Charlie Nitschelm

Pressure Lab

3/26/19

The natural frequency and the damping ratio were extracted from the data using fundamental equations assuming a second order differential system. The damping ratio was calculated by locating all of the major peaks from the data file and using those values as inputs into the damping ratio

$$\zeta = \frac{\frac{1}{n-1}\ln(\frac{y_1}{y_n})}{\sqrt{4\pi^2 + \frac{1}{n-1}\ln(\frac{y_1}{y_n})}} \quad (1)$$

The equation above provides a list of damping ratios for each peak observed in the data sets obtained, including the valve and balloon sets. A mean is then obtained for each data set that displays the predicted overall damping ratio of the system.

Once the damping ratio was determined, the natural frequency of each data set can be determined. To do this, the time of each peak was recorded and used to find the period of the cycle. The period constant can then be inputted into the equation for the damped natural frequency:

$$\omega_d = \frac{2\pi}{Period} \quad (2)$$

Finally, the damping ratio and damped natural frequency can be the inputs to the natural frequency equation

$$\omega_n = \frac{\omega_d}{\sqrt{1-\zeta^2}} \quad (3)$$

Both the damping ratio and the natural frequency of each data set can then be implemented to predict the output of a system given its initial conditions and simulate an arithmetic solution to the curve.

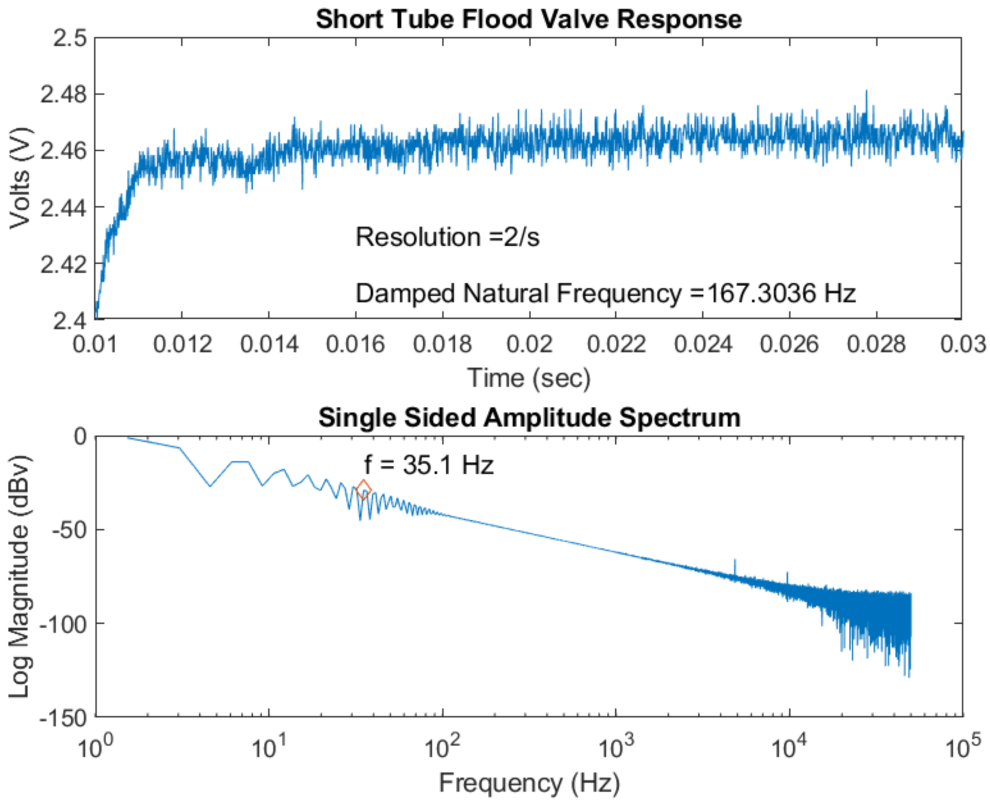


Figure 1 - The 0.17 meter tube with a quick flood valve showing no measurable oscillations impeding data analysis

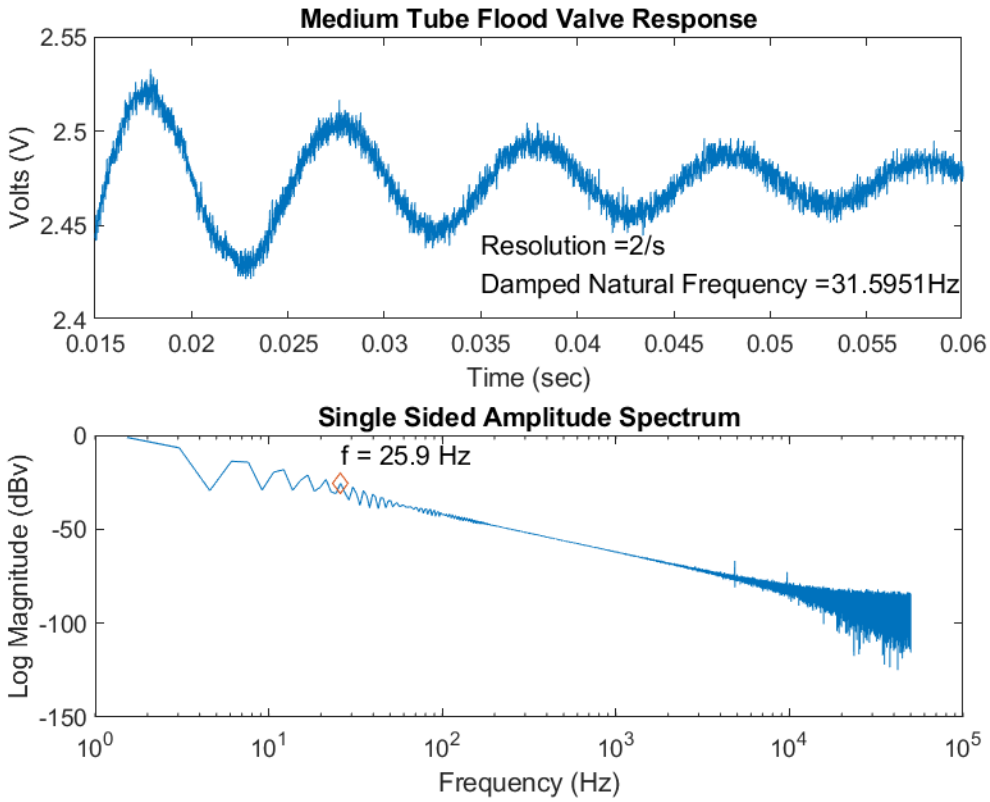


Figure 2 - 0.795 meter long tube with a quick flood valve response imparting measurable peaks for data analysis. FFT calculating the single-sided amplitude spectrum was not able to find the damped natural frequency accurately.

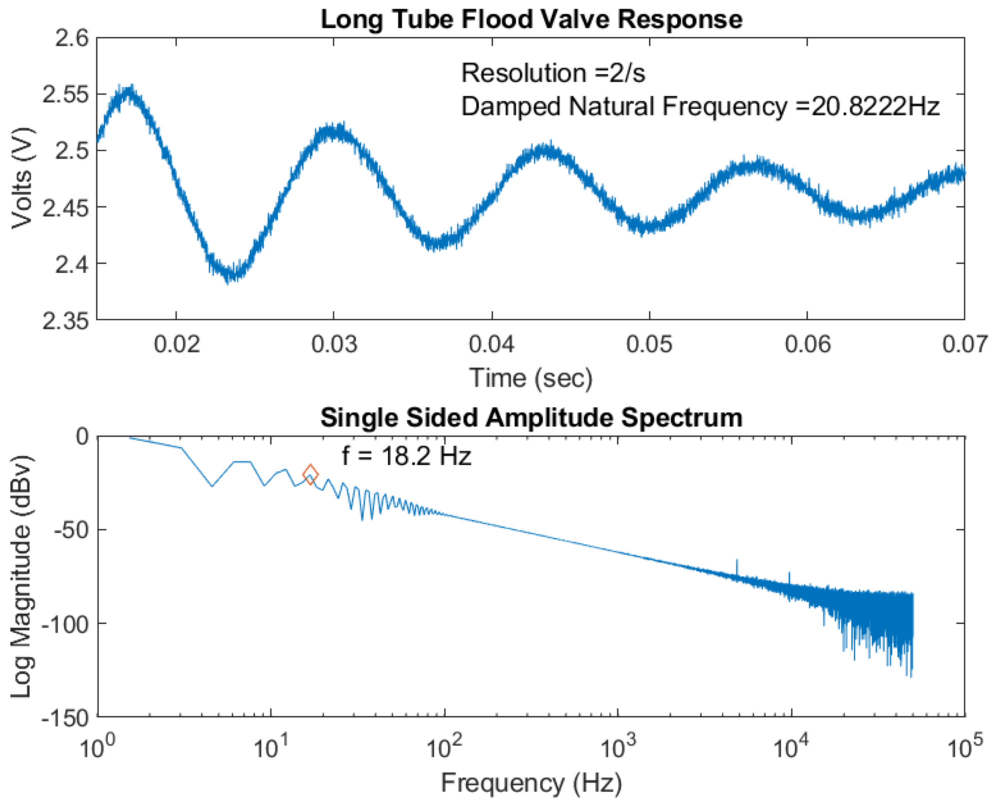


Figure 3 - 1.05 meter long tube with a quick flood valve response imparting measurable peaks for data analysis. FFT calculating the single-sided amplitude spectrum was able to find the damped natural frequency but with significant error.

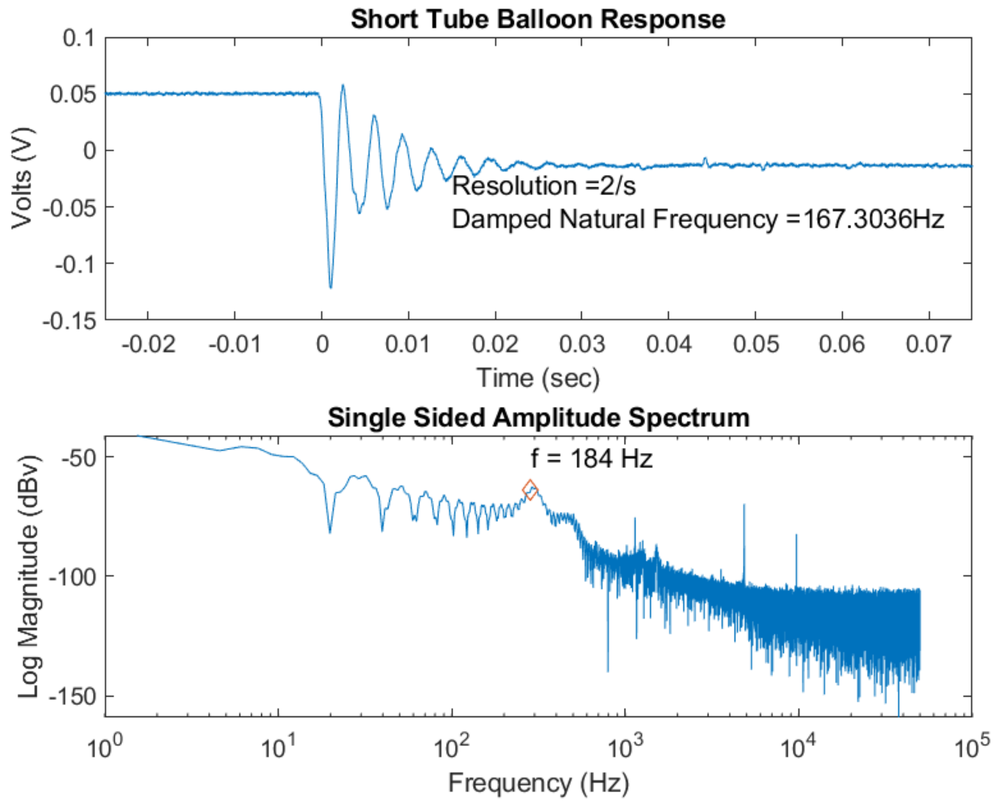


Figure 4 - 0.17 meter long tube response with an inflated balloon attached displaying the damped natural frequency using equations and FFT. Accuracy of the FFT is only 7% off from the actual from the data.

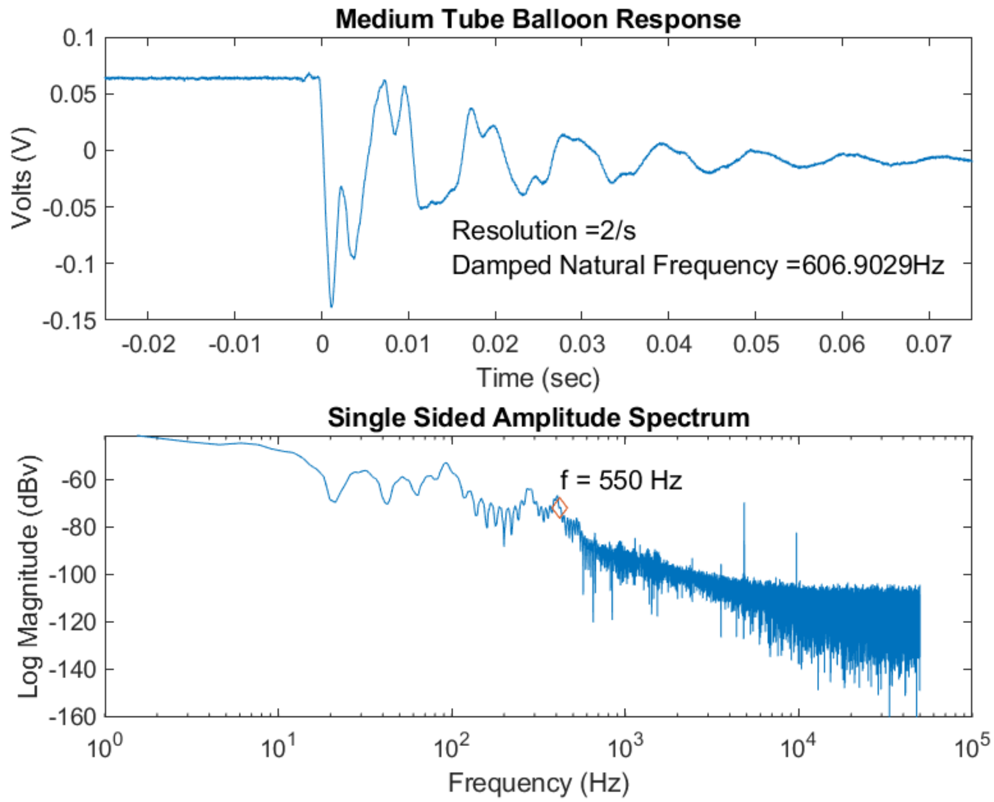


Figure 5 - 0.795 meter long tube response with an inflated balloon attached displaying the damped natural frequency using equations and FFT. Accuracy of the FFT is only 9% off from the actual from the data.

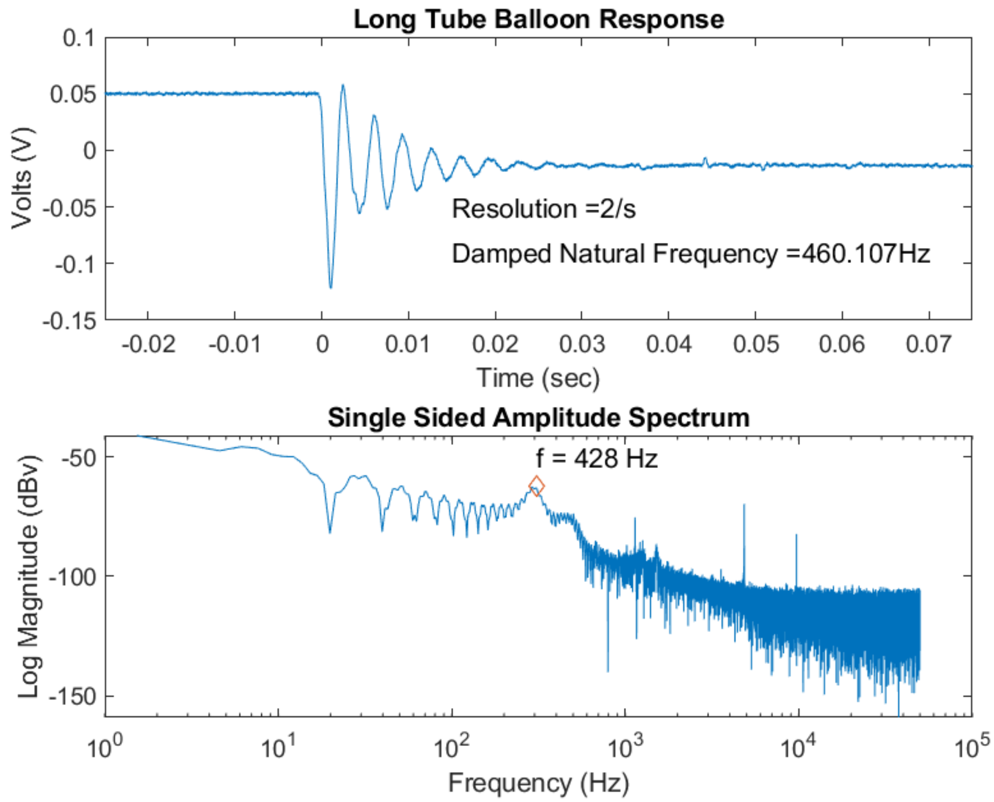


Figure 6 – 1.05 meter long tube response with an inflated balloon attached displaying the damped natural frequency using equations and FFT. Accuracy of the FFT is only 7% off from the actual from the data.

