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Appendix A

Constants and Numerical values

Constants

Specific gas constant, R = 287 J/kg K
Specific heat constant, k = 1.4
Standard atmospheric pressure, P_{atm} = 1bar

Numerical values

$$C_o = \sqrt{\frac{k}{R\left(\left(k+1\right)/2\right)^{(k+1)/(k-1)}}} = 0.040$$

$$C_k = \sqrt{\frac{2}{\left(k-1\right)}\left(\frac{k+1}{2}\right)^{(k+1)/(k-1)}} = 3.864$$

$$P_{cr} = \left(\frac{2}{k+1}\right)^{k/(k-1)} = 0.528$$

Appendix B

Simulation Programs

Program for Obtain Constant values of the Stiffness Parameter

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%To obtain a constant valves of the stiffness parameter given in Eq.(3.5)
%from the experimental data
%At the same time the program generate the comparison plot of experimental
%and model results
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
clear
load ink25a.txt                    %Load experimental data from the text file
D=ink25a;                          %Assign in common format

L=D(:,1);%Assigning a length value from the loaded data to obtain a constant
P=D(:,2);%Assigning a pressure value from the loaded data to obtain a constant
F=D(:,3);%Assigning a force value from the loaded data to obtain a constant

Lii=D(:,1);%Assigning a length value from the loaded data to generate a plot of experimental
results
Pii=D(:,2);%Assigning a pressure value from the loaded data to generate a plot of experimental
results
Fii=D(:,3);%Assigning a force value from the loaded data to generate a plot of experimental
results

%Constant calculation
s1=L.*P.^2;
s2=P.*L.^2;
s3=(L.^3);
s4=L;

L2=Lii.^2;
P2=Pii.^2;

s5=P2;
s6=Pii.*Lii;
s7=L2;
s8=Pii.\Pii;


S=[s1,s2,s3,s4];
S1=[s5,s6,s7,s8];
A25=(inv((S.')*S))*(S.')*F
k25=S1*A25;
Fk=Lii.*k25;

% Plot of experimental data
plot3(Lii,Pii,Fii,'ro'),xlabel('length difference'),ylabel('Pressure'),zlabel('load') grid on;
hold on;
% Plot of model behavior
plot3(Lii,Pii,Fk,'r*'),xlabel('length
difference(cm)'),ylabel('Pressure(bar)'),zlabel('load(Kg)')

hold on;
grid on;
```

Generation of the Plot of Stiffness Parameter

Extraction

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%To generate behaviour of the stiffness parameter according to the proposed
%model when PAM extract and display as mesh plot
%For PAM with diameter of 2cm and the length of 30cm
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
clear
p=[0.5:0.1:5.5]; %Selected pressure range to generate the plot
l=[0:0.1:7.0];   %Selected stretched length range

n1=length(p);
n2=length(l);
for i=1:n1
    for j=1:n2

        if p(i)<2.5
            % stiffness parameter in the low pressure range
            K(i,j)=[-2.299*p(i).^2-5.741*p(i).*l(j)+2.741*(l(j).^2)+119.304];

        else
            % stiffness parameter in the high pressure range
            K(i,j)=[4.182*p(i).^2-3.127*p(i).*l(j)+1.818*(l(j).^2)+70.377];

        end

   end
end
mesh(l,p,K),xlabel('Ls(cm)'),ylabel('P(bar)'),zlabel('K(N/cm)')
hold on;
```

Contraction

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%To generate behavior of the stiffness parameter according to the proposed
%model when PAM contraction and display as mesh plot
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
clear
p=[0.5:0.1:5.5];%Selected pressure range to generate the plot
l=[0:0.1:7.0];  %Selected stretched length range

n1=length(p);
n2=length(l);
for i=1:n1
    for j=1:n2

        if p(i)<2.5
            % stiffness parameter in the low pressure range
            K(i,j)=[-2.977*p(i).^2-5.890*p(i).*l(j)+3.203*(l(j).^2)+104.824];%.*l(j);

        else
            % stiffness parameter in the high pressure range
            K(i,j)=[3.837*p(i).^2-2.389*p(i).*l(j)+1.850*(l(j).^2)+53.021];%.*l(j);
        end


    end
end
mesh(l,p,K),xlabel('Ls( cm)'),ylabel('P( bar)'),zlabel('K(N/cm)')
hold on;
```

Case Study I

Increasing load

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%Case Study I%
%Program to study the performance of the proposed model and the dynamic behaviours of the PAM%
%for Increasing the Load%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

clear                                   % Clears the data
load inc_f.txt                          % Load the required experimental data
n=length(inc_f(:,1));                   % Define the length of the data
delt=0.05;                              % Assigning of the time step


for i=1:n
Pk=inc_f(i,1);                          % Assigning the loaded pressure valves
Fk=inc_f(i,3);                          % Assigning the loaded force valves
if Pk>= 2.5                               % Starting the calculation of length of PAM according to
the model
c(1)=1.818;
c(2)=-3.127*(Pk);
c(3)=4.182*(Pk)^2+70.377;
c(4)=-5.3*(Pk)*0-Fk;
else
c(1)=2.741;
c(2)=-5.741*(Pk);
c(3)=-2.299*(Pk)^2+119.304;
c(4)=-5.3*(Pk)*0-Fk;
end
r_L=roots([c(1) c(2) c(3) c(4)]);
Lmax=30-(0.262*(Pk)^2-2.991*(Pk)+30.1);

for j=1:3
if imag(r_L(j))== 0
   if r_L(j)>=0 & r_L(j)<=Lmax
       Lsk=r_L(j);
   end
end
end

Lk=(0.262*(Pk)^2-2.991*(Pk)+30.1)+Lsk;                  % Calculation of new length
rk=abs((-0.005*Lk^2+6.735)^(1/2));                      % Calculation of new radius
s_Lss(i)=(0.262*(Pk)^2-2.991*(Pk)+30.1);
s_Lsk(i)=Lsk;
s_Lk(i)=Lk;
s_Pk(i)=Pk;
s_rk(i)=rk;
s_t(i)=delt*i;                                          % Time calculation
end
subplot(3,1,1)
plot(s_t,inc_f(:,1),'*r'),xlabel('Time(s)'),ylabel('Pressure(bar)')
grid on
subplot(3,1,2)
plot(s_t,inc_f(:,4),'*r'),xlabel('Time(s)'),ylabel('Force(N)')
grid on
subplot(3,1,3)
plot(s_t,s_Lk,s_t,inc_f(:,2),'*r'),xlabel('Time(s)'),ylabel('Muscle Length(cm)')
grid on
```

Decreasing load

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%Program to study the performance of the proposed model and the dynamic behaviours of the PAM%
% Decreasing the Load %
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

clear                                       % Clear the data
load dec_f.txt                              % Load the data
n=length(dec_f(:,1));                  % Calculate the length
delt=0.05;                             % Assigning the time step


for i=1:n
Pk=dec_f(i,1);                           % Assigning the pressure from the loaded data
Fk=dec_f(i,3);                           % Assigning the pressure from the loaded data
if Pk>= 2.5                              % Starting length calculation according to the models
c(1)=1.850;
c(2)=-2.389*(Pk);
c(3)=3.837*(Pk)^2+53.021;
c(4)=0*5.3*(Pk)-Fk;
else
c(1)=3.203;
c(2)=-5.890*(Pk);
c(3)=-2.977*(Pk)^2+104.824;
c(4)=0*5.3*(Pk)-Fk;
end
r_L=roots([c(1) c(2) c(3) c(4)]);
Lmax=30-(0.262*(Pk)^2-2.991*(Pk)+30.1);

for j=1:3
if imag(r_L(j))== 0
   if r_L(j)>=0 & r_L(j)<=Lmax
       Lsk=r_L(j);
   end
end
end

