TECHNOLOGY
727 CENTER LANE
SANTA PAULA, CA 93060
(805) 933-1429

REGISTERED PROFESSIONAL ENGINEER
LARRY CROSSLEY
No. M018600
MECH. ENGR.
STATE OF CALIFORNIA
Exp. 9/30/11

Hydraulic Transient Analyses
Salinas Dam Booster Pump Station
San Luis Obispo, California

Introduction

Cannon Associates is currently designing upgrades to this pump station and has asked us to investigate the pressure surges associated with system operation and recommend appropriate surge control equipment. Pressure surges in piping mains are generally created by pump startup and shutdown, and computer modeling has been performed for the pump station and pipeline system to evaluate several scenarios. This report summaries the results of our analyses.

Water Hammer

Water hammer and pressure surges are created in pipelines whenever a change in flow rate occurs. The change in flow may be intentional, such as opening and closing a valve, or starting and stopping a pump. The pressure surges caused by normal operation are usually not a problem, as valves can generally be made to operate slower, and pumps can be provided with variable speed drives or control valves to limit the effect of startup and shutdown. Sudden and unplanned changes in flow occur on a loss of power to pumps, which can often result in severe water hammer being generated within a piping system. It is this “power failure” scenario that provides a worst case for the modeling that follows.

The transient pressures created by an unscheduled pump shutdown, and the protection provided by various protection devices can be accurately predicted by the application of Newton’s Laws of motion. The software used for transient modeling of this system was developed by the University of Kentucky, which utilizes a “wave plan” approach to solve the appropriate time dependent equations for flow and pressure. The accuracy of this method has been verified by alternate techniques including exact solutions, method of characteristics, and numerous field and experimental testing.

TECHNOLOGY
727 CENTER LANE
SANTA PAULA, CA 93060
(805) 933-1429

System Description

This water system is comprised of a booster pump station with three 200 horsepower pumps and a 24" diameter concrete transmission main. The booster station takes suction from a nearby reservoir at elevation 1150. The pipeline profile slopes generally uphill with a transition to gravity flow occurring about 7000 feet downstream with a net elevation change of about 180 feet. For modeling the pipeline is divided into segments or reaches with transient pressures and flows computed at each junction or node. For reference, the SURGE5 node numbers and corresponding pipeline locations are listed below.

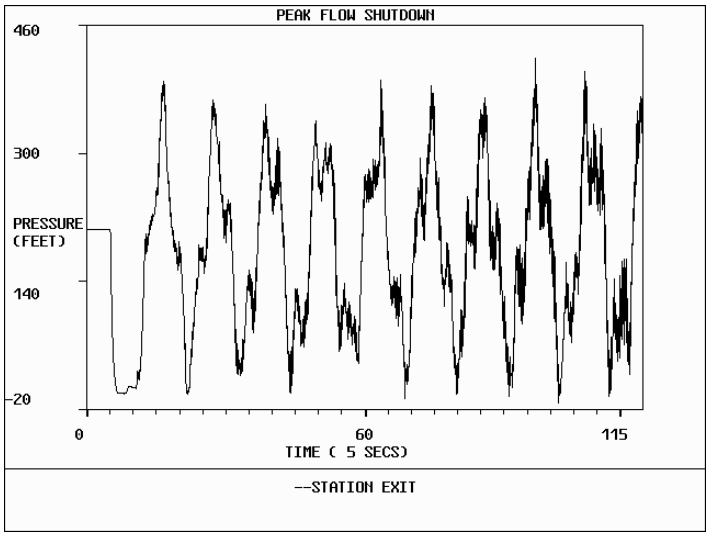
SURGE5 Node	Location
901	Suction Reservoir
1,2	Pump Station
3	Station 500+95
4	Station 507+00
5	Station 514+00
6	Station 516+45
7	Station 525+00
8	Station 533+00
9	Station 541+00
10	Station 550+00
11	Station 553+20
12	Station 557+80
902	Station 560+00

System Analysis – Pump Shutdown

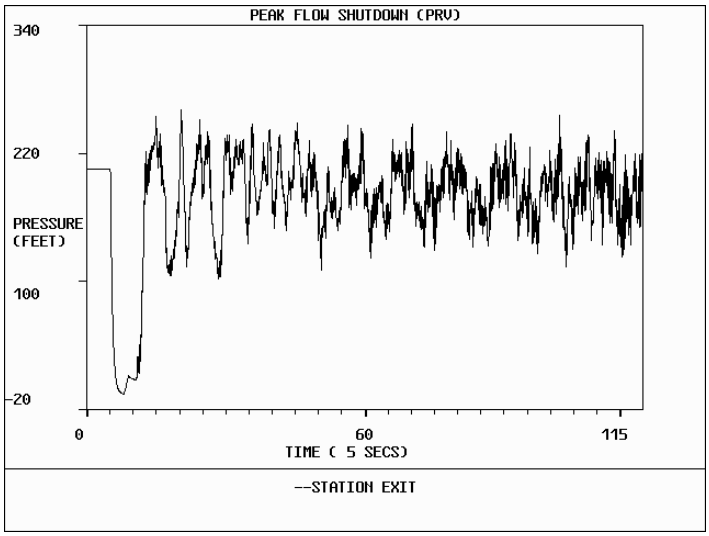
Computations modeling steady-state gradients and transient shutdown pressures are attached assuming three pumps in operation. Transient models include an unprotected scenario as well as using a relief valve and air chamber as surge control options. Results are presented in a time-marching format with pressures tabulated for several system nodes. Maximum and minimum pressures for all nodes are summarized at the end of the transient run.

Steady-state computations are presented first and predict a station flow of 6323 gpm and discharge pressures near 89 psig. Transient computations without protection indicate downsurge pressures are very severe. Negative pressure fall to –33.2 feet at all nodes indicating vapor cavity formation and the potential for "hammer-like" rejoining pressures. Pressure signature at the booster discharge is shown below.

