PIPENET TRANSIENT MODULE AND CAESARII

TRANSIENT FLOW ANALYSIS AND PIPE STRESS ANALYSIS IN UNISON

TANKER LOADING SYSTEM EXAMPLE

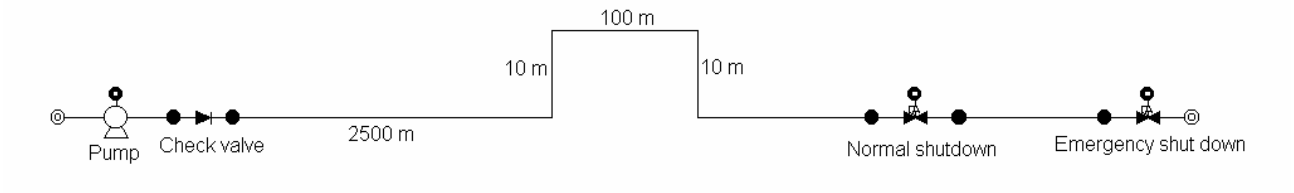
1. Introduction:

In this application we consider a problem solved by an engineering company that had been contracted to design the product export pipeline from Product Storage Tanks in a petrochemical plant to a Jetty into loading tankers. The environmental implications were of major concern in the design because leakage of the product into the sea could have serious consequences. An important aspect of the design was ensuring that pressure surges arising from the closure of valves would not cause damage to the pipework resulting in product spillage.

The objectives of the study are the following:

- To establish if the pressure surges experienced by the existing valves due to valve closures are below the allowable limit of 25.5 bar G.
- To calculate the force-time history for reading by CaesarII the leading pipe stress analysis program from Coade.

The network is shown below:



2. The Scenarios:

Two basic scenarios are considered:

2.1. Planned Shutdown

This is an everyday occurrence effected by the closure of normal shutdown valve by a local manual switch or from the control room. In this scenario two cases are considered:

- Two stage valve closure
- Single stage valve closure

2.2. Emergency Shutdown

This is an infrequent occurrence that takes place if the normal shutdown fails to close or if there is an emergency condition such as a storm, when the hydraulically operated ERC (Emergency Release Connection) comes into effect.

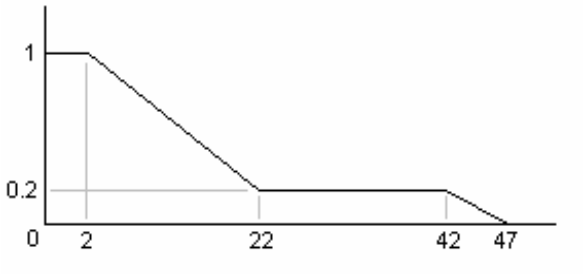
The valve closure pattern is not within our control in this scenarios.

Single stage closure of ERC valve

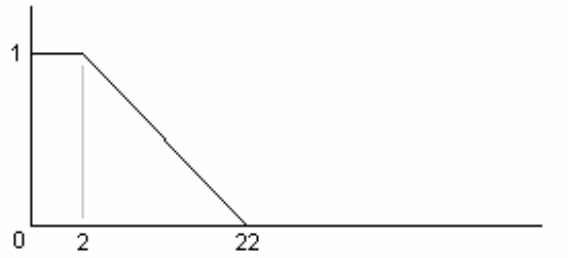
3. The data:

3.1. The valve closure patterns

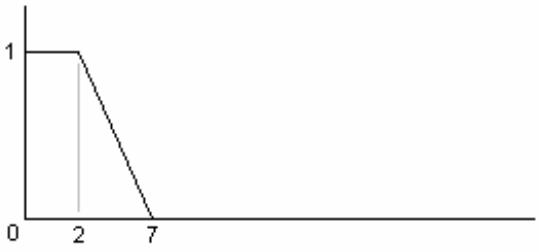
Case 1 - Two stage valve closure



Case 2 - Single stage valve closure:



Case 3 - Single stage closure of ERC valve:



Notes:

1. The y-axis in the above graphs is the valve position.

   1 – fully open
   0 – fully closed

2. The x-axis is time in secs

3.2. Units chosen:

The following table shows the units chosen for this example.