Lk=(0.262*(Pk)^2-2.991*(Pk)+30.1)+Lsk;              % Calculation of length
rk=abs((-0.005*Lk^2+6.735)^(1/2));                  % Calculation of radius
s_Lss(i)=(0.262*(Pk)^2-2.991*(Pk)+30.1);
s_Lsk(i)=Lsk;
s_Lk(i)=Lk;
s_Pk(i)=Pk;
s_rk(i)=rk;
s_t(i)=delt*i;                                        % Calculation of time
end
subplot(3,1,1)
plot(s_t,dec_f(:,1),'*r'),xlabel('Time(s)'),ylabel('Pressure(bar)')
grid on
subplot(3,1,2)
plot(s_t,dec_f(:,3),'*r'),xlabel('Time(s)'),ylabel('Force(N)')
grid on
subplot(3,1,3)
plot(s_t,s_Lk,s_t,dec_f(:,2),'*r'),xlabel('Time(s)'),ylabel('Muscle Length(cm)')
grid on
```

Case study II

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Case Study II
% This program is used to simulate and compare with the experimental results the models as
described in case study II%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%


clear
clc

T=input('Total running cycles - ');         % No of  program running cycle
t_in=0;                                     % Starting with the time zero
Pst=input('starting pressure-');            % Starting pressure
Fin=input('Hanging load-');                 % PAM carrying load when the data collecting time
[Lk_if,rk_if]=initial_positions(Pst,Fin);      % Determine a initial condition of the PAM
according to the given inputs(sub-program 1)

% Loop to calculate the behavior of the muscle according to the inputs

for i=1:T

% Program for supplying  air in first part (sub-program 2)
[t_s1,mdot_s1,P_s1,Lk_s1,rk_s1]=pro_test_com_fn1(t_in,Pst,Lk_if,rk_if);
% Maintaining a steady condition 1( valve close), (sub-program 3)
[t_in2,mdot_in2,P_in2,Lk_if2,rk_if2]=steady1(t_s1,mdot_s1,P_s1,Lk_s1,rk_s1);
% Program for supplying  air in second part, (sub-program 4)
[t_s2,mdot_s2,P_s2,Lk_s2,rk_s2]=pro_test_com_fn2(t_in2,mdot_in2,P_in2,Lk_if2,rk_if2);

% Maintaining a steady condition 2(valve close), (sub-program 5)
[t_of,mdot_in3,P_of,Lk_of,rk_of]=steady2(t_s2,mdot_s2,P_s2,Lk_s2,rk_s2);

% Program for discharging air, (sub-program 6)
[t_s3,mdot_s3,P_s3,Lk_s3,rk_s3]=pro_test_com_rev_fn(t_of,mdot_in3,P_of,Lk_of,rk_of);

% Maintaining a steady condition 3(valve close), (sub-program 7)

[t_in,Pst,Lk_if,rk_if]=steady3(t_s3,mdot_s3,P_s3,Lk_s3,rk_s3);

end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%sub-program 1
%this program is used to find the initial conditions of the muscle with the given initial load
and the pressure.
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

function[Lk_if,rk_if]=initial_positions(Pst,Fin)
Patm=1;                                     % Atmospheric pressure 1bar
P=Pst;                                      % Assigning of input pressure in the general form
inside the program
Pups=6;                                     %maximum operating pressure of the muscle.(supply
pressure)

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

Lsk=0;                                                  % Initial stretched length
Lk_if=(0.262*(P-Patm)^2-2.991*(P-Patm)+30.63)+Lsk;      % starting length without force and
use gage pressure.
rk_if=abs((-0.005*Lk_if^2+6.735)^(1/2));                % Initial radius calculation

Pk=P-Patm;                                              % Calculation of gauge pressure
Fk=Fin;                                                 % Assigning the input force

% Calculation of the stretched length according to the models
if Pk>= 2.5
c(1)=1.818;
```

```
c(2)=-3.127*(Pk);
c(3)=4.182*(Pk)^2+70.377;
c(4)=-Fk;
else
c(1)=2.741;
c(2)=-5.741*(Pk);
c(3)=-2.299*(Pk)^2+119.304;
c(4)=-Fk;
end
r_L=roots([c(1) c(2) c(3) c(4)]);

Lmax=30-(0.262*(Pups-Patm)^2-2.991*(Pups-Patm)+30.63);%  calculation  of  maximum  stretched
length
for j=1:3
if imag(r_L(j))== 0
   if r_L(j)>=0 & r_L(j)<=Lmax
       Lsk=r_L(j);
   end
end
end

Lk_if=(0.262*(Pk)^2-2.991*(Pk)+30.63)+Lsk;      % Calculation of final length
rk_if=abs((-0.005*Lk_if^2+6.735)^(1/2));        % Calculation of final radius

end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%sub-program 2
%this is a program is simulate the behaviour of the PAM when supplying the
%air
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function [t_s1,mdot_s1,P_s1,Lk_s1,rk_s1]=pro_test_com_fn1(t_in,Pst,Lk_if,rk_if)

Pu=6;                   %upstream pressure (supply pressure)

Tif=1;                  %running time 1 sec (valve opening time)
delt=0.0005;            %time step



V1=pi*((rk_if/100)^2)*(Lk_if/100); %calculation of initial volume
V2=V1;                             %initially both volumes make equal
vdot=(V2-V1)/delt;                 %calculation of rate of change of volume

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

Patm=1;
P=Pst;
% assigning of the constant values according to the models described in
% section 4
Cr=0.528;
Ck=3.864;
k=1.4;
Tu=300;
R=287;
t=0;

% Loop to obtain the behaviour of the PAM actuator when its supplying with
% air
for m=1:Tif/delt

    %calculation of fPr according to the instantaneous pressure
    Pr=P/Pu;
    if Pr>=Patm/Pu && Pr<=0.528
           fPr=Pu/sqrt(Tu);

            elseif Pr>0.528 && Pr<=1

                fPr=Pu*Ck*(((Pr^(2/k))-(Pr^((k+1)/k)))^0.5)/sqrt(Tu);
```

```
            else
        fPr=0;
    end

     mdot= (0.001939*fPr - 0.000002);                          %Calculation of the mass flow rate
according to the obtain model for supply
    out_Pr(m)=Pr;
    out_fPr(m)=fPr;
    out_mdot(m)=mdot;

    Pdot=(-k*(P*10^5)*vdot)/V1 +(k*R*Tu*mdot)/V1;          %Calculation of rate of change of
pressure according to the Eq. (4.11)

    out_P(m)=P;
    P=P+(Pdot/10^5)*delt;                                     %Calculation of the new pressure



    out_Lk(m)=Lk_if;
    out_rk(m)=rk_if;

    [Lk_if,rk_if]=muscle_model_cal_inst_len(P,Fin);        %Calling the program of PAM model
to find the position of the PAM when supplying (sub-program M1)

    out_v(m)=V1 ;
    V2=pi*((rk_if/100)^2)*(Lk_if/100);            %Calculation of new volume inside the loop

    vdot=(V2-V1)/delt;                          %Calculation of rate of change of volume

    V1=V2;                                        %Assigning the current volume to previous
volume for next step

    out_t(m)=(t+t_in);

    t=m*delt;                                      %Calculation of time

    t_s1=(t+t_in);
    mdot_s1=mdot;
    P_s1=P;
    Lk_s1=Lk_if;
    rk_s1=rk_if;
end

% Plot the graphs required
    subplot(3,1,1)
    plot(out_t,out_mdot,'b'),xlabel('time(s)'),ylabel('Mass flow rate(Kg/s)')
    hold on
    grid on
    subplot(3,1,2)
    plot(out_t,out_P,'b'),xlabel('time(s)'),ylabel('Pressure(bar)')
    hold on
    grid on
    subplot(3,1,3)
    plot(out_t,out_Lk,'b'),xlabel('time(s)'),ylabel('Muscle length (cm)')
    hold on
    grid on

end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%Sub-program 3
%%This section of program gives the behaviour of the PAM when valves are
%switched off and maintains the PAM condition
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

function [t_in2,mdot_in2,P_in2,Lk_if2,rk_if2]=steady1(t_s1,mdot_s1,P_s1,Lk_s1,rk_s1)

T2=1;           %Program running time 1 sec
```

```
t_in=t_s1;      %Time assigning inside the program where the time of the sub-program 2 stopped
Pu=6;           %upstream pressure
delt=0.0005;    %time step

V1=pi*((rk_s1/100)^2)*(Lk_s1/100);
V2=V1;
vdot=(V2-V1)/delt;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

Patm=1;
P=P_s1;

Cr=0.528;
Ck=3.864;
k=1.4;
Tu=300;
R=287;
t=0;

for m=1:T2/delt


    Pr=P/Pu;
    if Pr>=Patm/Pu & Pr<=0.528
           fPr=Pu/sqrt(Tu);

            elseif Pr>0.528 & Pr<=1

                fPr=Pu*Ck*(((Pr^(2/k))-(Pr^((k+1)/k)))^0.5)/sqrt(Tu);

            else
        fPr=0;
    end

    mdot=0;                          % Mass flow rate is taken as zero because all valves are
closed
    out_m(m)=mdot_s1;
    mdot_s1=mdot;

    Pdot=(-k*(P*10^5)*vdot)/V1 +(k*R*Tu*mdot)/V1;

    out_P(m)=P;
    P=P+(Pdot/10^5)*delt;

    out_L(m)=Lk_s1;
    out_r(m)=rk_s1;

    [Lk_if,rk_if]=muscle_model_cal_inst_len(P,Fin); %muscle model to find the position of the
muscle

    out_v(m)=V1 ;
    V2=pi*((rk_if/100)^2)*(Lk_if/100);

    vdot=(V2-V1)/delt;

    V1=V2;

    out_t(m)=(t+t_in);

    t=m*delt;


    P_s=P;
    Lk_s1=Lk_if;
    rk_s1=rk_if;


    out_P(m)=P_s;
    out_t(m)=m*delt+t_in;
```

```
    t_in2=m*delt+t_in;
    P_in2=P_s;
    mdot_in2=mdot_s1;
    Lk_if2=Lk_s1;
    rk_if2=rk_s1;

end

    subplot(3,1,1)
    plot(out_t,out_m,'r')
    hold on
    grid on
    subplot(3,1,2)
    plot(out_t,out_P,'r')
    hold on
    grid on
    subplot(3,1,3)
    plot(out_t,out_L,'r')
    hold on
    grid on

end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%Sub-program 4
%this program simulate the behaviours when the valve open for supply the air
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

function [t_s2,mdot_s2,P_s2,Lk_s2,rk_s2]=pro_test_com_fn2(t_in2,mdot_in2,P_in2,Lk_if2,rk_if2)

Pu=6;

Tif=1;
delt=0.0005;

V1=pi*((rk_if2/100)^2)*(Lk_if2/100);
V2=V1;
vdot=(V2-V1)/delt;

Patm=1;
P=P_in2;
Cr=0.528;
Ck=3.864;
k=1.4;
Tu=300;
R=287;
t=0;


for m=1:Tif/delt


    Pr=P/Pu;
    if Pr>=Patm/Pu && Pr<=0.528
          fPr=Pu/sqrt(Tu);

           elseif Pr>0.528 && Pr<=1

               fPr=Pu*Ck*(((Pr^(2/k))-(Pr^((k+1)/k)))^0.5)/sqrt(Tu);

           else
        fPr=0;
    end

    mdot= (0.001939*fPr - 0.000002);

    out_mdot(m)=mdot_in2;
    mdot_in2=mdot;

    Pdot=(-k*(P*10^5)*vdot)/V1 +(k*R*Tu*mdot)/V1;
```

```
    out_P(m)=P;
    P=P+(Pdot/10^5)*delt;



    out_Lk(m)=Lk_if2;
    out_rk(m)=rk_if2;

    [Lk_if,rk_if]=muscle_model_cal_inst_len(P,Fin);

    Lk_if2=Lk_if;
    rk_if2=rk_if;

    out_v(m)=V1 ;
    V2=pi*((rk_if/100)^2)*(Lk_if/100);

    vdot=(V2-V1)/delt;

    V1=V2;

    out_t(m)=(t+t_in2);

    t=m*delt;

    t_s2=(t+t_in2);
    mdot_s2=mdot_in2;
    P_s2=P;
    Lk_s2=Lk_if;
    rk_s2=rk_if;
end


    subplot(3,1,1)
    plot(out_t,out_mdot,'b'),xlabel('time(s)'),ylabel('Mass flow rate(Kg/s)')
    hold on
    grid on
    subplot(3,1,2)
    plot(out_t,out_P,'b'),xlabel('time(s)'),ylabel('Pressure(bar)')
    hold on
    grid on
    subplot(3,1,3)
    plot(out_t,out_Lk,'b'),xlabel('time(s)'),ylabel('Muscle length (cm)')
    hold on
    grid on

end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%Sub-program 5
%This section of program gives the behaviour of the PAM when valves are
%switched off and maintains the PAM condition
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function [t_of,mdot_in3,P_of,Lk_of,rk_of]=steady2(t_s2,mdot_s2,P_s2,Lk_s2,rk_s2)

T2=1;
t_in=t_s2;
delt=0.0005;
Pu=6;
delt=0.0005;
V1=pi*((rk_s2/100)^2)*(Lk_s2/100);
V2=V1;
vdot=(V2-V1)/delt;

Patm=1;
P=P_s2;

Cr=0.528;
Ck=3.864;
k=1.4;
```

```
Tu=300;
R=287;
t=0;

for m=1:T2/delt


    Pr=P/Pu;
    if Pr>=Patm/Pu & Pr<=0.528
           fPr=Pu/sqrt(Tu);

            elseif Pr>0.528 & Pr<=1

                fPr=Pu*Ck*(((Pr^(2/k))-(Pr^((k+1)/k)))^0.5)/sqrt(Tu);

            else
        fPr=0;
    end

    mdot=0;
    out_m(m)=mdot_s2;
    mdot_s2=mdot;

    Pdot=(-k*(P*10^5)*vdot)/V1 +(k*R*Tu*mdot)/V1;

    out_P(m)=P;
    P=P+(Pdot/10^5)*delt;

    out_L(m)=Lk_s2;
    out_r(m)=rk_s2;

    [Lk_if,rk_if]=muscle_model_cal_inst_len(P,Fin);

    Lk_s2=Lk_if;
    rk_s2=rk_if;

    out_v(m)=V1 ;
    V2=pi*((rk_if/100)^2)*(Lk_if/100);

    vdot=(V2-V1)/delt;

    V1=V2;

    out_t(m)=(t+t_in);

    t=m*delt;

    t_s=(t+t_in);
    P_s=P;

    out_P(m)=P_s;
    out_t(m)=m*delt+t_in;

    t_of=m*delt+t_in;
    P_of=P_s;
    mdot_in3=mdot_s2;
    Lk_of=Lk_s2;
    rk_of=rk_s2;

end

    subplot(3,1,1)
    plot(out_t,out_m,'r')
    hold on
    grid on
    subplot(3,1,2)
    plot(out_t,out_P,'r')
    hold on
    grid on
    subplot(3,1,3)
    plot(out_t,out_L,'r')
```

```
    hold on
    grid on

end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%Sub-program 6
%This section of program simulate the behaviours when the valve open for discharge the air
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

function [t_s3,mdot_s3,P_s3,Lk_s3,rk_s3]=pro_test_com_rev_fn(t_of,mdot_in3,P_of,Lk_of,rk_of)

Tof=2;
delt=0.0005;
V1=pi*((rk_of/100)^2)*(Lk_of/100);
V2=V1;
vdot=(V2-V1)/delt;
Patm=1;
Pd=Patm;
P=P_of;

Cr=0.528;
Ck=3.864;
k=1.4;
Tu=300;
R=287;

t1=t_of;

for m=1:Tof/delt


    Pr=Patm/P;
    if Pr>=Patm/P & Pr<=0.528
           fPr=P/sqrt(Tu);

            elseif Pr>0.528 & Pr<=1

                fPr=P*Ck*(((Pr^(2/k))-(Pr^((k+1)/k)))^0.5)/sqrt(Tu);

            else
        fPr=0;
    end

    mdot_release= (0.00148*fPr+0.000005);%Calculation of the mass flow rate according to the
obtain model for discharge

    mdot=(-mdot_release);
    out_mdot(m)=mdot_in3;
    mdot_in3=mdot_release;
    out_Lk(m)=Lk_of;
    out_rk(m)=rk_of;

    [Lk_of,rk_of]=muscle_model_cal_inst_len_re(P,Fin);%Calling the program of PAM model to
find the position of the PAM when discharging (sub-program M2)

    Pdot=(-k*(P*10^5)*vdot)/V1 +(k*R*Tu*mdot)/V1;

    out_P(m)=P;
    P=P+(Pdot/10^5)*delt;

    out_v(m)=V1;
    V2=pi*((rk_of/100)^2)*(Lk_of/100);

    V1=V2;

    t=t1+m*delt;
    out_t(m)=t;

    t_s3=t;
```

```
    mdot_s3=mdot_release;
    P_s3=P;
    Lk_s3=Lk_of;
    rk_s3=rk_of;

end


    subplot(3,1,1)
    plot(out_t,out_mdot,'g')
    hold on
    grid on
    subplot(3,1,2)
    plot(out_t,out_P,'g')
    hold on
    grid on
    subplot(3,1,3)
    plot(out_t,out_Lk,'g')
    hold on
    grid on

end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%Sub-program 7
%This section of program gives the behaviour of the PAM when valves are
%switched off finally and maintains the PAM condition
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

function [t_in,Pst,Lk_if,rk_if]=steady3(t_s3,mdot_s3,P_s3,Lk_s3,rk_s3)

T2=2;
t_in=t_s3;
Pu=6;
delt=0.0005;

V1=pi*((rk_s3/100)^2)*(Lk_s3/100);
V2=V1;
vdot=(V2-V1)/delt;

Patm=1;
P=P_s3;

Cr=0.528;
Ck=3.864;
k=1.4;
Tu=300;
R=287;
t=0;

for m=1:T2/delt


    Pr=P/Pu;
    if Pr>=Patm/Pu & Pr<=0.528
          fPr=Pu/sqrt(Tu);

          elseif Pr>0.528 & Pr<=1

              fPr=Pu*Ck*(((Pr^(2/k))-(Pr^((k+1)/k)))^0.5)/sqrt(Tu);

          else
        fPr=0;
    end

    mdot=0;
    out_m(m)=mdot_s3;
    mdot_s3=mdot;

    Pdot=(-k*(P*10^5)*vdot)/V1 +(k*R*Tu*mdot)/V1;
```

```
    out_P(m)=P;
    P=P+(Pdot/10^5)*delt;

    out_L(m)=Lk_s3;
    out_r(m)=rk_s3;

    [Lk_if,rk_if]=muscle_model_cal_inst_len_re(P,Fin);

    Lk_s3=Lk_if;
    rk_s3=rk_if;

    out_v(m)=V1 ;
    V2=pi*((rk_if/100)^2)*(Lk_if/100);

    vdot=(V2-V1)/delt;

    V1=V2;

    out_t(m)=(t+t_in);

    P_s3=P;
    out_P(m)=P_s3;
    out_t(m)=m*delt+t_s3;
    t_in=m*delt+t_s3;
    Pst=P_s3;
    Lk_if=Lk_s3;
    rk_if=rk_s3;

end

    subplot(3,1,1)
    plot(out_t,out_m,'r')
    hold on
    grid on
    subplot(3,1,2)
    plot(out_t,out_P,'r')
    hold on
    grid on
    subplot(3,1,3)
    plot(out_t,out_L,'r')
    hold on
    grid on

end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%Sub-program M1
%This program is used to find the muscle position when supply valve open.
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function[Lk_if,rk_if]=muscle_model_cal_inst_len(P,Fin)
Fin=220;
Patm=1;
Pups=6;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
Lsk=0;
Lk_if=(0.262*(P-Patm)^2-2.991*(P-Patm)+30.63)+Lsk;
rk_if=abs((-0.005*Lk_if^2+6.735)^(1/2));

Pk=P-Patm;
Fk=Fin;
if Pk>= 2.5
c(1)=1.818;
c(2)=-3.127*(Pk);
c(3)=4.182*(Pk)^2+70.377;
c(4)=-Fk;
else
c(1)=2.741;
c(2)=-5.741*(Pk);
```

```
c(3)=-2.299*(Pk)^2+119.304;
c(4)=-Fk;
end
r_L=roots([c(1) c(2) c(3) c(4)]);
Lmax=30-(0.262*(Pups-Patm)^2-2.991*(Pups-Patm)+30.63);
for j=1:3
if imag(r_L(j))== 0
   if r_L(j)>=0 & r_L(j)<=Lmax
       Lsk=r_L(j);
   end
end
end

Lk_if=(0.262*(Pk)^2-2.991*(Pk)+30.63)+Lsk;
rk_if=abs((-0.005*Lk_if^2+6.735)^(1/2));
end


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%Sub-program M2
%This program is used to find the muscle position when discharge valve open.
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function[Lk_of,rk_of]=muscle_model_cal_inst_len_re(P,Fin)
Patm=1;             % Atmospheric pressure
Pups=6;             % maximum operating pressure of the muscle.

Lsk=0;
Lk_of=(0.262*(P-Patm)^2-2.991*(P-Patm)+30.63)+Lsk;
rk_of=abs((-0.005*Lk_of^2+6.735)^(1/2));

Pk=P-Patm;
Fk=Fin;
if Pk>= 2.5
c(1)=1.850;
c(2)=-2.389*(Pk);
c(3)=3.837*(Pk)^2+53.021;
c(4)=-Fk;
else
c(1)=3.203;
c(2)=-5.890*(Pk);
c(3)=-2.977*(Pk)^2+104.824;
c(4)=-Fk;
end
r_L=roots([c(1) c(2) c(3) c(4)]);
Lmax=30-(0.262*(Pups-Patm)^2-2.991*(Pups-Patm)+30.63);

for j=1:3
if imag(r_L(j))== 0
   if r_L(j)>=0 & r_L(j)<=Lmax
       Lsk=r_L(j);
   end
end
end

Lk_of=(0.262*(Pk)^2-2.991*(Pk)+30.63)+Lsk;
rk_of=abs((-0.005*Lk_of^2+6.735)^(1/2));
end


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

Program to plot the experimental results of Case Study II

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%Program for plot the graph of the experimental data in Case study II
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
clc
clear
load test1.txt                  %Load the data from the text file
%Assigning the data of t-time, L- length, P-pressure, and m-mass flow rate
out_t=test1(:,1);
out_L=test1(:,2);
out_P=test1(:,3);
out_m=test1(:,4);

%plot the graps
    subplot(3,1,1)
    plot(out_t,out_m,'r*')
    hold on
    grid on
    subplot(3,1,2)
    plot(out_t,out_P,'r*')
    hold on
    grid on
    subplot(3,1,3)
    plot(out_t,out_L,'r*')
    hold on
    grid on
```

