APPENDIX H

Dual-Phase Extraction System Design Calculations

SVE System Friction Loss Calculations

SAMPLE CALCULATIONS - Cooper Drum SVE Pipe Network

Temperature =	65 °F
Kinemateic Viscosity of Air @ Temp =	0.00017 ft^2/s
Vacuum at Inlet =	-10 in Hg
Pressure (Absolute) =	19.92 inch Hg
Density (STD) =	0.075 lbm/ft^3
Density Factor =	0.672
Density (Actual) =	0.0504 lbm/ft^3

Assumptions:

1. Heat transfer effects are neglected (temperature inside piping and outside are not significantly different).
2. Compressibility effects are neglected.
3. The air is assumed to be dry (water vapor content is assumed to be very low).
4. The weight and volume of the contaminant in the air stream is ignored.

A. Calculate the Actual Density

$$\text{Density Factor} = \left(\frac{P_{abs}}{29.921}\right)\left(\frac{530}{T+460}\right)$$

where,

P_{abs} = absolute system pressure, in Hg

T = system temperatre, degrees Farenheit

$$\text{Density Factor} = \left(\frac{19.92}{29.921}\right)\left(\frac{530}{65+460}\right) = 0.672$$

$$\text{Density (Actual)} = (\text{Density Factor})(\text{Density})$$
$$= 0.672*0.075$$
$$= 0.0504$$

B. Calculate Velocity Pressure (VP)

$$VP = \left(\frac{V}{4005}\right)^2 (DF)$$

where,

V = velocity, feet per minute (derived from continuity relation: V = Q/A)
where V = velocity, Q = flow rate, and A = crosssectional area

DF = density factor

4005 = conversion factor assuming standard air density equal to 0.075 lbm/ft^3

At Blower inlet,

V = 3198 fpm

DF = 0.672

$$VP = \left(\frac{3198}{4005}\right)^2 (0.0504) = 0.4285 \text{ in wg}$$

delta VP = VP_0 - VP_1

Between the AWS outlet and inlet,

VP_0 = 0.4285 in wg

VP_1 = 0.0829 in wg

delta VP = 0.4285 - 0.0829 = 0.3456 in wg

B. Calculate Total Pressure (TP)

TP_1 = delta TP + TP_0

For a fitting,

delta TP = C VP_0

where,

C = friction loss coefficient

VP_0 = velocity pressure, in wg

delta TP = 0.45*0.4285 = 0.193 in wg

C = 0.45 for a 90 degree elbow

VP_0 = 0.4285 in wg

For a length of pipe,

delta TP = H_f L VP_0

where,

$H_f = a\frac{V^b}{Q^c}$ for PVC, a=0.0425, b=0.465, c=0.602

V = velocity, fpm

Q = flow, cfm

VP_0 = velocity pressure, in wg

L = length of pipe, ft

$$\text{delta TP} = \left(0.0425\frac{(4758)^{0.465}}{(372)^{0.602}}\right)(8)(0.4285) = 0.212 \text{ in wg}$$

V = 4758 afpm

Q = 372 acfm

VP_0 = 0.4285 in wg

L = 8 ft

C. Calculate Static Pressure (SP)

$$SP = TP - VP$$

At the blower inlet,

$TP = -136.087$ in wg

$VP = 0.429$ in wg

$SP = -136.087 - 0.4285 = -136.515$ in wg

Between the blower inlet and 90 degree elbow

$\text{delta } SP = SP_0 - SP_1$

$SP_0 = -136.515$ in wg

$SP_1 = -136.304$ in wg

$\text{delta } SP = -136.515 - (-136.304) = -0.2118$ in wg

Reference: *Industrial Ventilation* - A Manual of Recommended Practice - ACGIH (edition 22, 1995)

URS

CALCULATION SHEET

Calc No. _____

Signature _____ Date _____ Checked VS Date 3/26/2007

Project Cooper Drum Vadose Zone Remedial Action Job No. 18500147.08010

Subject SVE Friction Losses Calculation Sheet _____ of 4

Temperature =	65	^oF
Kinemateic Viscosity of Air @ Temp =	0.00017	ft^2/s
Vacuum at Inlet =	-10	in Hg
Pressure (Absolute) =	19.92	inch Hg
Density (STD) =	0.075	lbm/ft^3
Density Factor =	0.672	
Density (Actual) =	0.0504	lbm/ft^3

dTP = Friction Loss or Minor Loss
Friction Loss = Darcy Equation
Minor Loss = C_oVP_o