Item	Unit
Length	m
Diameter	mm
Pressure	Bar
Velocities	m/s
Flowrate Type	volume
Flowrate	m^3/hr
Density	kg/m^3
Viscosity	Cp
Bulk Modulus	psi
Volume	l
Time	s
Force	N
Mass	kg
Temperature	°C
Torque	Nm
Inertia	$kg.m^2$

3.3. Pipe Data:

Pipe Label	Size	i.d.,mm	o.d.,mm	Length m	Elevation m	Fittings k-factor
3	250	260.35	273.05	5697.33	1.45	197
5	250	260.35	273.05	150	0	none

Young's modulus = 29.6×10^6 psi

Poisson's ratio = 0.292

Pipe roughness = 0.0475mm

3.4. Fluid Properties:

The pipeline was transporting lube oil and its properties are shown below:

Density = 867 kg/m^3

Viscosity = 33.8 Cp

Bulk modulus = 178,400 psi

The temperature and vapour pressure are not used in this problem, so their values are irrelevant and left at their default values.

3.5. Valve Characteristics:

For the normal shutdown valve and the ERC valve, the characteristics were known and were assumed to be identical.

Valve Position	C_v (m^3/ s, Pa)
0	0
0.1	4.058×10^{-6}
0.2	2.629×10^{-5}
0.3	6.231×10^{-5}
0.4	1.094×10^{-4}
0.5	1.694×10^{-4}
0.7	3.366×10^{-4}
1.0	6.854×10^{-4}

3.6. Pump Data:

The pump data is shown in the following table.

Flow Rate (m^3/ s)	Pressure/ bar
0	12.15
100	11.48
240	10.81
320	9.19

3.7. Specifications:

There are two types of specification in this problem.

Pressure Specifications

There are pressure specifications at the inlet and at the outlet nodes.

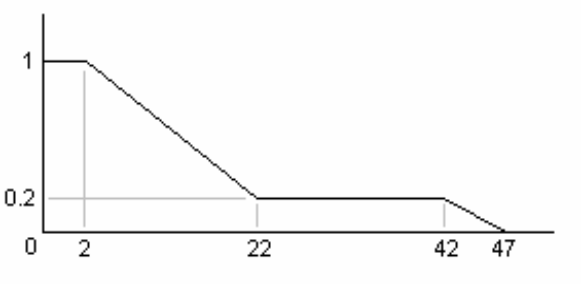
Pressure at the input node	–	1.71	barg
Pressure at the outlet node	-	0.00	barg

Information Specifications

The pump is assumed to work at a constant speed and so it would have a constant value specification.

The other information specification is on operation of the valve and three different cases are considered.

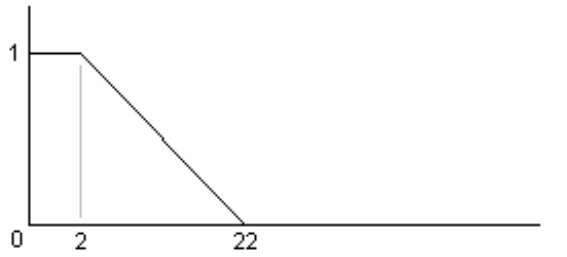
Two stage valve closure



Time, secs	Valve position (0 – 1)
0	1
2	1
22	0.2
42	0.2
47	0
120	0

Type of function - Linear Profile

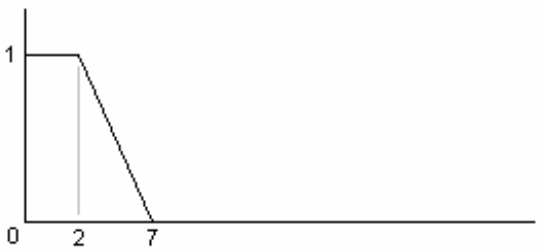
Single stage valve closure:



Time, secs	Valve position (0 – 1)
0	1
2	1
22	0
120	0

Type of function - Power Ramp

Single stage closure of ERC valve:

