure out of the low pressure Cylinder

% P2 is the Pressure into the high pressure Cylinder

% P3 is the Pressure out of the high pressure Cylinder

% P5 is the Pressure in the receiver tank

%

%---- Steady-State 1 at P5 = 164 psi

%

```

% Done by hand (from Data.xls).
Power_1 = 5.25;
Voltage_1 = 490;
Current_1 = 11.5;

% Done by computer (from KAB_COMP_LAB.xls).
T1_1 = 76.*ones(1,13);
T4_1 = 78.*ones(1,13);
T7_1 = 25.*ones(1,13);
T9_1 = [27, 27, 27, 28, 27, 27, 27, 27, 27, 27, 27, 27];
P1_1 = 51.*ones(1,13);
P2_1 = 49.*ones(1,13);
P3_1 = 146.*ones(1,13);
P5_1 = 164.*ones(1,13);
Ch15_1 = [2.83, 2.94, 3.37, 2.78, 3, 3.36, 2.76, 3.04, 3.34, 2.73, ...
          3.09, 3.3, 2.71];

%---- Steady-State 2 at P5 = 208 psi

% Done by hand (from Data.xls).
Power_2 = 6;
Voltage_2 = 490;
Current_2 = 12;

% Done by computer (from KAB_COMP_LAB.xls).
T1_2 = 76.*ones(1,12);
T4_2 = [81, 80, 81, 81, 81, 81, 81, 81, 81, 81, 81, 81];
T7_2 = 25.*ones(1,12);
T9_2 = 30.*ones(1,12);
P1_2 = 53.*ones(1,12);
P2_2 = 52.*ones(1,12);
P3_2 = [190 188 190 188 188 190 190 188 193 190 188 188];
P5_2 = [208 208 208 208 208 208 208 208 208 210 208 208];

```

```
Ch15_2 = [1.88
```

```
2.02
```

```
2.22
```

```
1.87
```

```
2.04
```

```
2.19
```

```
1.87
```

```
2.1
```

```
2.17
```

```
1.86
```

```
2.1
```

```
2.16];
```

```
%----- Steady-State 3 at P5 = 247 psi
```

```
% Done by hand (from Data.xls).
```

```
Power_3 = 6.5;
```

```
Vol tage_3 = 490;
```

```
Current_3 = 12.5;
```

```
% Done by computer (from KAB_COMP_LAB.xls).
```

```
T1_3 = [77 77 77 77 77 78 77 77 77 77 77 77 77 77];
```

```
T4_3 = [84 83 83 83 84 83 83 83 84 84 84 84 84 84];
```

```
T7_3 = 25.*ones(1,14);
```

```
T9_3 = [31 31 30 30 30 30 30 30 30 30 30 30 30 30];
```

```
P1_3 = [56 56 56 56 56 56 56 56 56 56 57 56 56 56
```

```
];
```

```
P2_3 = 55.*ones(1,14);
```

```
P3_3 = [227 227 227 227 227 227 227 227 227 227 227 227 227 227];
```

```
P5_3 = [247 247 244 247 247 247 247 247 247 247 247 247 247 247];
```

```
Ch15_3 = [1.44
```

```
1.85
```

1. 6
1. 44
1. 85
1. 6
1. 43
1. 85
1. 62
1. 43
1. 84
1. 62
1. 43
1. 83];

%----- Steady-State 4 at P5 = 286 psi

% Done by hand (from Data.xls).

Power_4 = 6.75;

Vol tage_4 = 490;

Current_4 = 13;

% Done by computer (from KAB_COMP_LAB.xls).

T1_4 = [78 78 78 78 78 78 78 78 78 77 78];

T4_4 = 86.*ones(1,11);

T7_4 = 25.*ones(1,11);

T9_4 = [32 32 32 32 32 32 32 31 31 31 31];

P1_4 = 59.*ones(1,11);

P2_4 = 58.*ones(1,11);

P3_4 = [266 266 264 266 266 266 266 266 266 266 266];

P5_4 = [283 283 286 283 283 286 286 286 286 286 286];

Ch15_4 = [1.23

1.55

1.2

1.21

1. 54
1. 22
1. 19
1. 54
1. 26
1. 17
1. 53];

%----- Steady-State 5 at P5 = 325 psi

% Done by hand (from Data.xls).