TECHNOLOGY
727 CENTER LANE
SANTA PAULA, CA 93060
(805) 933-1429

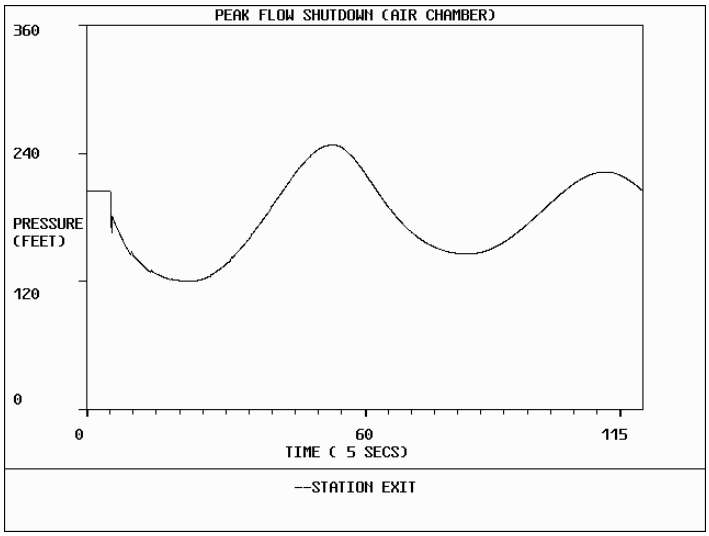


The second transient model includes parameters for an 8” pressure relief valve, set to open at 110 psig. Reviewing the transient printout, some upsurge attenuation is afforded near the pump station however downsurge is still a problem as vapor cavity formation occurs through most of the profile.



TECHNOLOGY
727 CENTER LANE
SANTA PAULA, CA 93060
(805) 933-1429

Our last model utilizes a 4000-gallon air chamber at the pump station. Computations show surges are well controlled as downsurge pressures fall to only – 3.0 psig for this scenario. Pressures drop gradually to 52 psig at the booster discharge with flow reversal and peak upsurge rising to about 108 psig at that location.



Conclusions

In summary, we have examined shutdown scenarios for this booster station to predict the surge levels to be encountered following a power outage. We found that without protection the pipeline will experience extreme downsurge resulting “hammer-like” pressures on vapor cavity collapse.

The use of a pressure relief valve was investigated and found lacking. A relief valve (simple or anticipatory) cannot attenuate the negative pressures created downstream, leaving the pipeline at risk of “water hammer”. An surge “anticipator” may marginally reduce the upsurge as it opens prior to a flow reversal, however they can be sensitive to open/closing times and can create a higher surge if not properly adjusted.

A 4000-gallon air chamber at the booster station was shown to offer superior protection. Downsurge was reduced to maintain positive line pressures through most of the profile, with maximum pressures on flow reversal limited to about 108 psig at the booster. Performance is based on a 96” diameter vertical vessel utilizing a 10-inch inlet connection. A bladder-type vessel can be used and will need a "pre-charge" pressure of 44 psig prior to connecting it to the pipeline. This vessel pre-charge will compress to about 2250 gallons when brought online and pumping pressures rise to 89 psig.

SALINAS DAM BOOSTER PUMP STATION
HYDRAULIC TRANSIENT ANALYSES
CALCULATIONS

***** SIC2 PROGRAM: **STEADY STATE - PEAK FLOW OPERATION** *****
Version 2.3 Dec. 1996

DATE = 10-08-2010

INPUT DATA FILE NAME FOR THIS SIMULATION = C:\SURGE5\DATA\SMPP1.SIC
OUTPUT DATA FILE NAME FOR THIS SIMULATION = C:\SURGE5\DATA\SMPP1.TIC

NUMBER OF LINE SEGMENTS = 12
NUMBER OF COMPONENTS = 1
NUMBER OF SDO CONNECTIONS = 1
FLOW UNITS = GALLONS / MINUTE
PRESSURE UNITS = PSI
THE HAZEN WILLIAMS HEAD LOSS RELATION IS USED FOR THIS SIMULATION

********** SUMMARY OF INPUT DATA **********

--- ELEMENT DATA (LINE SEGMENTS, COMPONENTS AND SDO CONNECTIONS) ---

ELEM NO.	NODE #1	NODE #2	LENGTH (FT.)	DIAM. (IN.)	PIPE RES.	SUM-M FACT.	WAVE SPEED
1	1	2	25.0	24.00	120.00	1.00	3200.0
2	2	3	945.0	24.00	120.00	0.00	3200.0
3	3	4	605.0	24.00	120.00	0.00	3200.0
4	4	5	700.0	24.00	120.00	0.00	3200.0
5	5	6	245.0	24.00	120.00	0.00	3200.0
6	6	7	855.0	24.00	120.00	0.00	3200.0
7	7	8	800.0	24.00	120.00	0.00	3200.0
8	8	9	800.0	24.00	120.00	0.00	3200.0
9	9	10	900.0	24.00	120.00	0.00	3200.0
10	10	11	320.0	24.00	120.00	0.00	3200.0
11	11	12	480.0	24.00	120.00	0.00	3200.0
12	12	902	220.0	24.00	120.00	0.00	3200.0
13	901	1	- COMPONENT: RESISTANCE = .028			PUMP TYPE = 1	
14	2	802	- SDO CONNECTION (air valve) : R = .0001 - .013 EXIT HEAD = 0				

--- DATA FOR PUMPS ---

PUMP TYPE # 1 IS DESCRIBED BY THE FOLLOWING DATA:

NOTE: When a pump file is used SIC will generate a pump curve for the steady state analysis using the head - discharge data shown below. The closer the operating point and rated conditions the better the result.