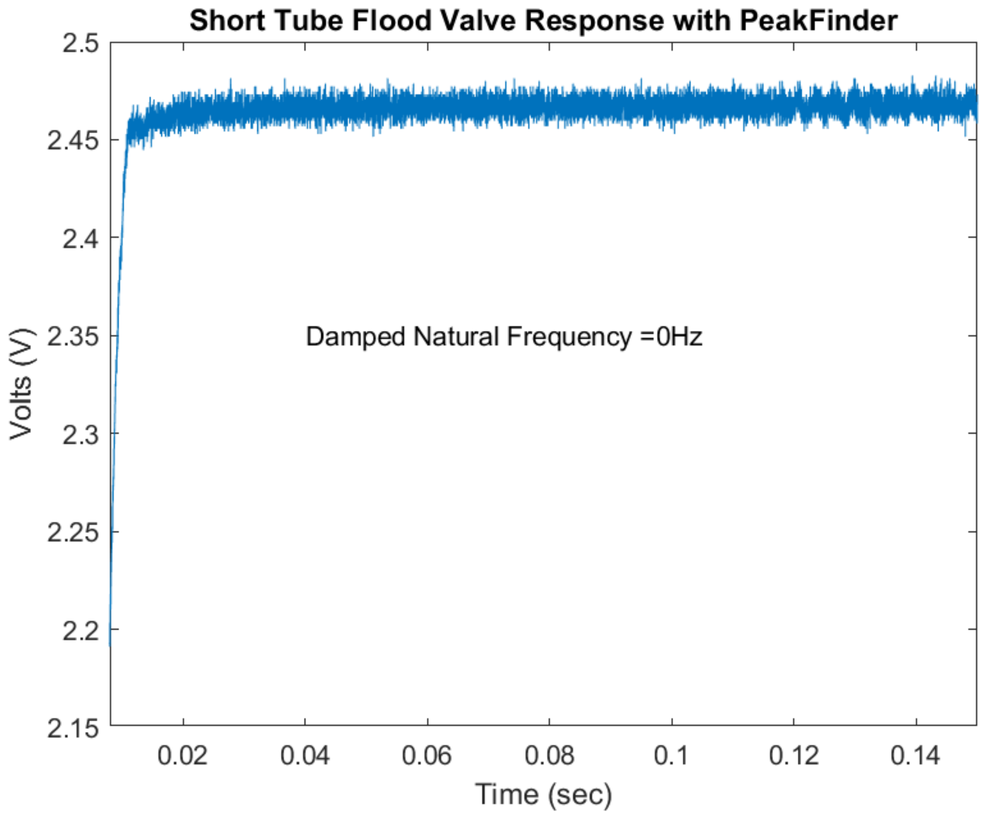


Figure 7 - No peaks found from 0.17 meter flood valve data by not opening the valve quick enough.

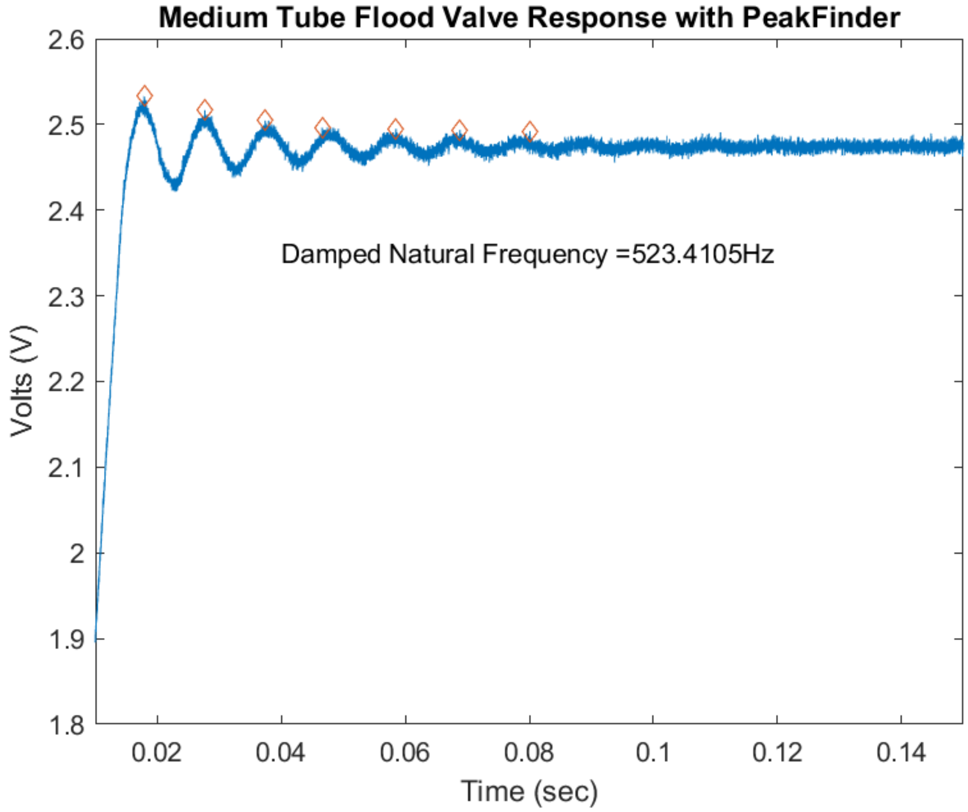


Figure 8 - The calculated damped natural frequency using the 0.795 meter tube and utilizing PeakFinder to identify locations of the peaks in the data

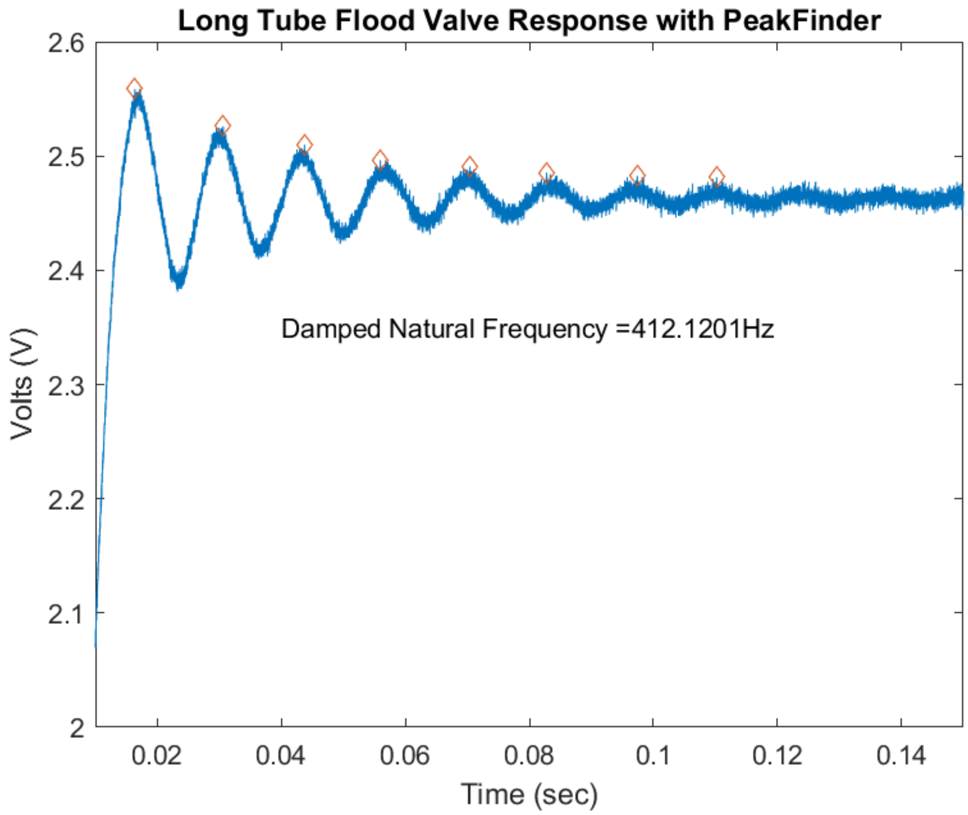


Figure 9 - The calculated damped natural frequency using the 1.05 meter tube and utilizing PeakFinder to identify locations of the peaks in the data

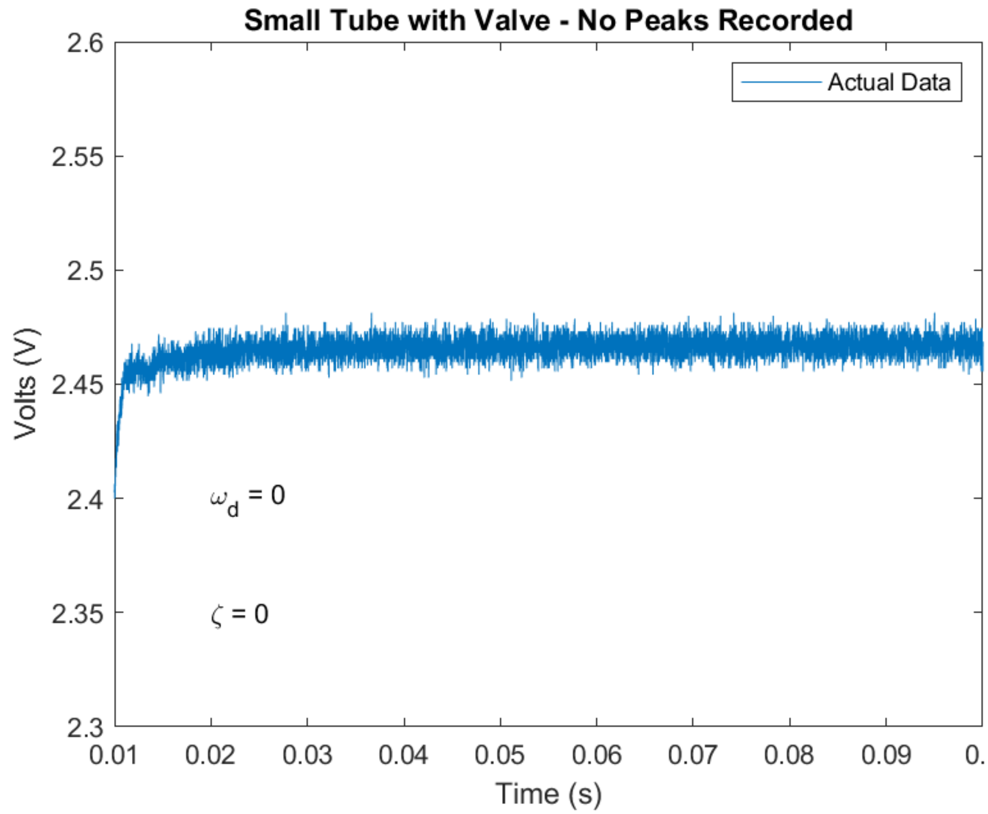


Figure 10 - With no measurable peaks, no prediction analysis could be implemented onto the 0.17 meter tube flood valve data set

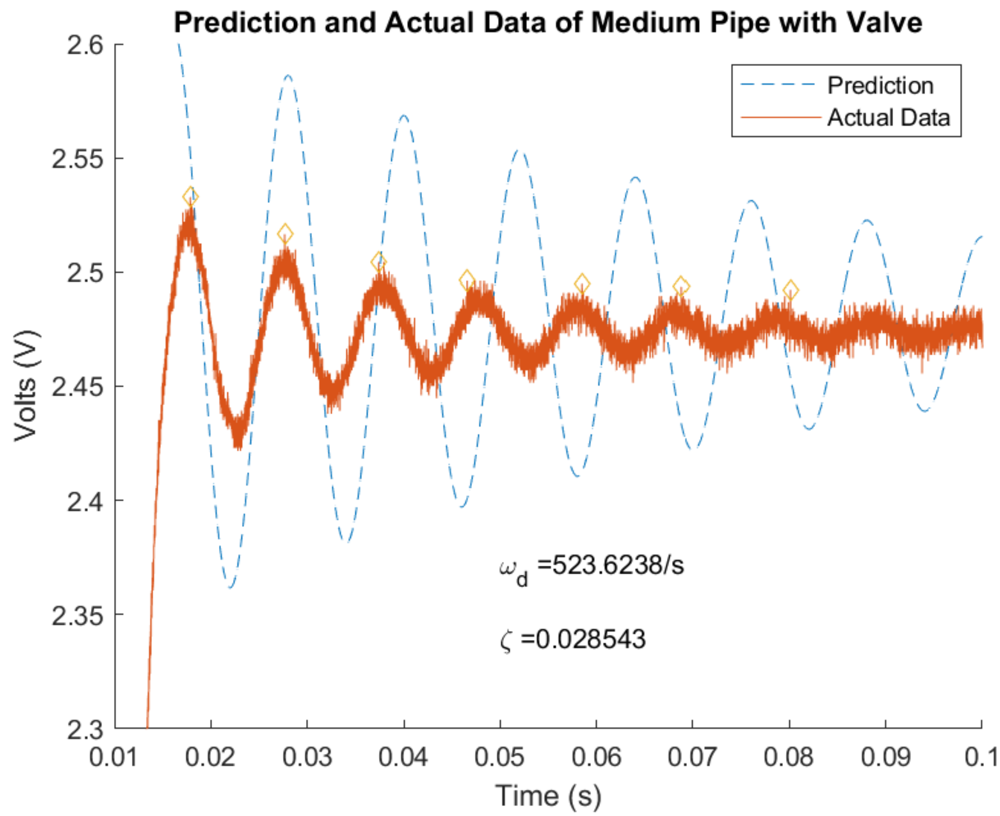


Figure 11 - Prediction and actual data curve utilizing equation 4 with the 0.795 meter tube with flood valve

$$y(t) = KA - KAe^{-\zeta\omega_n t}\left[\frac{\zeta}{\sqrt{1-\zeta^2}}\sin\left(\omega_n t\sqrt{1-\zeta^2}\right) + \cos\left(\omega_n t\sqrt{1-\zeta^2}\right)\right] \quad 0 \le \zeta < 1 \qquad (4)$$

Where KA is the settling voltage, and the Natural Frequency and the Damping Ratio were explained above. This way was chosen in competition with the clear code given as a challenge. Although the predictions are not completely in sync with the actual data, the predicted curves follow the same trends with acceptable accuracy. Figure 11 to Figure 15 uses equation 4 to predict the matching curves analytically.

