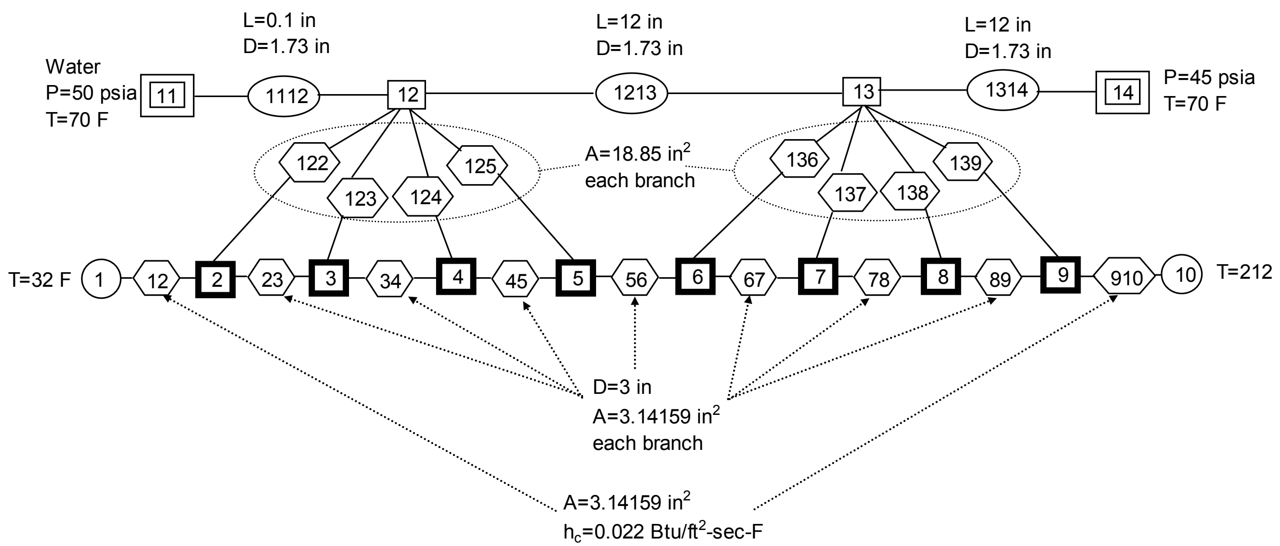
GFSSP Training Course Tutorials



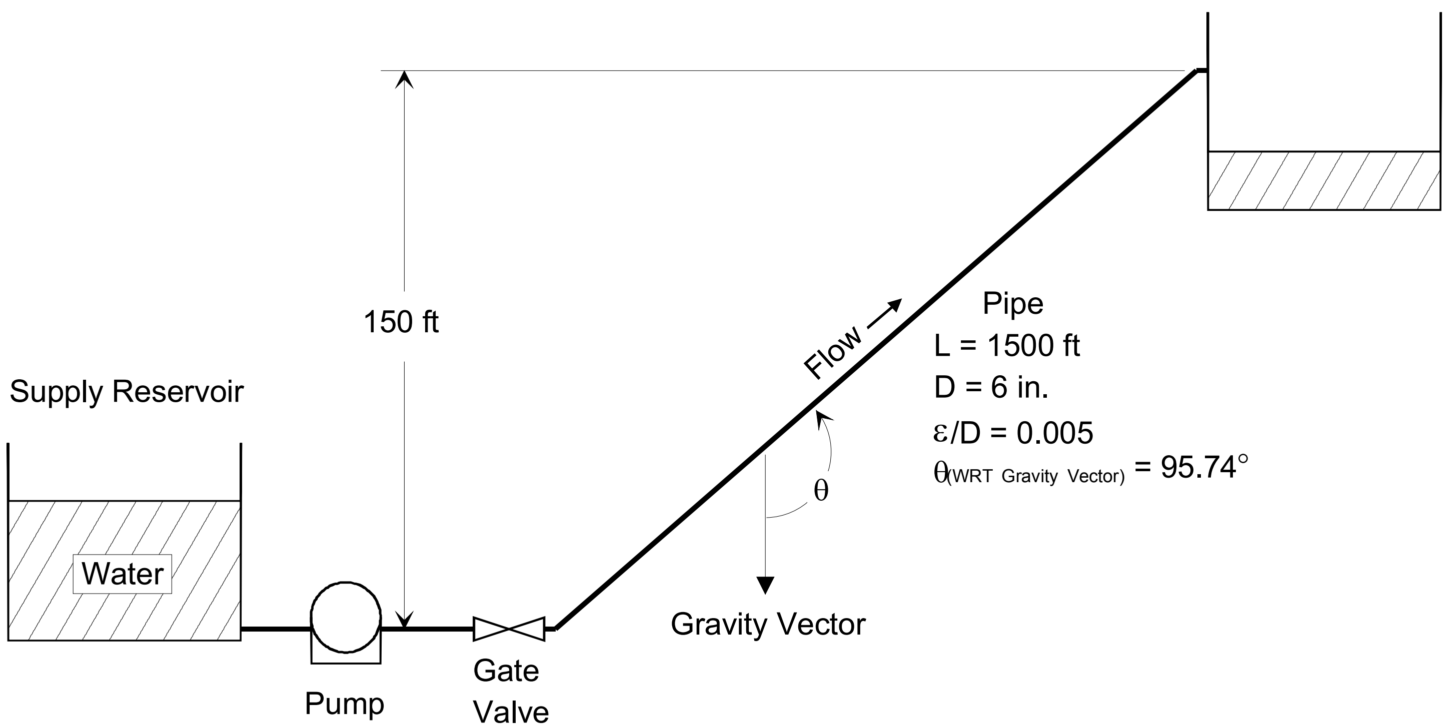
Thermal & Fluids Analysis Workshop

NASA/Kennedy Space Center & University of Central Florida

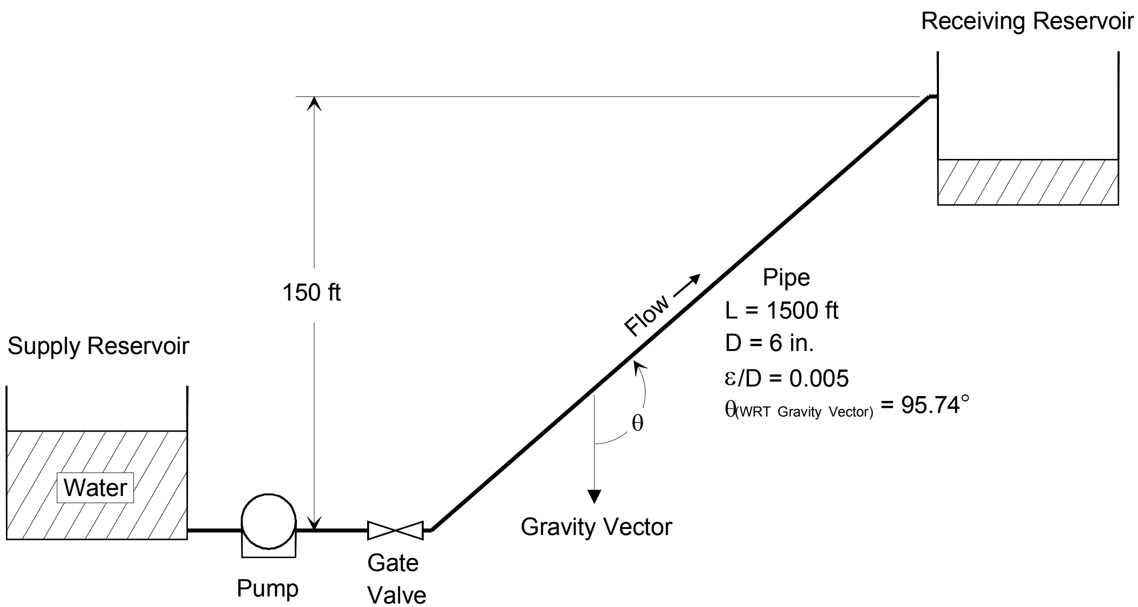
August 8-12, 2005

Tutorial – 1

SIMULATION OF A FLOW SYSTEM CONSISTING OF A PUMP, VALVE AND PIPE



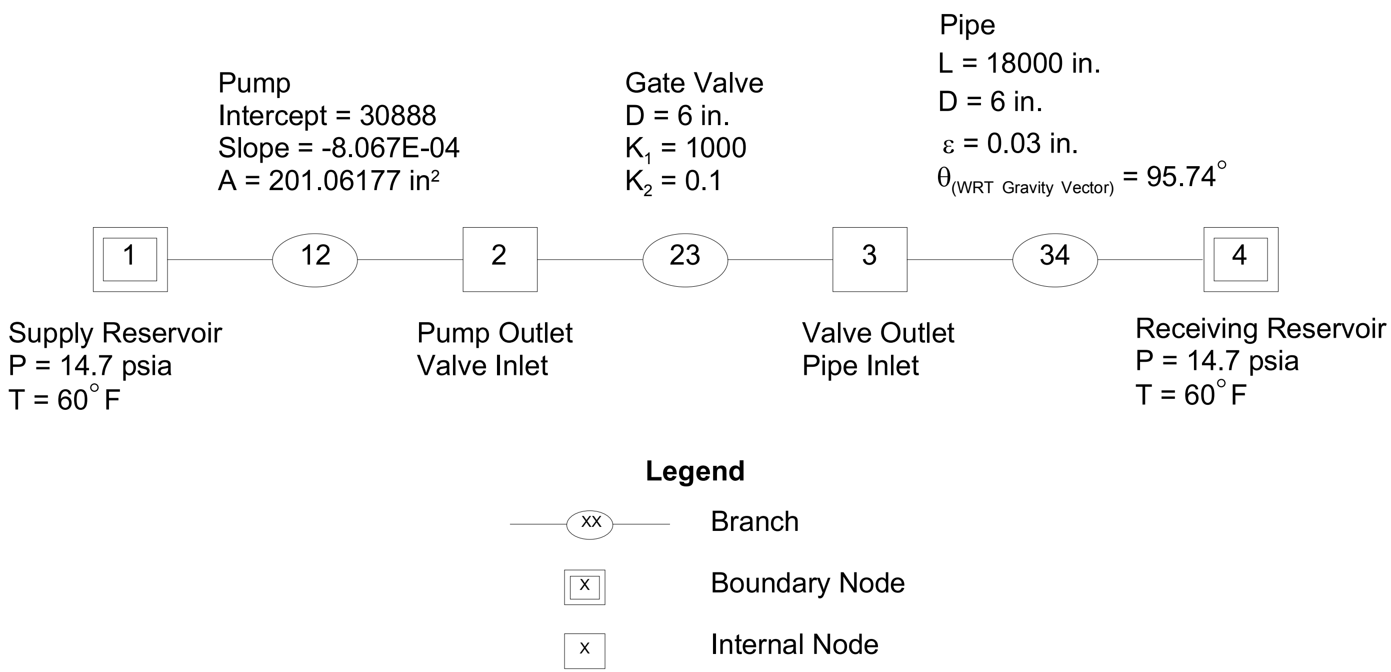
PUMPING SYSTEM AND RESERVOIRS SCHEMATIC



Problem Considered:

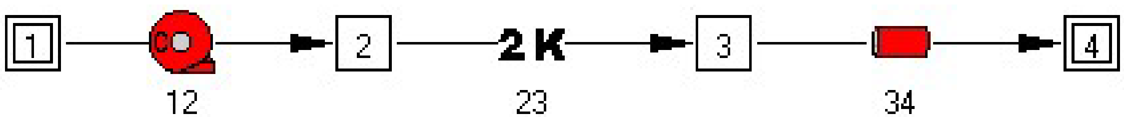
- Pressure rise across the pump
- Flow rate in the system

GFSSP MODEL CHARACTERISTICS



- Pump as Momentum Source
- Gravity Effects

VTASC MODEL

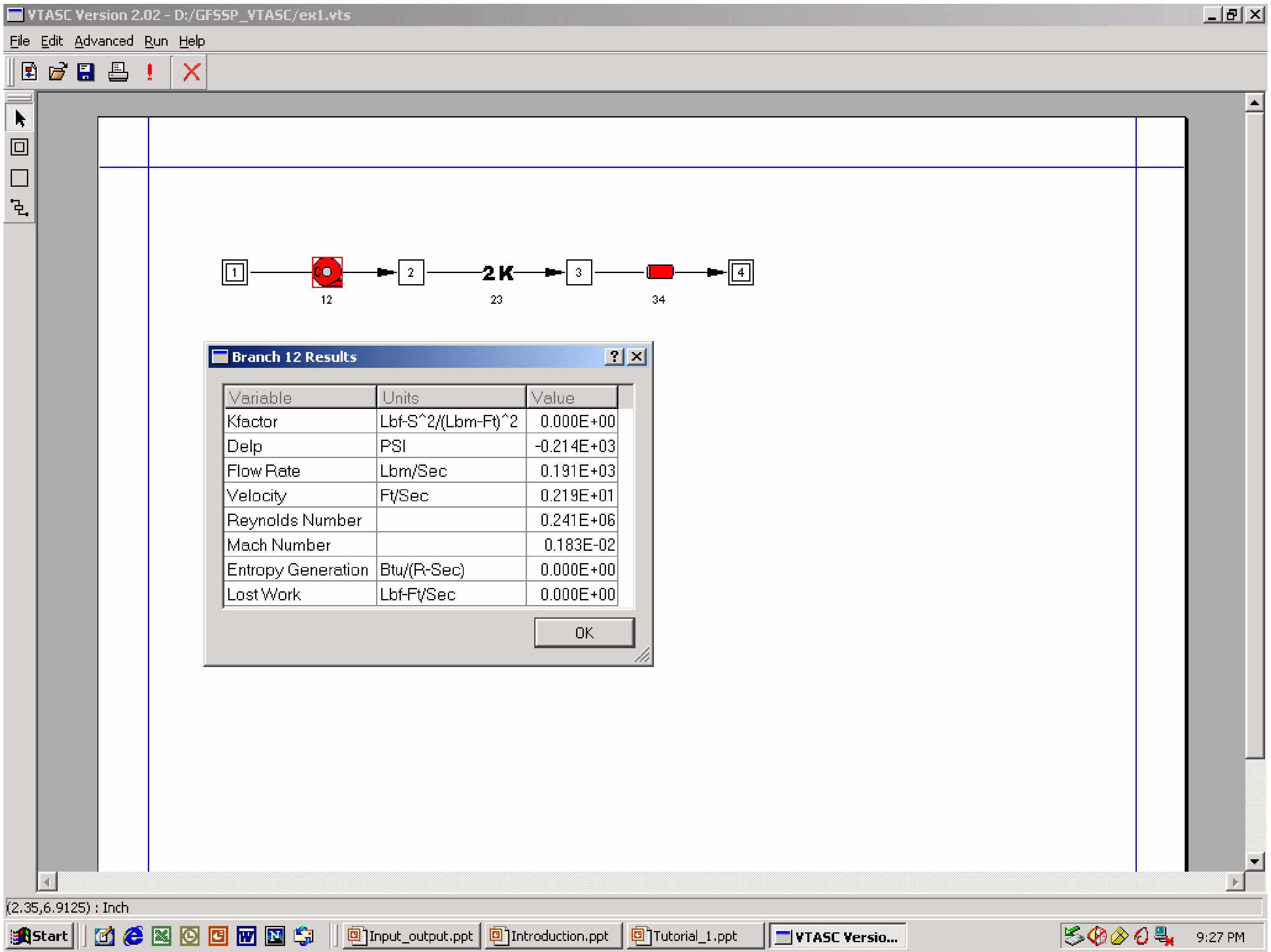


VTASC File : tut1.vts

Input data file : tut1.dat

