APPENDIX B
Landfill Off-Gas Collection System Calculations

B.1. **General**. The following is a hypothetical example that illustrates the calculations used in the design of an off-gas collection and treatment system (Emcon Associates 1980).

B.1.1. *Site Background Information.* The 25-acre Westslope Landfill is located near Omaha, Nebraska and accepted municipal, industrial and construction debris from the neighboring communities from 1970 to 1995. In 1972 the state required a 6-inch daily cover be used to minimize odors. In 1999, the State required that the landfill be closed with a multi-layer cap composed of a 6 inch grading layer, a 40-mil HDPE geomembrane, a geonet drainage layer, and 24 inches of cover soil. The State also required that an active gas control system be installed to limit off-site subsurface migration of landfill gas to 10% of the LEL for methane. A housing development is located adjacent to the landfill on the south side of Center Street. A plan view of the site is shown in Figure B.1.

B.1.2. *Site Geology.* Bedrock consisting of weathered limestone underlies the site at approximately elevation 980 in the central area of the landfill. The bedrock slopes gently to the east. The overburden soils consist of 20 to 30 feet of silty sand. Ground water fluctuates seasonally at the site and is approximately 15 feet below the original ground surface.

B.1.3. *Objective*

- Design an active landfill gas collection system that consists of vertical extraction wells to prevent the off-site migration of gas.
- Design an enclosed flare to destroy methane and non-methanogenic organic compounds (NMOCs) in the collected gas.

B.2. **Site Characteristics**

- Landfill footprint = 25 acres
- Volume of waste = 1,700,000 cy

B.3. **Refuse Characteristics**

- Average age of Refuse = 20 to 25 years
- In-Place Refuse Density = 1,200 lbs/cy
- Capping Material = 40 mil HDPE
- Maximum Depth = 45 feet

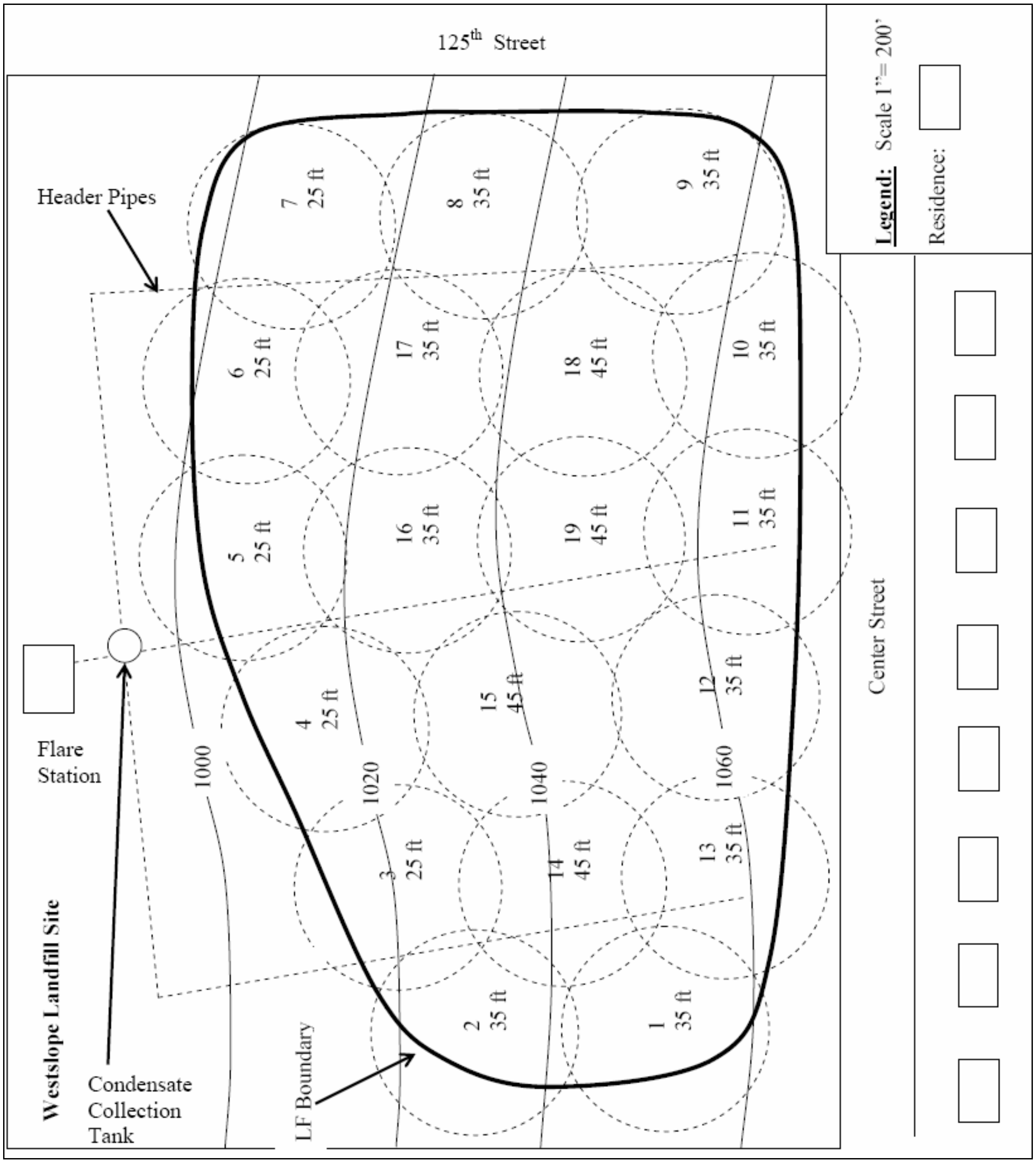


Figure B.1. Plan View of the Site.