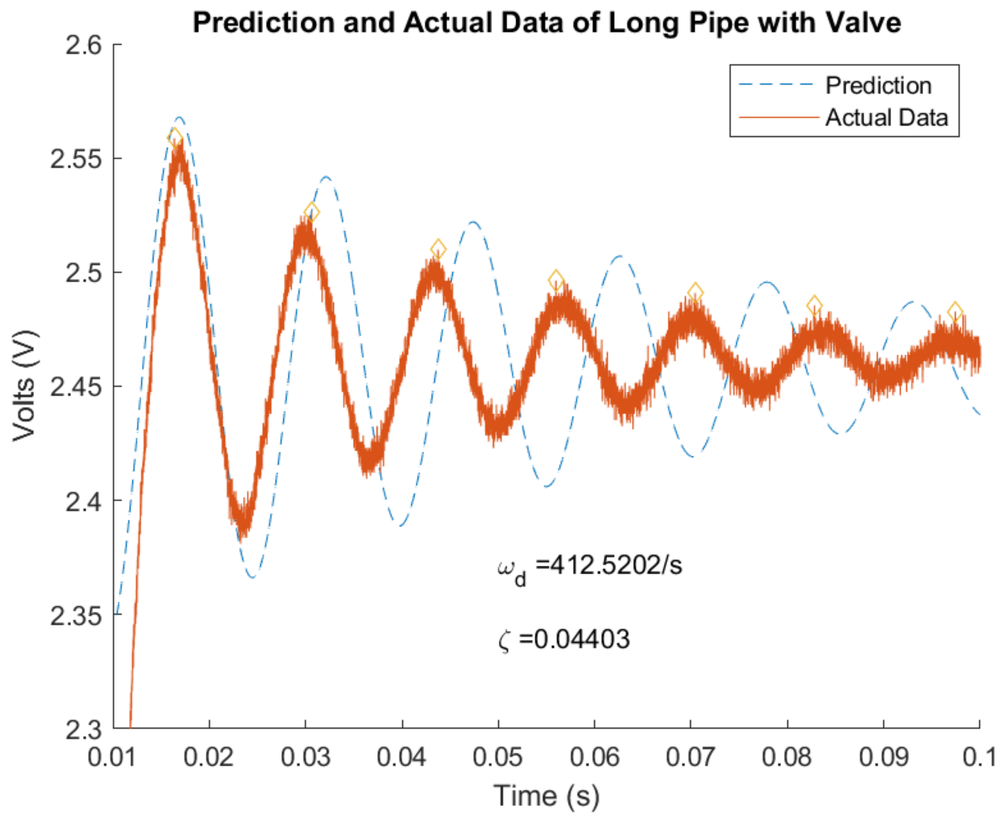


Figure 12 - Prediction and actual data curve utilizing the equation below with the 1.05 meter tube with flood valve using equation 4

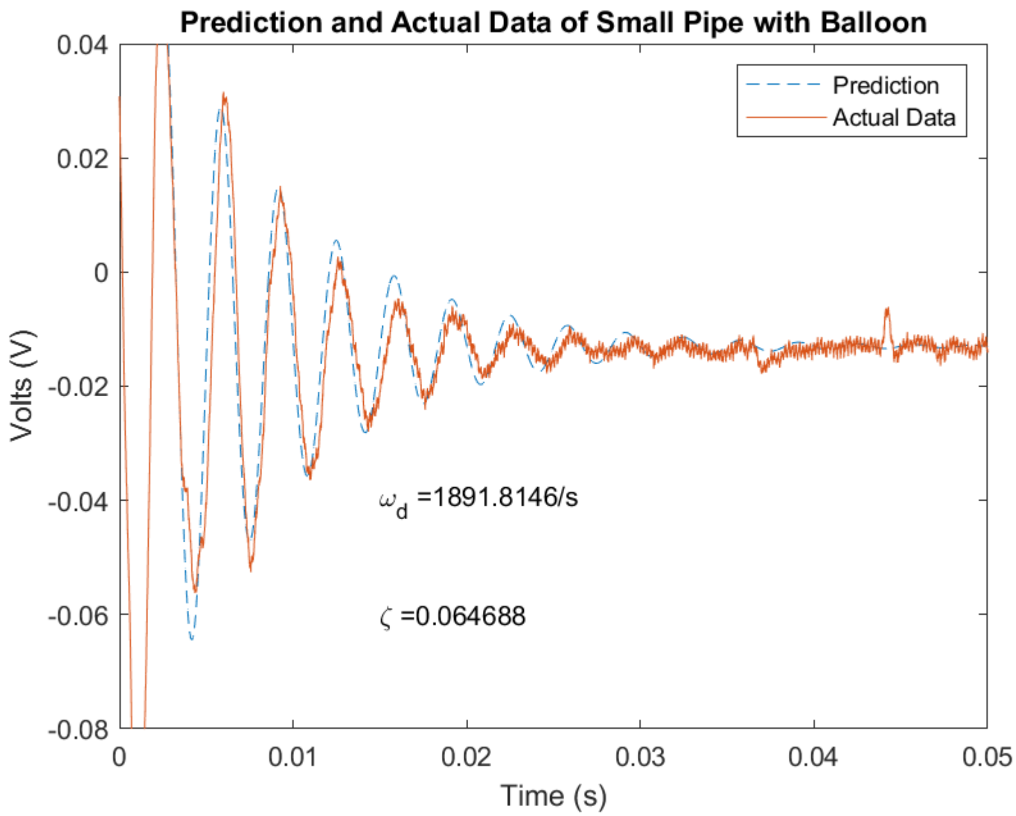


Figure 13 - Prediction and actual data curve utilizing equation 4 with the 0.17 meter tube with an inflated balloon attached

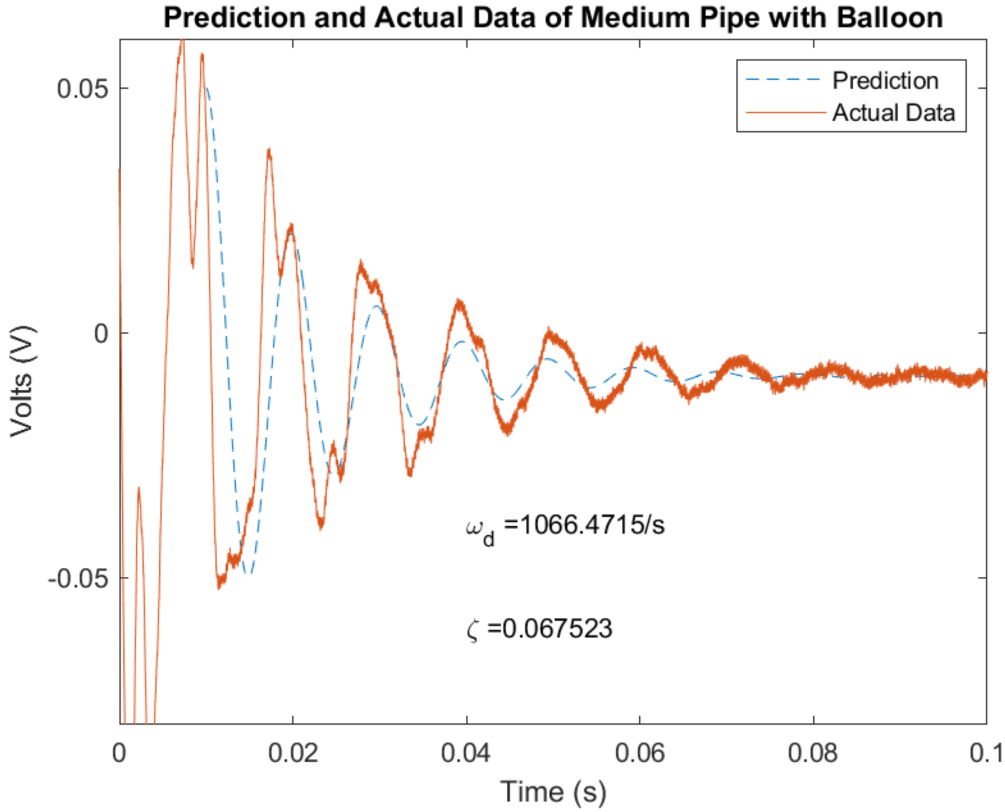


Figure 14 - Prediction and actual data curve utilizing equation 4 with the 0.795 meter tube with an inflated balloon attached

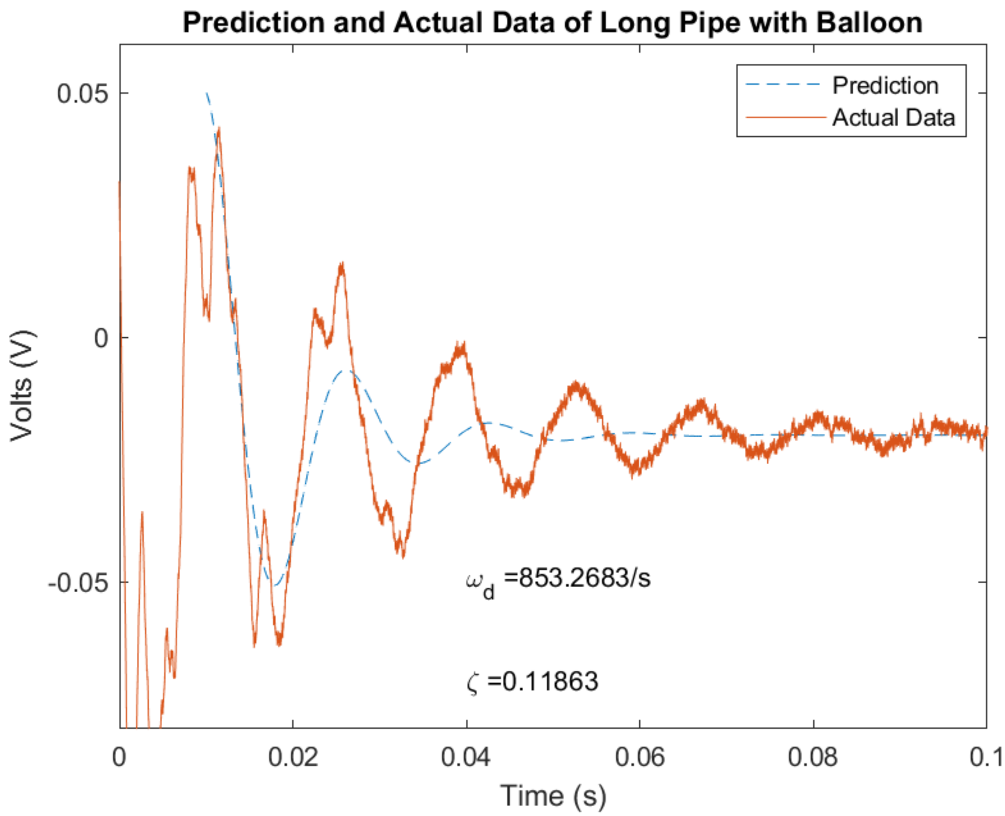


Figure 15 - Prediction and actual data curve utilizing equation 4 with the 1.05 meter tube with an inflated balloon attached

Two fundamental equations were used to calculate a curve to attempt to match with the calculated damping ratio and natural frequencies of each system analyzed. The equation for natural frequency is

$$\omega_n = \frac{a}{l\sqrt{0.5 + \frac{V}{V_t}}} \tag{5}$$

Where a is the speed of sound, 343 m/s, l is the length of the tube used for the test, V is the volume of the pressure transducer, and V_t is the volume of the tube used. By knowing the inputs, a prediction graph could be calculated to obtain a graphical display of predicted and actual natural frequencies.

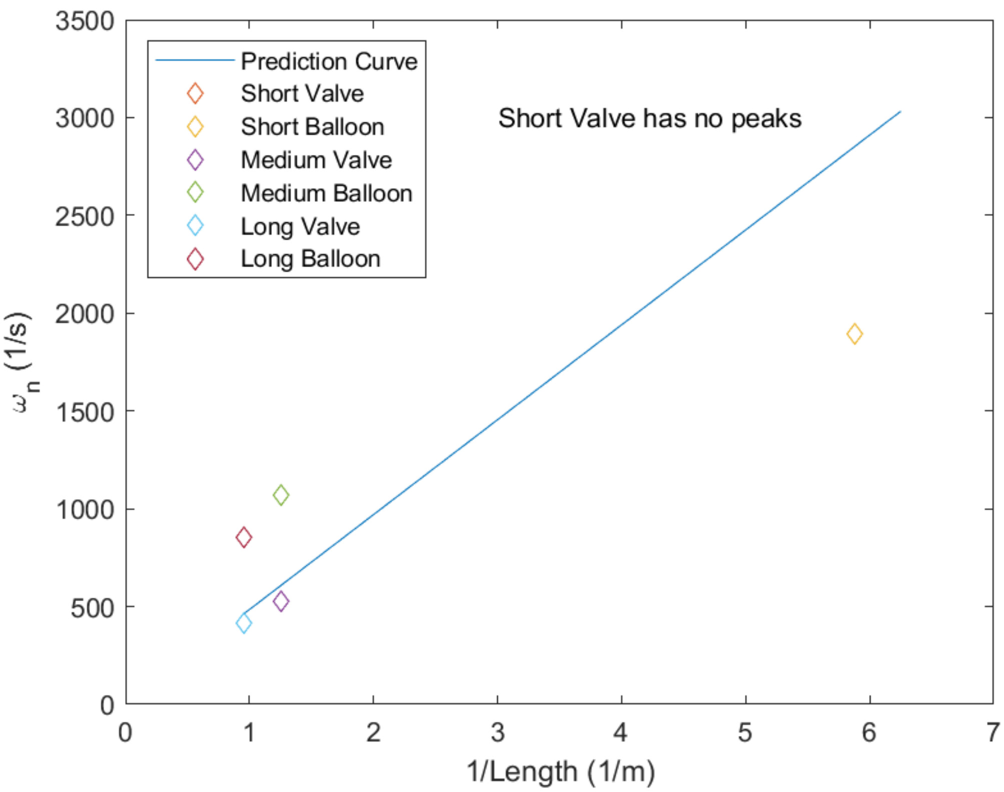


Figure 16 - Predicted curve for the natural frequency of the system with any tube length plotted with actual recorded data

There is a clear linear relationship between natural frequency and the inverse of the tube length. The actual precision of the data to the curve is within +- 500/s for the longest and the second longest tube, while the short tube exhibits and error closer -1000/s. With any data set, a significant amount of error can exist. Within the pressure experiment, the valve data especially exhibited a larger error as the change in voltage from the pressure sensor was quick and large. Second order systems are also known to be difficult to precisely predict an appropriate curve.

The equation for natural frequency is

$$\zeta = \frac{16\mu l}{a\rho d^2}\sqrt{0.5 + \frac{V}{V_t}} \tag{6}$$

Where μ is kinematic viscosity, 1.81*10^{-5} kg/ms, l is the length of the tube used for the test, V is the volume of the pressure transducer, and V_t is the volume of the tube used, a is the speed of sound, 343 m/s, ρ is the density of air, 1.225 kg/m^3, and d is the diameter of the tube used. By knowing the inputs, a prediction graph could be calculated to obtain a graphical display of predicted and actual damping ratios.

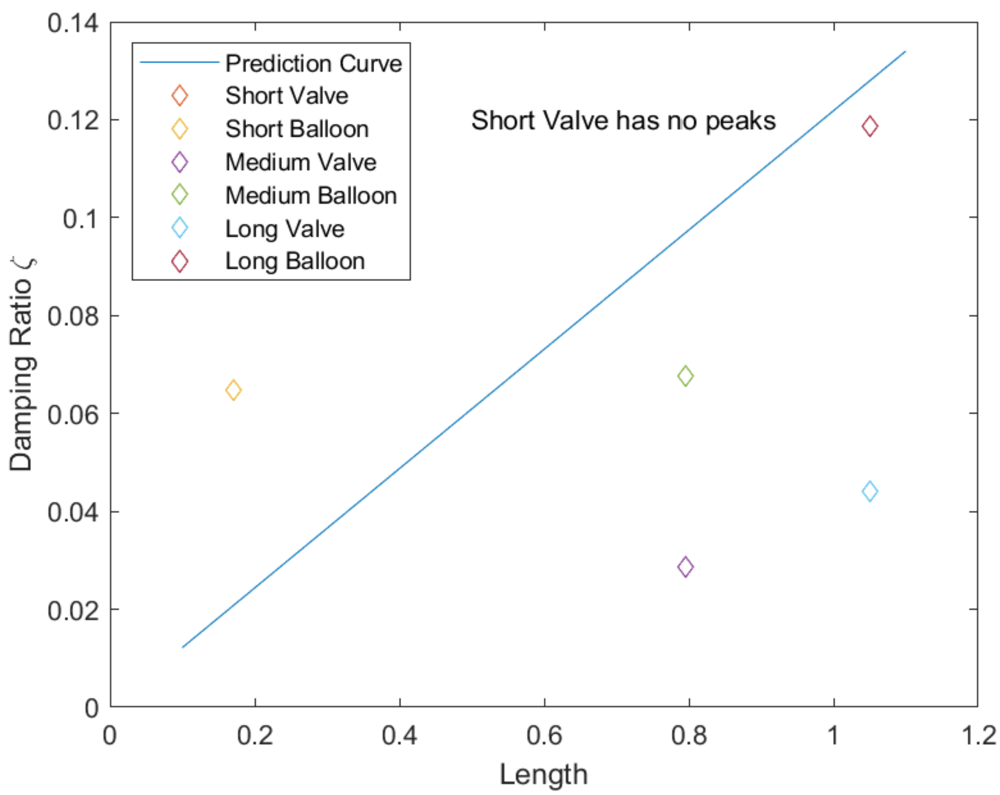


Figure 17 - Predicted curve for the Damping Ratio of the system with any tube length plotted with actual recorded data

There is a clear linear relationship between the damping ratio and the tube length. The actual precision of the data to the curve is within an order of magnitude for the longest and the second longest tube, while the short tube exhibits and error closer to half and order of magnitude. With any data set, a significant amount of error can exist. Within the pressure experiment, the valve data especially exhibited a larger error as the change in voltage from the pressure sensor was quick and large. Second order systems are also known to be difficult to precisely predict an appropriate curve.