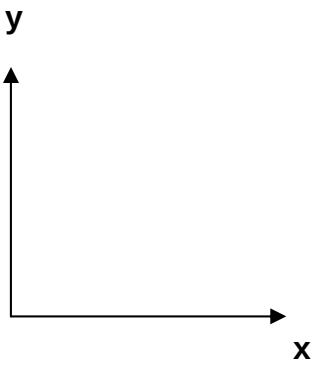


Time, secs	Valve position (0 – 1)
0	1
2	1
7	0
120	0

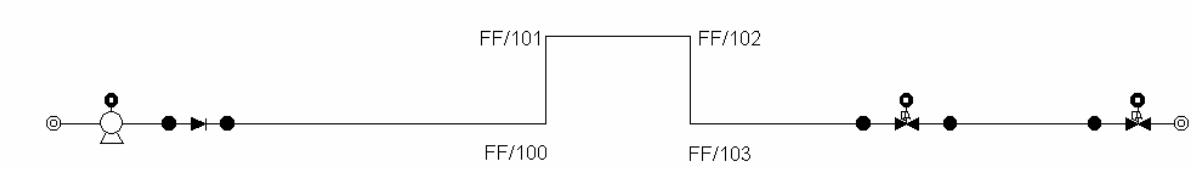
Type of function - Power Ramp

4. Force Calculations:

Co-ordinate axes



Dynamic Forces at Fittings

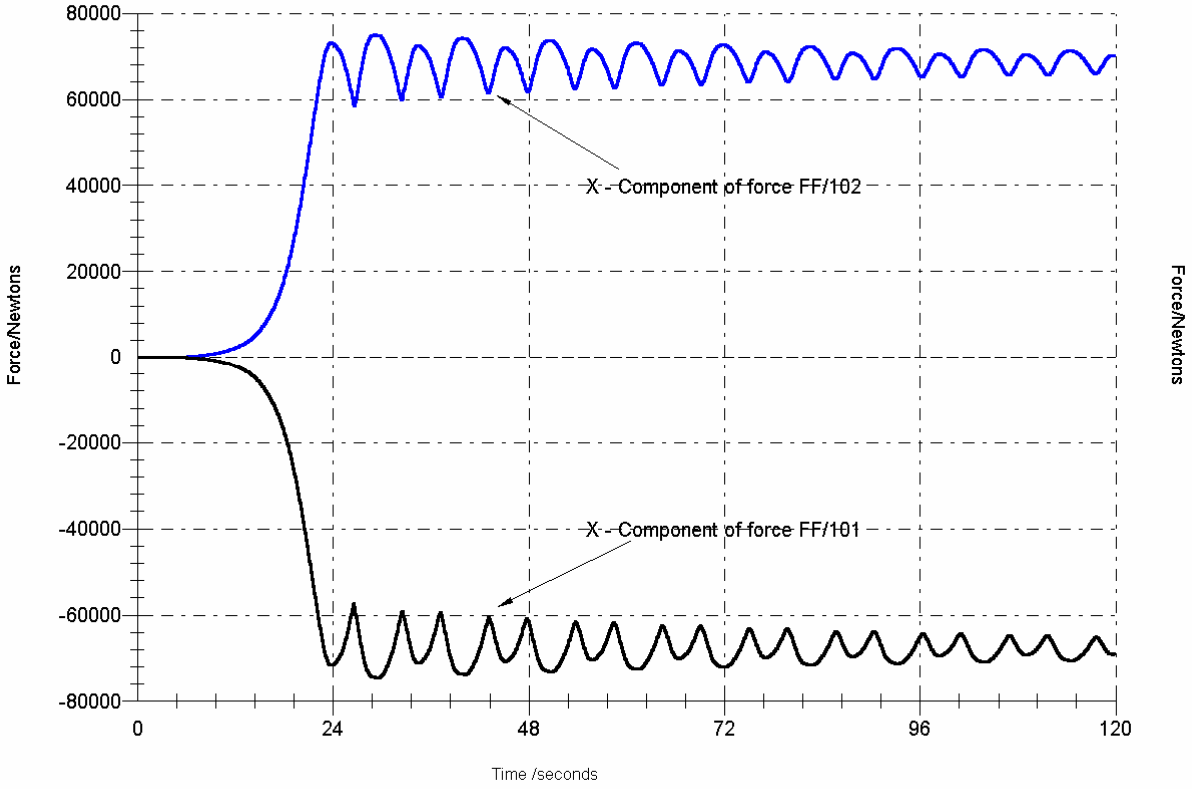


The above forces are all on the 90º bends. The forces have three components because they act at a single point on the pipe and are vectors.