Output data file : tut1.out

RESULTS



Variable	Units	Value
Kfactor	Lbf-S^2/(Lbm-Ft)^2	0.000E+00
Delp	PSI	-0.214E+03
Flow Rate	Lbm/Sec	0.191E+03
Velocity	Ft/Sec	0.219E+01
Reynolds Number		0.241E+06
Mach Number		0.183E-02
Entropy Generation	Btu/(R-Sec)	0.000E+00
Lost Work	Lbf-Ft/Sec	0.000E+00

EXERCISE

- Estimate Pump Horsepower assuming 75% Pump Efficiency

Pump Horsepower = $$\frac{\dot{m}}{\rho}\frac{\Delta p}{\eta} = \frac{\left(191\frac{lbm}{\sec}\right)\left(214\frac{lbf}{in^2}\right)\left(144\frac{in^2}{ft^2}\right)}{\left(62.4\frac{lbm}{ft^3}\right)\left(550\frac{ft-lbf}{hp}\right)(0.75)} = 228 \text{ HP}$$

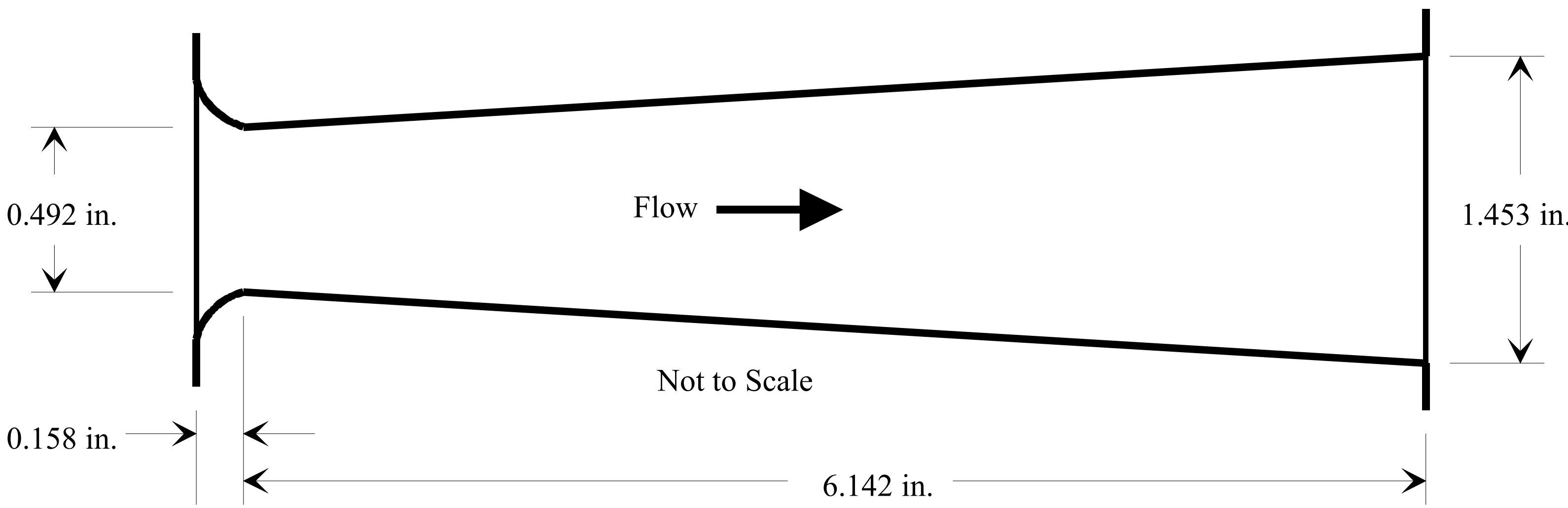
- Rerun the model with 228 HP and 75% Efficiency