To DPE-9

Point / Run		Description	Q_{STD} ft^3/min_{STD}	Q_{ACT} ft^3/min_{ACT}	Diameter (in)	Manufac. Diam. (in)	Area ft^2	$Velocity_{STD}$ ft/min_{STD}	$Velocity_{STD}$ ft/s_{STD}	$Velocity_A$ ft/min_{ACT}	$Velocity_A$ ft/s_{ACT}	inches WG VP_A	Delta VP_A	TP_A	Delta TP_A	SP_A	Delta SP_A	Length ft	Coefficient C_o	Remarks
Treatment System @ Treatment Pad		Blower Inlet	250	372	3	2.839	0.04396	5687	94.8	8461	141.0	1.3552		-136.087		-137.442				
													0.0000		0.109			1		sch 80 PVC pipe
		Reducer Outlet	250	372	3	2.839	0.04396	5687	94.8	8461	141.0	1.3552		-135.978		-137.333				
													0.9267		0.786				0.58	Reducer, Crane p. A 29
		Reducer inlet	250	372	4	3.786	0.07818	3198	53.3	4758	79.3	0.4285		-135.192		-135.620				
													0.0000		0.212		-2.0340	8		
		90-degree elbow outlet	250	372	4	3.786	0.07818	3198	53.3	4758	79.3	0.4285		-134.980		-135.408				
													0.0000		0.193		-0.1928		0.45	90 degree elbow, Crane p. A-29
		90-degree elbow intlet	250	372	4	3.786	0.07818	3198	53.3	4758	79.3	0.4285		-134.787		-135.215				
													0.0000		0.053		-0.0530	2		sch 80 PVC pipe
		90-degree elbow outlet	250	372	4	3.786	0.07818	3198	53.3	4758	79.3	0.4285		-134.734		-135.162				
													0.0000		0.193		-0.1928		0.45	90 degree elbow, Crane p. A-29
		90-degree elbow intlet	250	372	4	3.786	0.07818	3198	53.3	4758	79.3	0.4285		-134.541		-134.970				
													0.0000		0.026		-0.0265	1		sch 80 PVC pipe
		AWS Outlet	250	372	4	3.786	0.07818	3198	53.3	4758	79.3	0.4285		-134.515		-134.943				
													0.3456		27.217		-27.5630			dP across knockout pot = 2 in Hg
		AWS Inlet	250	372	6	5.709	0.17777	1406	23.4	2092	34.9	0.0829		-107.297		-107.380				
													0.0000		0.003		-0.0035	1		sch 80 PVC pipe
		90-degree elbow outlet	250	372	6	5.709	0.17777	1406	23.4	2092	34.9	0.0829		-107.294		-107.377				
													0.0000		0.037		-0.0373		0.45	90 degree elbow, Crane p. A-29
		90-degree elbow intlet	250	372	6	5.709	0.17777	1406	23.4	2092	34.9	0.0829		-107.256	`	-107.339				
													0.0000		0.021		-0.0210	6		sch 80 PVC pipe
		90-degree elbow outlet	250	372	6	5.709	0.17777	1406	23.4	2092	34.9	0.0829		-107.235		-107.318				
													0.0000		0.037		-0.0373		0.45	90 degree elbow, Crane p. A-29
		90-degree elbow inlet	250	372	6	5.709	0.17777	1406	23.4	2092	34.9	0.0829		-107.198		-107.281				
													0.0000		0.122		-0.1223	35		sch 80 PVC pipe
		45-degree elbow outlet	250	372	6	5.709	0.17777	1406	23.4	2092.4	34.9	0.0829		-107.076		-107.159				
													0.0000		0.020		-0.0199		0.24	45 degree elbow, Crane p. A-29
		45-degree elbow inlet	250	372	6	5.709	0.17777	1406	23.4	2092	34.9	0.0829		-107.056		-107.139				
													0.0000		0.098		-0.0979	28		sch 80 PVC pipe
North Branch		Tee (Line flow/Run of Tee) Outlet	250	372	6	5.709	0.17777	1406	23.4	2092.4	34.9	0.0829		-106.958		-107.041				
													0.0737		0.025		-0.0986		0.30	Tee Line Flow, Crane p. A-29
		Tee (Line flow/Run of Tee) Inlet	83	123	6	5.709	0.17777	467	7.8	694.7	11.6	0.0091		-106.933		-106.942				
													0.0000		0.066		-0.0663	148		sch 80 PVC pipe
		45-degree elbow outlet	83	123	6	5.709	0.17777	467	7.8	694.7	11.6	0.0091		-106.867		-106.876				
													0.0000		0.002		-0.0022		0.24	45 degree elbow, Crane p. A-29
		45-degree elbow inlet	83	123	6	5.709	0.17777	467	7.8	694.7	11.6	0.0091		-106.865		-106.874				
													0.0000		0.002		-0.0022	5		sch 80 PVC pipe

URS

CALCULATION SHEET

Calc No. _____

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Project Cooper Drum Vadose Zone Remedial Action Job No. 18500147.08010

Subject SVE Friction Losses Calculation Sheet _____ of 4

Temperature =	65	^oF
Kinemateic Viscosity of Air @ Temp =	0.00017	ft^2/s
Vacuum at Inlet =	-10	in Hg
Pressure (Absolute) =	19.92	inch Hg
Density (STD) =	0.075	lbm/ft^3
Density Factor =	0.672	
Density (Actual) =	0.0504	lbm/ft^3

dTP = Friction Loss or Minor Loss
Friction Loss = Darcy Equation
Minor Loss = C_oVP_o