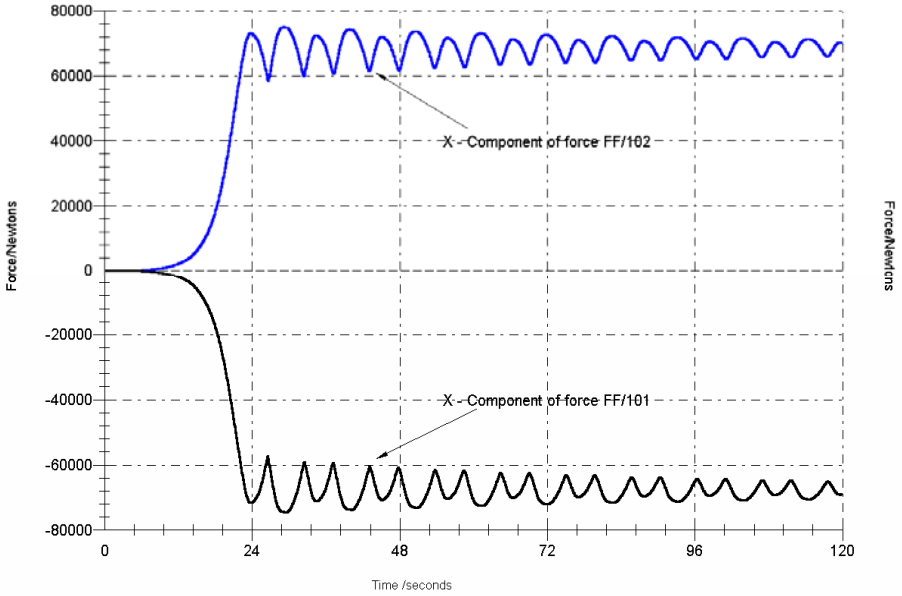
The graphs shown in this document is a small selection of the forces which have been calculated by PIPENET. The X – Component of the forces are shown on the graphs. The Z – Component will be 0 at all times and is of no interest. The Y – Component for the forces are non-zero and significant but are not shown here.

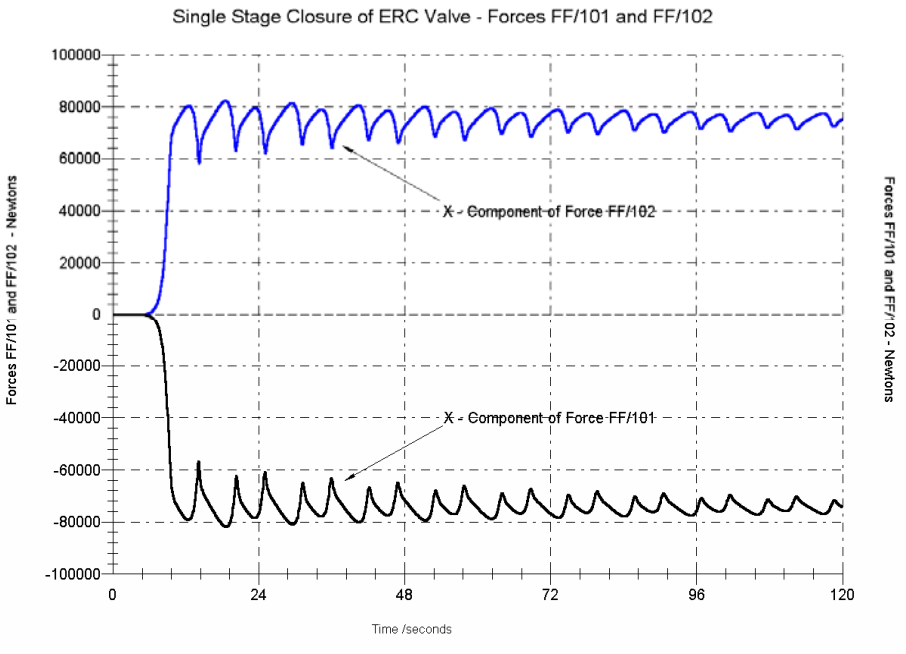
Two Stage Closure of Normal Shutdown Valve - Forces FF/101 and FF/102