PUMP FILE (9991) IS USED. THE FOLLOWING CONDITIONS APPLY:
HR = 210 QR = 6000 speed = 1785 rpm
efficiency = .78 inertia = 100

HEAD	DISCHARGE
243.6	4200
210	6000
149.1	7800

THE FOLLOWING COEFFICIENTS ARE CALCULATED FOR THE PUMP CHARACTERISTIC:
A = 215.833 B = 10.91 C = -.849

--- NODE DATA ---

NODE NO.	ELEVATION	DEMAND
3	1126.0	0.0
4	1165.0	0.0

5	1166.0	0.0
6	1175.0	0.0
7	1205.0	0.0
8	1242.0	0.0
9	1248.0	0.0
10	1272.0	0.0
11	1303.0	0.0
12	1312.0	0.0
901	1150.0	- SUPPLY NODE: EXIT HEAD = 8
902	1332.0	- SUPPLY NODE: EXIT HEAD = .1

**** THE RESULTS FOR THE STEADY STATE SIMULATION FOLLOW ****

NO. OF TRIALS = 8 - ACCURACY ATTAINED = 0

ELEM NO.	NODE #1	NODE #2	FLOW RATE	HEAD LOSS	MINOR LOSS	PUMP HEAD	LINE VELOCITY	HL 1000
1	1	2	6323.29	0.08	0.31	0.00	4.48	3.06
2	2	3	6323.29	2.89	0.00	0.00	4.48	3.06
3	3	4	6323.29	1.85	0.00	0.00	4.48	3.06
4	4	5	6323.29	2.14	0.00	0.00	4.48	3.06
5	5	6	6323.29	0.75	0.00	0.00	4.48	3.06
6	6	7	6323.29	2.62	0.00	0.00	4.48	3.06
7	7	8	6323.29	2.45	0.00	0.00	4.48	3.06
8	8	9	6323.29	2.45	0.00	0.00	4.48	3.06
9	9	10	6323.29	2.75	0.00	0.00	4.48	3.06
10	10	11	6323.29	0.98	0.00	0.00	4.48	3.06
11	11	12	6323.29	1.47	0.00	0.00	4.48	3.06
12	12	902	6323.29	0.67	0.00	0.00	4.48	3.06
13	901	1	6323.29	0.00	5.56	201.07 - COMPONENT ELEMENT		

SDO CONNECTION AT NODE 2 IS CLOSED

JUNCTION NO.	ELEVATION (FT.)	DEMAND	PRESSURE (PSI)	PRESSURE HEAD	HYDRAULIC GRADE	DEMAND RESISTANCE
1	1153.0	0.0	86.9	200.5	1353.5	
2	1148.0	0.0	88.9	205.1	1353.1	
3	1126.0	0.0	97.2	224.2	1350.2	
4	1165.0	0.0	79.5	183.4	1348.4	
5	1166.0	0.0	78.1	180.2	1346.2	
6	1175.0	0.0	73.9	170.5	1345.5	
7	1205.0	0.0	59.7	137.9	1342.9	
8	1242.0	0.0	42.7	98.4	1340.4	
9	1248.0	0.0	39.0	90.0	1338.0	
10	1272.0	0.0	27.4	63.2	1335.2	
11	1303.0	0.0	13.5	31.2	1334.2	
12	1312.0	0.0	9.0	20.8	1332.8	

THE NET SYSTEM DEMAND = 0

SUMMARY OF INFLOWS(+) AND OUTFLOWS(-)

NODE NO.	FLOW
902	-6323.29
901	6323.29

********** - **SURGE PROGRAM - PEAK FLOW SHUTDOWN** - **********

COPYRIGHTED BY DON J. WOOD, JAMES E. FUNK - LEXINGTON, KENTUCKY, 1996

DATE = 10-08-2010 - TIME = 15:34:49

INPUT DATA FILE NAME = C:\SURGE5\DATA\SMPP1.DAT
OUTPUT DATA FILE NAME = C:\SURGE5\DATA\SMPP1.OUT

THE FOLLOWING DEFAULT OVERRIDES HAVE BEEN DEFINED:
LIQUID SPECIFIC GRAVITY = 1
TIME INCREMENT FACTOR = 1
FLOW CONVERSION FACTOR = 448.86
HEAD CONVERSION FACTOR = 1

TOTAL SIMULATION TIME = 120 TIME INCREMENT = .0076

ENGLISH UNITS ARE SPECIFIED: FLOW = CFS - HEAD = FT.

**** SUMMARY OF PIPE SYSTEM DATA ****

NUMBERS OF SPECIFIC ELEMENTS

LINE SEGMENTS = 12 COMPONENTS = 1
JUNCTIONS = 11 BYPASS LINES = 0
SIDE ORIFICES = 1 RELIEF VALVES = 0
CHECK VALVES = 1 VARIABLE INPUTS= 1

LINE SEGMENT DATA

POSITION OF ENDS		TRAVEL INCREMENTS	C/GA	INITIAL FLOWRATE	SEGMENT RESISTANCE
1	2	10	3.17	6323.29	0.00
13	3	39	31.66	6323.29	0.01
14	4	25	31.66	6323.29	0.01
15	5	29	31.66	6323.29	0.01
16	6	10	31.66	6323.29	0.00
17	7	35	31.66	6323.29	0.01
18	8	33	31.66	6323.29	0.01
19	9	33	31.66	6323.29	0.01
20	10	37	31.66	6323.29	0.01
21	11	13	31.66	6323.29	0.00
22	12	20	31.66	6323.29	0.01
23	902	9	31.66	6323.29	0.00

COMPONENT DATA

DATA FOR PUMP FILES

POS. #1	POS. #2	-REFERENCE (RATED) CONDITIONS- HEAD	FLOW	SPEED	EFFIC.	INITIAL SPEED	TOTAL INERTIA	SPECIFIC SPEED	FILE NUMBER
901	1	210.0	13.37	1785	0.780	1785	100.00	2506.39	9991

Pump File Units: Flow (CFS), Head (ft.), Speed (RPM), Inertia (lb ft ft)

COMPONENT CHARACTERISTICS AND INITIAL CONDITIONS

POS. #1	POS. #2	- CHARACTERISTICS - (A)	(B)	(C)	INITIAL FLOW	HEAD #1	HEAD #2	
901	1		(pump file)		6323.29	5.94	200.52	
		0.00	0.00	-0.03				- mult. comp.