Simulation Program of Fuzzy PWM controller

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%Simulation program of proposed control scheme
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

clear all                                   %clear the data
clc                                         %clear command prompt


Ref=input('Input the reference point-            '); % final position of the muscle
Pst=input('Input starting pressure-             ');        %starting pressure ( this should be
changed according to the supply and discharge)
Fin=('Input the Load-             ');                %load attached with the muscle
Patm=1;                                             %atmospheric pressure

t_in=0;                                     %initial time
t=0;                                        %program time
delt_fuzzy=0.06;                                  % time step used in the program(taken as the
same value as it has been taken in experiment.
delt=0.0005;                                %time step for run the program
delt_valve=0.015;
s_in=0;                                           %initially valve is close therefore initial
value make as zero
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

[Lk_if,rk_if]=initial_positions(Pst,Fin);       % function to find the initial position of the
muscle according to load and initial pressure
V1=pi*((rk_if/100)^2)*(Lk_if/100);          % calculation of initial volume
V2=V1;                                            % initial volume is equal to next volume in
the beginning
vdot=(V2-V1)/delt;                          %calculation of rate of change of volume

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%Defining a fuzzy rule in the program
E1=-0.1;                                    %error margin
E2=0;
E3=0.1;
S1=10;
U1=0.00045;                                 % given mass flow rate in the controller
U2=0;
U3=-0.00045;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

P=Pst;                                        %P is a general letter to assign the pressure in
the program
Y=Lk_if;                                       %Y is the length of the muscle, start with the
initial length
er=Ref-Y;                                   %position error calculation error calculation

%Loop start
for m=1:80                                 %this run the program for given iterations


    T=t+t_in;
    out_er(m)=er;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

    if er>0.1
        mdot=U3;

    elseif er>0
        Ei=E2;
        Eii=E3;
        Ui=U2;
        Uii=U3;
        Si=S1;
        mdot=(1-Si*(er-Ei))*Ui+(1-Si*(Eii-er))*Uii;
```

```
    elseif er==0
        Ei=0;
        Eii=0;
        Ui=0;
        Uii=0;
        Si=S1;
        mdot=(1-Si*(er-Ei))*Ui+(1-Si*(Eii-er))*Uii;

    elseif er>-0.1
        Ei=E1;
        Eii=E2;
        Ui=U1;
        Uii=U2;
        Si=S1;
        mdot=(1-Si*(er-Ei))*Ui+(1-Si*(Eii-er))*Uii;

    else
        mdot=U1;
    end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    % selection of mass flow and calculation of the mass flow rate
    Pin=P;
    Pout=P;

    if mdot>0                               %The controller output compared and select the
mass flow model according
        [m_dot]=mdotin(Pin);                %Calculate the supply flow rate

    elseif mdot<0
        [m_dot]=mdotout(Pout);              %Calculate the discharge flow rate
    else
         m_dot=0;
    end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    %PWM section

    prcnt=abs(mdot/m_dot)*100;       %calculate the percentage for the switching action of PWM
    out_prcnt(m)=prcnt;

    if prcnt>75
        n_vop=1*4;
    elseif prcnt>50
        n_vop=1*3;
    elseif prcnt>25
        n_vop=1*2;
    elseif prcnt>0
        n_vop=1*1;
    elseif prcnt==0
        n_vop=0;
    elseif prcntISNaN
        break

    end

    t_vop=n_vop*delt_valve;
    t_vof=(delt_fuzzy-(n_vop*delt_valve));
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    %simulation of valve operating
    if n_vop<4
        [t_out_vop,s_in]=valve_open(t_vop,delt, T,s_in,mdot);
        [t_out_vof,s_in]=valve_close(t_vof,delt,t_out_vop,s_in);
    else
        [t_out_vop,s_in]=valve_open(t_vop,delt, T,s_in,mdot);
    end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
   % simulation of PAM actuator behaviours
    if n_vop<4
        [t_m_out,P,Lk_if,rk_if]=massflow_valve_open(mdot,t_vop,T,P,Lk_if,rk_if,Fin);
        [t_m_out_of,P,Lk_if,rk_if]=massflow_valve_close(mdot,t_vof,t_m_out,P,Lk_if,rk_if,Fin);
```

```
    else
        [t_m_out,P,Lk_if,rk_if]=massflow_valve_open(mdot,t_vop,T,P,Lk_if,rk_if,Fin);
    end


    out_t(m)=t+t_in;

    out_mdot1(m)=mdot;
    out_ref(m)=Ref;                                 %plot a reference

    t=m*delt_fuzzy;
    Y=Lk_if;
    er=Ref-Y;                                       %Calculation of error
end

 %Plot the reference
    subplot(4,1,4)
    plot(out_t,out_ref,'r')
    hold on
    grid on

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%The program is used to find the initial conditions of the muscle with the load and the
pressure.
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function[Lk_if,rk_if]=initial_positions(Pst,Fin)
Patm=1;
P=Pst;
Pups=6;
Lsk=0;
Lk_if=(0.262*(P-Patm)^2-2.991*(P-Patm)+30.63)+Lsk;
rk_if=abs((-0.005*Lk_if^2+6.735)^(1/2));

Pk=P-Patm;
Fk=Fin;
if Pk>= 2.5
c(1)=1.818;
c(2)=-3.127*(Pk);
c(3)=4.182*(Pk)^2+70.377;
c(4)=-Fk;
else
c(1)=2.741;
c(2)=-5.741*(Pk);
c(3)=-2.299*(Pk)^2+119.304;
c(4)=-Fk;
end
r_L=roots([c(1) c(2) c(3) c(4)]);

Lmax=30-(0.262*(Pups-Patm)^2-2.991*(Pups-Patm)+30.63);

for j=1:3
if imag(r_L(j))== 0
   if r_L(j)>=0 & r_L(j)<=Lmax
       Lsk=r_L(j);
   end
end
end

Lk_if=(0.262*(Pk)^2-2.991*(Pk)+30.63)+Lsk;
rk_if=abs((-0.005*Lk_if^2+6.735)^(1/2));

end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%Calculation of Mass flow rate when supply
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function [m_dot]=mdotin(Pin)
P=Pin;
Pu=6;
```

```
Ck=3.864;
k=1.4;
Patm=1;
Tu=300;


    Pr=P/Pu;
    if Pr>=Patm/Pu && Pr<=0.528
           fPr=Pu/sqrt(Tu);

            elseif Pr>0.528 && Pr<=1

                fPr=Pu*Ck*(((Pr^(2/k))-(Pr^((k+1)/k)))^0.5)/sqrt(Tu);

            else
        fPr=0;
    end

    mdot_in= (0.001939*fPr - 0.000002);


m_dot=mdot_in;
end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%Calculation of Mass flow rate when discharge
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function [m_dot]=mdotout(Pout)
P=Pout;
Patm=1;
Ck=3.864;
k=1.4;
Tu=300;

Pr=Patm/P;
    if Pr>=Patm/P && Pr<=0.528
           fPr=P/sqrt(Tu);

            elseif Pr>0.528 && Pr<=1

                fPr=P*Ck*(((Pr^(2/k))-(Pr^((k+1)/k)))^0.5)/sqrt(Tu);

            else
        fPr=0;
    end

    mdot_release=(0.00148*fPr+0.000005);

    m_dot=mdot_release;


end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%Program for simulate the switching action when the PWM signal for Switch on
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function [t_out_vop,s_in]=valve_open(t_vop,delt, T,s_in,mdot)
s_op=s_in;
t_out=T;
for i=1:t_vop/delt
    %if mass flow rate positive program select the supply valve else
    %discharge valve
    if mdot>0
        S_P=1;
    else
        S_P=-1;
    end

    out_S_P(i)=s_op;
    s_op=S_P;
    out_t_on(i)=t_out;
```

```
    t1=i*delt;  %calculation of time
    t_out=T+t1;
    t_out_vop=t_out;
    s_in=s_op;
end
    subplot(4,1,2)
    plot(out_t_on,out_S_P,'b'),xlabel('time(s)'),ylabel('step(Valve opening)')
    hold on
    grid on

end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%Program for simulate the switching action when the PWM signal for Switch
%off
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function [t_out_vof,s_in]=valve_close(t_vof,delt,t_out_vop,s_in)
s_of=s_in;
t_out=t_out_vop;
for i=1:t_vof/delt
    S_P=0;
    out_S_P(i)=s_of;
    s_of=S_P;
    out_t_off(i)=t_out;

    t1=i*delt;      %calculation of time
    t_out=t_out_vop+t1;
    t_out_vof=t_out;
    s_in=s_of;
end
    subplot(4,1,2)
    plot(out_t_off,out_S_P,'r'),xlabel('time(s)'),ylabel('step(Valve opening)')
    hold on
    grid on

end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%This program simulate the Controlled behaviour of PAM according to the
%proposed method when the valves On step
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

function [t_m_out,P,Lk_if,rk_if]=massflow_valve_open(mdot,t_vop,T,P,Lk_if,rk_if,Fin)

    t_out=T;
    delt=0.0005;

    V1=pi*((rk_if/100)^2)*(Lk_if/100);
    V2=V1;
    vdot=(V2-V1)/delt;

    for i=1:(t_vop)/delt                              %starting for loop

        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        out_P(i)=P;
        out_Lk(i)=Lk_if;
        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

        k=1.4;                                        %specific heat constant
        Tu=300;                                       %temperature
        R=287;                                        %gas constant


        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
            %calculation of mass flow rate according to the controller
            %output
            P_in=P;
            P_out=P;

            if mdot>0
```

```
            [mdot_v]=mdotin_mod(P_in);
        elseif mdot<0
            [mdot_vout]=mdotout_mod(P_out);
            mdot_v=-mdot_vout;
        else
            mdot_v=0;
        end

        out_mdot(i)=mdot_v;
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%



        Pdot=(-k*(P*10^5)*vdot)/V1 +(k*R*Tu*mdot_v)/V1;      %Calculation of rate of change
of pressure
        P=P+(Pdot/10^5)*delt;                                %Calculation of pressure

        if mdot>=0
            [Lk_if,rk_if]=muscle_model_cal_inst_len(P,Fin);           %muscle model to find
the position of the muscle when muscle extract
        else
            [Lk_if,rk_if]=muscle_model_cal_inst_len_re(P,Fin);        %muscle model to find
the position of the muscle when muscle contracted
        end