For both Figure 16 and Figure 17, a relationship to length for both of these parameters are clear, but significant error is involved limiting the accuracy of the equation to actual calculations.

Appendix

```
% Lab 4 %
clear all
close all
```

Import Data

```
% Reading in entire data set
Header=29;
Small_Flood    = importdata('SmallPipe_Flood.lvm','\t',Header);
Small_Balloon  = importdata('SmallPipe_Balloon.lvm','\t',Header);
Medium_Flood   = importdata('MediumPipe_Flood.lvm','\t',Header);
Medium_Balloon = importdata('MediumPipe_Balloon.lvm','\t',Header);
Long_Flood     = importdata('LongPipe_Flood.lvm','\t',Header);
Long_Balloon   = importdata('LongPipe_Balloon.lvm','\t',Header);

% Separating entire data sets into vectors of Time and Voltage
Time_Small_Flood    = Small_Flood.data(:,1);
Time_Small_Balloon  = Small_Balloon.data(:,1);
Time_Medium_Flood   = Medium_Flood.data(:,1);
Time_Medium_Balloon = Medium_Balloon.data(:,1);
Time_Long_Flood     = Long_Flood.data(:,1);
Time_Long_Balloon   = Long_Balloon.data(:,1);

Voltage_Small_Flood    = Small_Flood.data(:,2);
Voltage_Small_Balloon  = Small_Balloon.data(:,2);
Voltage_Medium_Flood   = Medium_Flood.data(:,2);
Voltage_Medium_Balloon = Medium_Balloon.data(:,2);
Voltage_Long_Flood     = Long_Flood.data(:,2);
Voltage_Long_Balloon   = Long_Balloon.data(:,2);
```

Flood Tests

```
% Small Pipe

T = Time_Small_Flood(2)-Time_Small_Flood(1); % Calculated time interval between data
points
Freq = 1/T; % Sampling Frequency
Length = size(Voltage_Small_Flood); % Number of points in vector
Power_2 = 2^nextpow2(Length(1)); % power of 2 from length y
FFT = fft(Voltage_Small_Flood,Power_2)./Length(1); % fft bull
Spaced_Points = Freq/2*linspace(0,1,Power_2/2+1); % spaced point vector using length
FFT_A = 20*log10(abs(FFT(1:Power_2/2+1))); % amplitude
Length_2 = length(Voltage_Small_Flood);
Freq_Reso_Flood_Small = 1/(Length_2*T); %FOR GRAPH

a = 343;
```

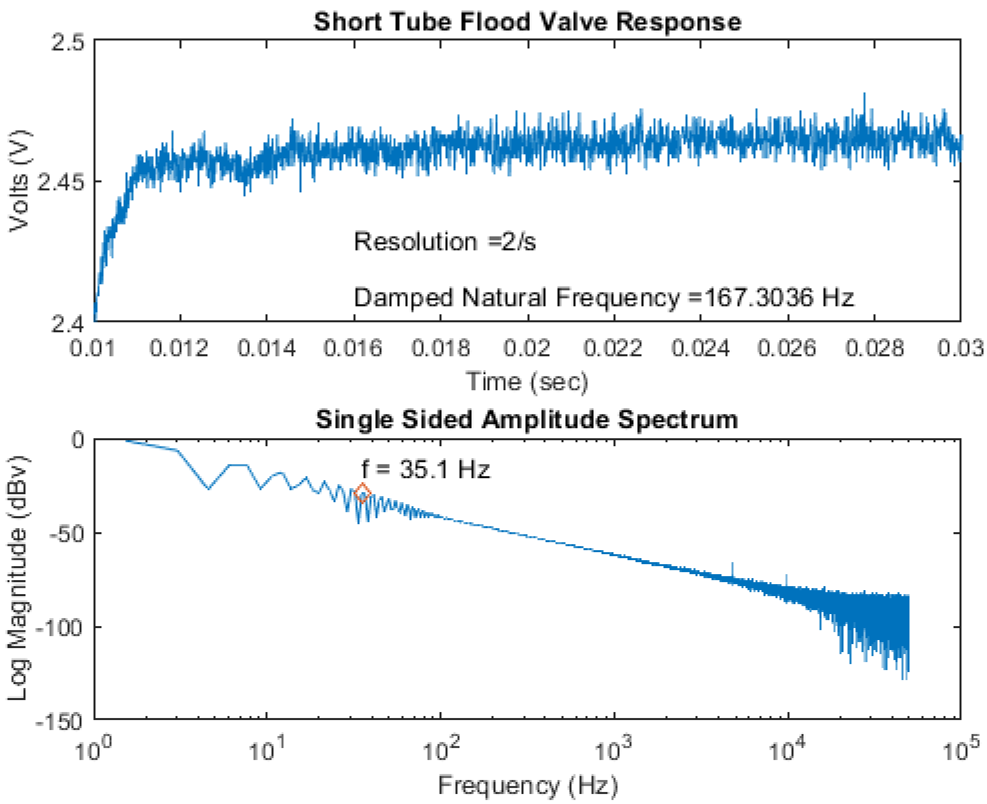
```
l = .17;
V = l*pi*.0042^2;
Vt = 6.5*10^-8;
Damp_Natural_Freq_Small_Flood = a/(l*sqrt(0.5+(V/Vt))); % FOR GRAPH

f1 = figure(1)

subplot(2,1,1)
plot (Time_Small_Flood,Voltage_Small_Flood);
title('Short Tube Flood Valve Response')
xlabel ('Time (sec)')
ylabel ('Volts (V)')
text(.016,2.43,strcat('Resolution =',num2str(Freq_Reso_Flood_Small),'/s'))
text(.016,2.41,strcat('Damped Natural Frequency =
',num2str(Damp_Natural_Freq_Small_Flood),' Hz'))
xlim([0.01,0.03])

subplot(2,1,2)
semilogx(Spaced_Points,FFT_A);
hold on
plot(35.1,-29.14,'d')
text(35.1,-15,'f = 35.1 Hz')
title('Single Sided Amplitude Spectrum')
xlabel ('Frequency (Hz)')
ylabel ('Log Magnitude (dBv)')



% Medium Pipe

T = Time_Medium_Flood(2)-Time_Medium_Flood(1); % Calculated time interval between data
points
Freq = 1/T; % Sampling Frequency
Length = size(Voltage_Medium_Flood); % Number of points in vector
Power_2 = 2^nextpow2(Length(1)); % power of 2 from length y
FFT = fft(Voltage_Medium_Flood,Power_2)./Length(1); % fft bull
Spaced_Points = Freq/2*linspace(0,1,Power_2/2+1); % spaced point vector using length
FFT_A = 20*log10(abs(FFT(1:Power_2/2+1))); % amplitude
Length_2 = length(Voltage_Medium_Flood);
Freq_Reso_Flood_Medium = 1/(Length_2*T); %FOR GRAPH

a = 343;
l = .795;
V = l*pi*.0022^2;
Vt = 6.5*10^-8;
Damp_Natural_Freq_Medium_Flood = a/(l*sqrt(0.5+(V/Vt)));

f2 = figure(2)

subplot(2,1,1)
plot (Time_Medium_Flood,Voltage_Medium_Flood);
```

```
title('Medium Tube Flood Valve Response')
xlabel ('Time (sec)')
ylabel ('Volts (V)')
text(.035,2.44,strcat('Resolution =',num2str(Freq_Reso_Flood_Medium),'/s'))
text(.035,2.42,strcat('Damped Natural Frequency =
',num2str(Damp_Natural_Freq_Medium_Flood),'Hz'))
xlim([0.015,0.06])

subplot(2,1,2)
semilogx(Spaced_Points,FFT_A);
hold on
plot(25.9,-25.52,'d')
text(25.9,-10,'f = 25.9 Hz')
title('Single Sided Amplitude Spectrum')
xlabel ('Frequency (Hz)')
ylabel ('Log Magnitude (dBv)')




% Long Pipe

T = Time_Long_Flood(2)-Time_Long_Flood(1); % Calculated time interval between data
points
Freq = 1/T; % Sampling Frequency
Length = size(Voltage_Small_Flood); % Number of points in vector
Power_2 = 2^nextpow2(Length(1)); % power of 2 from length y
FFT = fft(Voltage_Small_Flood,Power_2)./Length(1); % fft bull
Spaced_Points = Freq/2*linspace(0,1,Power_2/2+1); % spaced point vector using length
FFT_A = 20*log10(abs(FFT(1:Power_2/2+1))); % amplitude
Length_2 = length(Voltage_Long_Flood);
Freq_Reso_Flood_Long = 1/(Length_2*T); %FOR GRAPH

a = 343;
l = 1.05;
V = l*pi*.0022^2;
Vt = 6.5*10^-8;
Damp_Natural_Freq_Long_Flood = a/(l*sqrt(0.5+(V/Vt)));

f3 = figure(3)

subplot(2,1,1)
plot (Time_Long_Flood,Voltage_Long_Flood);
title('Long Tube Flood Valve Response')
xlabel ('Time (sec)')
ylabel ('Volts (V)')
text(.038,2.57,strcat('Resolution =',num2str(Freq_Reso_Flood_Long),'/s'))
text(.038,2.54,strcat('Damped Natural Frequency =
',num2str(Damp_Natural_Freq_Long_Flood),'Hz'))
xlim([0.015,.07])
```

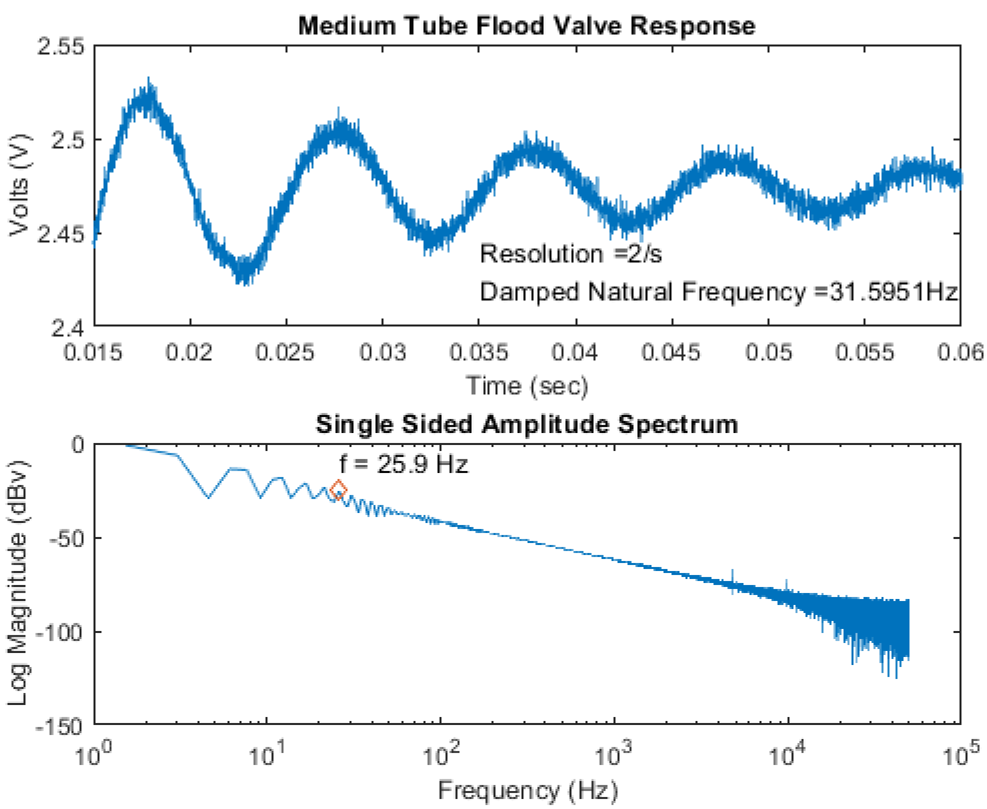
```
subplot(2,1,2)
semilogx(Spaced_Points,FFT_A);
hold on
plot(16.78,-20.82,'d')
text(25.78,-10,'f = 18.2 Hz')
title('Single Sided Amplitude Spectrum')
xlabel ('Frequency (Hz)')
ylabel ('Log Magnitude (dBv)')
```

```
f1 =

  Figure (1) with properties:

      Number: 1
        Name: ''
       Color: [0.9400 0.9400 0.9400]
    Position: [488 342 560 420]
       Units: 'pixels'

  Use GET to show all properties


f2 =

  Figure (2) with properties:

      Number: 2
        Name: ''
       Color: [0.9400 0.9400 0.9400]
```

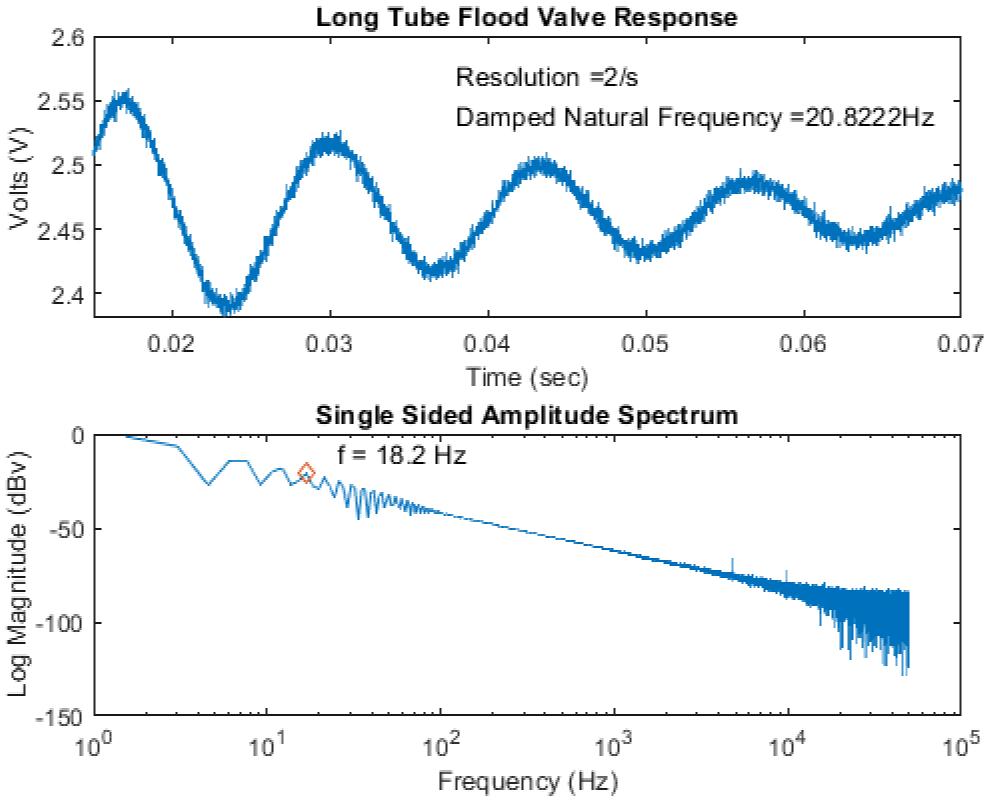
```
    Position: [488 342 560 420]

       Units: 'pixels'


  Use GET to show all properties




f3 = 


  Figure (3) with properties:


      Number: 3

        Name: ''

       Color: [0.9400 0.9400 0.9400]

    Position: [488 342 560 420]

       Units: 'pixels'


  Use GET to show all properties
```