JUNCTION DATA

JUNCTION LOCATION	NUMBER OF LEGS	INITIAL HEAD	CONNECTING POSITIONS
3	2	224.2	14
4	2	183.4	15
5	2	180.2	16
6	2	170.5	17
7	2	137.9	18
8	2	98.4	19
9	2	90.0	20
10	2	63.2	21
11	2	31.2	22
12	2	20.8	23
902	0	0.1	

SIDE DISCHARGE ORIFICE DATA

POS. #1	POS. #2	EXT. POS.	RESISTANCES* OUT	IN	LINE HEAD	INITIAL FLOW	- SURGE TANK DATA - (diam. depth volume)
2	13	802	0.00	0.01	205.13	0.00	- air relief valve *

* - For air relief valve use effective areas (not resistances)

CHECK VALVE DATA

THERE IS A CHECK VALVE AT POSITION 901 to 1 (non reopening)
TIME DELAY (closure time) FOR VALVE = .25 - CV RESISTANCE = .028
THE INITIAL HEAD LOSS DUE TO THE CHECK VALVE RESISTANCE = 5.56

NOTE: CHECK VALVE RESISTANCES MUST BE INCLUDED WITH THE COMPONENT DATA

VARIABLE INPUT DATA

INPUT # 1 - PUMP START UP OR SHUT DOWN IS SPECIFIED AT POSITION NO. 901

TIME - RATIO INPUT DATA

TIME	RATIO
0	1
5	1

PUMP TRIP SPECIFIED - TRIP INITIATED AT 5.0008 SEC.

THE FOLLOWING INITIAL VALUE IS CALCULATED FOR THIS VARIABLE INPUT:
... These should agree with initial values previously input (in parenthesis)
THE INITIAL PUMP SPEED RATIO = 1 (1)

**** SUMMARY OF INITIAL CONDITIONS FOR LINE SEGMENTS ****

END POSITION DESIGNATIONS: J - JUNCTION, C - COMPONENT, S - SDO
* - THIS DENOTES AN UNDESIGNATED END POSITION (UNACCEPTABLE) - CORRECT DATA

END POSITIONS #1	#2	FLOW 1 to 2	HEAD #1	#2	HEAD LOSS	ELEVATION DIFFERENCE
1 C	2 S	6323.29	200.5	205.1	0.4	-5.0
13 S	3 J	6323.29	205.1	224.2	2.9	-22.0
14 J	4 J	6323.29	224.2	183.4	1.9	39.0
15 J	5 J	6323.29	183.4	180.2	2.1	1.0
16 J	6 J	6323.29	180.2	170.5	0.7	9.0
17 J	7 J	6323.29	170.5	137.9	2.6	30.0
18 J	8 J	6323.29	137.9	98.4	2.4	37.0
19 J	9 J	6323.29	98.4	90.0	2.4	6.0
20 J	10 J	6323.29	90.0	63.2	2.8	24.0
21 J	11 J	6323.29	63.2	31.2	1.0	31.0
22 J	12 J	6323.29	31.2	20.8	1.5	9.0
23 J	902 J	6323.29	20.8	0.1	0.7	20.0

****** FLOWRATE AND PRESSURE RESULTS ******

TIME	H- 2	H- 5	H- 8	H- 11	Q- 3
3.002	205.1	180.2	98.4	31.2	-6323.3
6.004	21.5	100.5	98.4	31.2	-4112.8
9.006	9.0	28.0	-33.2	-11.0	-1992.9
CV CLOSURE OCCURS AT POSITION # 901					
12.008	90.6	109.2	78.1	29.1	2295.7
15.010	242.6	294.1	199.1	-33.2	1125.6
18.012	238.4	263.9	115.1	109.0	-1186.1
21.014	80.0	-20.9	12.5	26.4	-2548.8
24.017	148.8	55.2	-33.2	-33.2	341.7
27.019	346.4	225.6	139.0	36.4	889.5
30.021	207.8	259.7	184.9	42.2	371.1
33.023	32.0	128.6	116.4	17.5	413.0
36.025	101.5	155.6	141.6	-6.6	-168.7
39.026	325.2	238.5	152.9	20.9	-1000.3
42.028	240.5	206.0	-24.3	12.4	-1417.1
45.029	113.4	-31.2	-33.2	-33.2	504.1
48.031	144.8	218.5	90.9	-14.1	2680.4
51.033	265.5	221.2	262.3	30.4	135.5
54.034	79.5	238.8	181.0	-33.2	-1839.7
57.036	90.5	37.4	-33.2	9.8	-397.3
60.037	256.1	191.8	49.8	-3.3	773.2
63.039	287.3	324.6	148.8	10.4	2481.5
66.040	116.4	127.2	97.4	69.5	-413.4
69.042	17.9	139.2	77.0	-33.2	-96.7
72.043	248.7	180.7	204.0	51.2	-594.9
75.045	333.6	194.2	46.2	-33.2	-466.1
78.047	181.7	-33.2	-33.2	34.4	-1505.5
81.048	87.3	164.2	-33.2	16.0	1984.6
84.050	266.6	373.4	136.6	167.7	1776.4
87.051	245.5	241.2	218.3	39.7	-1848.9
90.053	75.2	177.2	-33.2	6.0	479.6
93.054	185.8	-26.4	-15.4	79.1	1513.9
96.056	342.3	257.3	122.2	-10.7	1912.2
99.057	227.0	144.7	7.5	22.4	447.9
102.059	-0.8	191.6	148.5	-33.2	-246.8
105.061	147.5	28.9	156.9	98.0	1459.4
108.062	271.6	223.9	66.5	-14.9	-1280.9
111.064	308.5	222.3	69.9	-33.2	-984.2
114.065	90.8	-33.2	-33.2	-33.2	-435.6
117.067	79.6	318.3	196.0	0.1	-692.3