    V2=pi*((rk_if/100)^2)*(Lk_if/100);                          %Volume calculation
    vdot=(V2-V1)/delt;                                          %Rate of change of volume
    V1=V2;                                                      %exchange volume

    out_t_on(i)=t_out;
    t1=i*delt;
    t_out=T+t1;
    t_m_out=t_out;

    end                                         %end of for loop
    subplot(4,1,1)
    plot(out_t_on,out_mdot,'b'),xlabel('time(s)'),ylabel('Mass flow rate(Kg/s)')
    hold on
    grid on
    subplot(4,1,3)
    plot(out_t_on,out_P,'b'),xlabel('time(s)'),ylabel('Pressure (bar)')
    hold on
    grid on
    subplot(4,1,4)
    plot(out_t_on,out_Lk,'b'),xlabel('time(s)'),ylabel('Muscle length (cm)')
    hold on
    grid on
end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%This program simulate the Controlled behaviour of PAM according to the
%proposed method when the valves Off step
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function [t_m_out_of,P,Lk_if,rk_if]=massflow_valve_close(mdot,t_vof,t_m_out,P,Lk_if,rk_if,Fin)

    t_out=t_m_out;
    delt=0.0005;

    V1=pi*((rk_if/100)^2)*(Lk_if/100);
    V2=V1;
    vdot=(V2-V1)/delt;

    for i=1:(t_vof)/delt                        %starting for loop

        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
        out_P(i)=P;
        out_Lk(i)=Lk_if;
        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

        k=1.4;                                  %heat constant
        Tu=300;                                 %temperature
```

```
        R=287;                                  %gas constant

        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
            P_in=P;
            P_out=P;

                mdot_v=0;                               %mass flow rate is zero because of closed
valves

            out_mdot(i)=mdot_v;
        %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%



            Pdot=(-k*(P*10^5)*vdot)/V1 +(k*R*Tu*mdot_v)/V1;      %Calculation of rate of change
of pressure
            P=P+(Pdot/10^5)*delt;                               %Calculation of pressure

            if mdot>=0
                [Lk_if,rk_if]=muscle_model_cal_inst_len(P,Fin);      %muscle model to find the
position of the muscle when muscle extract
            else
                [Lk_if,rk_if]=muscle_model_cal_inst_len_re(P,Fin); %muscle model to find the
position of the muscle when muscle contracte
            end

        V2=pi*((rk_if/100)^2)*(Lk_if/100);                          %Volume calculation
        vdot=(V2-V1)/delt;                                          %Rate of change of volume
        V1=V2;                                                      %exchange volume

        out_t_on(i)=t_out;
        t1=i*delt;
        t_out=t_m_out+t1;
        t_m_out_of=t_out;

    end                                         %end of for loop

    subplot(4,1,3)
    plot(out_t_on,out_P,'b'),xlabel('time(s)'),ylabel('Pressure (cm)')
    hold on
    grid on
    subplot(4,1,4)
    plot(out_t_on,out_Lk,'b'),xlabel('time(s)'),ylabel('Muscle length (cm)')
    hold on
    grid on
end


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%this program is used to find the instantaneous muscle position when the air
%supply
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
function[Lk_if,rk_if]=muscle_model_cal_inst_len(P,Fin)

Patm=1;
Pups=6;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

Lsk=0;
Lk_if=(0.262*(P-Patm)^2-2.991*(P-Patm)+30.63)+Lsk; % for the initial condition and use a gage
pressure
rk_if=abs((-0.005*Lk_if^2+6.735)^(1/2));

Pk=P-Patm;
Fk=Fin;
if Pk>= 2.5
c(1)=1.818;
c(2)=-3.127*(Pk);
c(3)=4.182*(Pk)^2+70.377;
c(4)=-Fk;
```

```
else
c(1)=2.741;
c(2)=-5.741*(Pk);
c(3)=-2.299*(Pk)^2+119.304;
c(4)=-Fk;
end
r_L=roots([c(1) c(2) c(3) c(4)]);
Lmax=30-(0.262*(Pups-Patm)^2-2.991*(Pups-Patm)+30.63);
for j=1:3
if imag(r_L(j))== 0
   if r_L(j)>=0 & r_L(j)<=Lmax
       Lsk=r_L(j);
   end
end
end

Lk_if=(0.262*(Pk)^2-2.991*(Pk)+30.63)+Lsk;
rk_if=abs((-0.005*Lk_if^2+6.735)^(1/2));
end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%this program is used to find the instantaneous muscle position when the air
%discharge
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

function[Lk_if,rk_if]=muscle_model_cal_inst_len_re(P,Fin)
%Fin=0;
Patm=1;
Pups=6; % maximum operating pressure of the muscle.

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
Lsk=0;
Lk_if=(0.262*(P-Patm)^2-2.991*(P-Patm)+30.63)+Lsk;
rk_if=abs((-0.005*Lk_if^2+6.735)^(1/2));

Pk=P-Patm;
Fk=Fin;
if Pk>= 2.5
c(1)=1.850;
c(2)=-2.389*(Pk);
c(3)=3.837*(Pk)^2+53.021;
c(4)=-Fk;
else
c(1)=3.203;
c(2)=-5.890*(Pk);
c(3)=-2.977*(Pk)^2+104.824;
c(4)=-Fk;
end
r_L=roots([c(1) c(2) c(3) c(4)]);
Lmax=30-(0.262*(Pups-Patm)^2-2.991*(Pups-Patm)+30.63); % this should be come with the maximum
operating pressure of the Muscle

for j=1:3
if imag(r_L(j))== 0
   if r_L(j)>=0 & r_L(j)<=Lmax
       Lsk=r_L(j);
   end
end
end

Lk_if=(0.262*(Pk)^2-2.991*(Pk)+30.63)+Lsk;
rk_if=abs((-0.005*Lk_if^2+6.735)^(1/2));
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

Appendix C

Experimental Data

Experimental Data to Obtain the Constants of Stiffness Parameters

PAM-A

Extraction						Contraction					
0-2.5 bar			2.5-5.0 bar			0-2.5 bar			2.5-5.0 bar		
Ls(cm)	Pressure (bar)	Force (Kg)	Ls (cm)	Pressure (bar)	Force (Kg)	Ls (cm)	Pressure (bar)	Force (Kg)	Ls (cm)	Pressure (bar)	Force (Kg)
0.0000	0.6450	0.0000	0.0000	3.0359	0.0000	1.0424	0.6257	20.3576	6.7442	3.0164	87.7144
0.2082	0.6315	5.3226	0.2162	3.0278	4.7212	0.9546	0.6351	15.5464	6.4433	3.0174	75.6864
0.3934	0.6420	8.3296	0.6850	3.0108	8.9310	0.8348	0.6314	12.5394	5.8555	3.0343	61.8542
0.5353	0.6283	10.1338	1.0786	3.0194	13.1408	0.7490	0.6341	10.7352	5.2176	3.0181	51.0290
0.7013	0.6265	13.1408	1.5473	3.0184	16.7492	0.5052	0.6364	6.5254	4.6503	3.0401	43.2108
0.8382	0.6272	16.1478	1.9945	3.0219	20.9590	0.2865	0.6343	3.5184	3.9137	3.0051	35.3926
1.0350	0.6486	20.3576	2.5541	3.0168	26.9730	0.1058	0.6454	1.1128	3.2142	3.0213	28.1758
0.0000	1.1088	0.0000	3.1871	3.0148	32.3856	0.0078	0.6432	0.5114	2.4023	3.0299	20.9590
0.2227	1.1107	4.7212	3.7181	3.0041	37.1968	0.0000	0.6382	0.0000	2.0159	3.0229	17.3506
0.4749	1.1154	7.7282	4.2619	3.0173	43.2108	2.5825	1.1054	35.9940	1.6046	3.0166	14.3436
0.6861	1.1093	8.9310	4.9234	3.0096	52.2318	2.4603	1.1176	29.3786	1.1523	3.0194	10.7352
1.0780	1.1072	11.9380	5.6536	3.0201	61.8542	2.2926	1.1040	25.1688	0.8006	3.0207	7.7282
1.2921	1.1067	14.3436	6.2560	3.0315	74.4836	2.0224	1.1081	19.1548	0.2293	3.0133	2.9170
1.5998	1.1107	17.9520	6.7134	3.0267	87.7144	1.8002	1.0962	16.1478	0.0000	3.0328	0.0000
2.1117	1.0954	25.1688	0.0000	3.5689	0.0000	1.5756	1.1119	13.1408	6.8480	3.5516	91.9242
2.4137	1.0940	31.7842	0.1517	3.5702	4.7212	1.3278	1.0930	10.1338	6.1132	3.5676	71.4766
2.5839	1.1075	36.5954	0.8991	3.5651	12.5394	0.9280	1.1088	7.1268	5.7809	3.5672	65.4626
0.0000	1.5606	0.0000	1.6310	3.5932	19.7562	0.6950	1.1081	4.7212	5.3303	3.5739	57.6444
0.2493	1.5606	4.1198	2.8037	3.6011	31.7842	0.2638	1.1154	2.3156	5.0243	3.5554	53.4346
0.8914	1.5798	8.9310	3.3823	3.5563	37.1968	0.1287	1.1001	1.1128	4.6510	3.5603	49.2248
1.3079	1.5572	10.7352	3.7993	3.613	43.2108	0.0000	1.0966	0.0000	4.0089	3.5700	41.4066
1.7150	1.5350	13.7422	4.3119	3.619	49.8262	4.1660	1.5527	45.6164	3.6019	3.5608	36.5954
2.1866	1.5466	17.3506	5.0948	3.6356	60.6514	3.9437	1.5670	37.7982	3.0939	3.5682	31.1828
2.6242	1.5472	20.9590	5.8469	3.6085	72.0780	3.6307	1.5621	31.1828	2.5018	3.5668	25.1688
3.1812	1.5678	26.9730	6.4805	3.5642	84.1060	3.3941	1.5480	26.9730	1.9370	3.5499	19.1548
3.7831	1.5596	37.1968	6.8561	3.5637	93.1270	2.8988	1.5668	19.7562	1.4125	3.5682	14.9450
3.9739	1.5500	42.0080	0.0000	4.0797	0.0000	2.4801	1.5777	16.1478	0.7826	3.5767	8.9310
4.1731	1.5559	47.4206	0.0413	4.0724	2.9170	2.2435	1.5513	13.7422	0.0204	3.5616	1.7142
0.0000	2.1117	0.0000	0.5712	4.0725	8.9310	1.8447	1.5740	11.3366	0.0000	3.5584	0.0000
0.2571	2.1035	4.7212	1.0225	4.0771	14.3436	1.3979	1.5565	8.9310	6.7168	4.0525	90.7214
0.9206	2.1092	9.5324	1.5468	4.0865	20.3576	1.0185	1.5560	5.9240	5.7096	4.0748	69.0710
1.5864	2.0954	14.3436	2.0765	4.0548	25.7702	0.6117	1.5530	3.5184	5.4061	4.0743	64.2598
2.4143	2.0973	20.3576	2.5584	4.0881	31.1828	0.2243	1.5331	1.7142	5.0634	4.0707	59.4486
2.9120	2.1137	25.1688	3.4277	4.0665	41.4066	0.0000	1.5435	0.0000	4.5726	4.0798	52.2318
3.4512	2.0966	29.3786	4.4291	4.077	53.4346	5.3653	2.1112	60.0500	3.7987	4.0623	42.0080
4.1434	2.1170	37.1968	5.0157	4.0695	61.2528	5.0462	2.0994	49.2248	3.0674	4.0676	33.5884
4.5269	2.0992	43.2108	5.6006	4.0683	64.2598	4.7325	2.0942	42.6094	2.5948	4.0686	28.1758
4.9695	2.0978	51.0290	6.0571	4.0671	70.8752	4.4327	2.1077	37.1968	2.0590	4.0731	22.1618
5.3610	2.1027	61.2528	6.4613	4.072	78.0920	4.0649	2.1007	31.7842	1.5115	4.0710	16.7492
0.0000	2.5816	0.0000	6.7047	4.0649	91.3228	3.5511	2.1092	26.3716	0.9828	4.0658	11.3366
0.8185	2.5225	8.3296	0.0000	4.6537	0.0000	3.0464	2.1072	21.5604	0.4543	4.0658	5.3226
1.3081	2.5087	11.9380	0.1140	4.6287	4.7212	2.5285	2.0723	17.3506	0.0508	4.0849	1.7142
1.7218	2.5048	14.9450	0.6619	4.6259	11.9380	2.0349	2.0911	13.7422	0.0000	4.0755	0.0000
2.4453	2.5155	20.9590	1.2863	4.6424	19.1548	1.6868	2.1015	11.3366	6.5224	4.6387	93.7284