To DPE-9

Point / Run		Description	Q_{STD} ft^3/min_{STD}	Q_{ACT} ft^3/min_{ACT}	Diameter (in)	Manufac. Diam. (in)	Area ft^2	$Velocity_{STD}$ ft/min_{STD}	$Velocity_{STD}$ ft/s_{STD}	$Velocity_A$ ft/min_{ACT}	$Velocity_A$ ft/s_{ACT}	inches WG VP_A	Delta VP_A	TP_A	Delta TP_A	SP_A	Delta SP_A	Length ft	Coefficient C_o	Remarks
DPE-7		Tee (Line flow/Run of Tee) Outlet	83	123	6	5.709	0.17777	467	7.8	694.7	11.6	0.0091		-106.862		-106.872				
													0.0051		0.003		-0.0112		0.30	Tee Line Flow, Crane p. A-29
		Tee (Line flow/Run of Tee) Inlet	55	82	6	5.709	0.17777	309	5.2	460	7.7	0.0040		-106.860		-106.864				
													0.0000		0.003		-0.0033	16		sch 80 PVC pipe
DPE-8		Tee (Line flow/Run of Tee) Outlet	55	82	6	5.709	0.17777	309	5.2	460.3	7.7	0.0040		-106.856		-106.860				
													0.0030		0.001		-0.0042		0.30	Tee Line Flow, Crane p. A-29
		Tee (Line flow/Run of Tee) Inlet	28	42	6	5.709	0.17777	158	2.6	234.3	3.9	0.0010		-106.855		-106.856				
													0.0000		0.002		-0.0024	40		sch 80 PVC pipe
		90-degree elbow outlet	28	42	6	5.709	0.17777	158	2.6	234.3	3.9	0.0010		-106.853		-106.854				
													0.0000		0.000		-0.0005		0.45	90 degree elbow, Crane p. A-29
		90-degree elbow intlet	28	42	6	5.709	0.17777	158	2.6	234	3.9	0.0010		-106.852		-106.853				
													0.0000		0.000		0.0000	0		Reducing bushing in tee
		Transition outlet, round, 6"	28	42	6	5.709	0.17777	158	2.6	234.3	3.9	0.0010		-106.852		-106.853				
													-0.0043		0.000		0.0039		0.4	Abrupt expnasion, D2/D1 = 2:1
		Transition inlet, round, 4"	28	42	4	3.786	0.07818	358	6.0	532.9	8.9	0.0054		-106.852		-106.857				
													0.0000		0.0049		-0.0049	11		sch 80 PVC pipe
Well Vaults		Gate Vavle Outlet	28	42	4	3.786	0.07818	358	6.0	532.9	8.9	0.0054		-106.847		-106.852				
													0.0000		0.001		-0.0007		0.136	4-in gate Valve
		Gate Valve Inlet	28	42	4	3.786	0.07818	358	6.0	532.9	8.9	0.0054		-106.846		-106.852				
													0.0000		0.0004		-0.0004	1		sch 80 PVC pipe
		90-degree elbow outlet	28	42	4	3.786	0.07818	358	6.0	533	8.9	0.0054		-106.846		-106.851				
													0.0000		0.0024		-0.0024		0.45	90 degree elbow, Crane p. A-29
		90-degree elbow intlet	28	42	4	3.786	0.07818	358	6.0	532.9	8.9	0.0054		-106.843		-106.849				
													0.0000		0.00013		-0.0001	0.3		sch 80 PVC pipe
		Vacuum pipe inlet at well head	28	42	4	3.786	0.07818	358	6.0	532.9	8.9	0.0054		**-106.843**		-106.849				

Vacuum @ well head =	7.9	in Hg
Loss through conveyance system =	-2.15	in Hg
Vacuum Desired at Well Head =	6	in Hg
Design =	**OK**	

URS

CALCULATION SHEET

Calc No. _____

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Project Cooper Drum Vadose Zone Remedial Action Job No. 18500147.08010

Subject SVE Friction Losses Calculation Sheet _____ of 4

Temperature =	65	°F
Kinemateic Viscosity of Air @ Temp =	0.00017	ft^2/s
Vacuum at Inlet =	-10	in Hg
Pressure (Absolute) =	19.92	inch Hg
Density (STD) =	0.075	lbm/ft^3
Density Factor =	0.672	
Density (Actual) =	0.0504	lbm/ft^3

dTP = Friction Loss or Minor Loss
Friction Loss = Darcy Equation
Minor Loss = C_oVP_o