Short Tube Flood Valve Response
Volts (V)
2.5
2.45
2.4
Resolution =2/s
Damped Natural Frequency =167.3036 Hz
0.01
0.012
0.014
0.016
0.018
0.02
0.022
0.024
0.026
0.028
0.03
Time (sec)
Single Sided Amplitude Spectrum
f = 35.1 Hz
Log Magnitude (dBv)
0
-50
-100
-150
10^0
10^1
10^2
10^3
10^4
10^5
Frequency (Hz)



Medium Tube Flood Valve Response
Volts (V)
2.55
2.5
2.45
2.4
Resolution =2/s
Damped Natural Frequency =31.5951Hz
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05
0.055
0.06
Time (sec)
Single Sided Amplitude Spectrum
f = 25.9 Hz
Log Magnitude (dBv)
0
-50
-100
-150
10^0
10^1
10^2
10^3
10^4
10^5
Frequency (Hz)



Balloon Tests

```
% Small Pipe

T = Time_Small_Balloon(2)-Time_Small_Balloon(1); % Calculated time interval between
data points
Freq = 1/T; % Sampling Frequency
Length = size(Voltage_Small_Balloon); % Number of points in vector
Power_2 = 2^nextpow2(Length(1)); % power of 2 from length y
FFT = fft(Voltage_Small_Balloon,Power_2)./Length(1); % fft bull
Spaced_Points = Freq/2*linspace(0,1,Power_2/2+1); % spaced point vector using length
FFT_A = 20*log10(abs(FFT(1:Power_2/2+1))); % amplitude
Length_2 = length(Voltage_Small_Balloon);
Freq_Reso_Balloon_Small = 1/(Length_2*T); %FOR GRAPH

a = 343;
l = .17;
V = l*pi*.0042^2;
Vt = 6.5*10^-8;
Damp_Natural_Freq_Small_Balloon = a/(l*sqrt(0.5+(V/Vt)));

f4 = figure(4)

subplot(2,1,1)
plot (Time_Small_Balloon,Voltage_Small_Balloon);
```

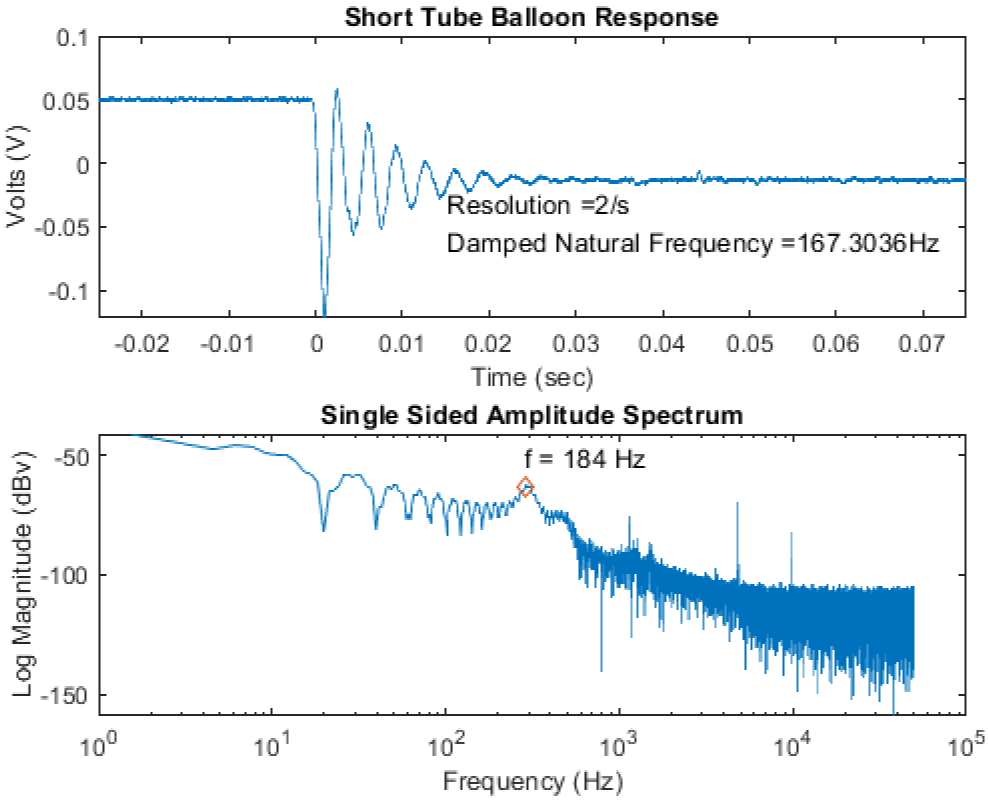
```
title('Short Tube Balloon Response')
xlabel ('Time (sec)')
ylabel ('Volts (V)')
text(.015,-.03,strcat('Resolution =',num2str(Freq_Reso_Balloon_Small),'/s'))
text(.015,-.06,strcat('Damped Natural Frequency =
',num2str(Damp_Natural_Freq_Small_Balloon),'Hz'))
xlim([-.025,.075])

subplot(2,1,2)
semilogx(Spaced_Points,FFT_A);
hold on
plot(285,-63.6,'d')
text(285,-50,'f = 184 Hz')
title('Single Sided Amplitude Spectrum')
xlabel ('Frequency (Hz)')
ylabel ('Log Magnitude (dBv)')


% Medium Pipe

T = Time_Medium_Balloon(2)-Time_Medium_Balloon(1); % Calculated time interval between
data points
Freq = 1/T; % Sampling Frequency
Length = size(Voltage_Medium_Balloon); % Number of points in vector
Power_2 = 2^nextpow2(Length(1)); % power of 2 from length y
FFT = fft(Voltage_Medium_Balloon,Power_2)./Length(1); % fft bull
Spaced_Points = Freq/2*linspace(0,1,Power_2/2+1); % spaced point vector using length
FFT_A = 20*log10(abs(FFT(1:Power_2/2+1))); % amplitude
Length_2 = length(Voltage_Medium_Balloon);
Freq_Reso_Balloon_Medium = 1/(Length_2*T); %FOR GRAPH

a = 343;
l = .795;
Vt = l*pi*.0022^2;
V = 6.5*10^-8;
Damp_Natural_Freq_Medium_Balloon = a/(l*sqrt(0.5+(V/Vt)));

f5 = figure(5)

subplot(2,1,1)
plot (Time_Medium_Balloon,Voltage_Medium_Balloon);
title('Medium Tube Balloon Response')
xlabel ('Time (sec)')
ylabel ('Volts (V)')
text(.015,-.07,strcat('Resolution =',num2str(Freq_Reso_Balloon_Medium),'/s'))
text(.015,-.10,strcat('Damped Natural Frequency =
',num2str(Damp_Natural_Freq_Medium_Balloon),'Hz'))
xlim([-.025,.075])

subplot(2,1,2)
semilogx(Spaced_Points,FFT_A);
```

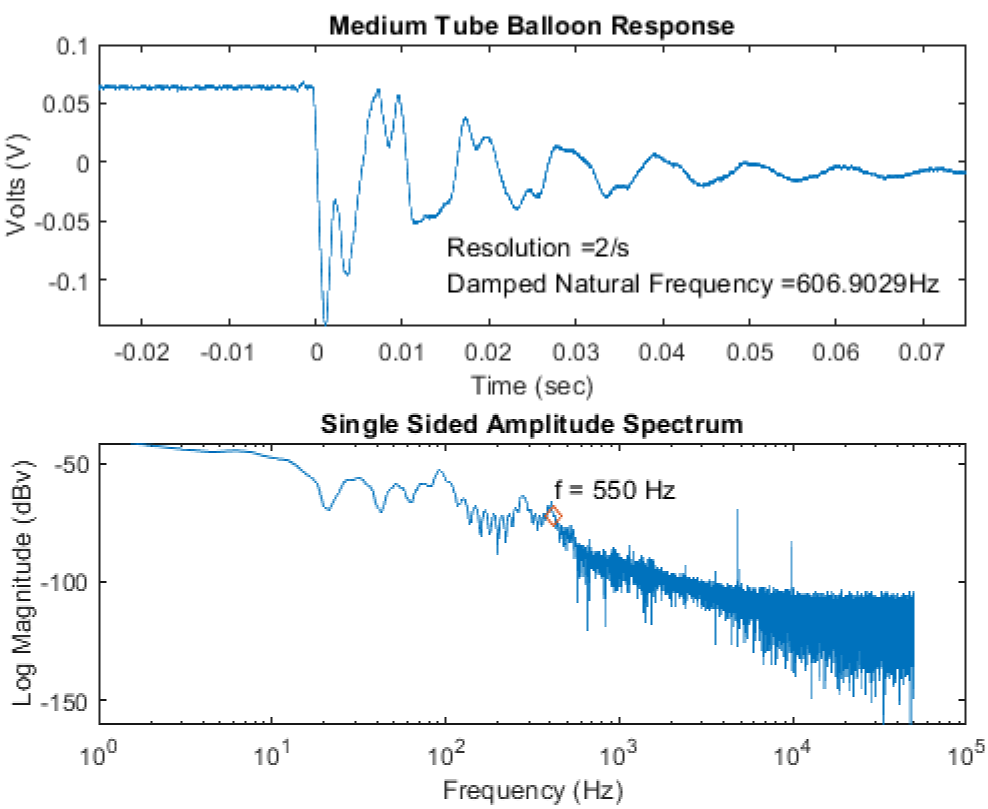
```
hold on
plot(420,-71.9,'d')
text(420,-60,'f = 550 Hz')
title('Single Sided Amplitude Spectrum')
xlabel ('Frequency (Hz)')
ylabel ('Log Magnitude (dBv)')



% Long Pipe

T = Time_Long_Balloon(2)-Time_Long_Balloon(1); % Calculated time interval between data
points
Freq = 1/T; % Sampling Frequency
Length = size(Voltage_Small_Balloon); % Number of points in vector
Power_2 = 2^nextpow2(Length(1)); % power of 2 from length y
FFT = fft(Voltage_Small_Balloon,Power_2)./Length(1); % fft bull
Spaced_Points = Freq/2*linspace(0,1,Power_2/2+1); % spaced point vector using length
FFT_A = 20*log10(abs(FFT(1:Power_2/2+1))); % amplitude
Length_2 = length(Voltage_Long_Balloon);
Freq_Reso_Balloon_Long = 1/(Length_2*T); %FOR GRAPH

a = 343;
l = 1.05;
Vt = l*pi*.0022^2;
V = 6.5*10^-8;
Damp_Natural_Freq_Long_Balloon = a/(l*sqrt(0.5+(V/Vt)));

f6 = figure(6)

subplot(2,1,1)
plot (Time_Long_Balloon,Voltage_Small_Balloon);
title('Long Tube Balloon Response')
xlabel ('Time (sec)')
ylabel ('Volts (V)')
text(.015,-.05,strcat('Resolution =',num2str(Freq_Reso_Balloon_Long),'/s'))
text(.015,-.09,strcat('Damped Natural Frequency =
',num2str(Damp_Natural_Freq_Long_Balloon),'Hz'))
xlim([-.025,.075])

subplot(2,1,2)
semilogx(Spaced_Points,FFT_A);
hold on
plot(308,-62,'d')
text(308,-50,'f = 428 Hz')
title('Single Sided Amplitude Spectrum')
xlabel ('Frequency (Hz)')
ylabel ('Log Magnitude (dBv)')
```

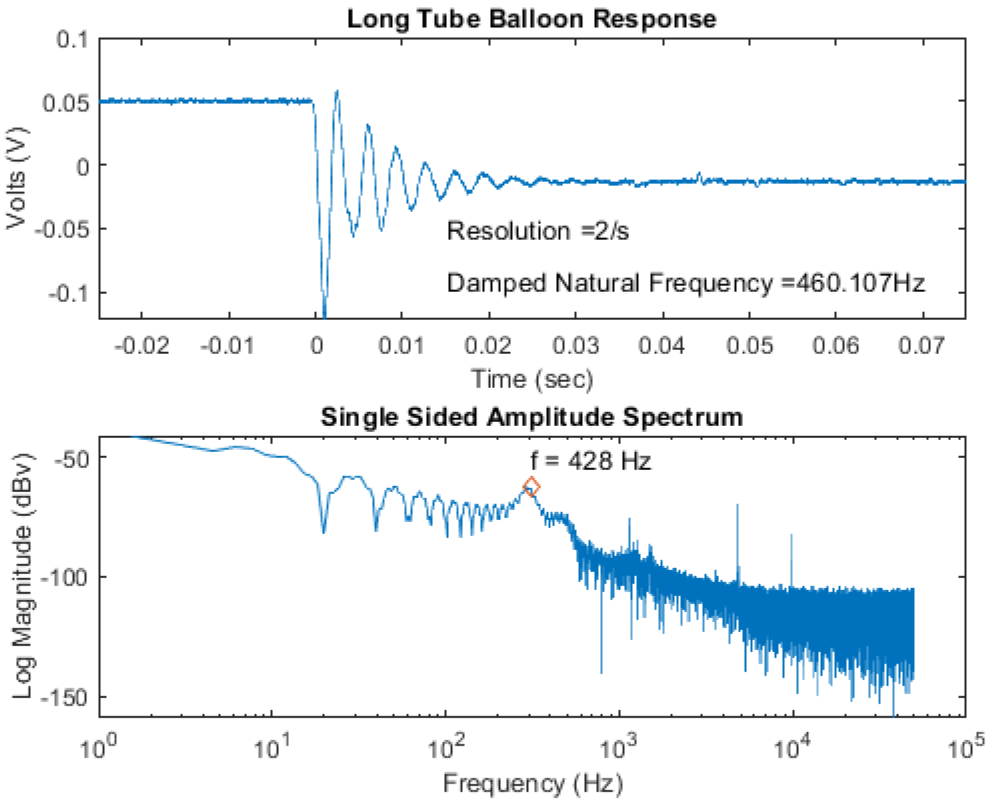
```
f4 =
```

```
  Figure (4) with properties:

      Number: 4
        Name: ''
       Color: [0.9400 0.9400 0.9400]
    Position: [488 342 560 420]
       Units: 'pixels'

  Use GET to show all properties


f5 =

  Figure (5) with properties:

      Number: 5
        Name: ''
       Color: [0.9400 0.9400 0.9400]
    Position: [488 342 560 420]
       Units: 'pixels'

  Use GET to show all properties
```

```
f6 =

  Figure (6) with properties:

      Number: 6
        Name: ''
       Color: [0.9400 0.9400 0.9400]
    Position: [488 342 560 420]
       Units: 'pixels'

  Use GET to show all properties
```


Short Tube Balloon Response
Volts (V)
Time (sec)
Resolution =2/s
Damped Natural Frequency =167.3036Hz
Single Sided Amplitude Spectrum
Log Magnitude (dBv)
Frequency (Hz)
f = 184 Hz


Medium Tube Balloon Response
Volts (V)
Time (sec)
Resolution =2/s
Damped Natural Frequency =606.9029Hz
Single Sided Amplitude Spectrum
Log Magnitude (dBv)
Frequency (Hz)
f = 550 Hz