Power_5 = 7.25;

Voltage_5 = 490;

Current_5 = 14;

% Done by computer (from KAB_COMP_LAB.xls).

T1_5 = 78.*ones(1,12);

T4_5 = 89.*ones(1,12);

T7_5 = 25.*ones(1,12);

T9_5 = [32 32 32 32 32 32 32 32 31 32 32 32];

P1_5 = 62.*ones(1,12);

P2_5 = 61.*ones(1,12);

P3_5 = [305 305 305 305 305 305 308 305 305 305 305];

P5_5 = 325.*ones(1,12);

Ch15_5 = [1.17

0.96

1.23

1.22

0.98

1.17

1.24

1.01

- 1. 12
- 1. 26
- 1. 04
- 1. 07];

Calculations

% 1. Get average values for the variables T1, T4, T7, T9, P1, P2, P3, P5, % and Ch15 for each of the five states measured.

%Means for steady-state 1, P5_1 = 164 psi = 1130.8 kPa

T1_1 = mean(T1_1); T4_1 = mean(T4_1); T7_1 = mean(T7_1); T9_1 = mean(T9_1);
 P1_1 = mean(P1_1); P2_1 = mean(P2_1); P3_1 = mean(P3_1); P5_1 = mean(P5_1);
 Ch15_1 = mean(Ch15_1);

%Means for steady-state 2, P5_2 = 208 psi = 1435.3 kPa

T1_2 = mean(T1_2); T4_2 = mean(T4_2); T7_2 = mean(T7_2); T9_2 = mean(T9_2);
 P1_2 = mean(P1_2); P2_2 = mean(P2_2); P3_2 = mean(P3_2); P5_2 = mean(P5_2);
 Ch15_2 = mean(Ch15_2);

%Means for steady-state 3, P5_3 = 247 psi = 1702.6 kPa

T1_3 = mean(T1_3); T4_3 = mean(T4_3); T7_3 = mean(T7_3); T9_3 = mean(T9_3);
 P1_3 = mean(P1_3); P2_3 = mean(P2_3); P3_3 = mean(P3_3); P5_3 = mean(P5_3);
 Ch15_3 = mean(Ch15_3);

%Means for steady-state 4, P5_4 = 286 psi = 1964.4 kPa

T1_4 = mean(T1_4); T4_4 = mean(T4_4); T7_4 = mean(T7_4); T9_4 = mean(T9_4);
 P1_4 = mean(P1_4); P2_4 = mean(P2_4); P3_4 = mean(P3_4); P5_4 = mean(P5_4);
 Ch15_4 = mean(Ch15_4);

%Means for steady-state 5, P5_5 = 325 psi = 2240.9 kPa

T1_5 = mean(T1_5); T4_5 = mean(T4_5); T7_5 = mean(T7_5); T9_5 = mean(T9_5);
 P1_5 = mean(P1_5); P2_5 = mean(P2_5); P3_5 = mean(P3_5); P5_5 = mean(P5_5);
 Ch15_5 = mean(Ch15_5);

```

T1 = [T1_1; T1_2; T1_3; T1_4; T1_5];
T4 = [T4_1; T4_2; T4_3; T4_4; T4_5];
T7 = [T7_1; T7_2; T7_3; T7_4; T7_5];
T9 = [T9_1; T9_2; T9_3; T9_4; T9_5];
P1 = [P1_1; P1_2; P1_3; P1_4; P1_5];
P2 = [P2_1; P2_2; P2_3; P2_4; P2_5];
P3 = [P3_1; P3_2; P3_3; P3_4; P3_5];
P5 = [P5_1; P5_2; P5_3; P5_4; P5_5];
Ch15 = [Ch15_1; Ch15_2; Ch15_3; Ch15_4; Ch15_5];

Power_sup = [Power_1; Power_2; Power_3; Power_4; Power_5];

```

```

% 2. Get Pi, Ti, Pd, and Td for both the low pressure cylinder and
% the high pressure cylinder.