To DPE-3

Point / Run		Description	Q_{STD} ft^3/min_{STD}	Q_{ACT} ft^3/min_{ACT}	Diameter (in)	Manufac. Diam. (in)	Area ft^2	$Velocity_{STD}$ ft/min_{STD}	$Velocity_{STD}$ ft/s_{STD}	$Velocity_A$ ft/min_{ACT}	$Velocity_A$ ft/s_{ACT}	inches WG VP_A	Delta VP_A	TP_A	Delta TP_A	SP_A	Delta SP_A	Length ft	Coefficient C_o	Remarks
Treatment System @ Treatment Pad		Blower Inlet	250	372	3	2.839	0.04396	5687	94.8	8461	141.0	1.3552		-136.087		-137.442				
													0.0000		0.109			1		sch 80 PVC pipe
		Reducer Outlet	250	372	3	2.839	0.04396	5687	94.8	8461	141.0	1.3552		-135.978		-137.333				
													0.9267		0.786				0.58	Reducer, Crane p. A 29
		Reducer inlet	250	372	4	3.786	0.07818	3198	53.3	4758	79.3	0.4285		-135.192		-135.620				
													0.0000		0.212		-2.0340	8		sch 80 PVC pipe
		90-degree elbow outlet	250	372	4	3.786	0.07818	3198	53.3	4758	79.3	0.4285		-134.980		-135.408				
													0.0000		0.193		-0.1928		0.45	90 degree elbow, Crane p. A-29
		90-degree elbow intlet	250	372	4	3.786	0.07818	3198	53.3	4758	79.3	0.4285		-134.787		-135.215				
													0.0000		0.053		-0.0530	2		sch 80 PVC pipe
		90-degree elbow outlet	250	372	4	3.786	0.07818	3198	53.3	4758	79.3	0.4285		-134.734		-135.162				
													0.0000		0.193		-0.1928		0.45	90 degree elbow, Crane p. A-29
		90-degree elbow intlet	250	372	4	3.786	0.07818	3198	53.3	4758	79.3	0.4285		-134.541		-134.970				
													0.0000		0.026		-0.0265	1		sch 80 PVC pipe
		AWS Outlet	250	372	4	3.786	0.07818	3198	53.3	4758	79.3	0.4285		-134.515		-134.943				
													0.3456		27.217		-27.5630			dP across knockout pot = 2 in Hg
		AWS Inlet	250	372	6	5.709	0.17777	1406	23.4	2092	34.9	0.0829		-107.297		-107.380				
													0.0000		0.003		-0.0035	1		sch 80 PVC pipe
		90-degree elbow outlet	250	372	6	5.709	0.17777	1406	23.4	2092	34.9	0.0829		-107.294		-107.377				
													0.0000		0.037		-0.0373		0.45	90 degree elbow, Crane p. A-29
		90-degree elbow intlet	250	372	6	5.709	0.17777	1406	23.4	2092	34.9	0.0829		-107.256	`	-107.339				
													0.0000		0.021		-0.0210	6		sch 80 PVC pipe
		90-degree elbow outlet	250	372	6	5.709	0.17777	1406	23.4	2092	34.9	0.0829		-107.235		-107.318				
													0.0000		0.037		-0.0373		0.45	90 degree elbow, Crane p. A-29
		90-degree elbow inlet	250	372	6	5.709	0.17777	1406	23.4	2092	34.9	0.0829		-107.198		-107.281				
													0.0000		0.098		-0.0979	28		sch 80 PVC pipe
		45-degree elbow outlet	250	372	6	5.709	0.17777	1406	23.4	2092.4	34.9	0.0829		-107.100		-107.183				
													0.0000		0.020		-0.0199		0.24	45 degree elbow, Crane p. A-29
		45-degree elbow inlet	250	372	6	5.709	0.17777	1406	23.4	2092	34.9	0.0829		-107.080		-107.163				
													0.0000		0.098		-0.0979	28		sch 80 PVC pipe
South Branch		Tee (Branch) Outlet	250	372	6	5.709	0.17777	1406	23.4	2092.4	34.9	0.0829		-106.983		-107.065				
													0.0459		0.075		-0.1205		0.90	Tee Flow thru Branch, Crane p. A-29
		Tee (Branch) Inlet	167	248	6	5.709	0.17777	939	15.7	1397.7	23.3	0.0370		-106.908		-106.945				
													0.0000		0.066		-0.0659	40		sch 80 PVC pipe
DPE-5		Tee (Branch) Outlet	167	248	6	5.709	0.17777	939	15.7	1397.7	23.3	0.0370		-106.842		-106.879				
													0.0114		0.033		-0.0446		0.90	Tee Flow thru Branch, Crane p. A-29
		Tee (Branch) Inlet	139	207	6	5.709	0.17777	782	13.0	1163.4	19.4	0.0256		-106.809		-106.834				
													0.0000		0.066		-0.0656	56		sch 80 PVC pipe
DPE-4		Tee (Branch) Outlet	139	207	6	5.709	0.17777	782	13.0	1163.4	19.4	0.0256		-106.743		-106.769				
													0.0093		0.023		-0.0477		0.90	Tee Flow thru Branch, Crane p. A-29
		Tee (Branch) Inlet	111	165	6	5.709	0.17777	624	10.4	929	15.5	0.0163		-106.720		-106.736				
													0.0000		0.015		-0.0154	20		sch 80 PVC pipe
DPE-1		Tee (Line) Outlet	111	165	6	5.709	0.17777	624	10.4	929.0	15.5	0.0163		-106.705		-106.721				
													0.0070		0.005		-0.0119		0.30	Tee Line Flow, Crane p. A-29
		Tee (Line) Inlet	84	125	6	5.709	0.17777	473	7.9	703.0	11.7	0.0094		-106.700		-106.709				
													0.0000		0.009		-0.0092	20		sch 80 PVC pipe
DPE-6		Tee (Line) Outlet	84	125	6	5.709	0.17777	473	7.9	703.0	11.7	0.0094		-106.691		-106.700				
													0.0053		0.003		-0.0082		0.30	Tee Line Flow, Crane p. A-29
		Tee (Line) Inlet	55	82	6	5.709	0.17777	309	5.2	460	7.7	0.0040		-106.688		-106.692				
													0.0000		0.010		-0.0104	50		sch 80 PVC pipe
		90-degree elbow outlet	55	82	6	5.709	0.17777	309	5.2	460.3	7.7	0.0040		-106.677		-106.681				

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CALCULATION SHEET

Calc No. _____

Signature _____ Date _____ Checked VS Date 3/26/2007

Project Cooper Drum Vadose Zone Remedial Action

Job No. 18500147.08010

Subject SVE Friction Losses Calculation

Sheet _____ of 4

Temperature =	65	°F
Kinemateic Viscosity of Air @ Temp =	0.00017	ft^2/s
Vacuum at Inlet =	-10	in Hg
Pressure (Absolute) =	19.92	inch Hg
Density (STD) =	0.075	lbm/ft^3
Density Factor =	0.672	
Density (Actual) =	0.0504	lbm/ft^3

dTP = Friction Loss or Minor Loss
Friction Loss = Darcy Equation
Minor Loss = C_oVP_o