3.1622	2.5088	26.9730	2.2689	4.6949	32.3856	1.4035	2.1005	9.5324	5.9696	4.6300	80.4976
3.9631	2.5100	35.3926	3.0299	4.6182	41.4066	0.8947	2.1163	7.1268	5.6506	4.6348	75.0850
4.5280	2.5274	42.0080	3.4784	4.6252	47.4206	0.1801	2.0943	2.3156	5.2407	4.6175	67.8682
4.7872	2.5167	45.6164	4.2367	4.6293	57.6444	0.0000	2.0903	0.0000	4.3991	4.6294	55.8402
5.1185	2.5366	49.8262	4.9364	4.613	67.8682	6.3418	2.5391	76.2878	4.0823	4.6378	51.0290
5.6577	2.5113	59.4486	5.4138	4.6302	75.6864	5.7563	2.5129	57.6444	3.7636	4.6293	46.8192
6.3262	2.5282	77.4906	5.9418	4.6362	84.1060	5.3971	2.5118	49.8262	3.3318	4.6254	41.4066
0.0000	0.6166	0.0000	6.5016	4.6234	93.7284	4.9857	2.5334	43.2108	2.8212	4.6378	34.7912
0.0183	0.6182	0.6400	0.0000	5.196	0.0000	4.4582	2.5218	35.9940	2.4430	4.6235	29.3786
0.1425	0.5667	2.5200	0.3033	5.2061	8.9310	3.9410	2.5258	31.1828	1.9298	4.6326	23.3646
0.1758	0.5758	3.4600	0.5523	5.2095	11.9380	3.2787	2.5334	24.5674	1.3443	4.6273	16.7492
0.3278	0.5794	5.6300	0.9478	5.2171	17.3506	2.8205	2.5157	20.9590	0.9236	4.6471	11.3366
0.4242	0.5721	7.2700	1.3812	5.1992	23.3646	2.3588	2.5141	17.3506	0.3533	4.6417	4.7212
0.6024	0.5867	10.8900	1.7266	5.1957	28.1758	1.8667	2.5322	13.1408	0.0222	4.6301	1.7142
0.8281	0.5937	14.8100	2.3875	5.195	37.1968	1.7447	2.5274	12.5394	0.0000	4.6290	0.0000
1.0091	0.5743	19.5900	2.6312	5.2083	40.2038	1.0855	2.5305	7.7282	5.7657	5.2090	90.1200
0.0000	1.0992	0.0000	3.3598	5.1904	50.4276	0.5445	2.5289	3.5184	4.7416	5.2131	69.6724
0.0308	1.1183	1.4900	3.6711	5.2014	55.2388	0.0000	2.5307	0.0000	4.4915	5.2190	65.4626
0.0379	1.1017	2.0300	3.9075	5.2008	59.4486	1.0084	0.5859	19.3400	4.1726	5.2107	60.0500
0.2238	1.0939	4.8000	4.2303	5.2008	63.6584	0.8816	0.5621	14.4000	3.7718	5.2060	54.0360
0.5996	1.1095	8.8400	4.7187	5.1981	72.0780	0.7772	0.5734	11.3400	3.7724	5.2048	54.6374
0.9384	1.1143	11.7900	5.1728	5.2074	79.2948	0.5920	0.5717	8.8000	3.4116	5.2130	48.6234
1.2339	1.1267	15.1600	5.5249	5.1971	85.9102	0.5192	0.5833	7.4000	3.0222	5.2128	43.2108
1.5793	1.0886	19.8000	5.7238	5.1943	90.1200	0.4485	0.5867	6.0700	2.6375	5.2001	37.7982
1.8818	1.0549	25.8600	0.0000	3.0676	0.0000	0.3342	0.5877	4.1600	2.3585	5.2072	33.5884
2.2899	1.0895	37.4400	0.1993	3.0807	1.1500	0.2523	0.5541	2.6200	1.8433	5.2091	26.9730
0.0000	1.6693	0.0000	0.5081	3.0412	5.4000	0.1397	0.5725	1.5100	1.5007	5.2168	22.1618
0.1718	1.6705	1.1900	1.0999	3.0802	10.9500	0.0000	0.5412	0.0000	1.1656	5.2174	17.3506
0.3063	1.6641	2.4800	1.6974	3.0701	16.2800	2.2977	1.0972	36.7800	0.6938	5.2238	11.3366
0.6808	1.6482	4.8400	2.5895	3.0398	24.7100	2.1832	1.1044	31.3400	0.2414	5.2141	7.1268
1.4116	1.6704	9.7700	3.4203	3.0743	32.6800	2.0202	1.1161	25.4000	0.0833	5.2031	4.7212
2.0476	1.6545	14.7100	4.3289	3.0625	42.2100	1.7618	1.0825	19.8100	0.0321	5.2249	1.1128
2.6546	1.6546	20.1900	5.1317	3.0605	53.2200	1.4603	1.0777	14.3100	0.0000	5.2152	0.0000
3.0983	1.6770	25.0800	5.9039	3.0592	65.1400	1.0687	1.1011	10.6600	6.8476	3.0371	90.1800
3.4871	1.6623	30.2100	6.4082	3.0967	77.3000	0.8091	1.1062	8.6200	6.5927	3.0635	78.4000
3.8814	1.6747	37.7500	6.8234	3.0629	90.6600	0.5809	1.1008	6.6300	6.1748	3.0116	66.7000
4.2457	1.6220	47.6600	0.0000	3.5518	0.0000	0.2638	1.1032	2.9700	5.7511	3.0532	58.3100
4.5259	1.6542	58.4900	0.0524	3.5418	1.0300	0.0772	1.0957	1.5500	4.9086	3.0538	45.6300
0.0000	2.0981	0.0000	0.4539	3.531	5.6000	0.0000	1.0581	0.0000	4.0328	3.0621	35.2200
0.1457	2.0973	1.8500	1.1428	3.5424	12.2200	4.5315	1.6644	57.8700	3.3860	3.0712	28.5700
0.9375	2.1185	7.1600	2.0845	3.5184	21.8900	4.2439	1.6536	43.3800	2.4614	3.0794	19.8200
1.6276	2.0700	12.2000	2.7609	3.5303	29.2400	3.6664	1.6669	29.3100	1.6677	3.0424	12.7900
2.5032	2.0938	18.7200	3.8333	3.5309	40.5300	3.4603	1.6492	25.5000	0.9687	3.0420	7.3800
3.2560	2.0961	25.2700	4.6580	3.5403	50.5300	3.0336	1.6588	19.8600	0.5137	3.0460	3.2600
4.0762	2.0865	34.5400	5.3422	3.5358	59.9400	2.4813	1.6622	14.7100	0.2869	3.0214	1.7000
4.7495	2.1056	45.2100	6.3258	3.5283	76.8600	2.0321	1.6379	10.7600	0.0856	3.0229	0.0000
5.2754	2.0918	58.8000	6.8137	3.5196	87.6300	1.7669	1.6867	9.4300	7.0394	3.5295	94.5100
5.6013	2.0797	70.2600	7.0382	3.5197	95.1000	1.4745	1.6412	7.5100	6.8289	3.4971	84.4200
0.0000	2.5816	0.0000	0.0000	4.0941	0.0000	1.0862	1.6434	5.4300	6.0643	3.5224	67.1000
0.0628	2.5878	1.0500	0.1672	4.1048	2.1600	0.9329	1.6878	4.3000	5.1608	3.5366	52.9100
0.4014	2.5756	3.9300	0.6106	4.089	7.3000	0.4867	1.6650	2.1700	4.8118	3.5408	48.9500
1.2291	2.5796	10.6900	1.3445	4.1133	15.8200	0.0000	1.6534	0.0000	3.6896	3.5450	35.2100
2.1115	2.5756	17.9300	2.3312	4.0787	27.0400	5.5783	2.0915	69.6800	2.8757	3.5009	26.5000
2.8515	2.5752	23.7600	3.2274	4.0669	37.8100	5.3620	2.0691	57.4600	2.1462	3.5440	19.2200
3.3605	2.5720	28.9400	4.0293	4.1032	47.8600	4.7257	2.0701	39.9000	1.4554	3.5487	12.1400
4.2082	2.5903	37.5200	4.8888	4.055	60.1100	4.1618	2.0939	31.5300	0.5526	3.5318	4.1500
5.0742	2.5727	49.0700	5.6716	4.0619	71.5400	3.9732	2.0809	29.0600	0.2225	3.5367	1.2800
5.6630	2.5847	59.4300	6.4558	4.0749	84.7800	3.5941	2.0865	24.5600	0.0000	3.5381	0.0000
6.2815	2.5901	78.3600	6.5571	4.066	87.2800	2.8554	2.0855	18.1400	7.0115	4.0918	97.0600
6.4622	2.5927	84.5500	7.0024	4.082	97.5200	2.6558	2.0652	16.6800	6.7449	4.0647	88.5400
0.0000	0.6163	0.0000	0.0000	4.5279	0.0000	1.8635	2.1017	10.6800	6.4196	4.1040	81.0700
0.0056	0.6199	0.1400	0.1233	4.5296	2.0700	1.4938	2.0984	8.3900	6.0439	4.0741	73.6300

0.0489	0.6198	1.7000	0.6676	4.5405	9.2100	1.2004	2.0969	6.5000	5.2355	4.0675	60.4400
0.1418	0.6492	3.5800	1.3600	4.5367	17.3500	0.7600	2.1006	4.2500	4.3822	4.0850	48.7300
0.1875	0.6225	4.3400	2.0524	4.5539	26.3300	0.3747	2.0738	1.8100	3.6097	4.0719	38.3400
0.3413	0.6407	7.6800	2.6844	4.5362	34.1800	0.0000	2.0884	0.0000	2.8020	4.0662	28.9400
0.6657	0.6408	13.7800	3.7426	4.5659	47.9800	6.4620	2.5926	83.9900	2.0527	4.0546	20.8200
0.8040	0.6343	17.8800	4.4287	4.517	57.5500	6.2503	2.5749	70.9600	1.1325	4.0412	10.7900
0.8532	0.6185	19.9000	5.2556	4.5145	70.0300	5.8127	2.5787	58.2500	0.8244	4.0703	7.5200
1.1334	0.6353	30.5800	5.7588	4.5341	78.0100	5.3793	2.5766	49.2900	0.2283	4.0771	1.2900
0.0000	1.2220	0.0000	6.1706	4.5477	85.2500	4.6192	2.5741	37.9800	0.0000	4.0705	0.0000
0.0623	1.1890	1.0300	6.6583	4.5363	95.3700	3.5285	2.5823	26.2000	6.6717	4.5255	94.9900
0.1598	1.2046	2.3300	0.0000	5.0827	0.0000	2.6427	2.6030	18.6600	6.5461	4.5512	90.8900
0.5736	1.2166	5.6600	0.0353	5.0495	1.1200	1.9929	2.5952	13.6900	5.3400	4.5496	68.0000
0.8187	1.1998	7.6500	0.6714	5.0821	9.9600	1.5042	2.5991	10.1100	4.9374	4.5096	62.0600
0.9891	1.2264	9.2200	1.5336	5.0283	21.1200	1.0998	2.5923	7.0200	4.5006	4.5347	55.5700
1.3199	1.2342	12.3000	2.3304	5.0662	31.8800	0.6628	2.5787	3.9100	3.4916	4.5326	40.5500
1.5320	1.1988	14.8900	3.3107	5.0834	45.6700	0.2520	2.6079	1.2400	2.8938	4.5340	33.5800
1.6766	1.1985	17.1500	4.2481	5.0272	59.0200	0.0000	2.5821	0.0000	2.3517	4.5210	26.9600
1.8790	1.2135	20.0800	4.8873	5.0742	69.2400	1.1202	0.6288	30.2700	1.8736	4.5344	20.9500
2.1353	1.2113	25.6000	5.6049	5.0381	81.3000	1.1438	0.6328	29.8000	1.3170	4.5360	13.9800
2.3766	1.2270	30.8400	5.9000	5.0156	86.7200	1.1181	0.6327	24.5900	0.8624	4.5575	9.0500
2.5229	1.2360	36.0500	6.1898	5.0332	91.8300	1.0137	0.6248	19.8000	0.5113	4.5521	4.7600
2.6900	1.2243	42.4000	6.6164	5.0466	99.9300	0.7409	0.6120	9.7600	0.2476	4.5292	2.2600
2.8816	1.2483	50.8500	0.0000	3.0583	0.0000	0.6750	0.6292	8.4500	0.0000	4.5212	0.0000
0.0000	1.6155	0.0000	0.1732	3.0542	2.0700	0.4658	0.6450	4.0800	6.6300	5.0456	99.7700
0.0558	1.6098	0.6900	0.5286	3.0729	5.5200	0.3613	0.6138	2.6000	6.2446	5.0452	90.1500
0.1714	1.6295	1.3000	1.1400	3.0617	11.3600	0.2840	0.6340	1.3700	5.4735	5.0445	75.5600
0.5351	1.6317	4.4000	1.7792	3.0277	17.3600	0.1834	0.6561	0.4000	4.9108	5.0665	65.7100
0.7507	1.6135	5.9500	2.4817	3.0645	24.3300	0.0000	0.6529	0.0000	4.3279	5.0341	56.7200
0.8847	1.6281	7.3100	3.4250	3.0523	32.9500	2.9338	1.2369	50.1300	3.5448	5.0706	45.0400
1.1664	1.6262	9.6600	4.3244	3.0635	42.5400	2.7180	1.2285	36.1400	3.2968	5.0311	41.5300
1.5058	1.6142	12.0700	5.0524	3.0281	51.9000	2.4824	1.2427	26.8500	2.6978	5.0529	33.1900
2.1153	1.6362	17.6900	5.6027	3.0673	60.5400	2.1597	1.2396	18.7500	2.1971	5.0365	26.4200
2.5353	1.6228	22.2900	6.0859	3.0587	70.2200	1.8346	1.2321	13.5300	1.9509	5.0593	23.0000
2.8870	1.6008	27.4000	6.5167	3.0408	81.4000	1.5325	1.2180	10.2000	1.1854	5.0657	13.4400
3.2064	1.6082	33.7600	6.8201	3.0468	93.1100	1.0188	1.2075	5.3400	0.7678	5.0608	7.6400
3.4299	1.6356	38.3800	0.0000	3.5641	0.0000	0.6330	1.2294	2.7200	0.5527	5.0412	4.9400
3.5864	1.6183	43.9500	0.1162	3.5815	2.6000	0.4508	1.2287	1.4100	0.2171	5.0385	0.6000
3.8301	1.6054	52.4000	1.0845	3.5451	11.9700	0.2567	1.2230	0.7100	0.0000	5.0524	0.0000
4.0100	1.6185	60.3700	1.4993	3.5424	16.4800	0.0000	1.2248	0.0000	6.8095	3.0605	92.2600
0.0000	2.1645	0.0000	2.0480	3.5484	22.1300	3.9706	1.6311	59.7700	6.5720	3.0553	78.4500
0.0114	2.1450	0.3600	2.5705	3.5401	27.7900	3.9366	1.6102	51.1000	6.2557	3.0535	69.3800
0.0271	2.1595	1.4000	3.3183	3.5823	36.0300	3.7630	1.6392	44.5600	5.4177	3.0348	52.7800
0.1541	2.1649	2.6000	3.9733	3.59	43.8700	3.4957	1.6163	34.9400	4.8502	3.0592	44.0500
0.5578	2.1528	5.6600	4.4899	3.5702	49.6700	3.3460	1.6232	30.5400	4.3126	3.0493	38.0800
1.1786	2.1512	10.2400	5.0593	3.5532	58.5300	3.0147	1.6316	24.3300	3.7451	3.0674	31.7500
1.9083	2.1343	15.6000	5.6079	3.5655	66.1200	2.7360	1.6292	20.0000	3.1351	3.0641	25.9600
2.7221	2.1354	22.4500	6.2803	3.5621	78.8300	2.3762	1.6290	15.5400	2.6255	3.0317	21.2600
3.6435	2.1246	31.7400	6.8062	3.5946	93.4400	1.8967	1.6190	11.5000	2.0540	3.0505	16.1500
4.1665	2.1555	39.5200	0.0000	4.0909	0.0000	1.5514	1.6319	9.0900	1.3938	3.0756	10.1500
4.7698	2.1355	50.6300	0.1090	4.0916	1.6600	1.2625	1.6103	7.2100	0.7898	3.0637	5.7300
5.3894	2.1541	73.5800	0.3788	4.1145	5.3000	0.8561	1.6127	4.7400	0.4866	3.0535	3.2700
0.0000	2.5504	0.0000	1.3618	4.0957	17.0000	0.2571	1.6388	1.6000	0.2083	3.0509	1.0900
0.1114	2.5552	1.7900	2.3144	4.1186	27.3000	0.0080	1.6393	0.3600	0.0000	3.0745	0.0000
0.3326	2.5435	4.0400	3.0100	4.0965	35.5200	0.0000	1.6311	0.0000	6.8074	3.5825	92.9200
0.8686	2.5510	8.5200	3.7953	4.0655	45.1600	5.4116	2.1612	73.0600	6.7427	3.6017	88.7400
1.6057	2.5734	14.3700	4.6465	4.0758	55.7700	5.2328	2.1509	60.8900	6.5609	3.5672	82.1100
2.9180	2.5576	25.2900	5.5167	4.0771	68.3900	4.7449	2.1579	44.8500	5.9607	3.5681	68.3300
3.5432	2.5427	31.5600	6.2440	4.0699	80.7000	4.3544	2.1204	36.8500	4.9352	3.5753	51.6300
4.2902	2.5478	39.6400	6.5888	4.065	88.0200	3.8743	2.1320	29.9500	4.2506	3.5772	42.9000
5.0633	2.5378	50.7500	7.1388	4.0754	98.3200	3.3387	2.1377	23.8900	3.7050	3.5588	37.3300
5.4908	2.5424	59.9000	0.0000	4.5031	0.0000	2.8218	2.1448	18.9600	3.1144	3.5701	30.3900
5.7550	2.5169	65.9000	0.1549	4.4816	2.2200	2.3718	2.1541	15.6300	2.5744	3.5890	25.0000