Peakfinder

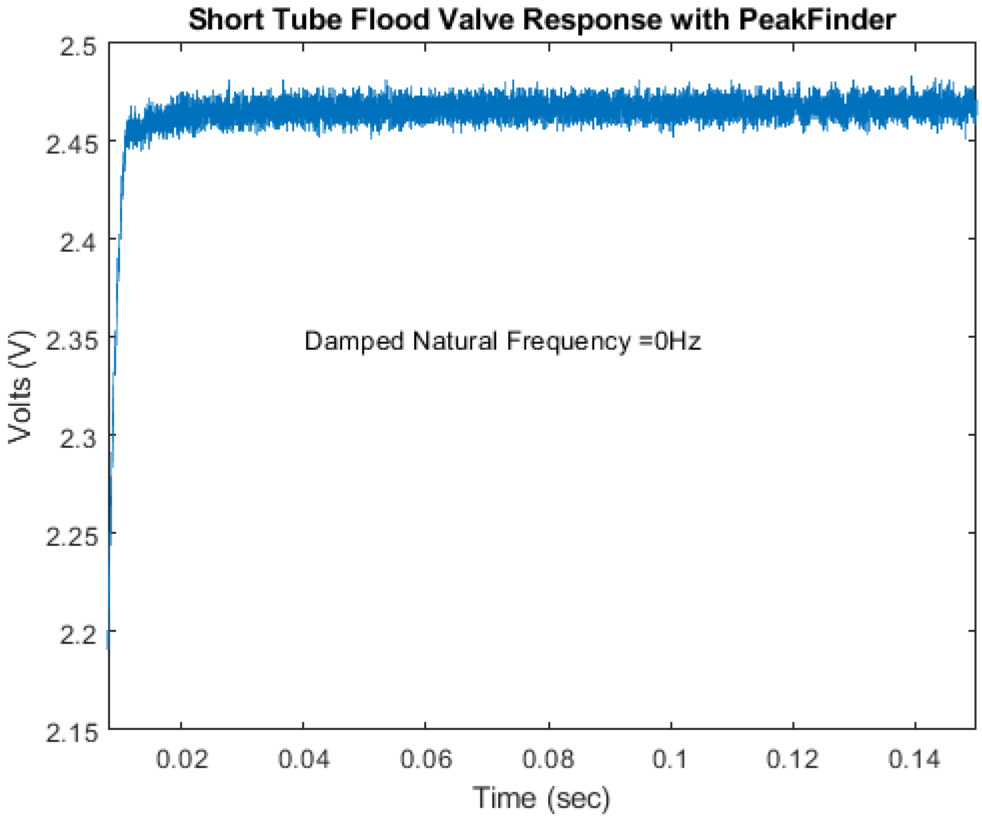
```
% Small Pipe
Constant = 1;
[Volt_Locations_Small,Volt_Small]=peakfinder(Voltage_Small_Flood,Constant);
Damping_Ratio_Small_Flood = zeros(length(Volt_Small),1);
for n = 1:length(Volt_Small)-1
    Period_Small = Time_Small_Flood(Volt_Locations_Small(n+1))-
Time_Small_Flood(Volt_Locations_Small(n));
    Damping_Ratio_Small_Flood(n) = (2*pi)/Period_Small;
end
Damp_Mean_Small = mean(Damping_Ratio_Small_Flood);
f7 = figure(7)
plot(Time_Small_Flood,Voltage_Small_Flood,Time_Small_Flood(Volt_Locations_Small),Volt_
Small,'d')
title('Short Tube Flood Valve Response with PeakFinder')
text(.04,2.35,strcat('Damped Natural Frequency =',num2str(Damp_Mean_Small),'Hz'))
xlabel ('Time (sec)')
ylabel ('Volts (V)')
xlim([.008,.15])


% Medium Pipe
Constant = 0.036;
[Volt_Locations_Medium,Volt_Medium]=peakfinder(Voltage_Medium_Flood,Constant);
```

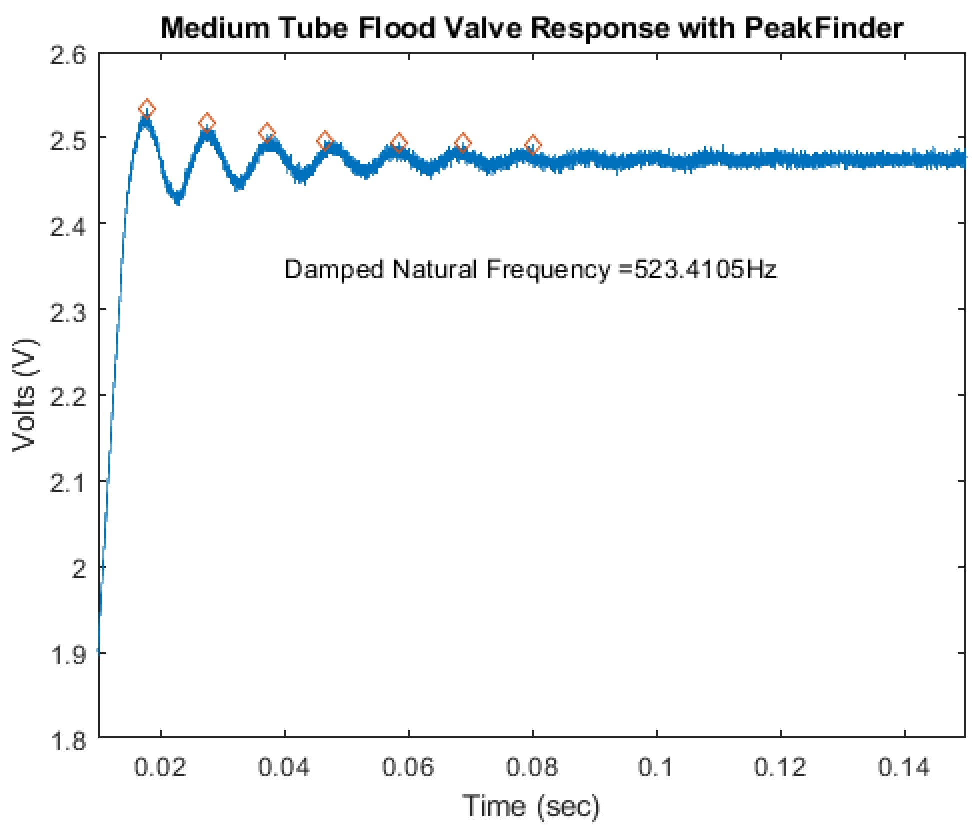
```
Damping_Ratio_Medium_Flood = zeros(length(Volt_Medium),1);
for n = 1:length(Volt_Medium)-1
    Period_Medium = Time_Medium_Flood(Volt_Locations_Medium(n+1))-
Time_Medium_Flood(Volt_Locations_Medium(n));
    Damping_Ratio_Medium_Flood(n) = (2*pi)/Period_Medium;
end
Damp_Mean_Medium = mean(Damping_Ratio_Medium_Flood);
f8 = figure(8)
plot(Time_Medium_Flood,Voltage_Medium_Flood,Time_Medium_Flood(Volt_Locations_Medium),V
olt_Medium,'d')
title('Medium Tube Flood Valve Response with PeakFinder')
text(.04,2.35,strcat('Damped Natural Frequency =',num2str(Damp_Mean_Medium),'Hz'))
xlabel ('Time (sec)')
ylabel ('Volts (V)')
xlim([.01,.15])

% Long Pipe
Constant = 0.035;
[Volt_Locations_Long,Volt_Long]=peakfinder(Voltage_Long_Flood,Constant);
Damping_Ratio_Long_Flood = zeros(length(Volt_Long),1);
for n = 1:length(Volt_Long)-1
    Period_Long = Time_Long_Flood(Volt_Locations_Long(n+1))-
Time_Long_Flood(Volt_Locations_Long(n));
    Damping_Ratio_Long_Flood(n) = (2*pi)/Period_Long;
end
Damp_Mean_Long = mean(Damping_Ratio_Long_Flood);
f9 = figure(9)
plot(Time_Long_Flood,Voltage_Long_Flood,Time_Long_Flood(Volt_Locations_Long),Volt_Long
,'d')
title('Long Tube Flood Valve Response with PeakFinder')
text(.04,2.35,strcat('Damped Natural Frequency =',num2str(Damp_Mean_Long),'Hz'))
xlabel ('Time (sec)')
ylabel ('Volts (V)')
xlim([.01,.15])
```

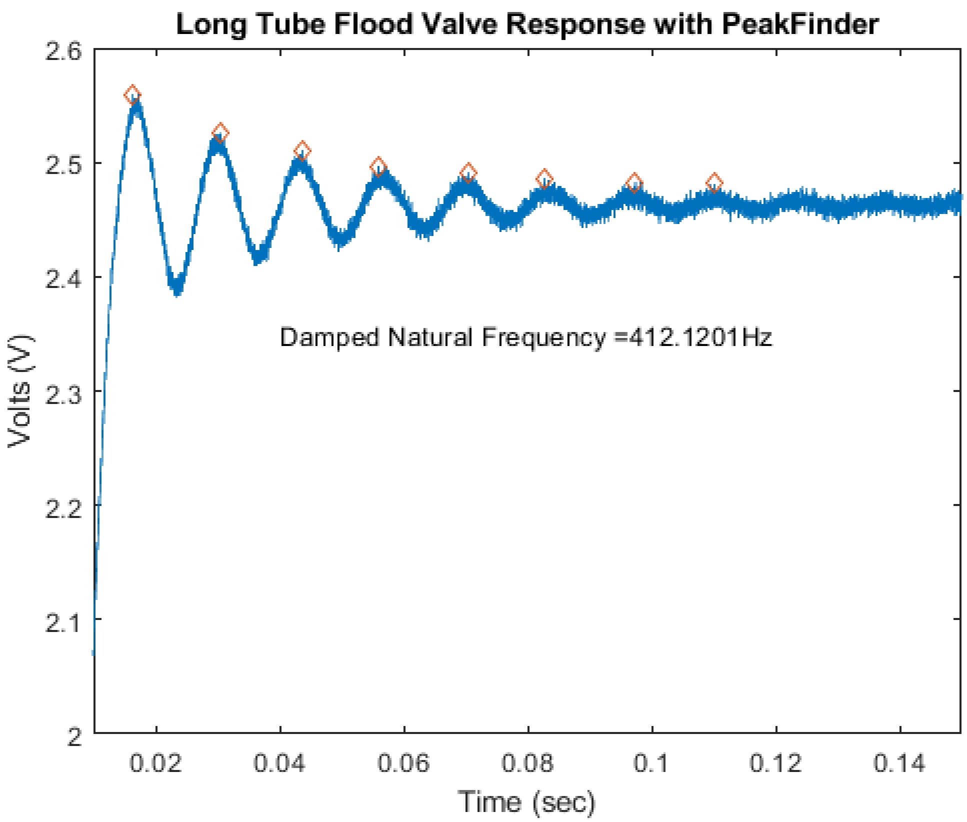
```
f7 =

  Figure (7) with properties:

      Number: 7
        Name: ''
       Color: [0.9400 0.9400 0.9400]
    Position: [488 342 560 420]
```

```
       Units: 'pixels'

  Use GET to show all properties


f8 =

  Figure (8) with properties:

      Number: 8
        Name: ''
       Color: [0.9400 0.9400 0.9400]
    Position: [488 342 560 420]
       Units: 'pixels'

  Use GET to show all properties


f9 =

  Figure (9) with properties:

      Number: 9
        Name: ''
```

```
     Color: [0.9400 0.9400 0.9400]

  Position: [488 342 560 420]

     Units: 'pixels'


Use GET to show all properties
```


Short Tube Flood Valve Response with PeakFinder
Damped Natural Frequency =0Hz
Volts (V)
Time (sec)
2.5
2.45
2.4
2.35
2.3
2.25
2.2
2.15
0.02
0.04
0.06
0.08
0.1
0.12
0.14


Medium Tube Flood Valve Response with PeakFinder
Damped Natural Frequency =523.4105Hz
Volts (V)
Time (sec)
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
0.02
0.04
0.06
0.08
0.1
0.12
0.14