B.4. **Gas Characteristics**

- Landfill gas emission rate = 1.6×10^{-4} $ft^3/(lb\ day)$
- Concentration of methane in gas = 50 percent
- Assumed radius of influence of extraction wells = 150 feet
- Temperature of landfill gas = 110ºF
- Landfill Gas Viscosity = 2.58×10^{-7} lb s/ft^2

B.5. **Calculations for the Off-Gas Collection System**

B.5.1. *Sample Problem Design Calculations*

B.5.1.1. *General Assumptions.*

V = volume of waste (1,700,000 cy)
D = density of waste (45 lb/ft^3)
G = methane production rate = 1.6×10^{-4} $ft^3/(lb\ day)$

B.5.1.2. *Flow Rate for Entire Landfill.*

Q_{tot} = (volume of waste)(D)(G)
Q_{tot} = (1,700,000 yd^3)(27ft^3/yd^3)(45lb/ft^3) [1.6×10^{-4} $ft^3/(lb\ day)$]
Q_{tot}= 330,480 ft^3/day = 230 ft^3/min (methane)

As methane is 50% of the landfill gas produced, the total flow rate of extracted landfill gas is:

2×230 ft^3/min = 460 ft^3/min

B.5.1.3. *Determine Flow Rates from a particular well (Cylinder Method).*

$$Q = \pi (R^2 - r^2)\, t\, D\, G$$

where:

Q = methane flow rate
R = radius of influence
r = borehole radius (assumed to be 12 inches for all wells [which is negligible])
t = waste thickness
D = density of waste (45 lb/ft^3)
G = methane production rate [1.6×10^{-4} $ft^3/(lb\ day)$]

B.5.1.3.1. *For 25-Foot-Deep Wells.*

R = 150 feet, t = 25 feet

$Q = \pi\,(150)^2\,(25\text{ ft})(45\text{ lb/ft}^3)[1.6 \times 10^{-4}\text{ ft}^3/(\text{lb day})] = 12{,}723\text{ ft}^3/\text{day}$

$Q = 8.84\text{ ft}^3/\text{min}$ (methane only)

Since landfill gas is 50% methane:

Landfill gas flow = 2 × 8.84 = 17.7 ft^3/min.

B.5.1.3.2. *For 35-Foot-Deep Wells.*

R = 150 feet, t = 35 feet

$Q = \pi\,(150)^2\,(35\text{ ft})(45\text{ lb/ft}^3)[1.6 \times 10^{-4}\text{ ft}^3/(\text{lb day})] = 17{,}812\text{ ft}^3/\text{day}$

$Q = 12.4\text{ ft}^3/\text{min}$ (methane only)

Landfill gas flow = 2 × 12.4 = 24.8 ft^3/min.

B.5.1.3.3. *For 45-Foot-Deep Wells.*

R = 150 feet, t = 45 feet

$Q = \pi\,(150)^2\,(45\text{ ft})(45\text{ lb/ft}^3)[1.6 \times 10^{-4}\text{ ft}^3/(\text{lb day})] = 22{,}900\text{ ft}^3/\text{day}$

$Q = 15.9\text{ ft}^3/\text{min}$ (methane only)

Landfill gas flow = 2 x 15.9 = 31.8 ft^3/min

5 wells at 17.6 ft^3/min	= 88 ft^3/min
10 wells at 24.8 ft^3/min	= 248 ft^3/min
4 wells at 31.8 ft^3/min	= 127 ft^3/min
Total	= 463 ft^3/min

B.5.1.4. *Determine Pressure Drop Required at Each Well to Maintain Assumed Radius of Influence.*

$$\Delta P = \mu G_{tot} D \left[R^2 \ln(R/r) + (r^2/2) - (R^2/2)\right] / \, 2\, K_s$$

where:

ΔP = pressure difference from the outer edge of the radius of influence to the gas vent
R = radius of influence
r = radius of borehole (assumed to be 12 inches for all wells)
μ = absolute viscosity of the landfill gas (1.21×10^{-5} N s/m^2 = 2.581×10^{-7} lb s/ft^2)
K_s = apparent permeability of the refuse (assumed to be 15 Darcy = 2.29×10^{-8} in.^{2})
D = density of the refuse (45 lb/ft^3)
G_{tot} = total landfill gas production rate (assumed to be $2 \times 1.6 \times 10^{-4}$ ft^3/(lb day).