6.0851	2.5085	78.5900	0.7400	4.5047	9.8400	1.9620	2.1280	12.3900	1.8883	3.5606	18.0000
0.0000	0.7557	0.0000	1.4796	4.4914	18.7600	1.6150	2.1254	10.0900	0.9572	3.5878	9.2100
0.2101	0.7749	3.9900	2.3636	4.4813	29.3300	1.1139	2.1339	6.7200	0.6352	3.5770	6.2600
0.2362	0.7484	4.1600	2.9946	4.4912	37.6600	0.5309	2.1388	3.2000	0.1516	3.5818	1.9800
0.5346	0.7455	10.0800	4.1982	4.4702	53.1300	0.1873	2.1689	1.2400	0.0395	3.5855	0.4800
0.6662	0.7664	15.7600	4.9630	4.5106	63.6800	0.0000	2.1300	0.0000	0.0000	3.5631	0.0000
0.8117	0.7596	18.4600	5.7221	4.4841	65.6100	6.0914	2.5198	77.7000	7.1364	4.0808	98.2800
0.8561	0.7566	23.3500	6.0157	4.4644	80.8500	5.9265	2.5474	68.3400	6.8256	4.0757	88.1400
0.0000	1.2539	0.0000	6.3553	4.505	87.2600	5.6387	2.5114	58.9700	5.9332	4.0681	70.4200
0.1562	1.2588	3.1300	6.7363	4.4821	94.7900	5.0678	2.5331	46.1900	5.3259	4.0831	60.6500
0.4101	1.2511	6.1100	0.0000	5.049	0.0000	4.3993	2.5416	36.5000	4.3717	4.0657	47.9300
0.7029	1.2426	9.5300	0.1681	5.065	2.8200	3.8851	2.5422	30.4300	4.0264	4.0733	43.4600
1.0090	1.2524	13.6200	0.4504	5.0897	7.0100	3.3094	2.5502	24.8000	3.2958	4.0892	34.5900
1.2786	1.2298	17.7000	1.1905	5.0766	16.9500	2.6965	2.5232	19.5100	2.7661	4.0584	28.9000
1.5806	1.2379	23.5500	2.2468	5.0867	31.2600	1.8774	2.5432	12.8900	2.4536	4.0766	24.8500
1.7411	1.2411	27.4100	2.8932	5.0552	39.9100	1.4934	2.5601	10.3100	1.6351	4.0776	16.2200
1.9493	1.2417	33.1800	3.4110	5.0846	47.6100	0.9408	2.5275	6.3900	1.1577	4.0717	10.4800
2.0545	1.2443	37.4200	4.1726	5.0675	58.6700	0.3548	2.5655	2.2400	0.7975	4.0514	7.1000
0.0000	1.7295	0.0000	5.0221	5.0691	71.9000	0.0772	2.5593	0.3500	0.2390	4.0737	1.5000
0.2055	1.7441	2.8300	5.5313	5.0638	80.0000	0.0000	2.5600	0.0000	0.0000	4.0582	0.0000
0.6572	1.7403	6.3300	5.9072	5.0523	86.9100	0.8919	0.7538	23.3000	6.7259	4.4864	94.3400
1.0678	1.7325	9.5300	6.3922	5.0706	96.4000	0.8536	0.7696	18.9000	6.3584	4.4778	84.2400
1.6446	1.7376	14.2500	0.0000	3.2176	0.0000	0.8324	0.7531	17.3100	5.8418	4.4730	74.1400
2.1240	1.7347	18.7500	0.5657	3.202	7.2400	0.7497	0.7639	14.7000	5.3263	4.4653	65.4700
2.6610	1.7350	24.2100	1.0129	3.197	11.7100	0.6804	0.7591	12.4000	4.2632	4.5005	50.1200
3.0793	1.7515	30.3300	1.5669	3.2089	17.2600	0.4986	0.7627	8.4100	3.4205	4.4765	39.0000
3.2740	1.7301	33.6000	2.4354	3.189	25.5300	0.3556	0.7549	5.5300	2.7637	4.4489	30.7500
3.5817	1.7120	39.4400	3.2529	3.1824	34.2600	0.2204	0.7524	3.0500	2.1404	4.4815	23.2600
3.7414	1.7342	43.3800	3.9873	3.2187	41.6200	0.0788	0.7583	1.2100	1.4466	4.4724	15.2500
3.8767	1.7153	46.3600	4.7693	3.2025	51.1000	0.0000	0.7533	0.0000	0.9853	4.4934	9.6900
3.9659	1.7235	48.4700	5.2665	3.1964	57.6300	2.0495	1.2330	37.2800	0.6311	4.4890	5.9300
0.0000	2.2285	0.0000	5.6381	3.1872	63.8900	1.9835	1.2436	32.8400	0.2214	4.4871	1.4500
0.4344	2.2225	4.5200	5.9774	3.1916	70.3200	1.9835	1.2436	32.8400	0.0000	4.4804	0.0000
0.8873	2.2449	8.5800	6.2573	3.1739	75.8600	1.4025	1.2257	17.2300	6.4341	5.0867	96.0800
1.5521	2.2348	13.4800	6.4395	3.1878	80.2200	1.0875	1.2197	11.4600	5.9166	5.0512	84.5500
2.0360	2.2434	17.8500	6.5788	3.1878	84.2500	0.9219	1.2307	9.5200	5.1590	5.0661	71.1000
2.6970	2.2441	23.4400	6.7308	3.1927	91.5500	0.7630	1.2201	8.0500	4.5349	5.0512	60.2800
3.4997	2.2470	31.0400	0.0000	3.6134	0.0000	0.3739	1.2338	4.5700	3.7123	5.0574	47.8700
3.8776	2.2353	36.2500	0.5202	3.6137	7.0300	0.0398	1.2357	2.0000	3.0585	5.0475	38.7300
4.3099	2.2365	42.6000	1.0328	3.6307	12.5700	0.0110	1.2375	0.7500	2.4268	5.0063	29.9100
4.5917	2.2155	47.2400	1.8868	3.6088	21.3200	0.0000	1.2347	0.0000	1.8009	5.0816	21.7300
4.7948	2.2378	52.4200	2.6185	3.6064	28.8100	3.9452	1.7189	48.1700	1.3332	5.0495	15.2300
4.9057	2.2272	55.2200	3.3949	3.6009	37.2400	3.9085	1.7265	45.6100	0.9123	5.0515	9.8500
4.9814	2.2226	56.6800	4.0382	3.6137	44.9700	3.6090	1.7358	37.3600	0.3963	5.0715	4.0600
5.0607	2.2209	59.7200	4.5973	3.6123	51.8000	3.1352	1.7263	26.6400	0.2654	5.0533	1.6200
0.0000	2.6173	0.0000	4.9144	3.626	55.6800	2.5588	1.7324	18.7000	0.0000	5.0449	0.0000
0.4427	2.6145	5.1500	5.3786	3.6169	62.0700	1.8945	1.7201	12.3600	6.7312	3.1931	91.2600
0.9617	2.6047	9.5800	5.6417	3.5995	65.8900	1.4557	1.7143	9.3100	6.6910	3.1970	88.8400
1.9106	2.6115	17.7800	6.3766	3.6277	84.2600	1.1380	1.7620	7.1300	6.3355	3.1899	75.5900
2.8543	2.6035	26.1600	6.7704	3.6142	91.1400	0.7836	1.7229	5.0900	5.4116	3.1607	54.6800
3.3775	2.6439	30.8300	0.0000	4.0741	0.0000	0.2732	1.7206	1.9100	4.6981	3.1604	44.4100
3.8948	2.5902	37.0300	0.5669	4.0603	8.2600	0.0628	1.7434	6.2000	4.0269	3.1546	36.7000
4.7150	2.5798	46.1100	1.0412	4.0684	13.3600	0.0000	1.7402	0.0000	3.1977	3.1595	28.2100
5.2326	2.5971	54.7800	1.5599	4.0745	19.9700	5.0688	2.2148	59.4200	2.3213	3.1435	19.9100
5.4874	2.5766	59.6300	2.4778	4.0686	30.3100	4.9006	2.2309	54.0500	1.6327	3.1654	13.6800
5.6756	2.6049	63.5800	3.1238	4.089	38.0100	4.8160	2.2267	50.7800	1.1152	3.1747	9.3400
5.9148	2.6064	71.0500	3.9454	4.0578	47.3400	4.3954	2.2224	40.8800	0.6799	3.1493	5.8500
0.0000	2.5000	0.0000	4.5016	4.0618	54.7400	3.8831	2.2313	32.4200	0.2516	3.1467	1.9300
0.0500	2.5000	0.4806	5.2445	4.0674	64.7500	3.2060	2.2309	24.4600	0.0000	3.1534	0.0000
0.1000	2.5000	0.9575	5.6170	4.0771	70.4500	2.5209	2.2274	17.7200	6.8119	3.6250	90.4200
0.1500	2.5000	1.4307	5.9798	4.0719	76.0500	1.6158	2.2355	11.0300	6.4745	3.6164	80.4200
0.2000	2.5000	1.9005	6.6058	4.0587	89.0300	1.2296	2.2262	8.6400	6.0110	3.6129	70.2800