```

```

% Low pressure cylinder:

```

```

Ti_low = T_room;
Td_low = T1;
% Pi_low = P_atm
Pi_low = 14.7;      % given that P_atm = 29.92 inHg = 14.7 psi
Pd_low = P1;

```

```

% High pressure cylinder:

```

```

Ti_high = T7;
Td_high = T4;
Pi_high = P2;
Pd_high = P3;

```

```

% 3. Convert all values to metric.

```

```

L = L/39.37;          % Meters
P5 = 6.895.*P5;      % kPa

```

```

T9 = 6.895.*T9;           % kPa

% Low pressure cylinder:
Ti_low = T_room + 273.15; % Kelvin
Td_low = T1 + 273.15;    % Kelvin
Pi_low = 101;           % given that P_atm = 29.92 inHg = 101kPa
Pd_low = 6.895.*P1;     % kPa
d_low = d_low/39.37;    % Meters

% High pressure cylinder:
Ti_high = T7 + 273.15;  % Kelvin
Td_high = T4 + 273.15;  % Kelvin
Pi_high = 6.895.*P2;    % kPa
Pd_high = 6.895.*P3;    % kPa
d_high = d_high/39.37;  % Meters

% 4. Find n, Vi, and Vd.

% Rearrange Td/Ti = (Pd/Pi)^((n-1)/n) to get
% n = -1/(ln(Td/Ti)/ln(Pd/Pi) - 1)... (eqn 1).
% Volume displaced by Piston/stroke (D): D = (L*pi*d^2)/4 ... (eqn 2).
% Assume: Vc = 0.05*Vi ... (eqn 3).
% Given: D = Vi - Vc ... (eqn 4).
% Combine (eqn 3) and (eqn 4): D = .95*Vi, Vi = D/.95 ... (eqn 5)
% Definition of polytropic process: Vi/Vd = (Pd/Pi)^(1/n) ... (eqn 6)

fprintf('%%%%4. First, get Vi through (eqn 2) and (eqn 5).%%%% \n')
D_low = (L*pi*d_low^2)/4 % units: m*m^2 = m^3
D_high = (L*pi*d_high^2)/4 % units: m*m^2 = m^3

Vi_low = D_low/.95 % units: m^3
Vi_high = D_high/.95 % units: m^3

```

```
fprintf('#####4. Second, use (eqn 6) and (eqn 1) to find Vd.##### \n')
```

```
n_low = -1./log(Td_low./Ti_low)./log(Pd_low./Pi_low) - 1)
```

```
n_high = -1./log(Td_high./Ti_high)./log(Pd_high./Pi_high) - 1)
```

```
Vd_low = Vi_low./(Pd_low./Pi_low).^(1./n_low) % units: kPa
```

```
Vd_high = Vi_high./(Pd_high./Pi_high).^(1./n_high) % units: kPa
```

```
% 5. Obtain constants (C's)
```

```
fprintf('#####5. Use P*V^n = C to solve for the constant C.##### \n')
```

```
C_low = Pi_low.*Vi_low.^n_low % Check both i and d values to make
```

```
C_low = Pd_low.*Vd_low.^n_low % sure they lead to the same C values.
```

```
C_high = Pi_high.*Vi_high.^n_high % Check both i and d values to make
```

```
C_high = Pd_high.*Vd_high.^n_high % sure they lead to the same C values.
```

```
#####4. First, get Vi through (eqn 2) and (eqn 5).###
```

```
D_low =
```

```
0.0032
```

```
D_high =
```

```
6.2844e-004
```

```
Vi_low =
```

```
0.0033
```