p-t response and predicted

```
Volt_Locations_Small;

Volt_Locations_Medium;

Volt_Locations_Long;

Volt_Small;

Volt_Medium;

Volt_Long;







Constant = 0.01;
```

```
[Volt_Locations_Balloon_Small,Volt_Small_Balloon]=peakfinder(Voltage_Small_Balloon,Con
stant);

Volt_Locations_Balloon_Small = Volt_Locations_Balloon_Small(2:end-1);

Volt_Small_Balloon = Volt_Small_Balloon(2:end-1);

% figure(10)
%
plot(Time_Small_Balloon,Voltage_Small_Balloon,Time_Small_Balloon(Volt_Locations_Balloo
n_Small),Volt_Small_Balloon,'d')

Constant = 0.02;
[Volt_Locations_Balloon_Medium,Volt_Medium_Balloon]=peakfinder(Voltage_Medium_Balloon,
Constant);
Volt_Locations_Balloon_Medium = Volt_Locations_Balloon_Medium(3:end);
Volt_Medium_Balloon = Volt_Medium_Balloon(3:end);
% figure(11)
%
plot(Time_Medium_Balloon,Voltage_Medium_Balloon,Time_Medium_Balloon(Volt_Locations_Bal
loon_Medium),Volt_Medium_Balloon,'d')

Constant = 0.015;
[Volt_Locations_Balloon_Long,Volt_Long_Balloon]=peakfinder(Voltage_Long_Balloon,Consta
nt);
Volt_Locations_Balloon_Long = Volt_Locations_Balloon_Long(3:end);
Volt_Long_Balloon = Volt_Long_Balloon(3:end);
% figure(12)
%
plot(Time_Long_Balloon,Voltage_Long_Balloon,Time_Long_Balloon(Volt_Locations_Balloon_L
ong),Volt_Long_Balloon,'d')

Damp_Small_Valve = zeros(length(Volt_Locations_Small)-1,1);
Damp_Medium_Valve = zeros(length(Volt_Locations_Medium)-1,1);
Damp_Long_Valve = zeros(length(Volt_Locations_Long)-1,1);
Damp_Small_Balloon = zeros(length(Volt_Locations_Balloon_Small)-1,1);
Damp_Medium_Balloon = zeros(length(Volt_Locations_Balloon_Medium)-1,1);
Damp_Long_Balloon = zeros(length(Volt_Locations_Balloon_Long)-1,1);

for n=2:length(Volt_Locations_Small)
    Num = (1/(n-1))*log(Volt_Small(2)./Volt_Small(n));
    Damp_Small_Valve(n-1) = Num./sqrt(4*pi^2+Num.^2);
end

for n=2:length(Volt_Locations_Medium)
    Num = 100*(1/(n-1))*log(Volt_Medium(2)/Volt_Medium(n));
    Damp_Medium_Valve(n-1) = Num/(sqrt(4*pi^2+Num^2));
end

for n=2:length(Volt_Locations_Long)
```

```
    Num = 100*(1/(n-1))*log(Volt_Long(2)./Volt_Long(n));
    Damp_Long_Valve(n-1) = Num./sqrt(4*pi^2+Num^2);
end

for n=2:length(Volt_Locations_Balloon_Small)
    Num = (1/(n-1))*abs(log(Volt_Small_Balloon(1)./Volt_Small_Balloon(n)));
    Damp_Small_Balloon(n-1) = 0.5*(Num./sqrt(4*pi^2+Num^2));
end

for n=2:length(Volt_Locations_Balloon_Medium)
    Num = (1/(n-1))*log(Volt_Medium_Balloon(1)./Volt_Medium_Balloon(n));
    Damp_Medium_Balloon(n-1) = Num./sqrt(4*pi^2+Num^2);
end

for n=2:length(Volt_Locations_Balloon_Long)
    Num = (1/(n-1))*abs(log(Volt_Long_Balloon(1)./Volt_Long_Balloon(n)));
    Damp_Long_Balloon(n-1) = Num./sqrt(4*pi^2+Num^2);
end



Ratio_Valve_Small = mean(Damp_Small_Valve);
Ratio_Valve_Medium = mean(Damp_Medium_Valve);
Ratio_Valve_Long = mean(Damp_Long_Valve);
Ratio_Balloon_Small = mean(Damp_Small_Balloon);
Ratio_Balloon_Medium = mean(Damp_Medium_Balloon);
Ratio_Balloon_Long = mean(Damp_Long_Balloon);


Damp_Mean_Small;
Damp_Mean_Medium;
Damp_Mean_Long;

for n = 1:length(Volt_Small_Balloon)-1
    Period_Small = Time_Small_Balloon(Volt_Locations_Balloon_Small(n+1))-
Time_Small_Balloon(Volt_Locations_Balloon_Small(n));
    Damping_Ratio_Small_Balloon(n) = 2*pi/Period_Small;
end
Damp_Mean_Small_Balloon = mean(Damping_Ratio_Small_Balloon);

for n = 1:length(Volt_Medium_Balloon)-1
    Period_Medium = Time_Medium_Balloon(Volt_Locations_Balloon_Medium(n+1))-
Time_Medium_Balloon(Volt_Locations_Balloon_Medium(n));
    Damping_Ratio_Medium_Balloon(n) = 2*pi/Period_Medium;
end
Damp_Mean_Medium_Balloon = mean(Damping_Ratio_Medium_Balloon);

for n = 1:length(Volt_Long_Balloon)-1
    Period_Long = Time_Long_Balloon(Volt_Locations_Balloon_Long(n+1))-
Time_Long_Balloon(Volt_Locations_Balloon_Long(n));
    Damping_Ratio_Long_Balloon(n) = 2*pi/Period_Long;
```

```
end
Damp_Mean_Long_Balloon = mean(Damping_Ratio_Long_Balloon);



Natural_Freq_Small_Valve = Damp_Mean_Small/sqrt(1-Ratio_Valve_Small^2);
Natural_Freq_Medium_Valve = Damp_Mean_Medium/sqrt(1-Ratio_Valve_Medium^2);
Natural_Freq_Long_Valve = Damp_Mean_Long/sqrt(1-Ratio_Valve_Long^2);

Natural_Freq_Small_Balloon = Damp_Mean_Small_Balloon/sqrt(1-Ratio_Balloon_Small^2);
Natural_Freq_Medium_Balloon = Damp_Mean_Medium_Balloon/sqrt(1-Ratio_Balloon_Medium^2);
Natural_Freq_Long_Balloon = Damp_Mean_Long_Balloon/sqrt(1-Ratio_Balloon_Long^2);


% Ratio_Valve_Small = mean(Damp_Small_Valve);
% Ratio_Valve_Medium = mean(Damp_Medium_Valve);
% Ratio_Valve_Long = mean(Damp_Long_Valve);
% Ratio_Balloon_Small = mean(Damp_Small_Balloon);
% Ratio_Balloon_Medium = mean(Damp_Medium_Balloon);
% Ratio_Balloon_Long = mean(Damp_Long_Balloon);

Time_Small_Flood2 = Time_Small_Flood+.05;
KA = 2.46;
e = exp((-Ratio_Valve_Small*Natural_Freq_Small_Valve.*Time_Small_Flood2));
a = Ratio_Valve_Small/(sqrt(1-Ratio_Valve_Small^2));
b = Natural_Freq_Small_Valve.*Time_Small_Flood2*sqrt(1-Ratio_Valve_Small^2);
Volt_Predict_Valve_Small = KA-KA.*e.*(a.*sin(b)+cos(b));

f13 = figure(13)
plot(Time_Small_Flood,Voltage_Small_Flood)
text(.02,2.4,'\omega_d = 0')
text(.02,2.35,'\zeta = 0')
title('Small Tube with Valve - No Peaks Recorded')
xlabel('Time (s)')
ylabel('Volts (V)')
legend('Actual Data','location','northeast')
xlim([0.01,.10])
ylim([2.3,2.6])


Time_Medium_Flood2 = Time_Medium_Flood +.0677;
KA = 2.479;
e = .0677.*exp((-Ratio_Valve_Medium*Natural_Freq_Medium_Valve.*Time_Medium_Flood2));
a = Ratio_Valve_Medium/(sqrt(1-Ratio_Valve_Medium^2));
b = Natural_Freq_Medium_Valve.*Time_Medium_Flood2*sqrt(1-Ratio_Valve_Medium^2);
Volt_Predict_Valve_Medium = KA-KA.*e.*(a.*sin(b)+cos(b));

f14 = figure(14)
hold on
plot(Time_Medium_Flood2-.002,Volt_Predict_Valve_Medium,'--')
```

```
plot(Time_Medium_Flood,Voltage_Medium_Flood,Time_Medium_Flood(Volt_Locations_Medium),V
olt_Medium,'d')
text(.05,2.37,strcat('\omega_d = ',num2str(Natural_Freq_Medium_Valve),'/s'))
text(.05,2.34,strcat('\zeta = ',num2str(Ratio_Valve_Medium)))
title('Prediction and Actual Data of Medium Pipe with Valve')
xlabel('Time (s)')
ylabel('Volts (V)')
legend('Prediction','Actual Data','location','northeast')
xlim([0.01,.10])
ylim([2.3,2.6])

Time_Long_Flood2 = Time_Long_Flood+.0664;
KA = 2.46;
e = .0664*exp((-Ratio_Valve_Long*Natural_Freq_Long_Valve.*Time_Long_Flood2));
a = Ratio_Valve_Long/(sqrt(1-Ratio_Valve_Long^2));
b = Natural_Freq_Long_Valve.*Time_Long_Flood2*sqrt(1-Ratio_Valve_Long^2);
Volt_Predict_Valve_Long = KA-KA.*e.*(a.*sin(b)+cos(b));

f15 = figure(15)
hold on
plot(Time_Long_Flood2-.006,Volt_Predict_Valve_Long,'--')
plot(Time_Long_Flood,Voltage_Long_Flood,Time_Long_Flood(Volt_Locations_Long),Volt_Long
,'d')
text(.05,2.37,strcat('\omega_d = ',num2str(Natural_Freq_Long_Valve),'/s'))
text(.05,2.34,strcat('\zeta = ',num2str(Ratio_Valve_Long)))
title('Prediction and Actual Data of Long Pipe with Valve')
xlabel('Time (s)')
ylabel('Volts (V)')
legend('Prediction','Actual Data','location','northeast')
xlim([0.01,.10])
ylim([2.3,2.6])






Time_Small_Balloon2 = Time_Small_Balloon+.05;
KA = -.014;
e = exp((-Ratio_Balloon_Small*Natural_Freq_Small_Balloon.*Time_Small_Balloon2));
a = Ratio_Balloon_Small/(sqrt(1-Ratio_Balloon_Small.^2));
b = Natural_Freq_Small_Balloon.*Time_Small_Balloon2*sqrt(1-Ratio_Balloon_Small^2);
Volt_Predict_Balloon_Small = .05+4.5*(KA-KA.*e.*(a.*sin(b)+cos(b))); % Added addition
multiplier to start at peak and multiplier for reaching KA


f16 = figure(16)
plot(Time_Small_Balloon2+.0025,Volt_Predict_Balloon_Small,'--
',Time_Small_Balloon,Voltage_Small_Balloon)
text(.015,-.04,strcat('\omega_d = ',num2str(Natural_Freq_Small_Balloon),'/s'))
text(.015,-.06,strcat('\zeta = ',num2str(Ratio_Balloon_Small)))
```

```
title('Prediction and Actual Data of Small Pipe with Balloon')
xlabel('Time (s)')
ylabel('Volts (V)')
legend('Prediction','Actual Data','location','northeast')
xlim([0,.05])
ylim([-.08,.04])

Time_Medium_Balloon2 = Time_Medium_Balloon+.05;
KA = -.008;
e = exp((-Ratio_Balloon_Medium*Natural_Freq_Medium_Balloon.*Time_Medium_Balloon2));
a = Ratio_Balloon_Medium/(sqrt(1-Ratio_Balloon_Medium^2));
b = 0.6*Natural_Freq_Medium_Balloon.*Time_Medium_Balloon2*sqrt(1-
Ratio_Balloon_Medium^2); % Added multiplier here for aligning data
Volt_Predict_Balloon_Medium = .05+7.35.*(KA-KA.*e.*(a.*sin(b)+cos(b)));% Added
addition multiplier to start at peak and multiplier for reaching KA

f17 = figure(17)
plot(Time_Medium_Balloon2+.01,Volt_Predict_Balloon_Medium,'--
',Time_Medium_Balloon,Voltage_Medium_Balloon)
text(.04,-.04,strcat('\omega_d = ',num2str(Natural_Freq_Medium_Balloon),'/s'))
text(.04,-.06,strcat('\zeta = ',num2str(Ratio_Balloon_Medium)))
title('Prediction and Actual Data of Medium Pipe with Balloon')
xlabel('Time (s)')
ylabel('Volts (V)')
legend('Prediction','Actual Data','location','northeast')
xlim([0,.1])
ylim([-.08,.06])

Time_Long_Balloon2 = Time_Long_Balloon+.05;
KA = -.02;
e = exp((-Ratio_Balloon_Long*Natural_Freq_Long_Balloon.*Time_Long_Balloon2));
a = Ratio_Balloon_Long/(sqrt(1-Ratio_Balloon_Long^2));
b = .45.*Natural_Freq_Long_Balloon.*Time_Long_Balloon2*sqrt(1-Ratio_Balloon_Long^2);
Volt_Predict_Balloon_Long = .05+3.5.*(KA-KA.*e.*(a.*sin(b)+cos(b)));

f18 = figure(18)
plot(Time_Long_Balloon2+.01,Volt_Predict_Balloon_Long,'--
',Time_Long_Balloon,Voltage_Long_Balloon)
text(.04,-.05,strcat('\omega_d = ',num2str(Natural_Freq_Long_Balloon),'/s'))
text(.04,-.07,strcat('\zeta = ',num2str(Ratio_Balloon_Long)))
title('Prediction and Actual Data of Long Pipe with Balloon')
xlabel('Time (s)')
ylabel('Volts (V)')
legend('Prediction','Actual Data','location','northeast')
xlim([0,.1])
ylim([-.08,.06])
```

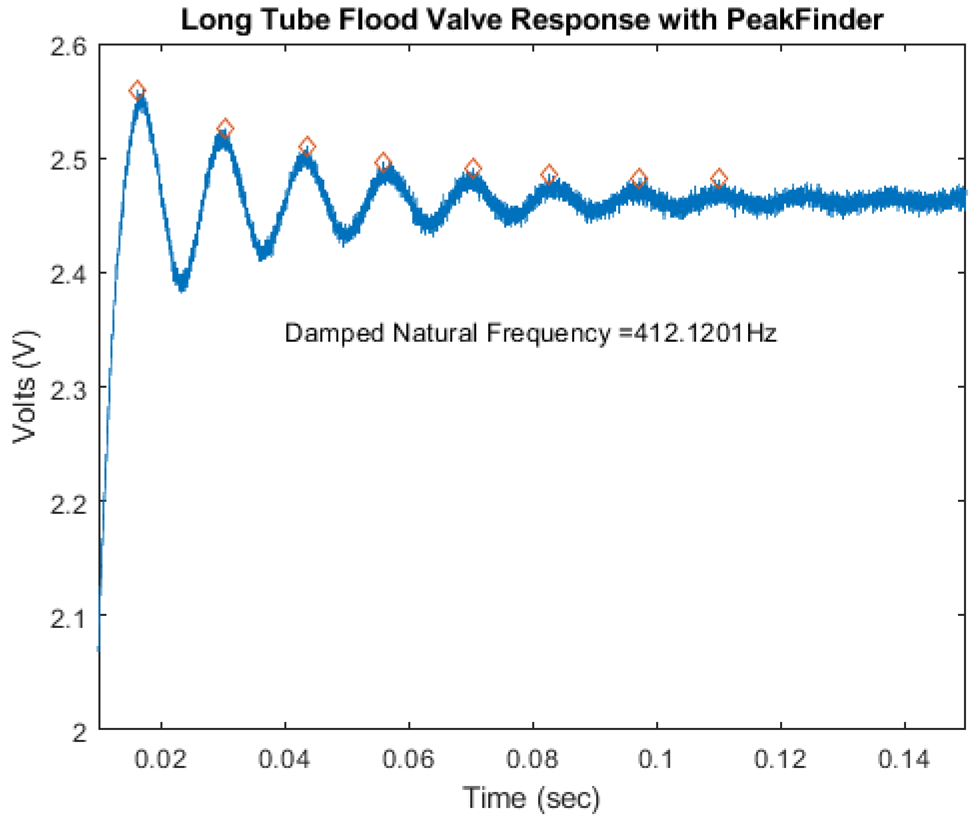
```
f13 =
```

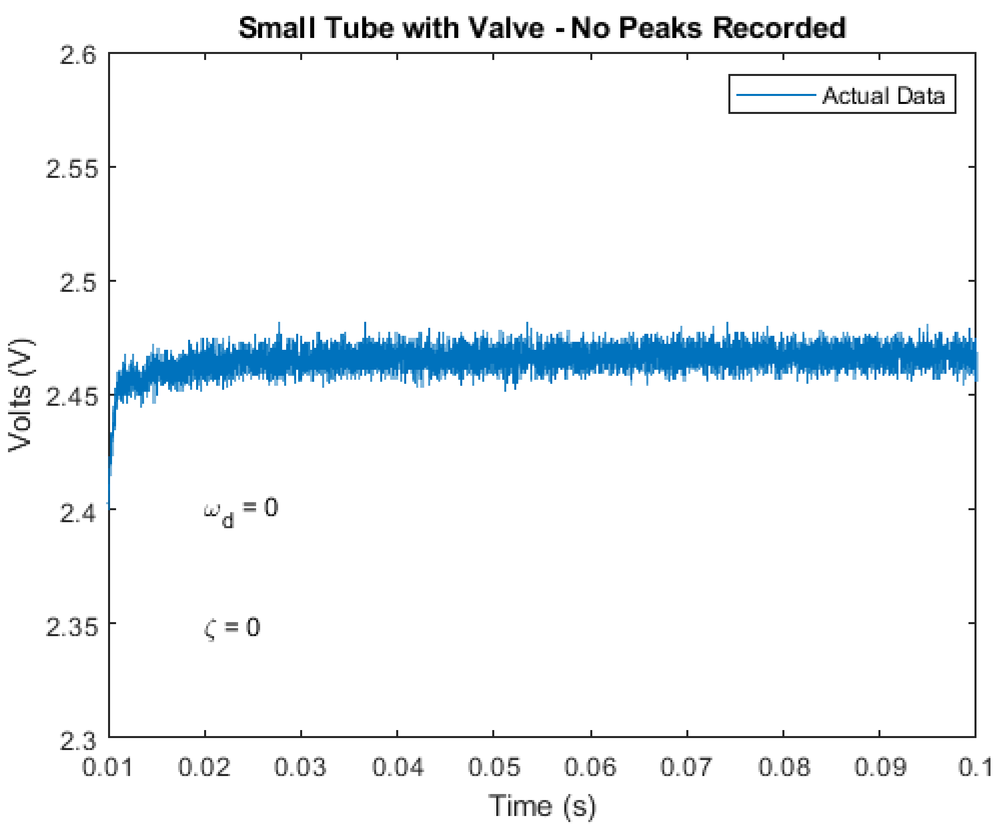
```
  Figure (13) with properties:

      Number: 13
        Name: ''
       Color: [0.9400 0.9400 0.9400]
    Position: [488 342 560 420]
       Units: 'pixels'

  Use GET to show all properties


f14 =

  Figure (14) with properties:

      Number: 14
        Name: ''
       Color: [0.9400 0.9400 0.9400]
    Position: [488 342 560 420]
       Units: 'pixels'

  Use GET to show all properties
```

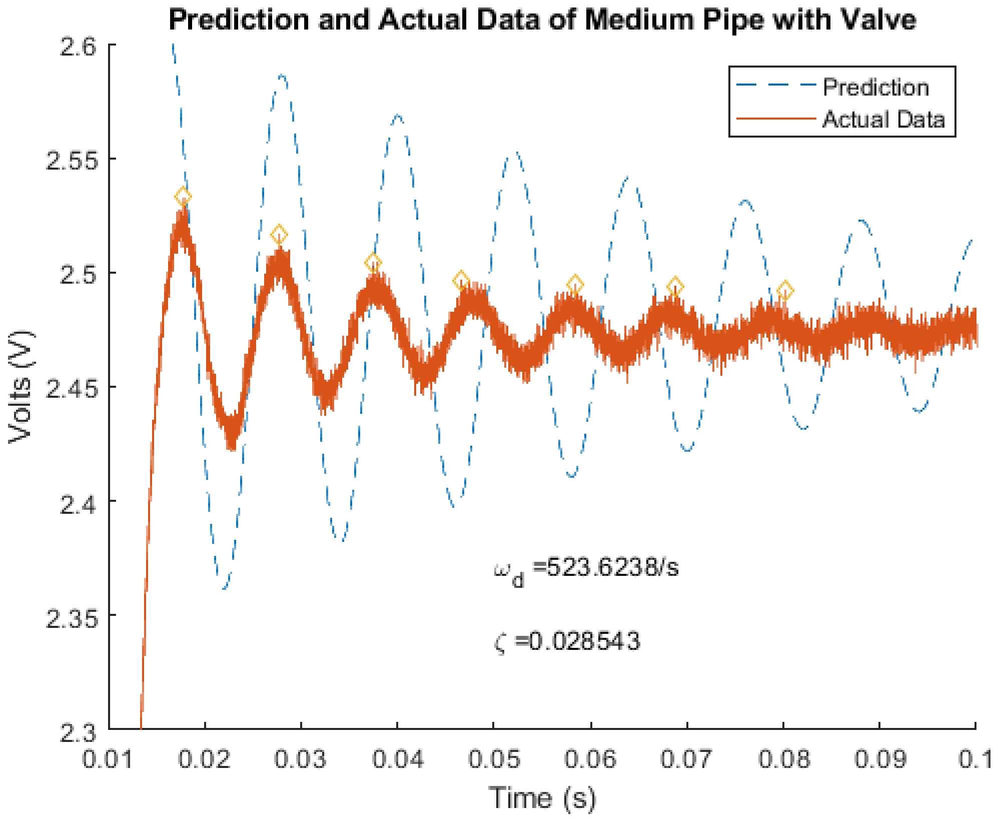
```
f15 =

  Figure (15) with properties:

      Number: 15
        Name: ''
       Color: [0.9400 0.9400 0.9400]
    Position: [488 342 560 420]
       Units: 'pixels'

  Use GET to show all properties


f16 =

  Figure (16) with properties:

      Number: 16
        Name: ''
       Color: [0.9400 0.9400 0.9400]
    Position: [488 342 560 420]
       Units: 'pixels'

  Use GET to show all properties
```