- Check the consistency of results

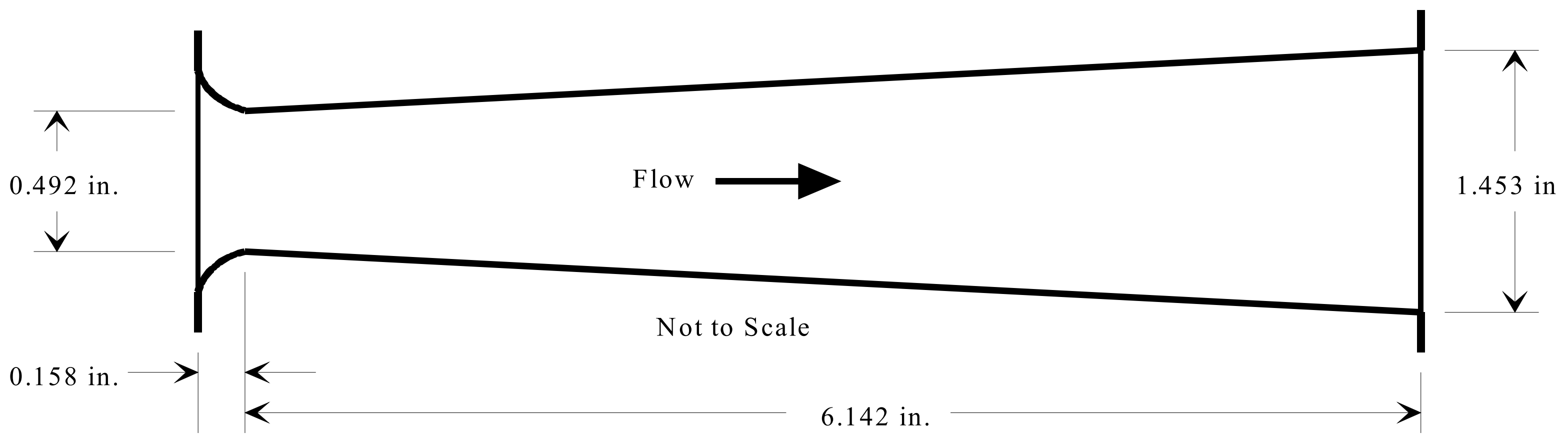
- Perform a few parametric runs with pump horsepower

Tutorial – 2

SIMULATION OF COMPRESSIBLE FLOW IN A CONVERGING-DIVERGING NOZZLE



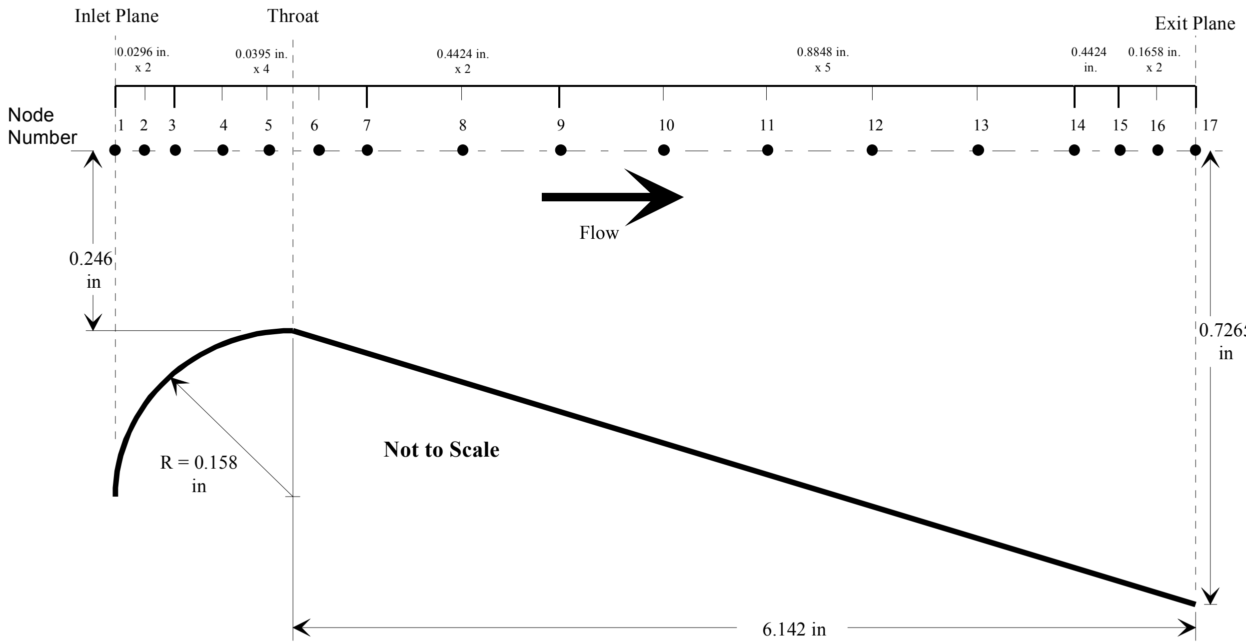
CONVERGING-DIVERGING NOZZLE GEOMETRY



Problem Considered:

- One-dimensional Pressure and Temperature distribution
- Flow rates in subsonic and supersonic flow

DISCRETIZATION AND BOUNDARY CONDITIONS



- Inertia Option
- Second Law Option

MODEL DETAILS

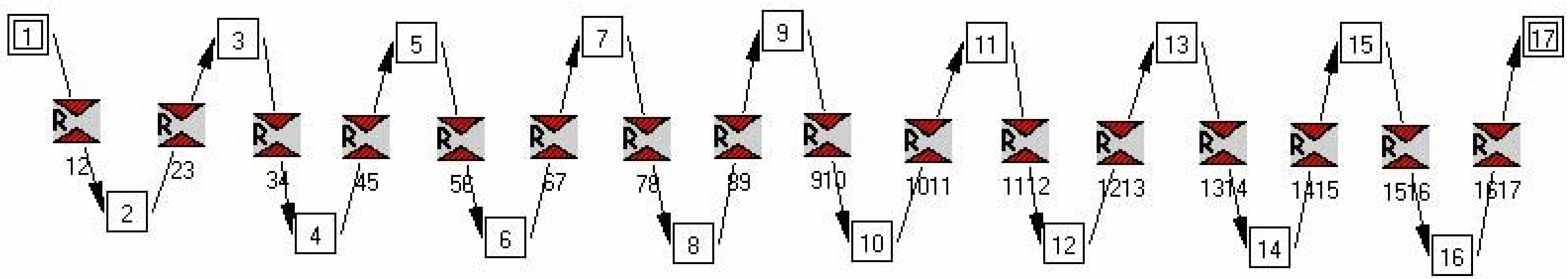
Geometry (C_L=0)

Branch	Area (in^2)	Branch	Area (in^2)
12	0.3587	910	0.3948
23	0.2717	1011	0.5640
34	0.2243	1112	0.7633
45	0.2083	1213	0.9927
56	0.1901	1314	1.2520
67	0.1949	1415	1.4668
78	0.2255	1516	1.5703
89	0.2875	1617	1.6286

Boundary Condition (Fluid=Water)

P_1 (psia)	T_1 ($^\circ F$)	P_{17} (psia)	T_{17} ($^\circ F$)
150	1000	134	1000
150	1000	100	1000
150	1000	60	1000
150	1000	30	1000
150	1000	15	1000

VTASC MODEL



VTASC File : tut2.vts

Input data file : tut2.dat

Output data file : tut2.out

RESULTS OF PARAMETRIC COMPUTATIONS

Determine the choked flow rate through the nozzle

P_1 (psia)	P_{17} (psia)	$\dot{m}$ (lbm/s)
150	134	
150	100	
150	60	
150	50	
150	45	