$V_{i_high} =$

6. 6152e-004

%%4. Second, use (eqn 6) and (eqn 1) to find V_d .%%

$n_{low} =$

1. 1520

1. 1468

1. 1428

1. 1391

1. 1339

$n_{high} =$

1. 1763

1. 1535

1. 1448

1. 1393

1. 1374

$V_{d_low} =$

0. 0011

0. 0011

0. 0010

0. 0010

0. 0009

$V_{d_high} =$

$1.0e-003 *$

0.2615

0.2159

0.1916

0.1739

0.1606

%%5. Use $P*V^n = C$ to solve for the constant C.%%

$C_{low} =$

0.1408

0.1450

0.1484

0.1516

0.1561

$C_{low} =$

0.1408

0.1450

0.1484

0.1516

0.1561

$C_{high} =$

0.0615

0.0771

0.0869

0.0954

0.1018

$C_{high} =$

0.0615

0.0771

0.0869

0.0954

0.1018

Graph of 3 Polytropic processes from i to d for the low pressure pump

% Three processes have been chosen to establish the general trend for how
% P5 (receiver tank pressure) values effect the polytropic processes. The
% three P5 values chosen are the smallest, middle, and largest values.

```
V_domain_1 = [Vd_low(1,1): 0.01*Vd_low(1,1): Vi_low(1,1)];
```

```
P_range_1 = C_low(1,1)./(V_domain_1.^n_low(1,1));
```

```
V_domain_3 = [Vd_low(3,1): 0.01*Vd_low(3,1): Vi_low(1,1)];
```

```
P_range_3 = C_low(3,1)./(V_domain_3.^n_low(3,1));
```

```
V_domain_5 = [Vd_low(5,1): 0.01*Vd_low(5,1): Vi_low(1,1)];
```

```
P_range_5 = C_low(5,1)./(V_domain_5.^n_low(5,1));
```

% Using "x"'s and "."'s because regular lines will not appear in the
% graph (they will be hidden underneath the other lines).

```
plot(V_domain_1, P_range_1, '.', ...
```

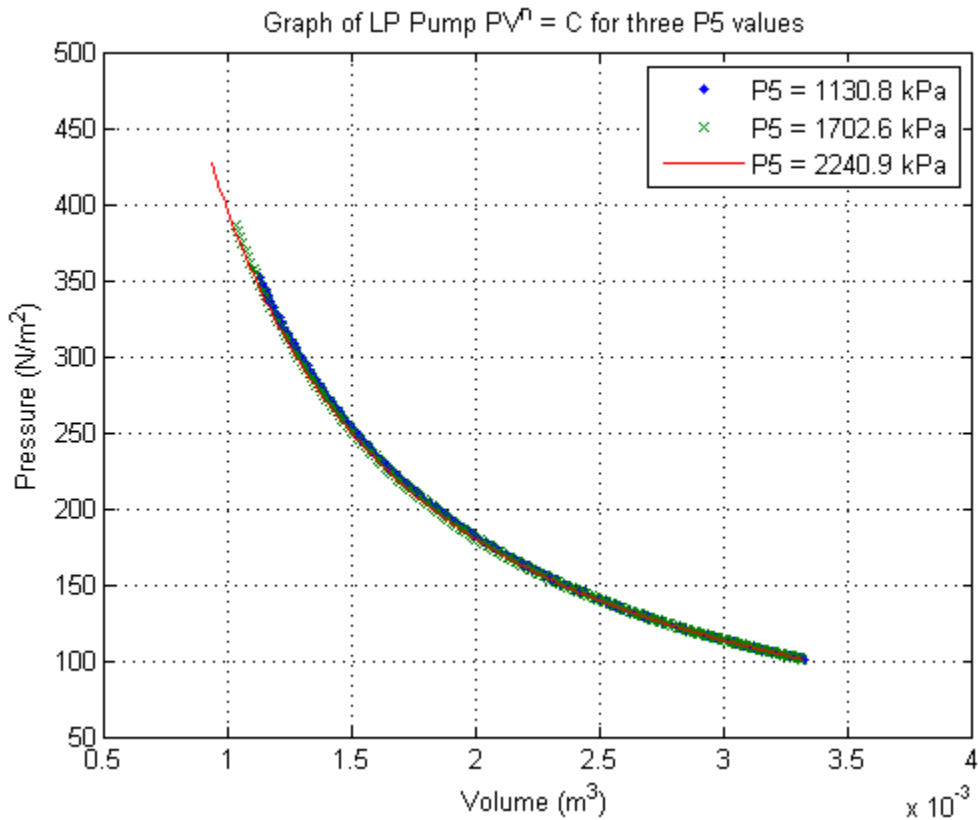
```
    V_domain_3, P_range_3, 'x', V_domain_5, P_range_5, 'r'), ...
```

```
    grid, axis([0.0005 0.004 50 500]), ...
```

```

title(' Graph of LP Pump  $PV^n = C$  for three P5 values'), ...
xlabel(' Volume (m^3)'), ylabel(' Pressure (N/m^2)'), ...
legend(' P5 = 1130.8 kPa', ' P5 = 1702.6 kPa', ' P5 = 2240.9 kPa')