To DPE-3

Point / Run		Description	Q_{STD} ft^3/min_{STD}	Q_{ACT} ft^3/min_{ACT}	Diameter (in)	Manufac. Diam. (in)	Area ft^2	$Velocity_{STD}$ ft/min_{STD}	$Velocity_{STD}$ ft/s_{STD}	$Velocity_A$ ft/min_{ACT}	$Velocity_A$ ft/s_{ACT}	inches WG VP_A	Delta VP_A	TP_A	Delta TP_A	SP_A	Delta SP_A	Length ft	Coefficient C_o	Remarks
													0.0000		0.002		-0.0018		0.45	90 degree elbow, Crane p. A-29
		90-degree elbow intlet	55	82	6	5.709	0.17777	309	5.2	460.3	7.7	0.0040		-106.676		-106.680				
													0.0000		0.0042		-0.0042	20		sch 80 PVC pipe
DPE-2		Tee (Line) Outlet	55	82	6	5.709	0.17777	309	5.2	460.3	7.7	0.0040		-106.671		-106.675				
													0.0030		0.001		-0.0042		0.30	Tee Line Flow, Crane p. A-29
		Tee (Line) Inlet	28	42	6	5.709	0.17777	158	2.6	234.3	3.9	0.0010		-106.670		-106.671				
													0.0000		0.0047		-0.0047	80		sch 80 PVC pipe
		Transition outlet, round, 6"	28	42	6	5.709	0.17777	158	2.6	234	3.9	0.0010		-106.665		-106.667				
													-0.0043		0.0004		0.0039		0.4	Abrupt expnasion, D2/D1 = 2:1
		Transition inlet, round, 4"	28	42	4	3.786	0.07818	358	6.0	532.9	8.9	0.0054		-106.665		-106.670				
													0.0000		0.005		-0.0049	11		sch 80 PVC pipe
		Gate Vavle Outlet	28	42	4	3.786	0.07818	358	6.0	532.9	8.9	0.0054		-106.660		-106.666				
DPE-3 Well Vaults													0.0000		0.001		-0.0007		0.136	4-in gate Valve
		Gate Valve Inlet	28	42	4	3.786	0.07818	358	6.0	532.9	8.9	0.0054		-106.659		-106.665				
													0.0000		0.000		-0.0004	1		sch 80 PVC pipe
		90-degree elbow outlet	28	42	4	3.786	0.07818	358	6.0	532.9	8.9	0.0054		-106.659		-106.664				
													0.0000		0.002		-0.0026		0.45	90 degree elbow, Crane p. A-29
		90-degree elbow intlet	28	42	4	3.786	0.07818	358	6.0	533	8.9	0.0054		-106.657		-106.662				
													0.0000		0.000		-0.0001	0.3		sch 80 PVC pipe
		Vacuum pipe inlet at well head	28	42	4	3.786	0.07818	358	6.0	532.9	8.9	0.0054		**-106.656**		-106.662				

Vacuum @ well head =	7.84	in Hg
Loss through conveyance system =	-2.16	in Hg
Vacuum Desired at Well Head =	6	in Hg
Design =	**OK**	

GWE System Friction Loss Calculations

SAMPLE CALCULATIONS - Cooper Drum GW Pipe Network

Temperature =	60	°F
Kinematic Viscosity of Water @ Temp =	1.217E-05	ft^2/s
RediFlo 4, 5E8 Total Dynamic Head (TDH) at 5 gpm =	100.00	ft (from pump performance curve)
Density =	62.37	lbm/ft^3
g =	32.2	ft/s^2
g_c =	32.2	$lbm\text{-}ft/lbf\text{-}s^2$

A. Calculate the velocity of the groundwater in the pipe

$$V = \frac{Q}{A}$$

where,

Q = flow rate, gallons per minute (gpm)

A = cross sectional area of pipe, square feet (ft^2)

For a 1 inch sch 80 PVC pipe,

A = 0.0048 ft^2

$$V = \frac{5\ gpm}{(0.0048\ ft^2 * 1.59\ gal/ft^3 * 60\ sec/min)} = 2.33 \text{ feet per second (fps)}$$

B. Calculate the Reynolds Number

$$Re = \frac{vd}{\upsilon}$$

where,

v = velocity in the pipe, fps

d = inner diameter of the pipe, in

υ = kinematic viscosity, ft^2/s

$$Re = \frac{(2.33\ fps)*(1.93\ in/12\ in/ft)}{1.217\ e\text{-}5\ ft^2/s} = 30{,}792$$

The flow is turbulent, Re > 3000

C. Calculate the Darcy friction factor (*f*)

$$f = \frac{0.316}{Re^{0.25}}$$

(Applying Blassius Equation for $Re<10^5$ in a smooth pipe)

$$f = \frac{0.316}{(30{,}792)^{0.25}} = 0.023$$

D. Calculate the Losses from the Pump through the Well Vault

Throughout the piping network, the friction losses and minor losses are calculated. The minor losses from the pump through the well vault is estimated via the method of loss coefficients. The minor losses throughout the network uses the method of equivalent lengths

D1. Calculate the losses from the pump discharge through the first fitting

The friction loss through pipe is:

$$h_L = \frac{f L v^2}{2 d g}$$

where,

L = the length of pipe (ft)
g = the gravitational constant (ft/s^2)

$$h_L = \frac{[0.023*1\ ft*(2.33\ fps)^2]}{(2*1.93\ in/12\ in/ft*32.2\ ft/s^2)} = 0.012\ ft$$

Calculate the change in the total dynamic head (TDH)

$$\text{delta TDH} = h_L + (z_i - z_o)$$

z_i = 45 ft
z_o = 44 ft

delta TDH = 0.03 ft + [45 ft- 44 ft]
delta TDH = 1.03 ft

The TDH at the check valve is then,

TDH = 100 ft - 1.03 ft
TDH = 98.97 ft

D2. Calculate the losses through the first fitting (gate valve)

The friction loss through the fitting (loss coefficient method)

$$h_L = K\frac{v^2}{2g}$$

where,

K = Loss coeficient (using value from Crane, Flow of Fluids (Technical Paper #410), page A-27)

K = 9.66 (from above reference)

$$h_L = \frac{(9.66)*(2.33\ fps)^2}{2*32.2\ ft/s^2} = 0.80\ ft$$

D2. (cont'd.)