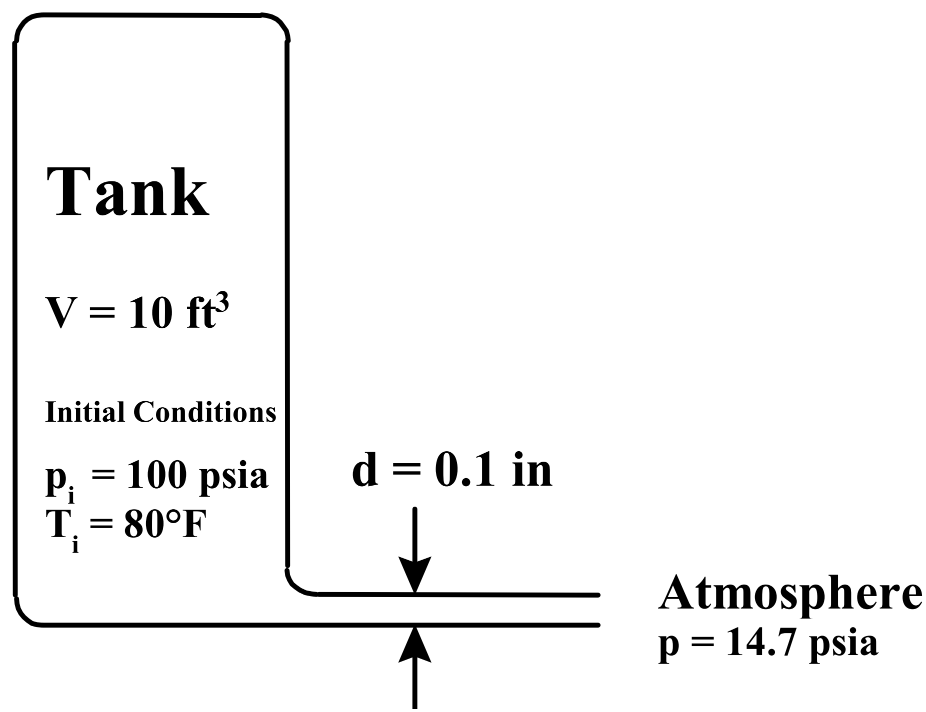
Use Restart option to perform parametric runs

STUDY OF THE RESULTS

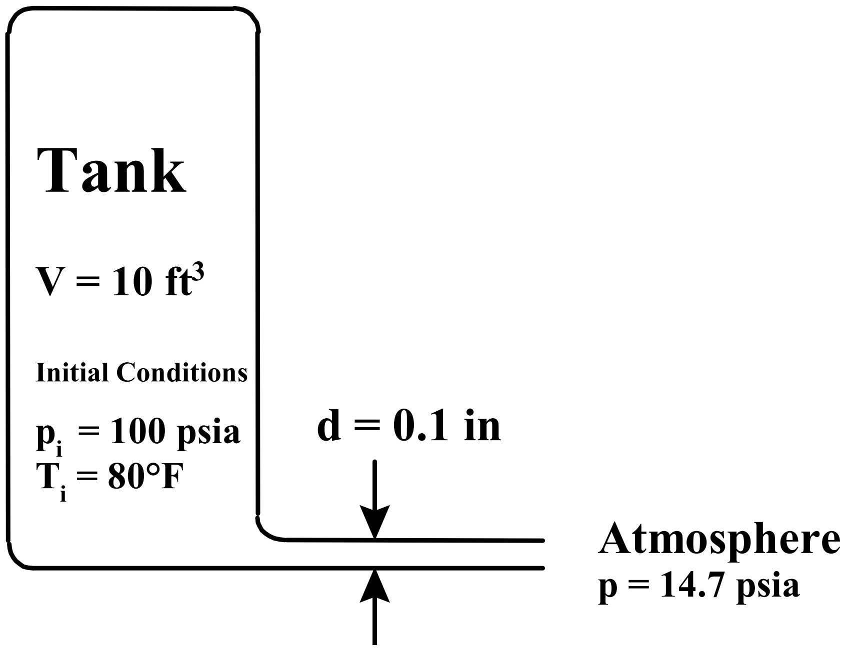
- Study results to note the following facts:
  - Pressure is decreasing from inlet to throat and increases from throat to exit in subsonic flow (Exit Pressure = 135 psia)
  - Temperature follows a similar trend; temperature changes due to expansion and compression
  - Entropy remains constant due to isentropic assumption
  - With lower exit pressure (60 psia), flow becomes supersonic in the diverging part and becomes subsonic with the formation of shock wave
  - Flow rate remains constant with exit pressure once choked flow rate is reached

Tutorial – 5

SIMULATION OF THE BLOW DOWN OF A PRESSURIZED TANK



NITROGEN TANK SCHEMATIC

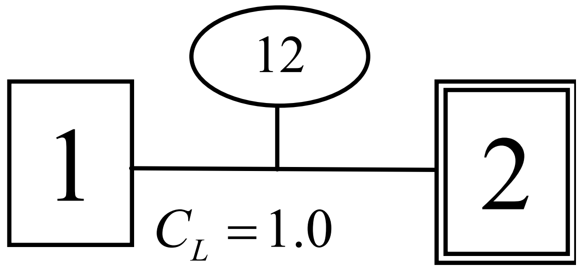


Problem Considered:

•Time dependent Pressure, Temperature, and Flow rate history

DISCRETIZATION AND BOUNDARY CONDITIONS

Fluid: Nitrogen
$P_{t=0}$=100 psia
$T_{t=0}$=80. °F
V=17280. in^3



$C_L = 1.0$

$A = 0.00785\ \text{in}^2$

$\dot{m}_i = 0.0177\ \text{lbm/s}$

Hist2.dat
P=14.7 psia
T=80. °F

- Unsteady Flow Formulation
- Second Law Option

ADDITIONAL MODEL DETAILS

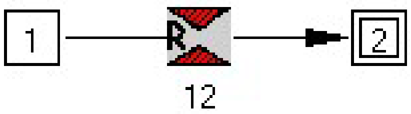
Model Run Duration – 200 seconds

Model Time Step – 0.1 seconds

“Hist2.dat” History File Format

```
2 - Number of data points
tau (sec)   p(psia)   T (°F)   Concentration
0           14.700    80.00         1.00
1000        14.700    80.00         1.00
```

VTASC MODEL



VTASC File : tut5.vts

Input data file : tut5.dat

Boundary Node history file : hist2.dat

Output data file : tut5.out

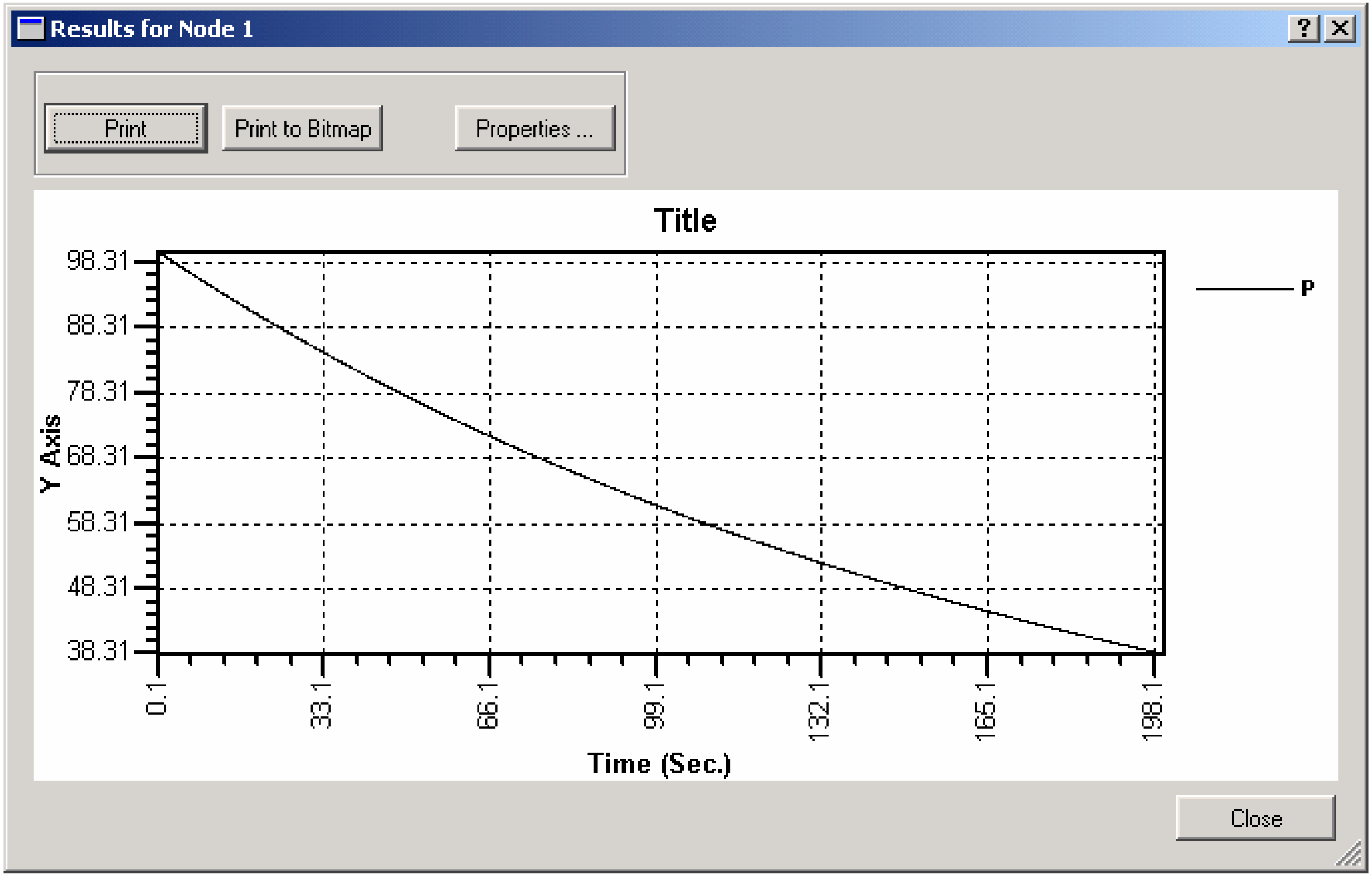
Node & Branch Output Excel files : HISTN.XLS & HISTBR.XLS