```



Graph of Polytropic processes from i to d for the high pressure pump

% Three processes have been chosen to establish the general trend for how
 % P5 (receiver tank pressure) values effect the polytropic processes. The
 % three P5 values chosen are the smallest, middle, and largest values.

```
V_domain_1 = [Vd_high(1, 1): 0.01*Vd_high(1, 1): Vi_high(1, 1)];
```

```
P_range_1 = C_high(1, 1) ./ (V_domain_1.^n_high(1, 1));
```

```
V_domain_3 = [Vd_high(3, 1): 0.01*Vd_high(3, 1): Vi_high(1, 1)];
```

```
P_range_3 = C_high(3, 1) ./ (V_domain_3.^n_high(3, 1));
```

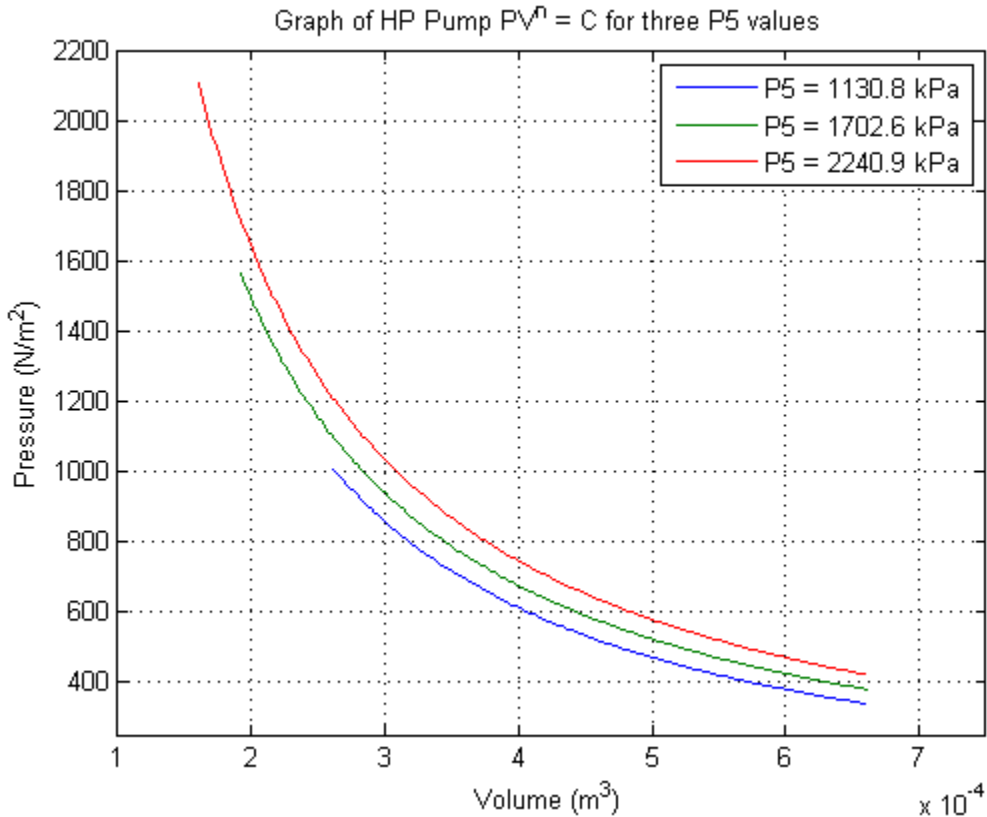
```
V_domain_5 = [Vd_high(5, 1): 0.01*Vd_high(5, 1): Vi_high(1, 1)];
```

```
P_range_5 = C_high(5, 1) ./ (V_domain_5.^n_high(5, 1));
```

```

plot(V_domain_1, P_range_1, V_domain_3, P_range_3, V_domain_5, P_range_5), ...
grid, axis([0.0001 0.00075 250 2200]), ...
title('Graph of HP Pump PV^n = C for three P5 values'), ...
xlabel('Volume (m^3)'), ylabel('Pressure (N/m^2)'), ...
legend('P5 = 1130.8 kPa', 'P5 = 1702.6 kPa', 'P5 = 2240.9 kPa')