At check valve,

z_i = 44 ft

z_o = 43 ft

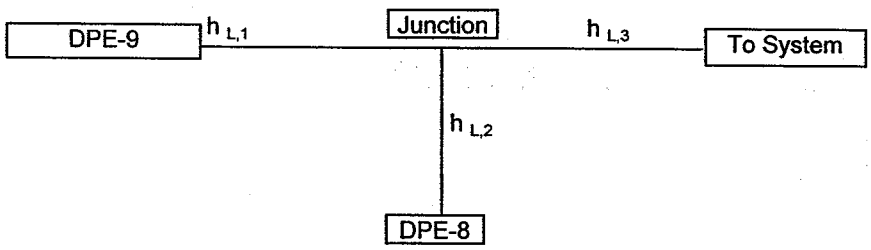
delta TDH = 0.8 ft + [44 ft -43 ft]
delta TDH = 1.08 ft

The TDH after the check valve is then,

TDH = 98.97 ft - 1.08 ft
TDH = 97.2 ft

E. Calculate the TDH leaving the junction from DPE-9 and DPE-8

Through the pipe network, the equivalent lengths method was used to calculate the losses through the system.



E1. Calculate the velocity from DPE-9

$$v = \frac{5\ \text{gpm}}{(0.0048\ \text{ft}^2 * 1.59\ \text{gal/ft}^3 * 60\ \text{sec/min})} = 2.33 \text{ feet per second (fps)}$$

E2. Calculate the friction loss, $h_{L,1}$. Use Bernoulli's equation to calculate the pressure at the junction, $P_{junction}$.

$$h_{L,1} = \frac{[0.023*202.27\ \text{ft}*(2.33\ \text{fps})^2]}{(2*1.93\ \text{in/12 in/ft}*32.2\ \text{ft/s}^2)} = 2.43\ \text{ft}$$

where,

L = 202.57 ft (see equivalent length calcualtion sheet)

Bernoulli's Equation

$$Z_{DPE-9} = Z_{junction} + \frac{P_{junction}}{\gamma} + h_{L,1}$$

where,

γ = the specific weight of water, 62.4 lb/ft^3
(From Crane Manual, page 4-8)

E2. (cont'd)

At this junction,

Z_{DPE-9} = 54.8 ft

$Z_{junction}$ = 3 ft

Since the distances and components between DPE-9 and the junction and DPE-8 and the junction are same, $h_{L,2} = h_{L,1}$ = 2.

$P_{jucntion}$ = 3216.1 lb/ft^2

$P_{jucntion}$ = 22.3 psi

E3. Use $P_{junction}$ to calculate the friction loss from DPE-8, $h_{L,2}$

Bernoulli's Equation

$$Z_{DPE-8} = Z_{junction} + \frac{P_{junction}}{\gamma} + h_{L,2}$$

where,

Z_{DPE-8} = 54.8 ft

$Z_{junction}$ = 3 ft

$h_{L,2}$ = 2.43 ft

E4. Calculate the friction loss after the junction, $h_{L,3}$

The combined flow from the junction is,

$Q_{junction} = Q_{DPE-9} + Q_{DPE-8}$

$Q_{junction}$ = 5 gpm + 5 gpm

$Q_{junction}$ = 10 gpm

The velocity in the 2 inch HDPE pipe is,

$$v = \frac{10 \text{ gpm}}{(0.0048 \text{ ft}^2 * 1.59 \text{ gal/ft}^3 * 60 \text{ sec/min})} = 4.66 \text{ fps}$$

Therefore,

Re = 29,886

f = 0.023

Therefore, the $h_{L,3}$ is:

$$h_{L,3} = \frac{[0.023*16 \text{ ft}* (4.66 \text{ fps})^2]}{(2*1.93 \text{ in/12 in/ft}*32.2 \text{ ft/s}^2)} = 0.77 \text{ ft.}$$

where,

L = 16 ft, the distance from the junction to the next junction

E5. Calulcate the TDH at the exit of the junction, Z_{system}

Bernoulli's Equation

$$Z_{system} = Z_{junction} + \frac{P_{junction}}{\gamma} - h_{L,3}$$

Z_{system} = 46.9 ft

References:
1. *Flow of Fluids through Valves, Fittings, and Pipe*. CRANE Technical Paper #410
2. *Industrial Ventilation - A Manual of Recommended Practice*. Edition 22, 1995

Equivalent Length Calculations

Well Vault

Description	Diameter (in)	Qty	L_e (ft)	Ext. L_e (ft)
90 degree elbow	1	2	5.2	10.4
Union	1	2	0.29	0.58
Ball Valve	1	1	0.29	0.29
Globe Valve	1	1	45	45
Swing Check Valve	1	1	11	11
In-line Check Valve (vertical)	1	1	33	33
Sch 80 PVC	1	50	1	50