Node & Branch Output Winplot files : winpltn.csv & winpltb.csv

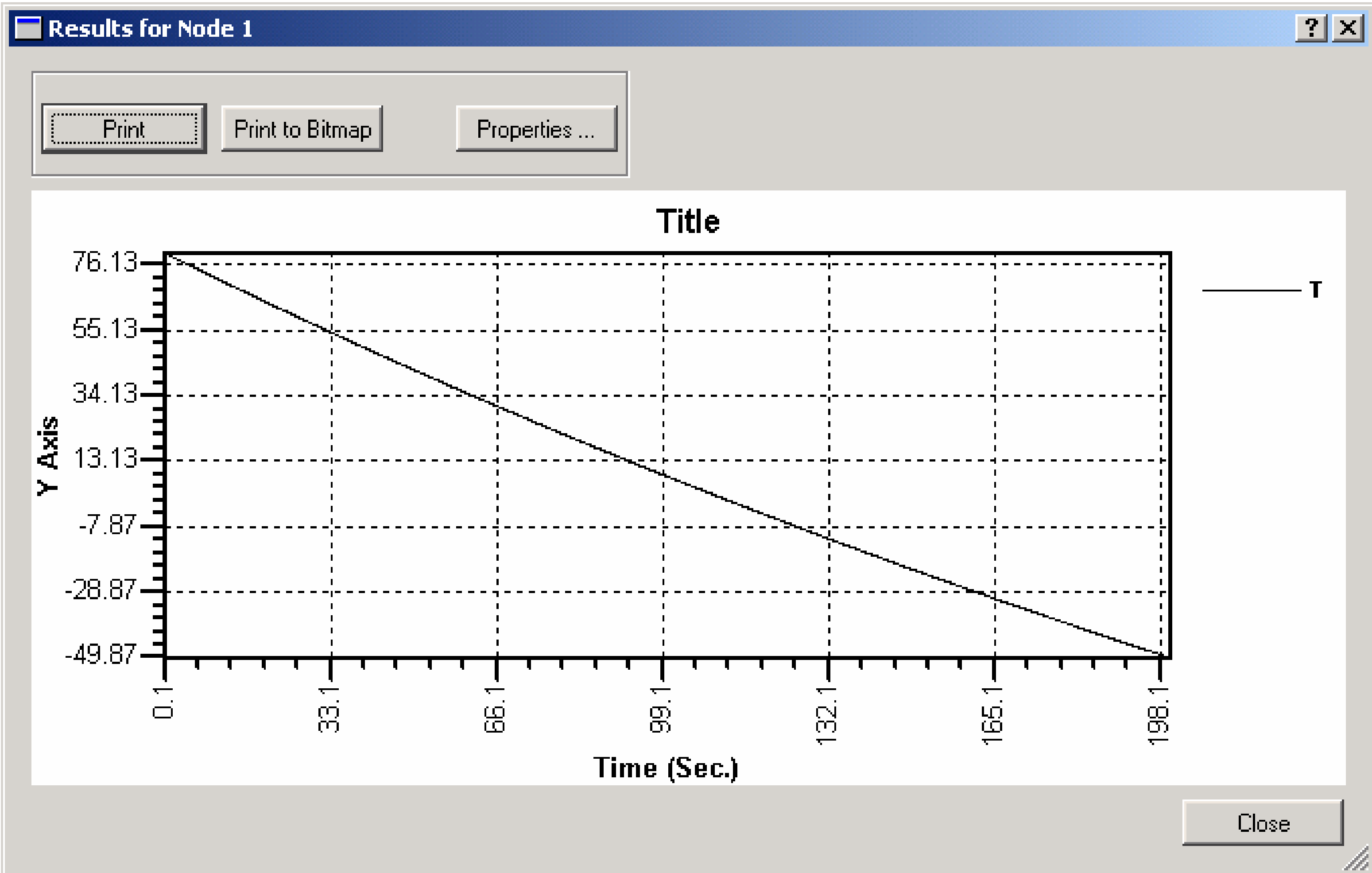
STUDY OF THE RESULTS

- Study *tut5.out, HISTN.XLS* and *HISTBR.XLS* to note the following facts:
  - Tank Pressure decreases from 100 psia to approximately 38 psia during the model run
  - As Tank Pressure drops, Temperature drops as well from 80. °F to approximately –50. °F.
  - As the Pressure Difference between the Tank and Atmosphere decreases, Mass Flow Rate decreases