```



Find the work done in a single, double-acting cylinder

```
% polytropic work: Wid = (PdVd - PiVi)/(1-n) - Pi(Vd - Vi) ... (eqn 7)
```

```
% Pc = Pd ... (eqn 8)
```

```
% Work done per stroke: Wdc = Pc(Vc - Vd) - Pi(Vc - Vd) ... (eqn 9)
```

```
% Total work for complete cycle: W = Wid + Wdc ... (eqn 10)
```

```
% W(low-pressure):
```

```
% use (eqn 7)
```

```
Wd_low = ((Pd_low * Vd_low - Pi_low * Vi_low) / (1 - nlow) - ...
```

```

    Pi_low.*(Vd_low - Vi_low)).*1000    % J per I sentropic compression
% use (eqn 3)
Vc_low = 0.05.*Vi_low;
% use (eqn 8)
Pc_low = Pd_low;
% use (eqn 9)
Wdc_low = (Pc_low.*(Vc_low - Vd_low) - ...
    Pi_low.*(Vc_low - Vd_low)).*1000    % J/Stroke
% use (eqn 10)
W_low = Wdc_low + Wi_d_low            % J

% W(hi gh-pressure)

% use (eqn 7)
Wi_d_hi gh = ((Pd_hi gh.*Vd_hi gh - Pi_hi gh.*Vi_hi gh)./(1-n_hi gh) - ...
    Pi_hi gh.*(Vd_hi gh - Vi_hi gh)).*1000    % J per I sentropic compression
% use (eqn 3)
Vc_hi gh = 0.05.*Vi_hi gh;
% use (eqn 8)
Pc_hi gh = Pd_hi gh;
% use (eqn 9)
Wdc_hi gh = (Pc_hi gh.*(Vc_hi gh - Vd_hi gh) - ...
    Pi_hi gh.*(Vc_hi gh - Vd_hi gh)).*1000    % J/Stroke
% use (eqn 10)
W_hi gh = Wdc_hi gh + Wi_d_hi gh        % J

```

Wi_d_low =

-172.8936

-182.6275

-197.0478

-210.4010

-223. 7432

Wdc_low =

-240. 1193

-242. 1145

-245. 4795

-247. 9820

-249. 4018

W_low =

-413. 0129

-424. 7420

-442. 5273

-458. 3831

-473. 1450

Wi_d_high =

-90. 2243

-130. 0337

-162. 2201

-193. 5202

-224. 1315

Wdc_high =

-152. 7613

-172. 9690

-188. 2101
-201. 7448
-214. 7157

$W_{high} =$

-242. 9855
-303. 0027
-350. 4302
-395. 2650
-438. 8471

Find the total work and power done in a 2-stage double-acting compressor

% Total work done by both compressors: $W_{tot} = W_{low} + W_{high}$... (eqn 11)

% Power consumed: $P = W_{tot} * 2 \text{ strokes/rev} * N / (60 \text{ min/sec}) / (1000 \text{ J/kJ})$... (eqn 12)

% use (eqn 11)

$W_{tot} = W_{low} + W_{high}$ % J

% use (eqn 12)