Single Stage Closure of Normal Shutdown Valve - Forces FF/101 and FF/102

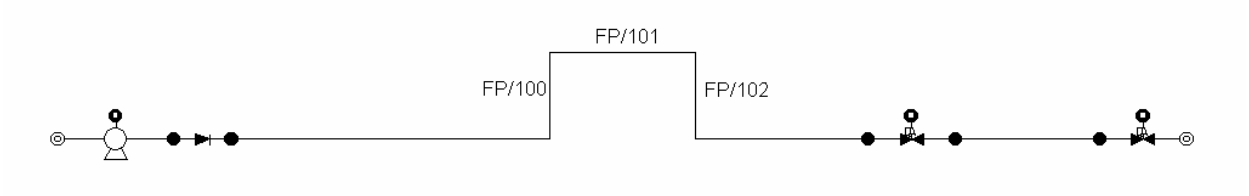


Single Stage Closure of Normal Shutdown Valve - Forces FF/101 and FF/102

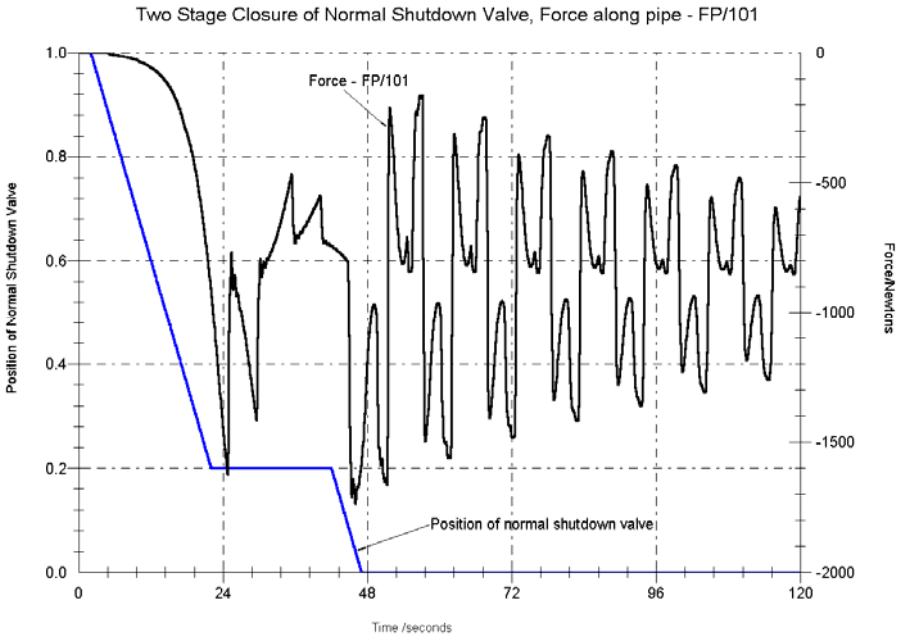


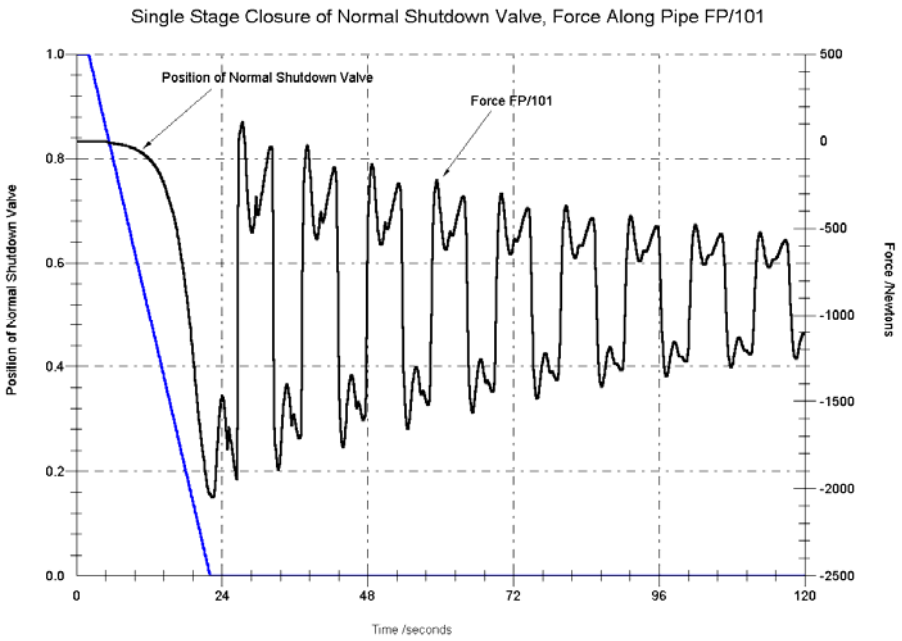


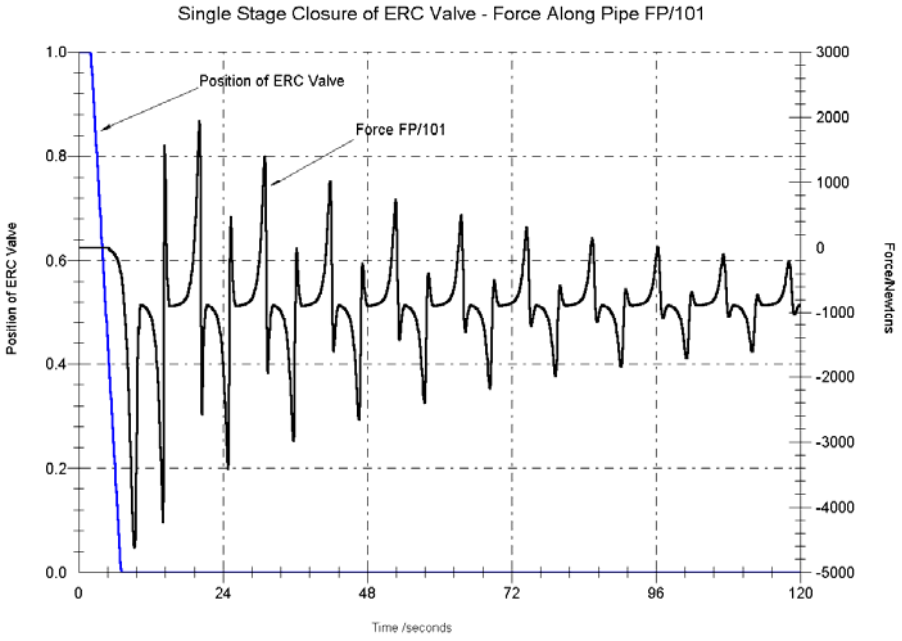
Dynamic Forces on Straight Pipe Sections