SUMMARY OF MAXIMUM AND MINIMUM HEADS

POSITION NO.	MAXIMUM	MINIMUM
1	425.6	-33.2
2	418.4	-33.2
3	523.3	-33.2
4	544.2	-33.2
5	510.2	-33.2
6	474.0	-33.2
7	469.7	-33.2
8	442.0	-33.2
9	439.5	-33.2
10	364.6	-33.2
11	294.6	-33.2
12	270.1	-33.2
901	5.9	5.9
902	0.1	0.1

*** END OF THIS SIMULATION ***

A PLOT FILE (C:\SURGE5\DATA\SMPP1.PLT) HAS BEEN CREATED WITH THE FOLLOWING DATA:

ITEM NO.	SPECIFIC RESULT
1	HEAD AT POS. # 2

********** - **SURGE PROGRAM - PEAK FLOW SHUTDOWN** - **********
WITH RELIEF VALVE

COPYRIGHTED BY DON J. WOOD, JAMES E. FUNK - LEXINGTON, KENTUCKY, 1996

DATE = 10-25-2010 - TIME = 15:30:51

INPUT DATA FILE NAME = C:\SURGE5\DATA\SMPP2.DAT
OUTPUT DATA FILE NAME = C:\SURGE5\DATA\SMPP2.OUT

THE FOLLOWING DEFAULT OVERRIDES HAVE BEEN DEFINED:
LIQUID SPECIFIC GRAVITY = 1
TIME INCREMENT FACTOR = 1
FLOW CONVERSION FACTOR = 448.86
HEAD CONVERSION FACTOR = 1

TOTAL SIMULATION TIME = 120 TIME INCREMENT = .0076

ENGLISH UNITS ARE SPECIFIED: FLOW = CFS - HEAD = FT.

**** SUMMARY OF PIPE SYSTEM DATA ****

NUMBERS OF SPECIFIC ELEMENTS

LINE SEGMENTS = 12 COMPONENTS = 1
JUNCTIONS = 11 BYPASS LINES = 0
SIDE ORIFICES = 1 RELIEF VALVES = 1
CHECK VALVES = 1 VARIABLE INPUTS= 1

LINE SEGMENT DATA

POSITION OF ENDS		TRAVEL INCREMENTS	C/GA	INITIAL FLOWRATE	SEGMENT RESISTANCE
1	2	10	3.17	6323.29	0.00
13	3	39	31.66	6323.29	0.01
14	4	25	31.66	6323.29	0.01
15	5	29	31.66	6323.29	0.01
16	6	10	31.66	6323.29	0.00
17	7	35	31.66	6323.29	0.01
18	8	33	31.66	6323.29	0.01
19	9	33	31.66	6323.29	0.01
20	10	37	31.66	6323.29	0.01
21	11	13	31.66	6323.29	0.00
22	12	20	31.66	6323.29	0.01
23	902	9	31.66	6323.29	0.00

COMPONENT DATA

DATA FOR PUMP FILES

POS. #1	POS. #2	-REFERENCE (RATED) CONDITIONS- HEAD	FLOW	SPEED	EFFIC.	INITIAL SPEED	TOTAL INERTIA	SPECIFIC SPEED	FILE NUMBER
901	1	210.0	13.37	1785	0.780	1785	100.00	2506.39	9991

Pump File Units: Flow (CFS), Head (ft.), Speed (RPM), Inertia (lb ft ft)

COMPONENT CHARACTERISTICS AND INITIAL CONDITIONS

POS. #1	POS. #2	- CHARACTERISTICS - (A)	(B)	(C)	INITIAL FLOW	HEAD #1	HEAD #2	
901	1	(pump file)			6323.29	5.94	200.52	
		0.00	0.00	-0.03				- mult. comp.

JUNCTION DATA

JUNCTION LOCATION	NUMBER OF LEGS	INITIAL HEAD	CONNECTING POSITIONS
3	2	224.2	14
4	2	183.4	15
5	2	180.2	16
6	2	170.5	17
7	2	137.9	18
8	2	98.4	19
9	2	90.0	20
10	2	63.2	21
11	2	31.2	22
12	2	20.8	23
902	0	0.1	

SIDE DISCHARGE ORIFICE DATA

POS. #1	POS. #2	EXT. POS.	RESISTANCES* OUT	IN	LINE HEAD	INITIAL FLOW	- SURGE TANK DATA - (diam. depth volume)
2	13	802	0.11	0.11	205.13	0.00	- not a tank connection

* - For air relief valve use effective areas (not resistances)

PRESSURE RELIEF VALVE AT SDO POSITION 802 SENSES HEAD AT POSITION 2
VALVE OPENS AT H= 250 IN 2 SEC
VALVE CLOSES AT H= 230 IN 15 SEC.