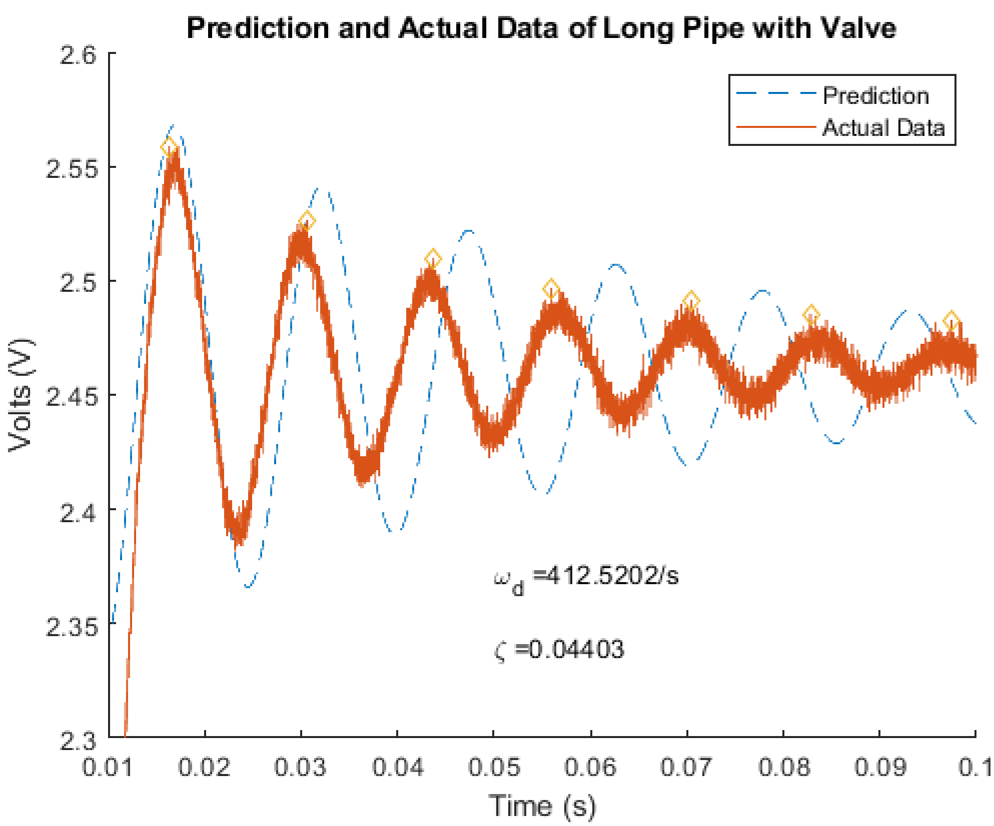
```
f17 =

  Figure (17) with properties:

      Number: 17
        Name: ''
       Color: [0.9400 0.9400 0.9400]
    Position: [488 342 560 420]
       Units: 'pixels'

  Use GET to show all properties

f18 =

  Figure (18) with properties:

      Number: 18
        Name: ''
       Color: [0.9400 0.9400 0.9400]
    Position: [488 342 560 420]
       Units: 'pixels'
```

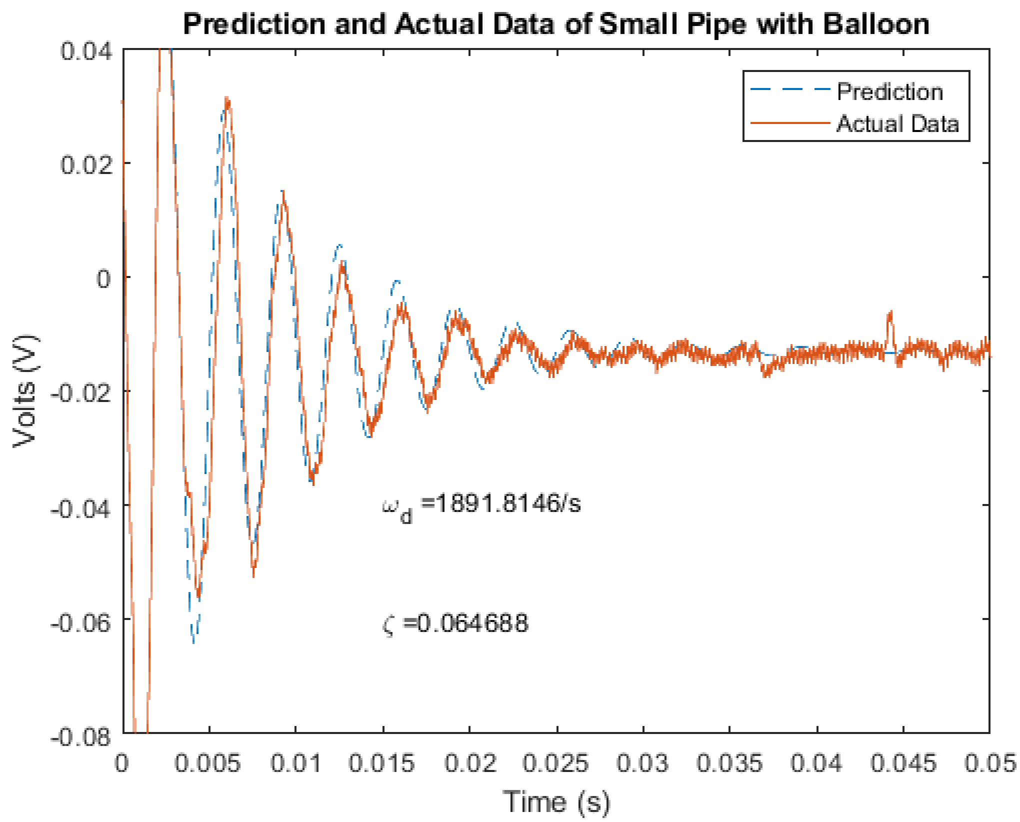
Use GET to show all properties


Long Tube Flood Valve Response with PeakFinder
Damped Natural Frequency =412.1201Hz
Volts (V)
Time (sec)
2.6
2.5
2.4
2.3
2.2
2.1
2
0.02
0.04
0.06
0.08
0.1
0.12
0.14

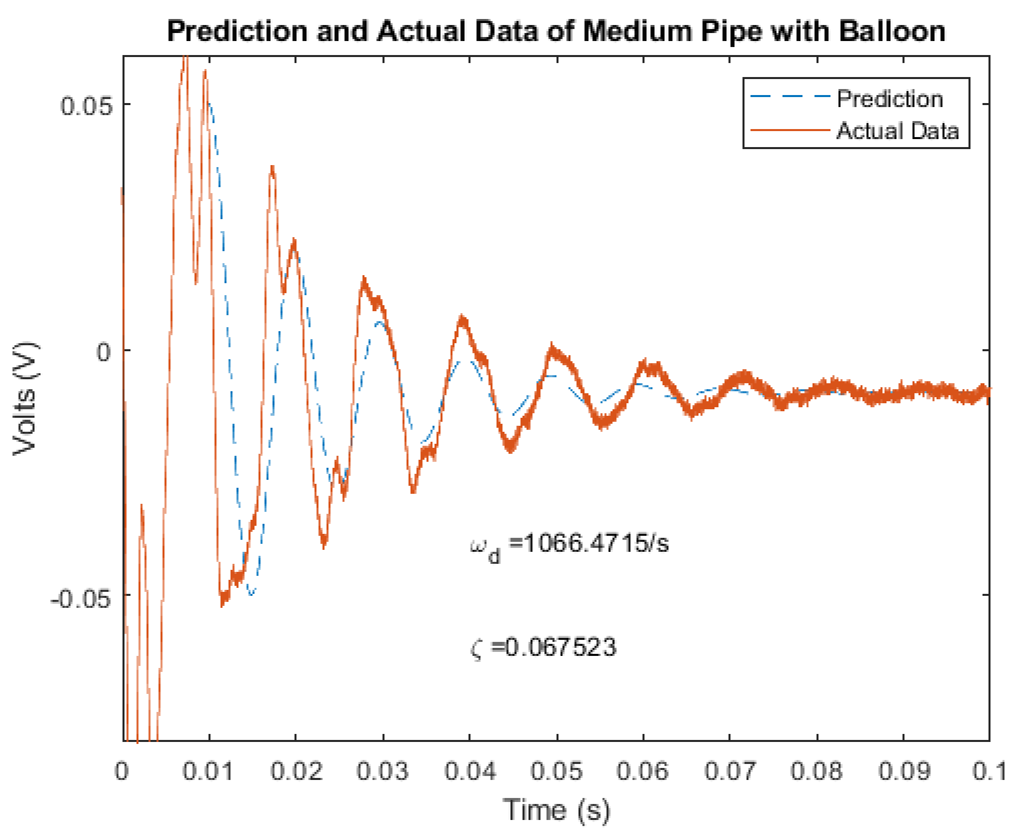

Small Tube with Valve - No Peaks Recorded
Actual Data
ω_d = 0
ζ = 0
Volts (V)
Time (s)
2.6
2.55
2.5
2.45
2.4
2.35
2.3
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1


Prediction and Actual Data of Medium Pipe with Valve
Prediction
Actual Data
ω_d =523.6238/s
ζ =0.028543
Volts (V)
Time (s)
2.6
2.55
2.5
2.45
2.4
2.35
2.3
0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.1

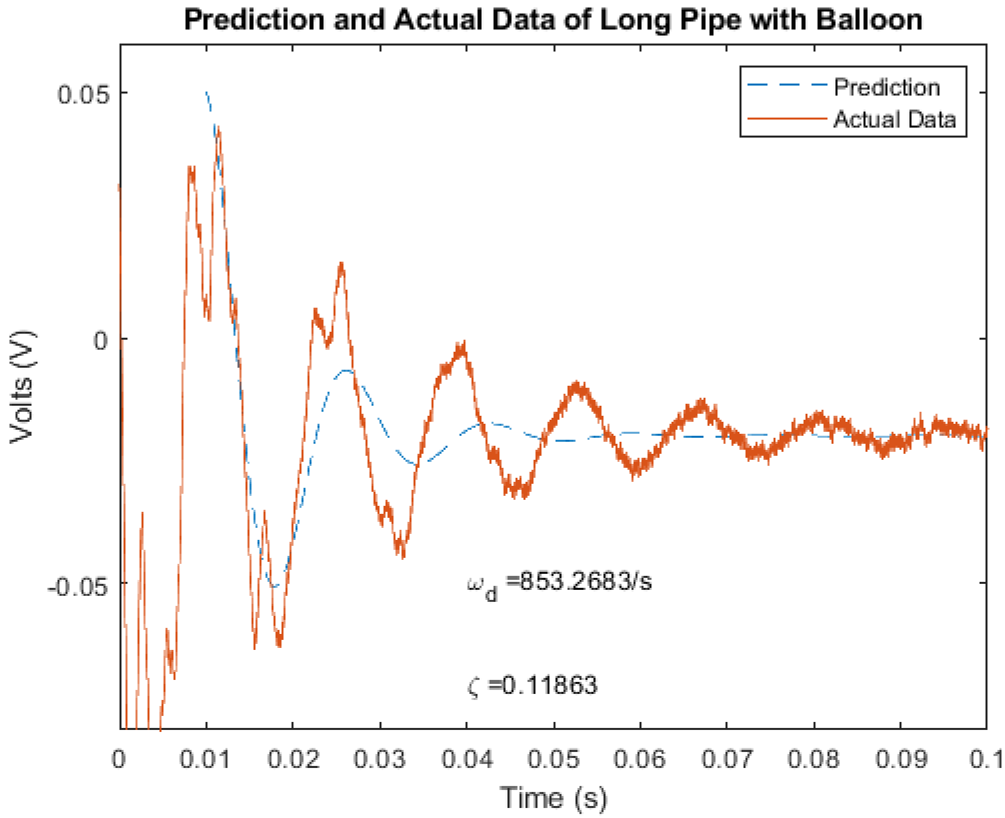

Prediction and Actual Data of Long Pipe with Valve
Prediction
Actual Data
ω_d =412.5202/s
ζ =0.04403
Volts (V)
Time (s)
2.6
2.55
2.5
2.45
2.4
2.35
2.3
0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.1



Prediction and Actual Data of Small Pipe with Balloon
Prediction
Actual Data
ω_d =1891.8146/s
ζ =0.064688
Volts (V)
Time (s)
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05



Prediction and Actual Data of Medium Pipe with Balloon
Prediction
Actual Data
ω_d =1066.4715/s
ζ =0.067523
Volts (V)
Time (s)
0.05
0
-0.05
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1



Damping Ratio and Natural Frequency Dependence on Length

```
a = 343; % m/s
nu = 1.81*10^-5; % kg/ms
density = 1.225; %kg/m3
l = linspace(.16,1.06,100);
omega_n = a./(l*sqrt(0.5));
l_long = 1.05;
l_medium = .795;
l_short = .17;

Natural_Freq_Small_Valve;
Natural_Freq_Medium_Valve;
Natural_Freq_Long_Valve;
Natural_Freq_Small_Balloon;
Natural_Freq_Medium_Balloon;
Natural_Freq_Long_Balloon;

f19 = figure(19)
plot(1./l,omega_n)
hold on
plot(1/l_short,Natural_Freq_Small_Valve,'d',1/l_short,Natural_Freq_Small_Balloon,'d')
plot(1/l_medium,Natural_Freq_Medium_Valve,'d',1/l_medium,Natural_Freq_Medium_Balloon,'
d')
plot(1/l_long,Natural_Freq_Long_Valve,'d',1/l_long,Natural_Freq_Long_Balloon,'d')
```

```
text(3,3000,'Short Valve has no peaks')
xlabel('1/Length (1/m)')
ylabel('\omega_n (1/s)')
legend('Prediction Curve','Short Valve','Short Balloon','Medium Valve','Medium
Balloon','Long Valve','Long Balloon','location','northwest')


% Damping Ratio
l = linspace(.10,1.1,100);
Damping = ((16*nu.*l)/(a*density*.002^2))*sqrt(.5);




f20 = figure(20)
plot(l,Damping)
hold on
plot(l_short,Ratio_Valve_Small,'d',l_short,Ratio_Balloon_Small,'d')
plot(l_medium,Ratio_Valve_Medium,'d',l_medium,Ratio_Balloon_Medium,'d')
plot(l_long,Ratio_Valve_Long,'d',l_long,Ratio_Balloon_Long,'d')
text(.5,.12,'Short Valve has no peaks')
xlabel('Length')
ylabel('Damping Ratio \zeta')
legend('Prediction Curve','Short Valve','Short Balloon','Medium Valve','Medium
Balloon','Long Valve','Long Balloon','location','northwest')




saveas(f1, 'C:\Users\User\Desktop\Classes\Junior Year\Spring 2019\J-Lab\Lab
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```

```
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saveas(f20, 'C:\Users\User\Desktop\Classes\Junior Year\Spring 2019\J-Lab\Lab
4\Figures\figure20.png','png');
```