These essentially represent the unbalanced forces along pipes. The direction of the force is the same as the direction of the pipe and so the force only has one component.





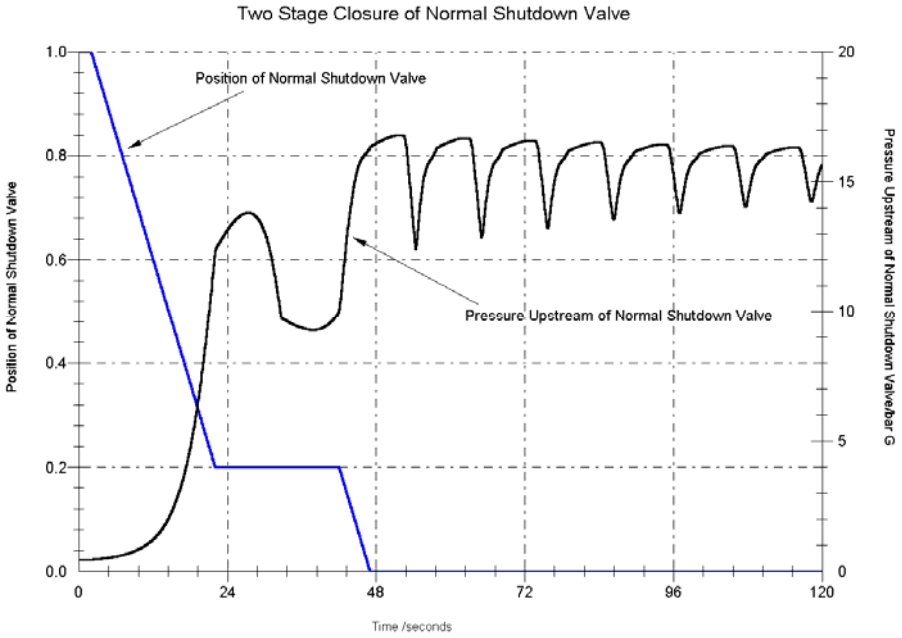


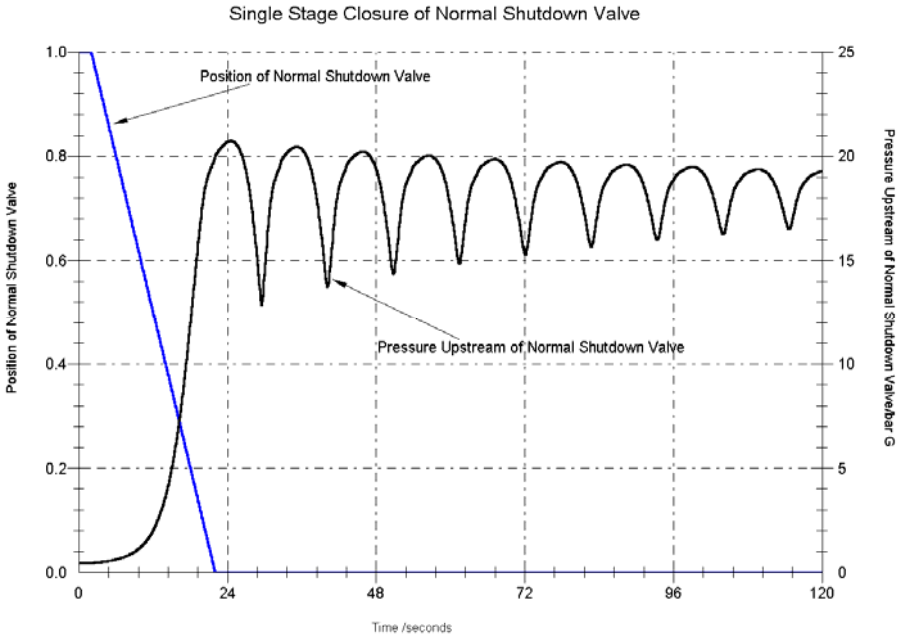
(Please see later section for tabular output of force-time history)