L_e = 150.27 ft

From DPE-9 to Junction 52 ft

L_e = 202.27 ft

URS

CALCULATION SHEET

Calc No. 1

Signature _____ Date 12/12/2006 Checked _____ Date _____

Project Cooper Drum

Job No. 18500147.08010

Subject Friction Losses - GWE System

Sheet 1 of 3

Temperature =	60	°F
Kinemateic Viscosity of Water @ Temp =	1.217E-05	ft^2/s
RediFlo 4, 5E8 TDH at 5 gpm =	100.00	ft
Density =	62.37	lbm/ft^3
g =	32.2	ft/s^2
g_c =	32.2	$lbm\text{-}ft/lbf\text{-}s^2$

delta TDH = Friction Loss or Minor Loss
Friction Loss = Darcy Equation
Minor Loss = $K(V^2/2g)$
SCH 80 PVC

Nom Dia.	ID (in)	ID (ft)
1	0.936	0.078
2	1.913	0.159

Point / Run	Description	Elevation ft	Q_{STD} gpm	Diameter (in)	Manufac. Diam. (in)	Area ft^2	Velocity ft/sec	Re	f	P psi	TDH ft	delta TDH ft	h_f ft	Length ft	Coefficient K	Remarks
	From DPE-7 junction	-3	15	2	1.913	0.0200	1.67	21934	0.026	18.4	42.6	-	1.3	182		From Southern Branch
	From DPE-5 junction	-3	30	2	1.913	0.0200	3.35	43869	0.022	11.0	25.5	-	0.95	40		From Northern branch
	From Main jucntion	-3	45	2	1.913	0.0200	5.02	65803	0.020	8.5	19.7	-	2.7	56		To treatment pad
	90 degree inlet	-3	45	2	1.913	0.0200	5.02	65803	0.020	8.5	19.7	0.22	0.2		0.57	From Crane, standard elbow K = $30f_T$
	90 degree outlet	-3	45	2	1.913	0.0200	5.02	65803	0.020	8.4	19.5	1.94	1.9	40		
	90 degree inlet	-3	45	2	1.913	0.0200	5.02	65803	0.020	7.6	17.6	0.22	0.2		0.57	From Crane, standard elbow K = $30f_T$
	90 degree outlet	-3	45	2	1.913	0.0200	5.02	65803	0.020	7.5	17.3	10.48	0.5	10		
	90 degree inlet	7	45	2	1.913	0.0200	5.02	65803	0.020	3.0	6.9	0.22	0.2		0.57	From Crane, standard elbow K = $30f_T$
	90 degree outlet	7	45	2	1.913	0.0200	5.02	65803	0.020	2.9	6.6	0.10	0.1	2		
	Pipe Exit inlet	7	45	2	1.913	0.0200	5.02	65803	0.020	2.8	6.5	0.39	0.4		1	From Crane
	Pipe Exit Outlet	7	45	2	1.913	0.0200	5.02	65803	0.020	2.7	6.2	-	-			

Pressure Loss through Branch= 5.9 psi

URS

CALCULATION SHEET

Calc No. _____

Signature _____ Date 12/12/2006 Checked _____ Date _____

Project Cooper Drum Job No. 18500147.08010

Subject Friction Losses - GWE System Sheet 2 of 3

Temperature =	60	°F
Kinemateic Viscosity of Water @ Temp =	1.217E-05	ft^2/s
RediFlo 4, 5E8 TDH at 5 gpm =	100.00	ft
Density =	62.37	lbm/ft^3
g =	32.2	ft/s^2
g_c =	32.2	$lbm\text{-}ft/lbf\text{-}s^2$

delta TDH = Friction Loss or Minor Loss
Friction Loss = Darcy Equation
Minor Loss = $K(V^2/2g)$
SCH 80 PVC

Nom Dia.	ID (in)	ID (ft)
1	0.936	0.078
2	1.913	0.159

Point / Run	Description	Elevation ft	Q_{STD} gpm	Diameter (in)	Manufac. Diam. (in)	Area ft^2	Velocity ft/sec	Re	f	P psi	TDH ft	h_f ft	Length ft	Remarks
	From DPE-3	-3	5	1	0.936	0.0048	2.33	14943	0.029	23.7	54.8	7.49	242.27	Eq. Length for vault and pipe run to junction, plus TDH calculated at well vault calculation
	From DPE-2	-3	5	1	0.936	0.0048	2.91	18666	0.027	21.8	50.3	7.49	155.27	Eq. Length for vault and pipe run to junction
	From DPE-2 junction	-3	10	1	0.936	0.0048	4.66	29886	0.024	16.5	38.2	9.15	88	From Junction to next junction
	From DPE-6	-3	5	1	0.936	0.0048	2.33	14943	0.029	13.9	32.0	25.80	225.27	Eq. Length for vault and pipe run to junction
	From DPE-6 junction	-3	15	2	1.913	0.0200	1.67	21934	0.026	12.5	28.9	0.09	12	From Junction to next junction
	From DPE-1	-3	5	1	0.936	0.0048	2.33	14943	0.029	13.8	31.8	25.97	155.27	Eq. Length for vault and pipe run to junction
	From DPE-1 junction	-3	20	2	1.913	0.0200	2.23	29246	0.024	12.4	28.6	0.23	20	From Junction to next junction
	From DPE-4	-3	5	1	0.936	0.0048	2.33	14943	0.029	13.6	31.4	26.44	210.27	Eq. Length for vault and pipe run to junction
	From DPE-4 junction	-3	25	2	1.913	0.0200	2.79	36557	0.023	11.9	27.4	0.97	56	From Junction to next junction
	From DPE-5	-3	5	1	0.936	0.0048	2.33	14943	0.029	12.7	29.4	28.38	155.27	Eq. Length for vault and pipe run to junction
	From DPE-5 junction	-3	30	2	1.913	0.0200	3.35	43869	0.022	11.0	25.5	0.95	40	From Junction to next junction