$P_{tot} = W_{tot} * 2 * N / 60 / 1000$ % kW

$W_{tot} =$

-655. 9984
-727. 7447
-792. 9575
-853. 6481
-911. 9922

P_tot =

-3.2800

-3.6387

-3.9648

-4.2682

-4.5600

Compare the supplied power consumed to the calculated one.

```
% Fit the data to a line
```

```
P_tot_line = polyfit(P5, abs(P_tot), 1)
```

```
P_sup_line = polyfit(P5, abs(Power_sup), 1)
```

```
fprintf('P_calc: Power = %g*P5 + %g \n', P_tot_line)
```

```
fprintf('P_sup: Power = %g*P5 + %g \n', P_sup_line)
```

```
eval = [P5(1,1):10:P5(5,1)];
```

```
P_calc_line = polyval(P_tot_line, eval);
```

```
P_sup_line = polyval(P_sup_line, eval);
```

```
% Graph Power Consumed as a function of Receiver Tank Pressure (P5)
```

```
plot(P5, abs(P_tot), 'o', eval, P_calc_line, P5, Power_sup, 'x', eval, P_sup_line), ...
```

```
    xlabel('P5, Receiver Tank Pressure (kPa)'), ...
```

```
    ylabel('Power Consumed (kW)'), ...
```

```
    text(1600, 6.0, 'Power sup = 0.00173413*P5 + 3.411 '), text(1600, 3.6, 'Power calc =  
0.00116031*P5 + 1.97585 '), ...
```

```
    title('Power Supplied and Calculated vs. Receiver Pressure'), ...
```

```
    legend('Power calc.', 'Line fit', 'Power supplied', 'Line fit', 'Location',  
'NorthWest')
```