5. Other Graphical Results of the Simulations

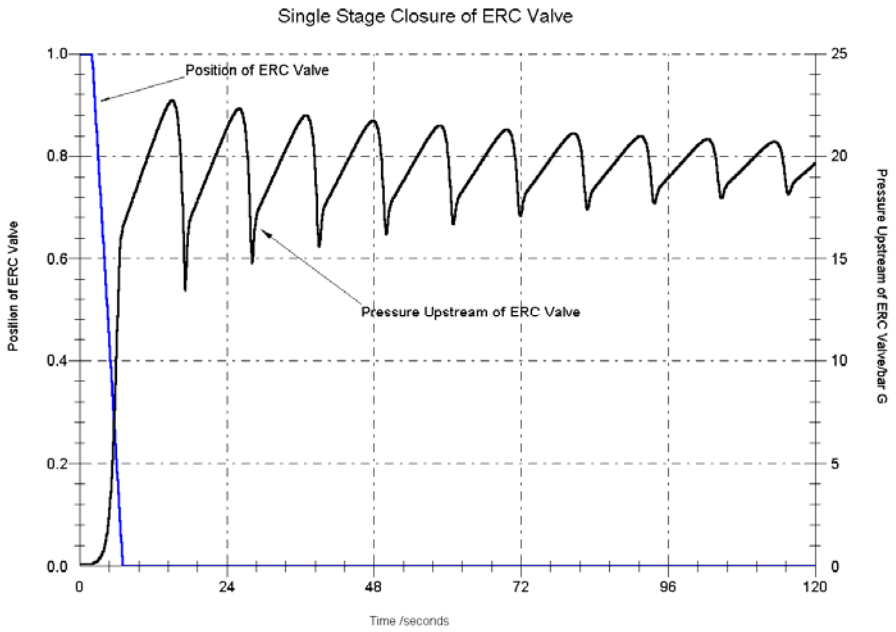
Planned Shutdown

Two Stage Closure of Normal Shutdown Valve





Emergency Shutdown



6 Extracts From Force-Time History File:

The force-time history file is intended to be read by CaesarII, and so it has a simple structure and consists mostly of numbers. The following extracts give an idea of their structure.

Planned Shutdown Force at a fitting

```
LGEN project 7A48 - Scenario 7 - 500N Transfer Line
Time units  : seconds
Force units : Newtons
Output interval :      0.068 seconds
Number of forces tabulated :      7
Number of points per table :   1765
COMP  : FF/100
.
.
.
.
.100028E+3    49946.6       -49956.6          0.000000
.100096E+3    50104.0       -50114.9          0.000000
.100164E+3    50313.1       -50324.7          0.000000
.100232E+3    50556.8       -50568.7          0.000000
.100300E+3    50820.8       -50832.9          0.000000
.100368E+3    51094.5       -51106.8          0.000000
.100436E+3    51370.6       -51382.9          0.000000
.100504E+3    51644.4       -51656.7          0.000000
.100572E+3    51912.7       -51924.9          0.000000
.100640E+3    52173.2       -52185.3          0.000000
```

(The first column is time and the other three columns are the three components of the forces.)