0.2500	2.5000	2.3668	7.0456	4.0445	97.6700	0.9117	2.2182	6.6100	5.3752	3.6166	58.7900
0.3000	2.5000	2.8300	0.0000	4.6532	0.0000	0.3439	2.2287	3.0100	4.7280	3.6028	49.8400
0.3500	2.5000	3.2900	0.4686	4.6735	7.7600	0.0500	2.2196	0.5600	3.8756	3.6214	38.9100
0.4000	2.5000	3.7471	0.9387	4.6418	13.7100	0.0000	2.2376	0.0000	3.2665	3.6158	32.3900
0.4500	2.5000	4.2014	1.7092	4.6615	23.2800	5.9407	2.6091	70.9500	2.5234	3.6205	24.7400
0.5000	2.5000	4.6530	2.3211	4.6527	31.0100	5.8489	2.6080	68.3600	1.6672	3.6245	16.4600
0.5500	2.5000	5.1021	2.9338	4.6455	39.2700	5.5207	2.5973	57.5900	1.0840	3.6152	10.4900
0.6000	2.5000	5.5487	3.6173	4.6496	48.4300	5.2948	2.6040	52.8900	0.0688	3.6170	0.8900
0.6500	2.5000	5.9931	4.3186	4.6373	58.2400	4.0394	2.5996	33.7500	0.0000	3.6168	0.0000
0.7000	2.5000	6.4353	5.0199	4.6537	68.7700	2.6623	2.6133	21.0200	7.0116	4.0535	97.6100
0.7500	2.5000	6.8756	5.5698	4.6441	77.2800	2.1672	2.6135	16.8000	6.7295	4.0765	89.2600
0.8000	2.5000	7.3139	6.0940	4.6562	86.6200	1.4741	2.6208	11.4300	5.9240	4.0751	72.8900
0.8500	2.5000	7.7506	6.4505	4.6455	93.0900	0.9759	2.5962	7.7600	5.2434	4.0961	61.3200
0.9000	2.5000	8.1856	6.6693	4.6372	97.6800	0.0410	2.6097	0.7500	4.5370	4.0642	51.4500
0.9500	2.5000	8.6192	0.0000	5.1011	0.0000	0.0000	2.6002	0.0000	3.6159	4.0840	39.7300
1.0000	2.5000	9.0515	0.3280	5.0994	5.8900	0.0000	2.5000	0.0000	2.7400	4.0685	29.7300
1.0500	2.5000	9.4826	1.0225	5.1013	15.2400	0.0500	2.5000	0.3835	2.2072	4.0667	23.8000
1.1000	2.5000	9.9127	1.0225	5.1013	15.2400	0.1000	2.5000	0.7642	1.8812	4.0612	20.0600
1.1500	2.5000	10.3420	1.7839	5.0965	25.3600	0.1500	2.5000	1.1422	1.1570	4.0776	12.0300
1.2000	2.5000	10.7700	2.5050	5.0946	35.5200	0.2000	2.5000	1.5176	0.7761	4.0643	7.8900
1.2500	2.5000	11.1980	3.1415	5.1041	44.5000	0.2500	2.5000	1.8906	0.0000	4.0764	0.0000
1.3000	2.5000	11.6250	3.7025	5.116	52.9400	0.3000	2.5000	2.2613	6.6693	4.6521	97.5300
1.3500	2.5000	12.0520	4.3860	5.0984	63.0300	0.3500	2.5000	2.6298	6.4528	4.6413	91.8300
1.4000	2.5000	12.4790	4.9439	5.0782	71.9900	0.4000	2.5000	2.9964	5.6900	4.6410	76.1100
1.4500	2.5000	12.9050	5.3348	5.1249	78.4000	0.4500	2.5000	3.3610	5.3238	4.6437	69.8300
1.5000	2.5000	13.3320	5.7547	5.1003	85.5400	0.5000	2.5000	3.7239	4.3028	4.6455	54.0500
1.5500	2.5000	13.7590	6.1065	5.1072	92.1000	0.5500	2.5000	4.0852	3.3044	4.6415	40.3500
1.6000	2.5000	14.1860	6.4059	5.0975	98.1000	0.6000	2.5000	4.4451	2.2128	4.6453	26.4800
1.6500	2.5000	14.6130				0.6500	2.5000	4.8036	1.0910	4.6410	12.8500
1.7000	2.5000	15.0410				0.7000	2.5000	5.1610	0.6976	4.6330	8.3900
1.7500	2.5000	15.4700				0.7500	2.5000	5.5173	0.1474	4.6270	1.9600
1.8000	2.5000	15.9000				0.8000	2.5000	5.8727	0.0000	4.6493	0.0000
1.8500	2.5000	16.3310				0.8500	2.5000	6.2273	6.4199	5.1132	98.0500
1.9000	2.5000	16.7630				0.9000	2.5000	6.5813	6.2362	5.1022	92.7600
1.9500	2.5000	17.1960				0.9500	2.5000	6.9348	5.8351	5.1036	84.7100
2.0000	2.5000	17.6300				1.0000	2.5000	7.2880	5.1878	5.1229	72.8300
2.0500	2.5000	18.0660				1.0500	2.5000	7.6409	4.5825	5.1115	62.7300
2.1000	2.5000	18.5040				1.1000	2.5000	7.9938	3.7927	5.0963	50.5800
2.1500	2.5000	18.9440				1.1500	2.5000	8.3468	2.9164	5.1016	37.8500
2.2000	2.5000	19.3850				1.2000	2.5000	8.6999	2.3798	5.1028	30.8000
2.2500	2.5000	19.8290				1.2500	2.5000	9.0534	1.5802	5.1276	19.9300
2.3000	2.5000	20.2750				1.3000	2.5000	9.4074	1.3409	5.1139	16.5000
2.3500	2.5000	20.7230				1.3500	2.5000	9.7620	0.5977	5.1221	7.1900
2.4000	2.5000	21.1740				1.4000	2.5000	10.1170	0.1363	5.1048	1.8500
2.4500	2.5000	21.6270				1.4500	2.5000	10.4740	0.0000	5.1098	0.0000
2.5000	2.5000	22.0830				1.5000	2.5000	10.8310			
2.5500	2.5000	22.5420				1.5500	2.5000	11.1890			
2.6000	2.5000	23.0040				1.6000	2.5000	11.5490			
2.6500	2.5000	23.4700				1.6500	2.5000	11.9100			
2.7000	2.5000	23.9380				1.7000	2.5000	12.2730			
2.7500	2.5000	24.4100				1.7500	2.5000	12.6380			
2.8000	2.5000	24.8860				1.8000	2.5000	13.0040			
2.8500	2.5000	25.3650				1.8500	2.5000	13.3730			
2.9000	2.5000	25.8490				1.9000	2.5000	13.7430			
2.9500	2.5000	26.3360				1.9500	2.5000	14.1160			
3.0000	2.5000	26.8270				2.0000	2.5000	14.4910			
3.0500	2.5000	27.3230				2.0500	2.5000	14.8690			
3.1000	2.5000	27.8230				2.1000	2.5000	15.2500			
3.1500	2.5000	28.3270				2.1500	2.5000	15.6330			
3.2000	2.5000	28.8370				2.2000	2.5000	16.0200			
3.2500	2.5000	29.3510				2.2500	2.5000	16.4090			
3.3000	2.5000	29.8700				2.3000	2.5000	16.8020			

3.3500	2.5000	30.3940				2.3500	2.5000	17.1980			
3.4000	2.5000	30.9230				2.4000	2.5000	17.5980			
3.4500	2.5000	31.4580				2.4500	2.5000	18.0010			
3.5000	2.5000	31.9980				2.5000	2.5000	18.4080			
3.5500	2.5000	32.5440				2.5500	2.5000	18.8200			
3.6000	2.5000	33.0960				2.6000	2.5000	19.2350			
3.6500	2.5000	33.6530				2.6500	2.5000	19.6540			
3.7000	2.5000	34.2170				2.7000	2.5000	20.0780			
3.7500	2.5000	34.7870				2.7500	2.5000	20.5060			
3.8000	2.5000	35.3630				2.8000	2.5000	20.9390			
3.8500	2.5000	35.9450				2.8500	2.5000	21.3770			
3.9000	2.5000	36.5340				2.9000	2.5000	21.8200			
3.9500	2.5000	37.1300				2.9500	2.5000	22.2670			
4.0000	2.5000	37.7330				3.0000	2.5000	22.7200			
4.0500	2.5000	38.3430				3.0500	2.5000	23.1790			
4.1000	2.5000	38.9600				3.1000	2.5000	23.6420			
4.1500	2.5000	39.5840				3.1500	2.5000	24.1120			
4.2000	2.5000	40.2150				3.2000	2.5000	24.5870			
4.2500	2.5000	40.8540				3.2500	2.5000	25.0680			
4.3000	2.5000	41.5010				3.3000	2.5000	25.5550			
4.3500	2.5000	42.1560				3.3500	2.5000	26.0480			
4.4000	2.5000	42.8180				3.4000	2.5000	26.5480			
4.4500	2.5000	43.4890				3.4500	2.5000	27.0540			
4.5000	2.5000	44.1680				3.5000	2.5000	27.5660			
4.5500	2.5000	44.8550				3.5500	2.5000	28.0860			
4.6000	2.5000	45.5510				3.6000	2.5000	28.6120			
4.6500	2.5000	46.2550				3.6500	2.5000	29.1450			
4.7000	2.5000	46.9680				3.7000	2.5000	29.6850			
4.7500	2.5000	47.6900				3.7500	2.5000	30.2330			
4.8000	2.5000	48.4210				3.8000	2.5000	30.7880			
4.8500	2.5000	49.1610				3.8500	2.5000	31.3500			
4.9000	2.5000	49.9110				3.9000	2.5000	31.9210			
4.9500	2.5000	50.6700				3.9500	2.5000	32.4990			
5.0000	2.5000	51.4390				4.0000	2.5000	33.0850			
5.0500	2.5000	52.2170				4.0500	2.5000	33.6790			
5.1000	2.5000	53.0050				4.1000	2.5000	34.2820			
5.1500	2.5000	53.8030				4.1500	2.5000	34.8920			
5.2000	2.5000	54.6120				4.2000	2.5000	35.5120			
5.2500	2.5000	55.4300				4.2500	2.5000	36.1400			
5.3000	2.5000	56.2590				4.3000	2.5000	36.7770			
5.3500	2.5000	57.0990				4.3500	2.5000	37.4220			
5.4000	2.5000	57.9490				4.4000	2.5000	38.0770			
5.4500	2.5000	58.8100				4.4500	2.5000	38.7410			
5.5000	2.5000	59.6820				4.5000	2.5000	39.4150			
5.5500	2.5000	60.5650				4.5500	2.5000	40.0980			
5.6000	2.5000	61.4590				4.6000	2.5000	40.7900			
5.6500	2.5000	62.3650				4.6500	2.5000	41.4930			
5.7000	2.5000	63.2820				4.7000	2.5000	42.2050			
5.7500	2.5000	64.2110				4.7500	2.5000	42.9270			
5.8000	2.5000	65.1520				4.8000	2.5000	43.6600			
5.8500	2.5000	66.1040				4.8500	2.5000	44.4030			
5.9000	2.5000	67.0690				4.9000	2.5000	45.1560			
5.9500	2.5000	68.0450				4.9500	2.5000	45.9200			
6.0000	2.5000	69.0340				5.0000	2.5000	46.6950			
						5.0500	2.5000	47.4800			
						5.1000	2.5000	48.2770			
						5.1500	2.5000	49.0850			
						5.2000	2.5000	49.9040			
						5.2500	2.5000	50.7350			
						5.3000	2.5000	51.5770			

						5.3500	2.5000	52.4310			
						5.4000	2.5000	53.2960			
						5.4500	2.5000	54.1740			
						5.5000	2.5000	55.0640			
						5.5500	2.5000	55.9660			
						5.6000	2.5000	56.8800			
						5.6500	2.5000	57.8080			
						5.7000	2.5000	58.7470			
						5.7500	2.5000	59.7000			
						5.8000	2.5000	60.6660			
						5.8500	2.5000	61.6440			
						5.9000	2.5000	62.6360			
						5.9500	2.5000	63.6410			
						6.0000	2.5000	64.6600			

PAM-B

Extraction						Contraction					
0-2.5 bar			2.5-5.0 bar			0-2.5 bar			2.5-5.0 bar		
Ls(cm)	Pressure (bar)	Force (Kg)	Ls (cm)	Pressure (bar)	Force (Kg)	Ls (cm)	Pressure (bar)	Force (Kg)	Ls (cm)	Pressure (bar)	Force (Kg)
0.0000	0.7913	0.0000	0.0000	2.7196	0.0000	0.3291	0.7557	6.9700	2.6018	2.6970	23.7500
0.0376	0.7508	0.9700	0.3192	2.7636	2.4200	0.3569	0.7539	5.7700	2.4987	2.7155	20.1100
0.0498	0.7436	1.2700	0.8787	2.7919	5.9000	0.2691	0.7342	4.0000	2.3415	2.7166	17.0300
0.0986	0.7392	2.0400	1.1599	2.7477	7.7700	0.1620	0.7721	2.0400	1.8909	2.7250	11.0100
0.1736	0.7331	3.2100	1.6087	2.6824	10.7800	0.0881	0.7489	0.8100	1.5285	2.6816	8.4700
0.3499	0.7303	6.9700	2.0414	2.7241	14.6500	0.0000	0.7280	0.0000	1.2501	2.7035	6.6200
0.0000	1.3331	0.0000	2.3098	2.7223	18.5300	0.8652	1.3016	13.7600	0.9601	2.7324	4.5400
0.0441	1.3266	0.5300	2.4989	2.726	21.6800	0.7772	1.3123	11.7700	0.5005	2.7057	2.6800
0.2057	1.3194	2.6000	2.6066	2.7206	23.8700	0.6426	1.3040	7.8200	0.2586	2.7400	1.5100
0.2952	1.2733	3.9200	0.0000	3.1712	0.0000	0.3478	1.3376	2.9600	0.0000	2.7128	0.0000
0.5406	1.3173	8.0300	0.0364	3.1811	1.3300	0.2635	1.3510	1.7800	3.5090	3.1940	29.6400
0.7274	1.3153	11.6400	0.4240	3.1922	3.2400	0.1435	1.3000	0.6900	3.3952	3.1600	26.0600
0.8247	1.3072	13.8500	1.1234	3.16	6.7900	0.0000	1.3234	0.0000	3.0966	3.1390	20.5200
0.0000	1.7216	0.0000	1.6623	3.1702	9.7800	0.9526	1.6978	15.2300	2.6441	3.1837	14.7200
0.0056	1.7253	1.0000	2.2603	3.1765	13.7100	0.9188	1.6970	13.8600	2.3209	3.2101	12.2900
0.0884	1.7067	1.9600	2.7345	3.1767	18.0000	0.6953	1.7036	8.3800	1.9082	3.1773	9.3200
0.2252	1.6917	3.7800	3.2736	3.1323	25.1300	0.5715	1.6998	6.5400	1.2415	3.1924	5.8100
0.5579	1.6849	7.4200	3.4876	3.1682	29.9700	0.4271	1.6920	4.4200	0.6965	3.1771	3.2000
0.7619	1.7012	11.2900	0.0000	3.7718	0.0000	0.2405	1.7091	2.7300	0.2076	3.1881	1.6500
0.8295	1.7019	12.5900	0.5113	3.7307	4.0600	0.1064	1.7043	1.6700	0.0000	3.1754	0.0000
0.9638	1.7119	15.3100	1.3019	3.7321	8.0000	0.0000	1.7219	0.0000	4.2021	3.7032	34.1600
0.0000	2.2446	0.0000	2.2307	3.7286	12.8800	1.7063	2.2461	19.2100	4.1756	3.7083	32.3500