CHECK VALVE DATA

THERE IS A CHECK VALVE AT POSITION 901 to 1 (non reopening)
TIME DELAY (closure time) FOR VALVE = .25 - CV RESISTANCE = .028
THE INITIAL HEAD LOSS DUE TO THE CHECK VALVE RESISTANCE = 5.56

NOTE: CHECK VALVE RESISTANCES MUST BE INCLUDED WITH THE COMPONENT DATA

VARIABLE INPUT DATA

INPUT # 1 - PUMP START UP OR SHUT DOWN IS SPECIFIED AT POSITION NO. 901

TIME - RATIO INPUT DATA

TIME	RATIO
0	1
5	1

PUMP TRIP SPECIFIED - TRIP INITIATED AT 5.0008 SEC.

THE FOLLOWING INITIAL VALUE IS CALCULATED FOR THIS VARIABLE INPUT:
... These should agree with initial values previously input (in parenthesis)
THE INITIAL PUMP SPEED RATIO = 1 (1)

**** SUMMARY OF INITIAL CONDITIONS FOR LINE SEGMENTS ****

END POSITION DESIGNATIONS: J - JUNCTION, C - COMPONENT, S - SDO
* - THIS DENOTES AN UNDESIGNATED END POSITION (UNACCEPTABLE) - CORRECT DATA

END POSITIONS #1	#2	FLOW 1 to 2	HEAD #1	HEAD #2	HEAD LOSS	ELEVATION DIFFERENCE
1 C	2 S	6323.29	200.5	205.1	0.4	-5.0
13 S	3 J	6323.29	205.1	224.2	2.9	-22.0
14 J	4 J	6323.29	224.2	183.4	1.9	39.0
15 J	5 J	6323.29	183.4	180.2	2.1	1.0
16 J	6 J	6323.29	180.2	170.5	0.7	9.0
17 J	7 J	6323.29	170.5	137.9	2.6	30.0
18 J	8 J	6323.29	137.9	98.4	2.4	37.0
19 J	9 J	6323.29	98.4	90.0	2.4	6.0
20 J	10 J	6323.29	90.0	63.2	2.8	24.0
21 J	11 J	6323.29	63.2	31.2	1.0	31.0
22 J	12 J	6323.29	31.2	20.8	1.5	9.0
23 J	902 J	6323.29	20.8	0.1	0.7	20.0

****** FLOWRATE AND PRESSURE RESULTS ******

TIME	H- 2	H- 5	H- 8	H- 11	Q- 3
3.002	205.1	180.2	98.4	31.2	-6323.3
6.004	21.5	100.5	98.4	31.2	-4112.8
9.006	10.0	29.6	-33.2	-11.0	-2034.6

CV CLOSURE OCCURS AT POSITION # 901

12.008	87.8	60.5	74.5	27.6	2276.4

OPENING IS INITIATED FOR THE RELIEF VALVE AT POS. # 802

15.010	240.7	260.4	207.5	3.4	1090.1
18.012	109.3	85.2	-2.1	26.5	683.1

RELIEF VALVE AT POS # 802 IS CLOSED

OPENING IS INITIATED FOR THE RELIEF VALVE AT POS. # 802

21.014	174.5	187.5	130.1	46.0	1191.7

RELIEF VALVE AT POS # 802 IS CLOSED

24.017	237.4	151.2	138.8	46.3	872.9

OPENING IS INITIATED FOR THE RELIEF VALVE AT POS. # 802

27.019	148.8	105.8	8.6	-33.2	1573.8

RELIEF VALVE AT POS # 802 IS CLOSED

30.021	213.3	107.3	121.0	36.5	1743.2

OPENING IS INITIATED FOR THE RELIEF VALVE AT POS. # 802

33.023	230.0	197.9	54.3	18.8	1552.3

RELIEF VALVE AT POS # 802 IS CLOSED

OPENING IS INITIATED FOR THE RELIEF VALVE AT POS. # 802

36.025	216.3	183.7	44.1	114.8	792.0

RELIEF VALVE AT POS # 802 IS CLOSED

39.026	211.6	216.8	74.9	-5.0	1103.8

OPENING IS INITIATED FOR THE RELIEF VALVE AT POS. # 802

RELIEF VALVE AT POS # 802 IS CLOSED

OPENING IS INITIATED FOR THE RELIEF VALVE AT POS. # 802

42.028	196.9	107.5	103.6	26.9	133.2

RELIEF VALVE AT POS # 802 IS CLOSED

45.029	238.0	182.7	106.2	-33.2	503.1
48.031	232.1	151.7	63.8	53.0	-354.1
51.033	172.3	180.3	79.6	50.0	856.2
54.034	166.7	167.4	102.1	56.5	-676.0
57.036	169.8	194.9	149.4	4.3	-390.6