Planned Shutdown Force on a Pipe Segment (Unbalanced Force)

```
DIFF  : FP/100
.000000E+0       0.000000
.680000E-1  -0.145519E-12
.136000E+0  -0.698492E-11
.204000E+0  -0.436557E-12
.272000E+0  -0.669388E-11
.340000E+0  -0.727596E-12
.408000E+0  -0.640284E-11
.
.
.
.
.495040E+2   -1008.18
.495720E+2   -1031.36
.496400E+2   -1125.36
.497080E+2   -1284.92
.497760E+2   -1430.56
.498440E+2   -1516.51
.499120E+2   -1522.44
.499800E+2   -1523.74
.500480E+2   -1550.75
.501160E+2   -1578.78
.501840E+2   -1587.49
.502520E+2   -1580.40
.503200E+2   -1570.46
.503880E+2   -1563.65
.504560E+2   -1563.16
```

(The first column is time and the second column is the unbalanced force along the pipe segment.)

Emergency Shutdown Force at a fitting

```
LGEN project 7A48 - Scenario 7 - 500N Transfer Line
Time units  : seconds
Force units : Newtons
Output interval :      0.068 seconds
Number of forces tabulated :      7
Number of points per table :   1765
COMP  : FF/100
.000000E+0       0.000000       0.000000       0.000000
.680000E-1  -0.727596E-11   0.145519E-12       0.000000
.136000E+0  -0.756700E-11   0.727596E-11       0.000000
.204000E+0  -0.141154E-10   0.727596E-11       0.000000
.272000E+0  -0.669388E-11   0.669388E-11       0.000000
.340000E+0  -0.727596E-12   0.727596E-12       0.000000
.408000E+0  -0.640284E-11   0.640284E-11       0.000000
.476000E+0   0.509317E-12  -0.152795E-11       0.000000
.544000E+0   0.305590E-11  -0.916771E-11       0.000000
.612000E+0   0.654836E-12  -0.196451E-11       0.000000
.680000E+0   0.291038E-11  -0.873115E-11       0.000000
.
.
.
.
.100640E+2    71295.0       -71309.0           0.000000
```

```
.101320E+2    71841.4       -71852.8          0.000000
.102000E+2    72228.4       -72237.9          0.000000
.102680E+2    72538.1       -72547.0          0.000000
.103360E+2    72828.3       -72837.2          0.000000
.104040E+2    73113.1       -73121.9          0.000000
.104720E+2    73395.8       -73404.6          0.000000
.105400E+2    73675.9       -73684.8          0.000000
.106080E+2    73954.1       -73963.1          0.000000
.106760E+2    74229.9       -74238.8          0.000000
.107440E+2    74503.1       -74512.1          0.000000
.108120E+2    74773.3       -74782.4          0.000000
.108800E+2    75040.4       -75049.5          0.000000
.109480E+2    75303.9       -75313.0          0.000000
.110160E+2    75563.7       -75572.9          0.000000
.110840E+2    75819.4       -75828.6          0.000000
```

(The first column is time and the other three columns are the three components of the forces.)

Emergency Shutdown Force on a Pipe Segment (Unbalanced Force)

```
DIFF  : FP/101
.000000E+0       0.000000
.680000E-1   0.144064E-10
.136000E+0   0.727596E-11
.204000E+0   0.727596E-11
.272000E+0   0.785803E-11
.340000E+0   0.138243E-10
.408000E+0   0.727596E-11
.476000E+0   0.982254E-11
.544000E+0   0.196451E-10
.612000E+0  -0.436557E-11
.680000E+0   0.203727E-10
.748000E+0   0.720320E-11
.816000E+0   0.283762E-10
.884000E+0   0.145519E-10
.952000E+0   0.135333E-10
.102000E+1   0.130967E-10
.108800E+1   0.170257E-10
.115600E+1   0.589353E-11
.122400E+1  -0.305590E-11
.129200E+1   0.814907E-11
.136000E+1   0.945874E-11
.
.
.
.
.
.816000E+1   -1940.72
.822800E+1   -2106.00
.829600E+1   -2280.92
.836400E+1   -2467.33
.843200E+1   -2666.31
.850000E+1   -2878.92
.856800E+1   -3104.91
.863600E+1   -3339.01
```

```
.870400E+1   -3571.93
.877200E+1   -3794.34
.884000E+1   -3997.26
.890800E+1   -4171.27
.897600E+1   -4310.09
.904400E+1   -4426.05
.911200E+1   -4532.63
.918000E+1   -4610.72
.924800E+1   -4626.15
.931600E+1   -4561.15
.938400E+1   -4408.51
.945200E+1   -4154.19
.952000E+1   -3760.69
.958800E+1   -3184.14
.965600E+1   -2522.21
.972400E+1   -1921.65
```

(The first column is time and the second column is the unbalanced force along the pipe segment.)

9 February 2003