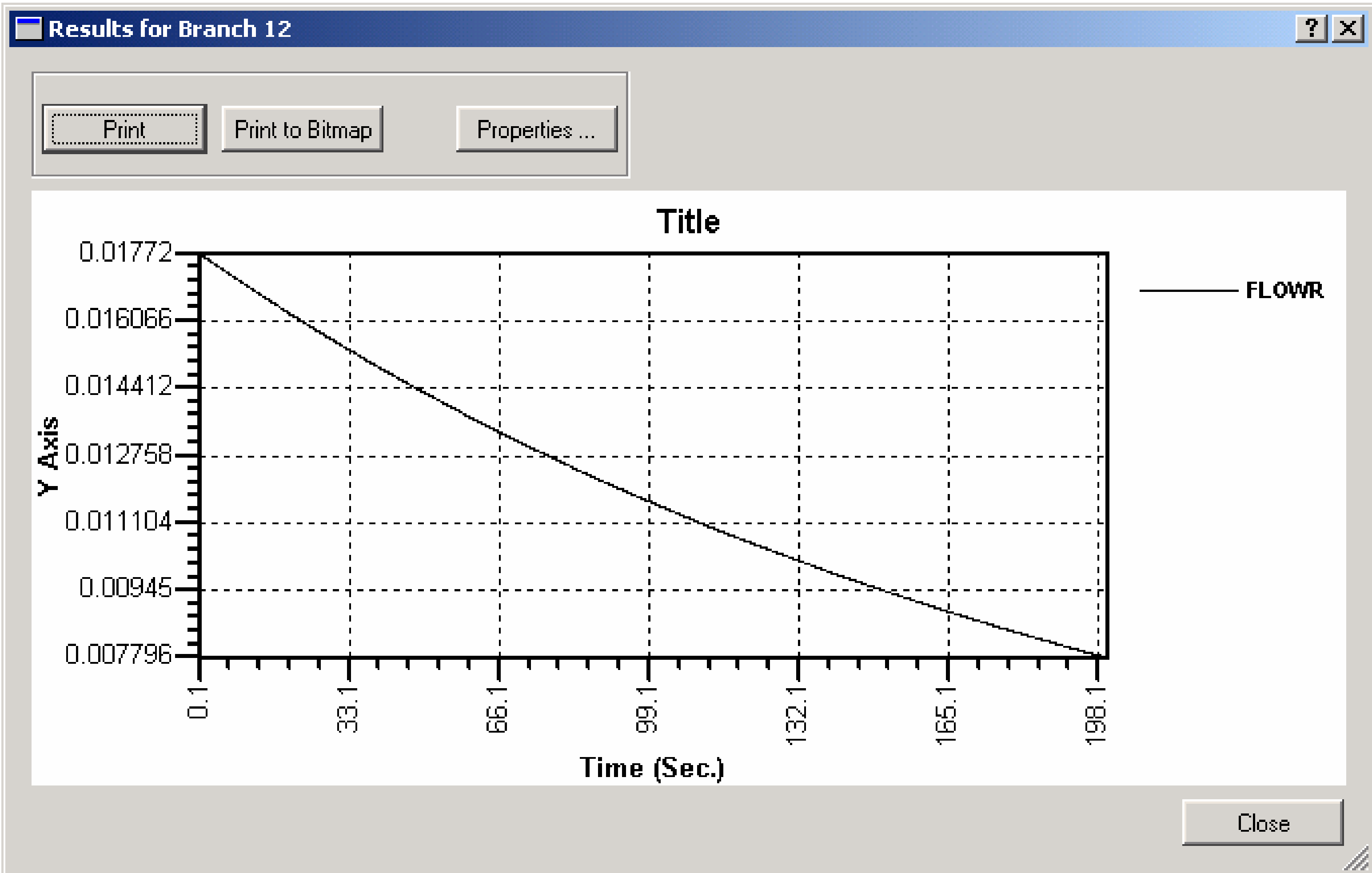
TANK PRESSURE HISTORY



TANK TEMPERATURE HISTORY

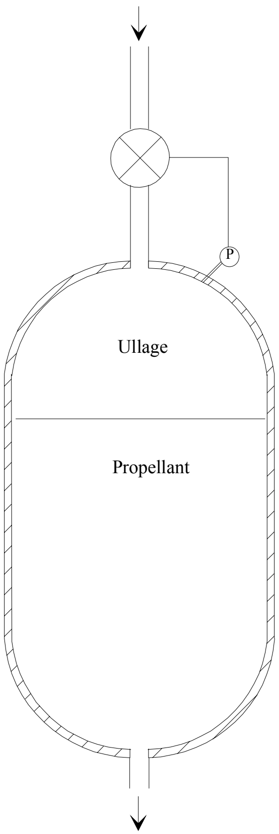


MASS FLOW RATE HISTORY

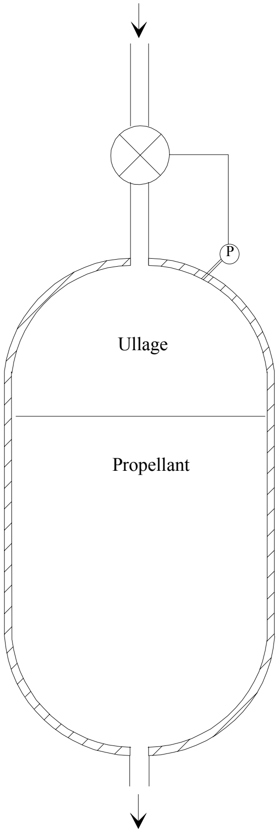


Tutorial – 7

VALVE-CONTROLLED PRESSURIZATION OF A PROPELLANT TANK



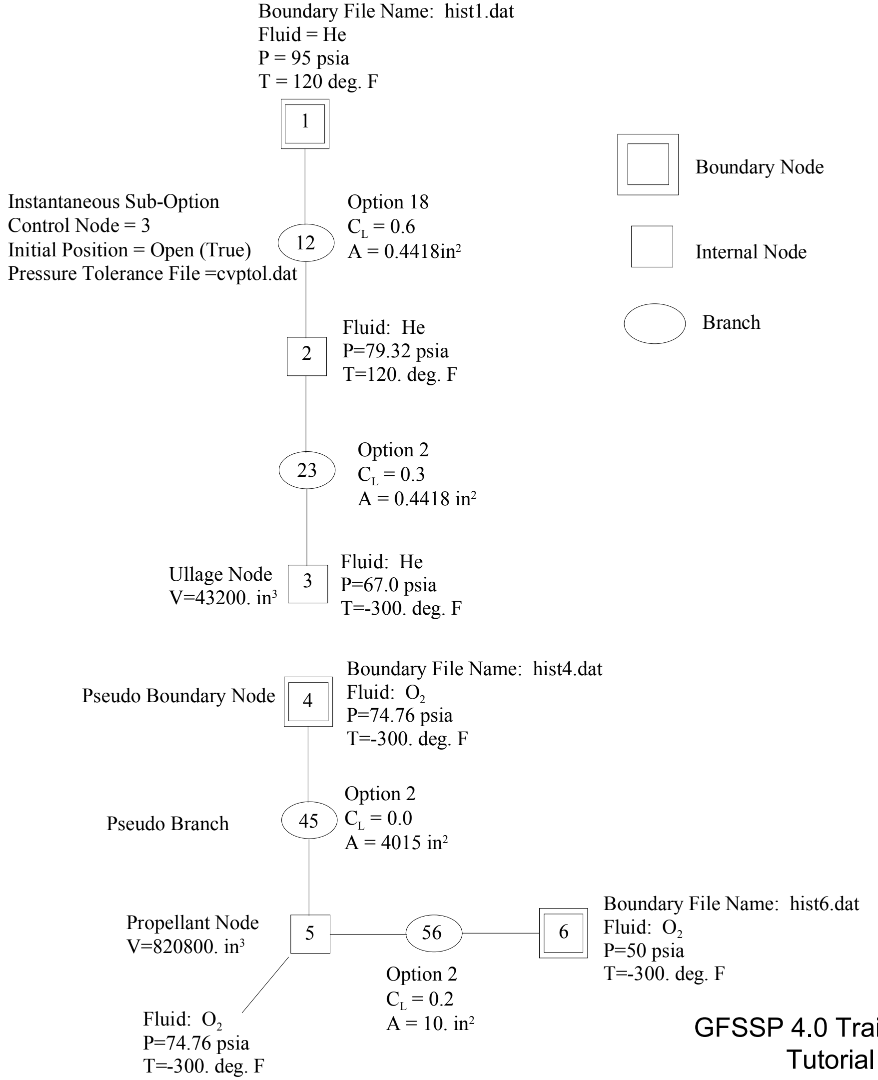
“BANG-BANG” PRESSURIZATION SYSTEM SCHEMATIC



Problem Considered:

• Control Tank Pressure Within a Specified Tolerance

DISCRETIZATION AND BOUNDARY CONDITIONS



- Pressurization Option
- Control Valve Branch Option
- Mixture

ADDITIONAL MODEL DETAILS

Tank Characteristics

Material: Aluminum

Density: 170. lbm/ft^3

Specific Heat: 0.2 Btu/lbm-R

Thermal Conductivity: 0.0362 Btu/ft-s-R

Diameter: 71.5 in.

Wall Thickness: 0.375 in.

Tank Surface Area: 6431.91 in^2

Ullage/Propellant Heat Transfer Area: 4015. in^2

T_{tank}: -300. °F

Conv. Heat Transfer Adj. Factor: 1.0

Pressure Tolerance File (cvptol.dat)

```
2
   0.00  70.00  64.00
1000.00  70.00  64.00
```

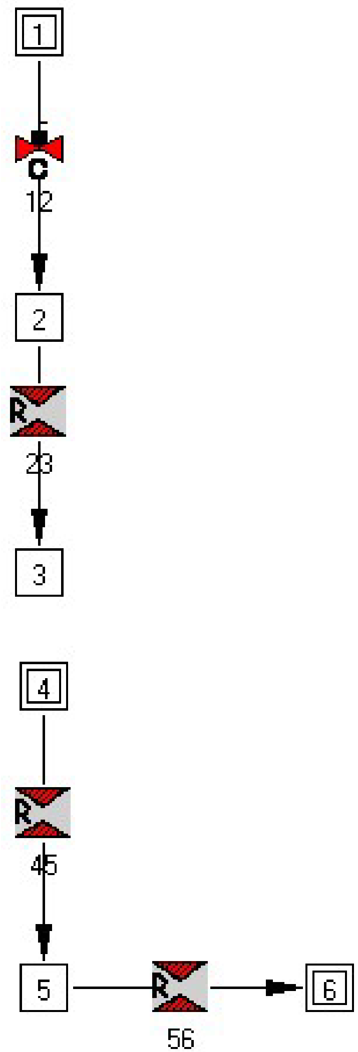
Other Characteristics

Run Duration: 60 seconds

Time Step: 0.05 seconds

Convergence Criteria: 0.005

RELAXK: 0.5



VTASC MODEL

VTASC File : tut7.vts

Input data file : tut7.dat

Boundary Node History Files: hist1.dat, hist4.dat, hist6.dat

Pressure Tolerance File: cvptol.dat

Output data file : tut7.out

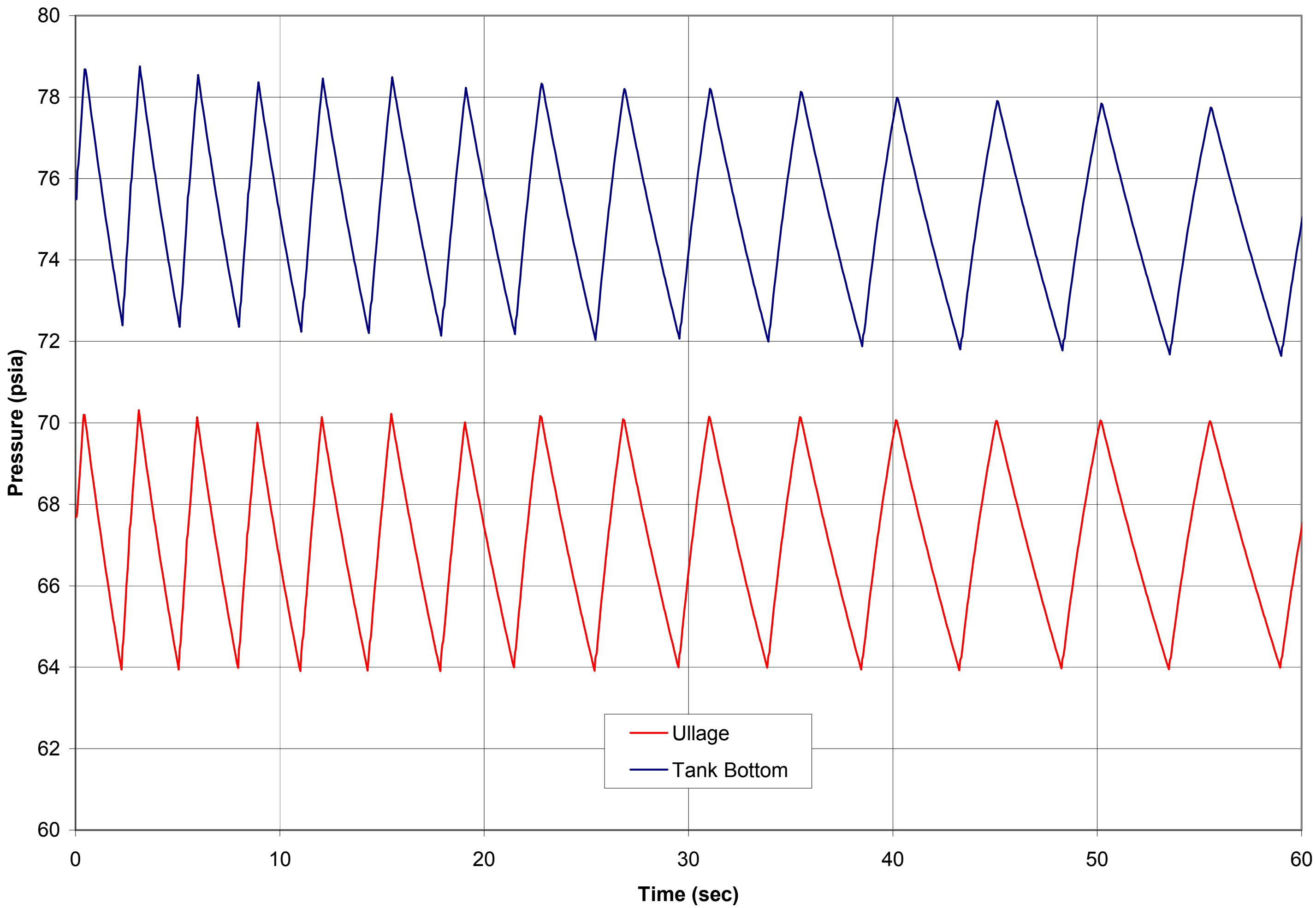
Output Excel files : HISTN.XLS & HISTBR.XLS