OPENING IS INITIATED FOR THE RELIEF VALVE AT POS. # 802

RELIEF VALVE AT POS # 802 IS CLOSED

```
 60.037  183.2    131.4     50.1     22.2    -531.1
 63.039  181.8    154.4     67.9    -33.2     -55.7
 66.040  215.8    142.3    109.6    -10.2     452.7
 69.042  185.1    184.3     71.8    -20.6     969.4
OPENING IS INITIATED FOR THE RELIEF VALVE AT POS. #  802
RELIEF VALVE AT POS #  802  IS CLOSED
 72.043  154.1    190.7     71.4     34.6    -588.7
 75.045  149.6    238.0    151.0    -33.2     170.6
 78.047  192.6    151.8    135.6     28.9    -706.2
 81.048  203.6    228.7     12.5     -3.9     517.4
 84.050  199.1     90.8    -21.9    -15.8     241.5
 87.051  213.2    270.1     33.0     65.6    -180.4
 90.053  215.6    169.4    178.9     34.2     417.4
 93.054  149.0    178.9    208.0    -33.2    -634.9
 96.056  162.4     70.1     86.1      3.4    -706.9
 99.057  182.7    167.2     43.1    124.4   -1618.6
OPENING IS INITIATED FOR THE RELIEF VALVE AT POS. #  802
102.059  227.0    197.7     85.4     83.4     268.5
RELIEF VALVE AT POS #  802  IS CLOSED
105.061  166.5    160.9     31.9     74.0    -238.4
OPENING IS INITIATED FOR THE RELIEF VALVE AT POS. #  802
108.062  231.3    191.4    163.9    -33.2     -77.6
RELIEF VALVE AT POS #  802  IS CLOSED
111.064  210.7    100.7    153.8    -33.2    -412.2
OPENING IS INITIATED FOR THE RELIEF VALVE AT POS. #  802
114.065  200.8    171.3     83.1     23.7     349.1
RELIEF VALVE AT POS #  802  IS CLOSED
117.067  176.3    199.0    -29.6     79.7      40.8
OPENING IS INITIATED FOR THE RELIEF VALVE AT POS. #  802
RELIEF VALVE AT POS #  802  IS CLOSED

SUMMARY OF MAXIMUM AND MINIMUM HEADS
 POSITION NO.   MAXIMUM    MINIMUM
       1         290.4     -10.7
       2         285.2      -5.7
       3         404.2     -16.6
       4         370.5     -26.7
       5         364.2     -27.3
       6         370.3     -33.2
       7         314.6     -33.2
       8         307.6     -33.2
       9         284.8     -33.2
      10         265.4     -33.2
      11         212.8     -33.2
      12         187.1     -33.2
     901           5.9       5.9
     902           0.1       0.1

*** END OF THIS SIMULATION ***


A PLOT FILE (C:\SURGE5\DATA\SMPP2.PLT) HAS BEEN CREATED WITH THE FOLLOWING DATA:

ITEM NO.   SPECIFIC RESULT
 1       HEAD AT POS. #  2
```

********** - **SURGE PROGRAM - PEAK FLOW SHUTDOWN** - **********
WITH AIR CHAMBER

COPYRIGHTED BY DON J. WOOD, JAMES E. FUNK - LEXINGTON, KENTUCKY, 1996

DATE = 10-08-2010 - TIME = 15:24:20

INPUT DATA FILE NAME = C:\SURGE5\DATA\SMPP3.DAT
OUTPUT DATA FILE NAME = C:\SURGE5\DATA\SMPP3.OUT

THE FOLLOWING DEFAULT OVERRIDES HAVE BEEN DEFINED:
LIQUID SPECIFIC GRAVITY = 1
TIME INCREMENT FACTOR = 1
FLOW CONVERSION FACTOR = 448.86
HEAD CONVERSION FACTOR = 1

TOTAL SIMULATION TIME = 120 TIME INCREMENT = .0076

ENGLISH UNITS ARE SPECIFIED: FLOW = CFS - HEAD = FT.

**** SUMMARY OF PIPE SYSTEM DATA ****

NUMBERS OF SPECIFIC ELEMENTS

LINE SEGMENTS = 12 COMPONENTS = 1
JUNCTIONS = 11 BYPASS LINES = 0
SIDE ORIFICES = 1 RELIEF VALVES = 0
CHECK VALVES = 1 VARIABLE INPUTS= 1

LINE SEGMENT DATA

POSITION OF ENDS		TRAVEL INCREMENTS	C/GA	INITIAL FLOWRATE	SEGMENT RESISTANCE
1	2	10	3.17	6323.29	0.00
13	3	39	31.66	6323.29	0.01
14	4	25	31.66	6323.29	0.01
15	5	29	31.66	6323.29	0.01
16	6	10	31.66	6323.29	0.00
17	7	35	31.66	6323.29	0.01
18	8	33	31.66	6323.29	0.01
19	9	33	31.66	6323.29	0.01
20	10	37	31.66	6323.29	0.01
21	11	13	31.66	6323.29	0.00
22	12	20	31.66	6323.29	0.01
23	902	9	31.66	6323.29	0.00

COMPONENT DATA

DATA FOR PUMP FILES

POS. #1	POS. #2	-REFERENCE (RATED) CONDITIONS- HEAD	FLOW	SPEED	EFFIC.	INITIAL SPEED	TOTAL INERTIA	SPECIFIC SPEED	FILE NUMBER
901	1	210.0	13.37	1785	0.780	1785	100.00	2506.39	9991

Pump File Units: Flow (CFS), Head (ft.), Speed (RPM), Inertia (lb ft ft)

COMPONENT CHARACTERISTICS AND INITIAL CONDITIONS

POS. #1	POS. #2	- CHARACTERISTICS - (A)	(B)	(C)	INITIAL FLOW	HEAD #1	HEAD #2	
901	1	(pump file)			6323.29	5.94	200.52	
		0.00	0.00	-0.03				- mult. comp.

JUNCTION DATA

JUNCTION LOCATION	NUMBER OF LEGS	INITIAL HEAD	CONNECTING POSITIONS
3	2	224.2	14
4	2	183.4	15
5	2	180.2	16
6	2	170.5	17
7	2	137.9	18
8	2	98.4	19
9	2	90.0	20
10	2	63.2	21
11	2	31.2	22
12	2	20.8	23
902	0	0.1	

SIDE DISCHARGE ORIFICE DATA

POS. #1	POS. #2	EXT. POS.	RESISTANCES* OUT	IN	LINE HEAD	INITIAL FLOW	- SURGE TANK DATA - (diam.	depth	volume)
2	13	802	0.11	0.11	205.13	0.00	8.0	5.0	300.0

* - For air relief valve use effective areas (not resistances)

CHECK VALVE DATA

THERE IS A CHECK VALVE AT POSITION 901 to 1 (non reopening)
TIME DELAY (closure time) FOR VALVE = .25 - CV RESISTANCE = .028
THE INITIAL HEAD LOSS DUE TO THE CHECK VALVE RESISTANCE = 5.56

NOTE: CHECK VALVE RESISTANCES MUST BE INCLUDED WITH THE COMPONENT DATA

VARIABLE INPUT DATA

INPUT # 1 - PUMP START UP OR SHUT DOWN IS SPECIFIED AT POSITION NO. 901

TIME - RATIO INPUT DATA

TIME	RATIO
0	1
5	1

PUMP TRIP SPECIFIED - TRIP INITIATED AT 5.0008 SEC.