P_tot_line =

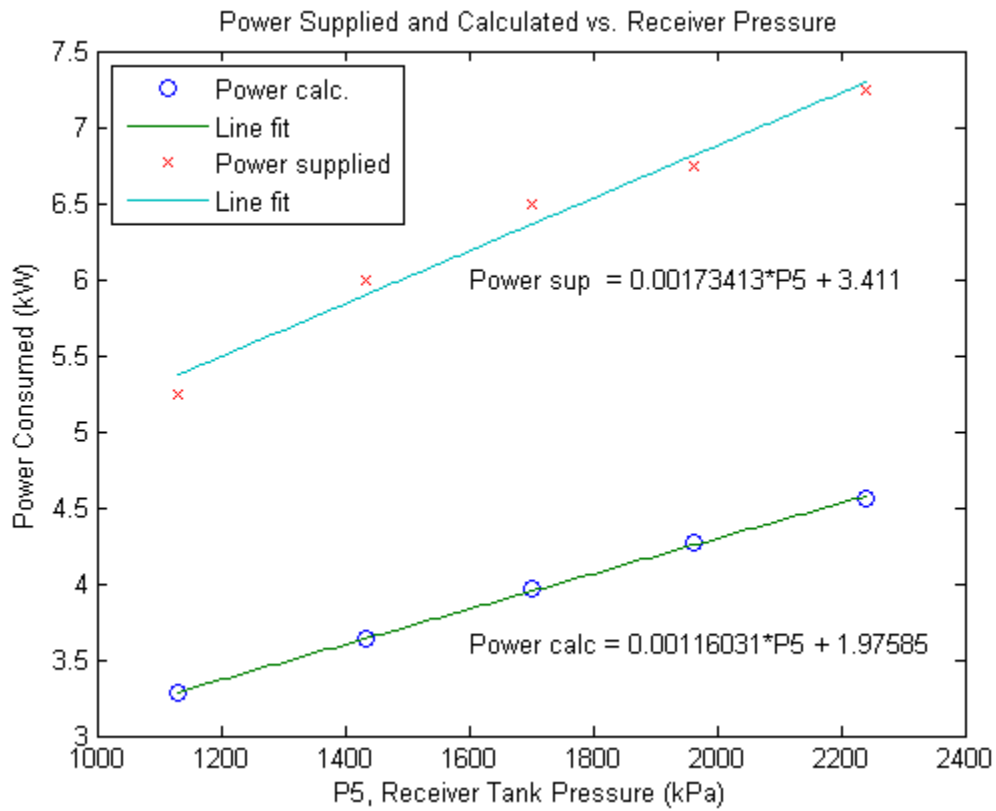
0.0012 1.9759

$P_{sup_line} =$

0.0017 3.4110

$P_{calc}: Power = 0.00116031 * P5 + 1.97585$

$P_{sup}: Power = 0.00173413 * P5 + 3.411$



Data located in Data.xls file

Stroke (in)	5
D low (in)	7
D high (in)	3.125

omega N (rpm)	150
T room (C)	23
P atm (in Hg)	30

Receiver P	Manually record		
	Power	Voltage	Current
psig	kw	Volts	Amps
abt 160	5.25	490	11.5
abt 200	6	490	12
abt 240	6.5	490	12.5
abt 280	6.75	490	13
abt 320	7.25	490	14

Data located in KAB_COMP_LAB.xls

LABTECH NOTEBOOK

Data file

Time is 22:14:48.39.

Date is 9-05-2008.

T-1	T-4	T-7	T-9	P1	P2	P3	P5	ch 15
deg c	deg c	deg c	deg c	psi	psi	psi	psi	In. H2O
76	78	25	27	51	49	146	164	2.83
76	78	25	27	51	49	146	164	2.94
76	78	25	27	51	49	146	164	3.37
76	78	25	28	51	49	146	164	2.78
76	78	25	27	51	49	146	164	3
76	78	25	27	51	49	146	164	3.36
76	78	25	27	51	49	146	164	2.76
76	78	25	27	51	49	146	164	3.04
76	78	25	27	51	49	146	164	3.34
76	78	25	27	51	49	146	164	2.73
76	78	25	27	51	49	146	164	3.09
76	78	25	27	51	49	146	164	3.3
76	78	25	27	51	49	146	164	2.71
76	81	25	30	53	52	190	208	1.88
76	80	25	30	53	52	188	208	2.02
76	81	25	30	53	52	190	208	2.22
76	81	25	30	53	52	188	208	1.87
76	81	25	30	53	52	188	208	2.04
76	81	25	30	53	52	190	208	2.19
76	81	25	30	53	52	190	208	1.87

76	81	25	30	53	52	188	208	2.1
76	81	25	30	53	52	193	208	2.17
76	81	25	30	53	52	190	210	1.86
76	81	25	30	53	52	188	208	2.1
76	81	25	30	53	52	188	208	2.16
77	84	25	31	56	55	227	247	1.44
77	83	25	31	56	55	227	247	1.85
77	83	25	30	56	55	227	244	1.6
77	83	25	30	56	55	227	247	1.44
77	84	25	30	56	55	227	247	1.85
78	83	25	30	56	55	227	247	1.6
77	83	25	30	56	55	227	247	1.43
77	83	25	30	56	55	227	247	1.85
77	84	25	30	56	55	227	247	1.62
77	84	25	30	56	55	227	247	1.43
77	84	25	30	57	55	227	247	1.84
77	84	25	30	56	55	227	247	1.62
77	84	25	30	56	55	229	247	1.43
77	84	25	30	56	55	227	249	1.83
78	86	25	32	59	58	266	283	1.23
78	86	25	32	59	58	266	283	1.55
78	86	25	32	59	58	264	286	1.2
78	86	25	32	59	58	266	283	1.21
78	86	25	32	59	58	266	283	1.54
78	86	25	32	59	58	266	286	1.22
78	86	25	32	59	58	266	286	1.19
78	86	25	31	59	58	266	286	1.54
78	86	25	31	59	58	266	286	1.26
77	86	25	31	59	58	266	286	1.17
78	86	25	31	59	58	266	286	1.53
78	89	25	32	62	61	305	325	1.17
78	89	25	32	62	61	305	325	0.96
78	89	25	32	62	61	305	325	1.23
78	89	25	32	62	61	305	325	1.22
78	89	25	32	62	61	305	325	0.98
78	89	25	32	62	61	305	325	1.17
78	89	25	32	62	61	305	325	1.24
78	89	25	32	62	61	308	325	1.01
78	89	25	31	62	61	305	325	1.12
78	89	25	32	62	61	305	325	1.26
78	89	25	32	62	61	305	325	1.04
78	89	25	32	62	61	305	325	1.07