0.0413	2.2867	0.9600	2.9919	3.7402	18.0900	1.6346	2.2280	17.1700	3.9484	3.7645	27.2300
0.1649	2.2248	2.2400	3.8156	3.7336	26.7500	1.4662	2.2425	13.6300	3.5879	3.7125	21.7700
0.4408	2.2390	4.2800	4.0790	3.7493	31.0700	1.1886	2.2282	8.8400	2.4815	3.7161	12.3500
0.8970	2.2223	8.1200	4.2041	3.7328	34.3500	0.9979	2.2159	7.0000	1.8812	3.7440	9.3300
1.3280	2.2123	13.2400	0.0000	4.2262	0.0000	0.7903	2.2366	5.4800	1.7146	3.7534	8.7300
1.4511	2.2057	15.1100	0.0343	4.2294	1.1400	0.4390	2.2184	2.9600	1.3758	3.7253	6.9000
1.6988	2.2256	19.3400	0.6318	4.2387	4.4600	0.1088	2.2418	1.3600	0.8538	3.7442	4.7900
0.0000	2.5000	0.0000	1.6030	4.2174	9.1600	0.0000	2.2264	0.0000	0.5643	3.7330	3.5800
0.2000	2.5000	1.5035	2.5311	4.191	13.9900	0.0000	2.5000	0.0000	0.0940	3.7318	1.7800
0.4000	2.5000	2.9446	3.2882	4.165	18.7300	0.2000	2.5000	1.3386	0.0000	3.7358	0.0000
0.6000	2.5000	4.3386	3.8037	4.2108	22.6600	0.4000	2.5000	2.6182	5.0972	4.1908	40.6900
0.8000	2.5000	5.7011	4.5454	4.2234	30.5200	0.6000	2.5000	3.8556	5.0312	4.1999	37.5600
1.0000	2.5000	7.0474	4.7062	4.1897	33.7900	0.8000	2.5000	5.0675	4.7109	4.2308	30.7600
1.2000	2.5000	8.3930	4.9435	4.2174	38.4500	1.0000	2.5000	6.2703	4.1873	4.1896	23.9000
1.4000	2.5000	9.7533	5.0824	4.2193	40.9500	1.2000	2.5000	7.4809	3.5935	4.2073	18.7500
1.6000	2.5000	11.1437	0.0000	4.7212	0.0000	1.4000	2.5000	8.7159	3.0246	4.2147	14.8500
1.8000	2.5000	12.5797	0.2673	4.744	2.4100	1.6000	2.5000	9.9919	2.7188	4.2228	13.0900
2.0000	2.5000	14.0768	1.3631	4.7001	8.3600	1.8000	2.5000	11.3257	2.2226	4.2084	10.3000
2.2000	2.5000	15.6502	2.2619	4.7047	13.2400	2.0000	2.5000	12.7338	1.8588	4.1952	8.8300
2.4000	2.5000	17.3156	3.0366	4.7216	17.7900	2.2000	2.5000	14.2329	1.1747	4.2321	5.7300
2.6000	2.5000	19.0882	3.8455	4.7374	23.0000	2.4000	2.5000	15.8397	0.6162	4.2090	3.3600
2.8000	2.5000	20.9836	4.5465	4.7112	29.2300	2.6000	2.5000	17.5709	0.2220	4.1939	1.6900
3.0000	2.5000	23.0171	4.9377	4.732	33.9700	2.8000	2.5000	19.4430	0.0000	4.1824	0.0000
3.2000	2.5000	25.2043	5.2490	4.7318	38.7500	3.0000	2.5000	21.4729	5.6153	4.6814	46.7300
3.4000	2.5000	27.5605	5.6211	4.7001	47.0800	3.2000	2.5000	23.6771	5.3912	4.7062	39.8000
3.6000	2.5000	30.1011	0.0000	5.1566	0.0000	3.4000	2.5000	26.0722	5.1718	4.7140	35.3400
3.8000	2.5000	32.8416	0.4620	5.1864	3.6200	3.6000	2.5000	28.6750	4.7944	4.7039	29.7500
4.0000	2.5000	35.7975	1.7853	5.1771	11.4800	3.8000	2.5000	31.5022	4.2246	4.7133	24.2300
4.2000	2.5000	38.9841	2.6381	5.1636	16.4200	4.0000	2.5000	34.5703	3.5131	4.7160	18.8900
4.4000	2.5000	42.4169	3.2200	5.1895	20.0100	4.2000	2.5000	37.8960	3.3510	4.7185	17.8400
4.6000	2.5000	46.1114	4.1963	5.1707	27.2800	4.4000	2.5000	41.4961	2.6240	4.7041	13.6000
4.8000	2.5000	50.0829	4.8965	5.1696	33.9100	4.6000	2.5000	45.3871	2.0418	4.7198	10.4400
5.0000	2.5000	54.3469	5.4232	5.176	39.6200	4.8000	2.5000	49.5857	1.1701	4.7185	6.4000
5.2000	2.5000	58.9188	5.7132	5.1569	45.4500	5.0000	2.5000	54.1086	0.3055	4.6948	2.2700
5.4000	2.5000	63.8140	6.0002	5.1658	51.5100	5.2000	2.5000	58.9725	0.0000	4.6986	0.0000
						5.4000	2.5000	64.1939	5.9691	5.1983	51.2300
									5.9062	5.1999	47.6200
									5.6061	5.2033	40.4400
									5.2806	5.1781	35.3900
									4.6694	5.1877	28.3000
									4.0873	5.1571	23.3700

									3.2360	5.2136	17.8800
									2.5780	5.1867	14.1400
									1.6897	5.1515	9.4400
									0.6032	5.1759	4.1000
									0.0487	5.1797	1.4000
									0.0000	5.1685	0.0000

PAM-C

Extraction						Contraction					
0-2.5 bar			2.5-5.0 bar			0-2.5 bar			2.5-5.0 bar		
Ls(cm)	Pressure (bar)	Force (Kg)	Ls (cm)	Pressure (bar)	Force (Kg)	Ls (cm)	Pressure (bar)	Force (Kg)	Ls (cm)	Pressure (bar)	Force (Kg)
0.0000	1.1245	0.0000	0.0000	2.653	0.0000	0.1936	1.1411	4.2300	0.6265	2.6509	13.0500
0.0649	1.1429	1.0000	0.0868	2.6513	1.2500	0.1847	1.1393	3.9200	0.6053	2.6494	12.0200
0.1145	1.1381	1.9900	0.2696	2.651	4.1600	0.1829	1.1252	2.7600	0.5413	2.6494	9.7000
0.1555	1.1286	2.9000	0.4484	2.6724	8.0200	0.1492	1.1551	1.7600	0.4744	2.6528	7.4900
0.1758	1.1366	4.2600	0.5324	2.6501	11.1100	0.1387	1.1509	1.0700	0.4145	2.6521	6.0000
0.0000	1.3830	0.0000	0.5932	2.6595	12.9900	0.1030	1.1446	0.5600	0.3291	2.6482	4.6000
0.0655	1.3896	1.1500	0.6169	2.6524	13.1300	0.0000	1.1409	0.0000	0.2604	2.6661	3.3200
0.1059	1.4000	2.1600	0.0000	3.1333	0.0000	0.2472	1.3892	6.7200	0.1557	2.6390	1.8700
0.1322	1.3931	3.0000	0.1492	3.1294	1.6700	0.2361	1.3766	5.5500	0.0297	2.6501	0.2800
0.1806	1.3927	4.3200	0.3007	3.1433	3.9300	0.2427	1.3909	4.8200	0.0000	2.6533	0.0000
0.2125	1.3880	5.1800	0.3959	3.1151	5.8600	0.2170	1.3817	3.4800	0.9173	3.1461	19.2400
0.2346	1.3966	6.7900	0.5908	3.1246	9.4800	0.1562	1.3831	2.4200	0.8783	3.1397	17.0300
0.0000	2.1659	0.0000	0.7221	3.1372	13.0200	0.1287	1.3939	1.2900	0.8031	3.1279	13.8500
0.1015	2.1398	1.1800	0.8349	3.1105	16.1100	0.0000	1.3967	0.0000	0.6856	3.1289	10.0600
0.2069	2.1484	3.1200	0.9114	3.13	19.3200	0.4879	2.1377	11.3700	0.5604	3.1320	7.6200
0.3263	2.1283	6.2000	0.0000	3.6346	0.0000	0.4539	2.1320	9.4700	0.4247	3.1331	5.0100
0.4404	2.1346	9.3000	0.0835	3.6273	1.4400	0.4410	2.1286	8.1900	0.3331	3.1336	3.6900
0.4690	2.1484	11.6100	0.2978	3.6454	4.9500	0.3828	2.1359	6.8800	0.2299	3.1341	2.1500
0.0000	2.5000	0.0000	0.5720	3.6349	9.8700	0.3079	2.1334	4.3600	0.0651	3.1371	0.2600
0.1000	2.5000	1.7520	0.6702	3.6431	12.5200	0.2486	2.1292	3.1700	0.0000	3.1305	0.0000
0.2000	2.5000	3.4896	0.7976	3.6272	15.9800	0.1573	2.1289	1.4300	0.9787	3.6297	23.0100
0.3000	2.5000	5.2610	0.9095	3.6313	18.9000	0.0000	2.1239	0.0000	0.9215	3.6321	19.6400
0.4000	2.5000	7.1140	0.9367	3.6295	20.6400	0.0000	2.5000	0.0000	0.8225	3.6296	15.2900
0.5000	2.5000	9.0969	0.9818	3.6289	23.0600	0.1000	2.5000	1.5351	0.5631	3.6303	8.8100
0.6000	2.5000	11.2580	0.0000	4.1423	0.0000	0.2000	2.5000	3.0445	0.5056	3.6336	7.6100
0.7000	2.5000	13.6440	0.1468	4.1374	2.0300	0.3000	2.5000	4.5993	0.4000	3.6370	5.9100
0.8000	2.5000	16.3040	0.3944	4.139	6.3400	0.4000	2.5000	6.2706	0.2924	3.6273	4.1800
0.9000	2.5000	19.2860	0.6376	4.1297	10.8700	0.5000	2.5000	8.1294	0.1890	3.6206	2.6900

1.0000	2.5000	22.6380	0.8285	4.1368	14.6500	0.6000	2.5000	10.2470	0.0000	3.6361	0.0000
1.1000	2.5000	26.4080	0.9945	4.1419	19.5500	0.7000	2.5000	12.6940	1.1922	4.1592	28.2300
1.2000	2.5000	30.6440	1.1203	4.1302	23.4800	0.8000	2.5000	15.5420	1.1525	4.1569	24.4200
1.3000	2.5000	35.3940	1.1532	4.1312	24.6800	0.9000	2.5000	18.8630	1.0704	4.1425	20.5300
1.4000	2.5000	40.7060	1.2233	4.1526	28.2900	1.0000	2.5000	22.7260	0.9705	4.1440	17.0600
1.5000	2.5000	46.6270	0.0000	4.5341	0.0000	1.1000	2.5000	27.2030	0.7529	4.1731	12.3300
			0.1347	4.515	2.1000	1.2000	2.5000	32.3660	0.6507	4.1448	9.2300
			0.3065	4.5306	4.9300	1.3000	2.5000	38.2850	0.4275	4.1334	5.7500
			0.5495	4.5183	10.3400	1.4000	2.5000	45.0320	0.2304	4.1444	2.3200
			0.7951	4.5331	15.2100	1.5000	2.5000	52.6770	0.1195	4.1490	1.1400
			0.9818	4.5076	19.9000				0.0000	4.1446	0.0000
			1.1468	4.5145	23.9500				1.2738	4.5137	32.0500
			1.1782	4.5163	26.7500				1.2322	4.5154	27.8300
			1.2723	4.5081	32.2400				1.1697	4.5251	24.4200
			0.0000	5.0018	0.0000				1.0310	4.5234	19.0500
			0.1732	4.9869	3.0100				0.8568	4.5014	14.8800
			0.3629	4.9768	6.9200				0.6013	4.4939	9.3500
			0.7392	4.9823	14.8300				0.4170	4.4966	6.0300
			0.9993	5.0046	19.6000				0.1833	4.4956	2.3200
			1.1056	4.9919	23.4900				0.0577	4.5136	0.7400
			1.2433	4.9883	29.1300				0.0000	4.5112	0.0000
			1.4014	4.979	35.6600				1.3841	4.9728	35.5100
									1.2984	4.9855	29.5000
									1.1630	4.9894	23.8300
									0.9472	4.9843	17.9700
									0.7008	4.9852	12.5000
									0.5427	4.9786	8.9900
									0.3067	5.0005	4.3300
									0.1669	4.9734	1.9000
									0.0000	4.9853	0.0000