Pressure Loss through Branch= 12.7 psi

URS

CALCULATION SHEET

Calc No. _____

Signature _____ Date 11/28/2006 Checked _____ Date _____

Project Cooper Drum Job No. 18500147.08010

Subject Friction Losses - GWE System Sheet 3 of 3

Temperature =	60	°F
Kinemateic Viscosity of Water @ Temp =	1.217E-05	ft^2/s
RediFlo 4, 5E8 TDH at 5 gpm =	100.00	ft
Density =	62.37	lbm/ft^3
g =	32.2	ft/s^2
g_c =	32.2	$lbm\text{-}ft/lbf\text{-}s^2$

delta TDH = Friction Loss or Minor Loss
Friction Loss = Darcy Equation
Minor Loss = $K(V^2/2g)$
SCH 80 PVC

Nom Dia.	ID (in)	ID (ft)
1	0.936	0.078
2	1.913	0.159

Point / Run	Description	Elevation ft	Q_{STD} gpm	Diameter (in)	Manufac. Diam. (in)	Area ft^2	Velocity ft/sec	Re	f	P psi	TDH ft	h_f ft	Length ft	Remarks
	DPE-9	-3	5	1	0.936	0.0048	2.33	14943	0.029	23.7	54.8	6.26	202.27	Eq. Length for vault and pipe run to junction, plus TDH calculated at well vault calculation
	From DPE-8	-3	5	1	0.936	0.0048	2.24	14385	0.029	22.3	51.6	6.26	218.27	Eq. Length for vault and pipe run to junction
	From DPE-8 junction	-3	10	1	0.936	0.0048	4.66	29886	0.024	20.3	46.9	1.66	16	From Junction to next junction
	From DPE-7	-3	5	1	0.936	0.0048	3.58	22959	0.026	23.7	54.8	10.94	178.27	
	From DPE-7 junction	-3	15	2	1.913	0.0200	1.67	21934	0.026	18.4	42.6	1.3	182	

Pressure Loss through Branch= 5.3 psi

URS

CALCULATION SHEET

Calc No. _____

Signature _____ Date 11/28/2006 Checked _____ Date _____

Project Cooper Drum Job No. 18500147.08010

Subject Friction Losses - GWE System Sheet 1 of 1

Temperature =	60	°F
Kinemateic Viscosity of Water @ Temp =	1.217E-05	ft^2/s
RediFlo 4, 5E8 TDH at 5 gpm =	100.00	ft
Density =	62.37	lbm/ft^3
g =	32.2	ft/s^2
g_c =	32.2	$lbm\text{-}ft/lbf\text{-}s^2$

delta TDH = Friction Loss or Minor Loss
Friction Loss = Darcy Equation
Minor Loss = $K(V^2/2g)$
SCH 80 PVC

Nom Dia.	ID (in)
1	0.936
2	1.913

Point / Run		Description	Elevation ft	Q_{STD} gpm	Diameter (in)	Manufac. Diam. (in)	Area ft^2	Velocity ft/sec	Re	f	P psi	TDH ft	delta TDH ft	h_L ft	Length ft	Coefficient K	Remarks
Well Vault		Well DPE-8 (Discharge)	-45	5	1	0.936	0.0048	2.33	14943	0.029	43.3	100.0					From literature, RediFlo4, 5E8, 5 gpm = 100 ft or 43.3 psi
													1.03	0.03	1		From pump discharge to the check valve
		Check Valve inlet	-44	5	1	0.936	0.0048	2.33	14943	0.029	42.8	99.0					
													1.82	0.82		9.66	From Crane, as foot valve with strainer K = $420f_T$
		Check Valve outlet	-43	5	1	0.936	0.0048	2.33	14943	0.029	42.1	97.2					
													43.4	1.39	45		From check valve to 90 degreee elbow
		90 degree inlet	-1	5	1	0.936	0.0048	2.33	14943	0.029	23.3	53.8					
													0.06	0.06		0.69	From Crane, standard elbow K = $30f_T$
		90 degree outlet	-1	5	1	0.936	0.0048	2.33	14943	0.029	23.2	53.7					
													-0.94	0.06	2		From one 90 degree to another 90 degree elbow
		Gate Valve Inlet	-2	5	1	0.936	0.0048	2.33	14943	0.029	23.7	54.6					
													0.66	0.66		7.82	From Crane, globe valve K = $340f_T$
		Gate Valve outlet	-2	5	1	0.936	0.0048	2.33	14943	0.029	23.4	54.0					
													0.03	0.03	1		From gate vlave outlet to 90 degree bend
		90 degree inlet	-2	5	1	0.936	0.0048	2.33	14943	0.029	23.4	54.0					
													0.06	0.06		0.69	From Crane, standard elbow K = $30f_T$
		90 degree outlet	-2	5	1	0.936	0.0048	2.33	14943	0.029	23.3	53.9					
													-0.97	0.03	1		From one 90 degree to another 90 degree elbow
		90 degree inlet	-3	5	1	0.936	0.0048	2.33	14943	0.029	23.7	54.9					
													0.06	0.06		0.69	From Crane, standard elbow K = $30f_T$
		90 degree outlet	-3	5	1	0.936	0.0048	2.33	14943	0.029	23.7	54.8					

Pressure Loss from Well through Vault

P = 19.6 psi