Output Winplot files : winpltn.csv & winpltb.csv

STUDY OF THE RESULTS

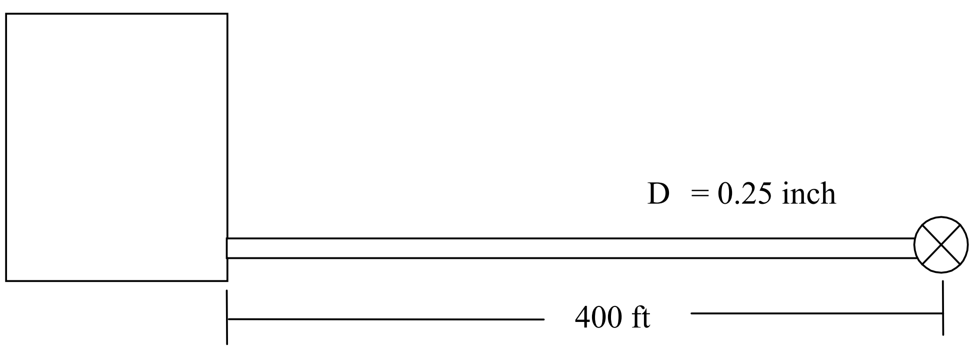
- Study output to note the following facts:
  - Ullage pressure is maintained between 64 and 70 psia by the control valve
  - Difference between ullage pressure and tank bottom pressure due to gravitational head
  - Tank bottom pressure decreases as propellant is expelled from the tank

Tank Pressure History

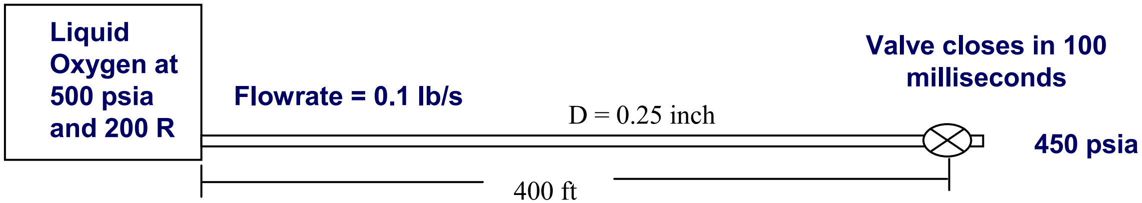


Tutorial – 9

SIMULATION OF FLUID TRANSIENT FOLLOWING SUDDEN VALVE CLOSURE



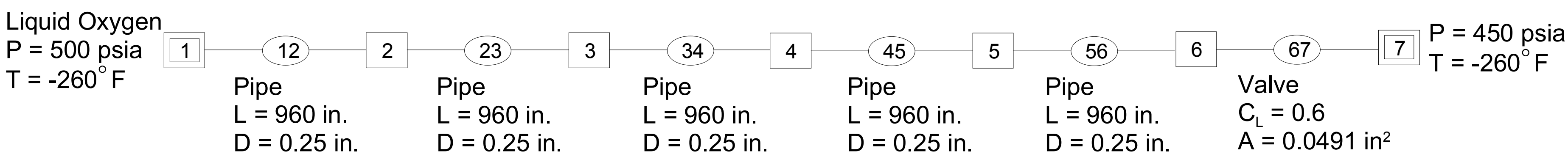
FLUID TRANSIENT SCHEMATIC



Problem Considered:

•Time dependent Pressure and Flow rate history during and after valve closure

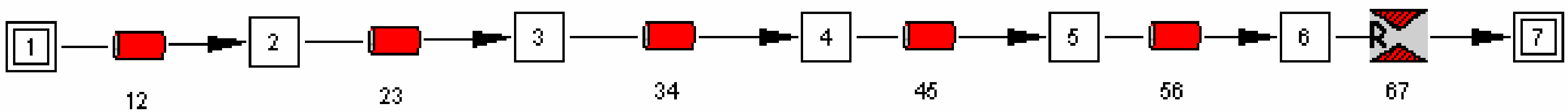
GFSSP MODEL CHARACTERISTICS



Valve Closure History

Time (Sec)	Area (in^2)
0.00	0.0491
0.02	0.0164
0.04	0.0055
0.06	0.0018
0.08	0.0006
0.10	0.00

VTASC MODEL



VTASC File : tut9.vts

Input data file : tut9.dat

Boundary Node history files : T9hist1.dat & T9hist7.dat

Valve Closure history file: T9hist67.dat

Output data file : tut9.out

Output Excel files : HISTN.XLS, HISTBR.XLS

Output Winplot files : winpltn.csv & winpltb.csv

ADDITIONAL MODEL DETAILS

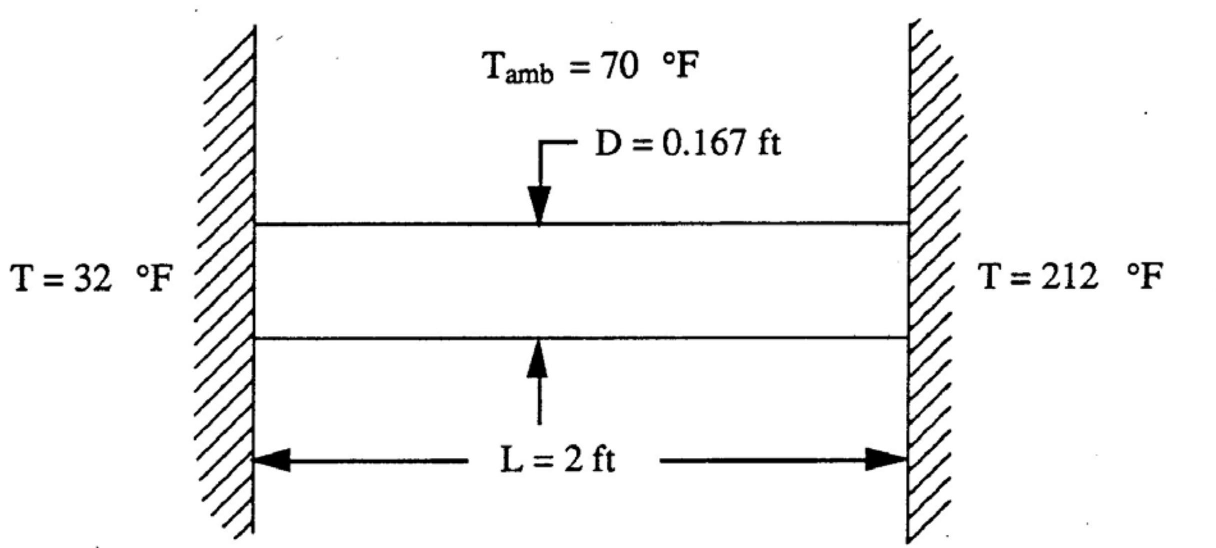
- Time step = 0.02 seconds
- Total time = 1 seconds
- Valve Closure
  - Check Valve Open/Close box on Edit->Options->Unsteady Options page
  - Select Advanced->Valve Open/Close dialog to define valve closure history
- Run steady state model first and save data for restart
- Run unsteady case using steady state results as initial condition

STUDY OF THE RESULTS

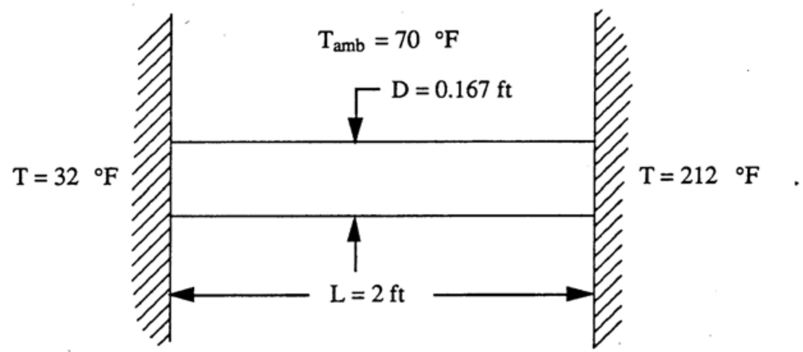
- Plot pressure and flowrate history
  - Peak pressure approximately 620 psia
- Estimate the predicted period of oscillation and compare with the following formula
  - Period of Oscillation = 4L/a
  - Where L = length of the pipe
  - And a = Speed of sound = 2462 ft/sec for LOX
- Plot compressibility history and note variation of compressibility with time