THE FOLLOWING INITIAL VALUE IS CALCULATED FOR THIS VARIABLE INPUT:
... These should agree with initial values previously input (in parenthesis)
THE INITIAL PUMP SPEED RATIO = 1 (1)

**** SUMMARY OF INITIAL CONDITIONS FOR LINE SEGMENTS ****

END POSITION DESIGNATIONS: J - JUNCTION, C - COMPONENT, S - SDO
* - THIS DENOTES AN UNDESIGNATED END POSITION (UNACCEPTABLE) - CORRECT DATA

END POSITIONS #1	#2	FLOW 1 to 2	HEAD #1	HEAD #2	HEAD LOSS	ELEVATION DIFFERENCE
1 C	2 S	6323.29	200.5	205.1	0.4	-5.0
13 S	3 J	6323.29	205.1	224.2	2.9	-22.0
14 J	4 J	6323.29	224.2	183.4	1.9	39.0
15 J	5 J	6323.29	183.4	180.2	2.1	1.0
16 J	6 J	6323.29	180.2	170.5	0.7	9.0
17 J	7 J	6323.29	170.5	137.9	2.6	30.0
18 J	8 J	6323.29	137.9	98.4	2.4	37.0
19 J	9 J	6323.29	98.4	90.0	2.4	6.0
20 J	10 J	6323.29	90.0	63.2	2.8	24.0
21 J	11 J	6323.29	63.2	31.2	1.0	31.0
22 J	12 J	6323.29	31.2	20.8	1.5	9.0
23 J	902 J	6323.29	20.8	0.1	0.7	20.0

****** FLOWRATE AND PRESSURE RESULTS ******

TIME	H- 2	H- 5	H- 8	H- 11	Q- 3	V- 2
3.002	205.1	180.2	98.4	31.2	-6323.3	300.0
CV CLOSURE OCCURS AT POSITION # 901						
6.004	175.5	146.3	98.4	31.2	-5954.4	312.3
9.006	148.3	166.5	81.6	26.8	-5595.3	350.0
12.008	135.2	127.0	59.3	36.0	-4279.0	381.3
15.010	127.1	125.2	74.9	25.6	-2987.2	405.7
18.012	121.7	132.7	70.5	24.0	-1719.1	422.3
21.014	120.3	117.5	55.6	23.3	-631.0	429.8
24.017	121.0	120.6	60.9	24.5	735.5	429.4
27.019	126.5	135.8	72.4	24.7	1958.0	421.2
30.021	136.0	128.4	72.1	24.7	2743.1	405.5
33.023	149.9	139.9	70.7	9.4	3563.0	384.3
36.025	166.4	152.8	87.0	28.4	3957.9	359.8
39.026	183.8	177.7	92.7	29.6	3822.2	334.0
42.028	203.2	176.3	93.0	34.9	3569.1	309.2
45.029	221.6	191.4	108.1	33.8	2948.7	288.0
48.031	236.4	205.7	113.3	35.2	2035.6	272.2
51.033	246.1	205.9	111.1	36.1	769.6	263.1
54.034	247.3	207.2	108.8	36.0	-411.0	261.9
57.036	238.2	205.6	113.6	35.5	-1563.6	268.5
60.037	221.1	189.8	110.3	33.5	-2468.8	281.4
63.039	202.1	176.6	94.9	27.3	-2889.7	298.7
66.040	184.5	168.0	91.6	29.3	-2971.1	318.0
69.042	169.9	161.5	85.6	28.0	-2790.6	336.9
72.043	159.4	148.4	78.4	26.5	-2318.8	353.5
75.045	152.2	145.2	78.5	25.9	-1683.9	366.7
78.047	147.6	143.3	76.6	25.7	-975.2	375.7
81.048	145.8	139.7	73.4	24.2	-283.0	379.8
84.050	146.4	139.7	69.5	25.2	497.6	379.1
87.051	150.4	145.0	77.6	25.9	1177.5	373.6
90.053	157.1	147.6	84.1	27.0	1742.3	363.8
93.054	166.5	153.0	81.1	27.3	2159.6	350.9
96.056	177.6	162.8	88.3	28.6	2389.1	336.0
99.057	189.4	170.2	93.5	30.1	2283.8	320.8
102.059	201.2	177.0	96.0	30.6	2015.9	306.5
105.061	211.5	182.7	101.4	32.0	1561.6	294.7
108.062	218.9	189.9	104.5	33.0	915.6	286.7
111.064	222.5	191.9	104.9	33.9	184.7	283.0
114.065	221.1	190.6	101.6	32.9	-544.6	284.1

117.067 214.5 187.7 102.8 32.3 -1213.6 289.8

SUMMARY OF MAXIMUM AND MINIMUM HEADS

POSITION NO.	MAXIMUM	MINIMUM
1	243.0	114.9
2	247.9	119.9
3	271.2	140.3
4	226.2	106.4
5	218.0	111.1
6	206.4	104.2
7	167.5	80.8
8	122.3	49.5
9	108.4	48.8
10	75.7	25.2
11	41.8	-6.8
12	35.2	-6.0
901	5.9	5.9
902	0.1	0.1

*** END OF THIS SIMULATION ***

A PLOT FILE (C:\SURGE5\DATA\SMPP3.PLT) HAS BEEN CREATED WITH THE FOLLOWING DATA:

ITEM NO.	SPECIFIC RESULT
1	HEAD AT POS. # 2