Tutorial – 12

STEADY STATE CONDUCTION THROUGH A CIRCULAR ROD



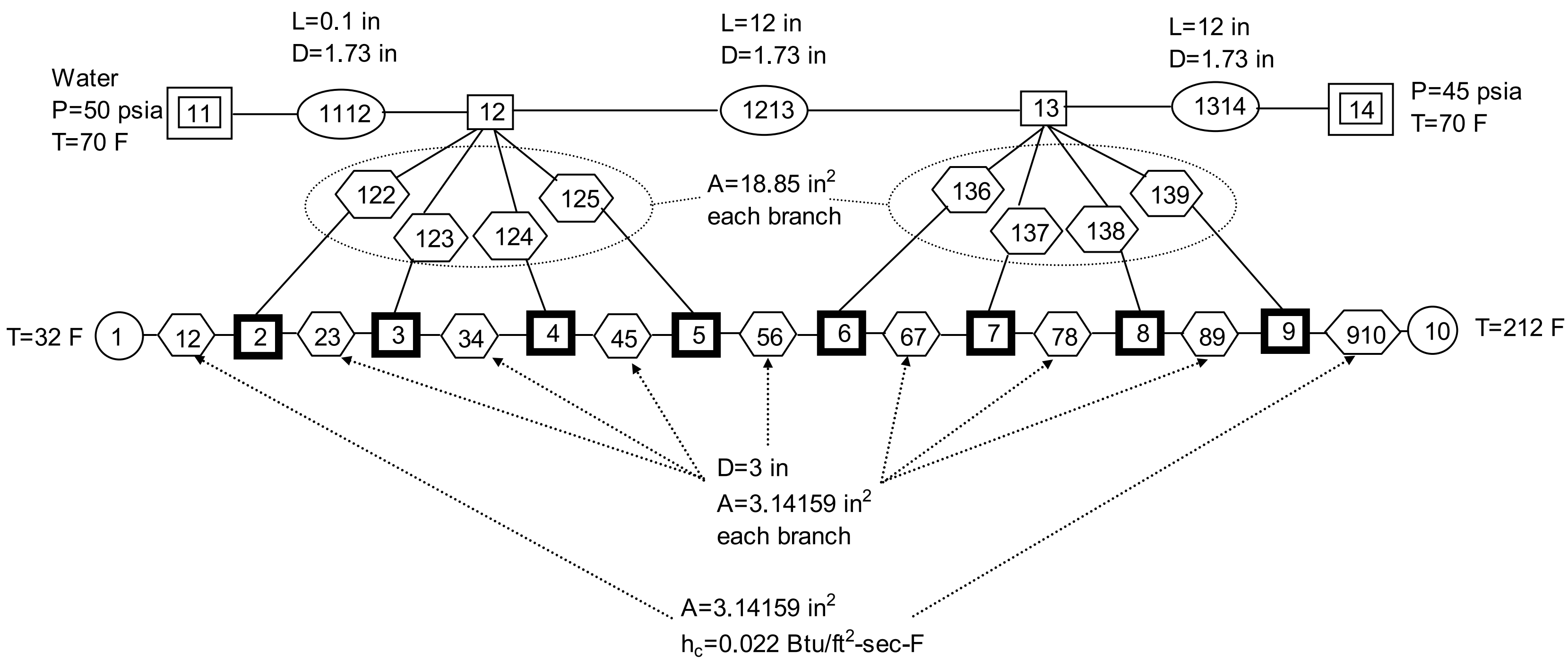
SYSTEM SCHEMATIC



Problem Considered:

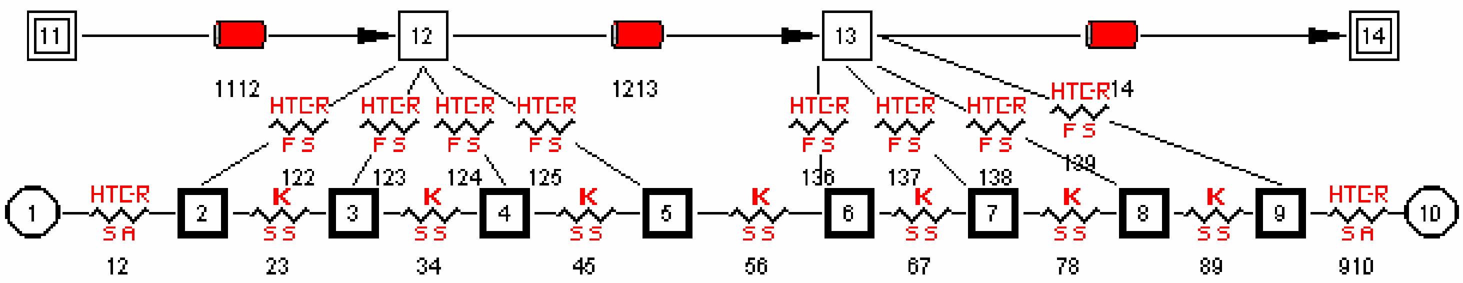
•Temperature variation along a circular rod

GFSSP MODEL CHARACTERISTICS



Solid Node Initial Temperatures=32F

VTASC MODEL

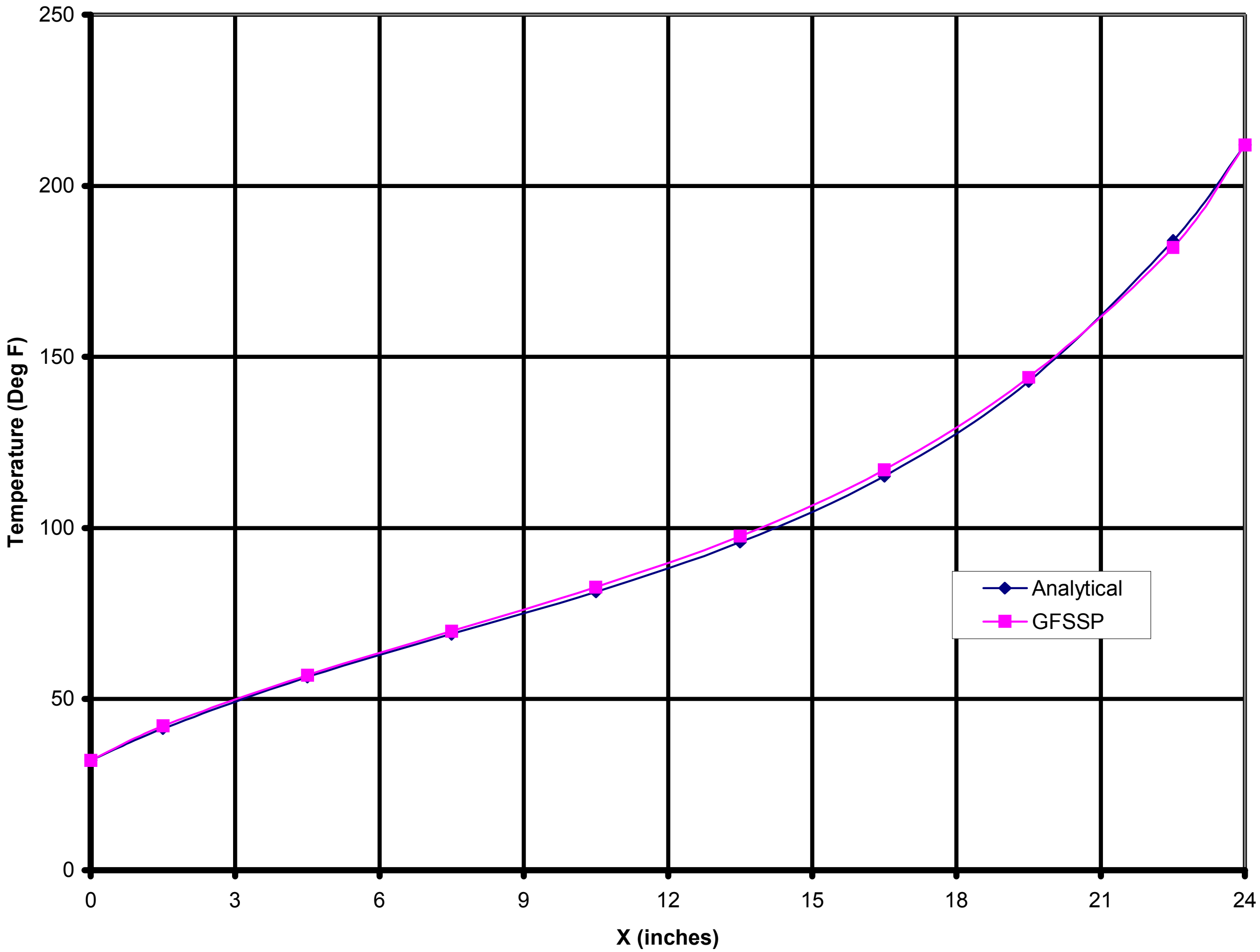


VTASC File : tut12.vts

Input data file : tut12.dat

Output data file : tut12.out

RESULTS


250
200
150
100
50
0
Temperature (Deg F)
0
3
6
9
12
15
18
21
24
X (inches)
Analytical
GFSSP