B.5.1.4.1. *For All Wells, M (Melema Factor) =* $\mu G_{tot} D / 2 K_s$

M = [(2.581×10^{-7} lb s/ft^2)(2)[1.6×10^{-4} ft^3/(lb day)](45 lb/ft^3) (day/86,400 s)] / [(2)(2.29×10^{-8} in.^{2})(1 ft^2/144 in.^{2})]

$M = 1.314 \times 10^{-4}$ lb/ft^4

B.5.1.4.2. *For All Wells, Assumed Radius of Influence is 150 Feet.*

$$\begin{aligned}\Delta P &= M\,[R^2 \ln(R/r) + (r^2/2) - (R^2/2)]\\ &= 1.314 \times 10^{-4}\ \text{lb/ft}^4\,[(150\text{ft})^2 \ln(150\text{ ft}/1\text{ ft}) + \{(1\text{ ft})^2/2) - (150\text{ ft})^2/2\}]\\ &= 1.314 \times 10^{-4}\ \text{lb/ft}^4\,[101{,}489\ \text{ft}^2]\\ &= 13.33\ \text{lb/ft}^2\\ &= 2.57\ \text{inches of water column.}\end{aligned}$$

B.5.2. *Header Pipe Sizing.* Pipe sizing is a trade off between the capital cost of the pipe and the energy requirements of the blower. The higher cost of larger pipe must be balanced against lower horsepower requirements of the blower due to less pressure loss due to friction.

- Header pipe size = 6 inches
- Connector pipes from wells to headers = 2 inches

B.5.3. *System Curve.* The system curve is determined by computing all head losses through the system at various flow rates due to the following:

- Subsurface head loss.
- Head loss in pipes.
- Head loss through fittings and valves.

The friction losses from the subsurface, the straight pipe lengths, and the valves and fittings are added together to obtain the total friction loss at a given flow rate. Note that these calculations are performed assuming that the valves are fully open.

B.5.3.1. *Subsurface Head Loss.* Assume 2.57 inches as computed in paragraph B-5.1.

B.5.3.2. *Calculate Pipe Head-Loss.* The most common method of predicting friction losses in straight pipes is to use the Darcy-Weisbach equation:

$$h_f = f\,(L/d)(v^2/2g)$$

where:

h_f = head loss, m (ft) of fluid
f = friction factor for the pipe, dimensionless (dimensionless)
L = length of segment, m (ft)
d = inside pipe diameter, m (ft)
v = average velocity of the flow, m/sec (ft/s)
g = acceleration due to gravity (9.81 m/s² = 32.2 ft/s²).

The head loss calculated by this formula is in feet of landfill gas. The ideal gas law can be used to estimate the density of the gas passing through the header pipe. Estimate the gas density to convert pressure in feet of landfill gas to inches of water column (in wc).

Gas Density = PM/R_UT

where:

P = absolute pressure within header pipe
Assuming 30 in. wc vacuum
1 atm = 407.2 inches of water column (in wc)
P = (407.2 in. wc –30 in. wc) /407.2 in. wc = 0.926 atm
M = molecular weight of landfill gas
= 0.5 (molecular weight methane, CH_4) + 0.5(molecular weight of carbon dioxide, CO_2)
= 0.5 (12+4) + 0.5 (12+2x16) = 30 kg/kg-mole
R_U = Universal gas constant
= 0.0821 L-atm/g-mole K
T = Absolute Temperature
= 110ºF = 43.3ºC + 273.16ºK = 316.5ºK.

Landfill Gas Density = PM/R_UT
= [(0.93 atm) × (30 kg/kg-mole)] / [(0.0821 L-atm/ g-mole K) × (316.3 K) × (1000 g-mole/kg-mole)]
= 1.069×10^{-3} kg/L

Landfill Gas Density = (0.001069 kg/L × 2.205 lb/kg × 28.32 L/ft³
= 0.0668 lb/ft³

1 pound-force/square inch (PSI) = 27.6799048 inch of water [4 °C]

To convert feet of landfill gas to inches of water column, the following factor (*F*') must be applied:

F' = 0.0668 lb/ft³ × 1 ft²/144 ft²/in.² × 27.7 in. wc/(lb/in.²)
= 0.01284 in. wc/ft

Head Loss, in. wc = 0.01284 × $fLV^2/2d \times g$ = 0.0002 fLV^2/d.

B.5.3.3. *Head Loss Through Valves and Fittings.* There are two primary methods for estimating head losses through valves and fittings.

- Look up *k* values in tables (where $k = f\,L/d$ and, therefore, $h_f = k\,v^2/2g$).
- Use tabulated values of equivalent length of straight pipe. For example, the resistance in a 6-inch standard tee is equivalent to that of approximately 30 feet of 6-inch straight pipe.

B.5.3.4. *Landfill Gas Piping Flow Diagram.* The piping system consists of headers that connect to 19 wells in three manifolds (Figure B.2). The manifolds connect to a flare stack through a condensate knockout tank, blower, and flame arrestor.

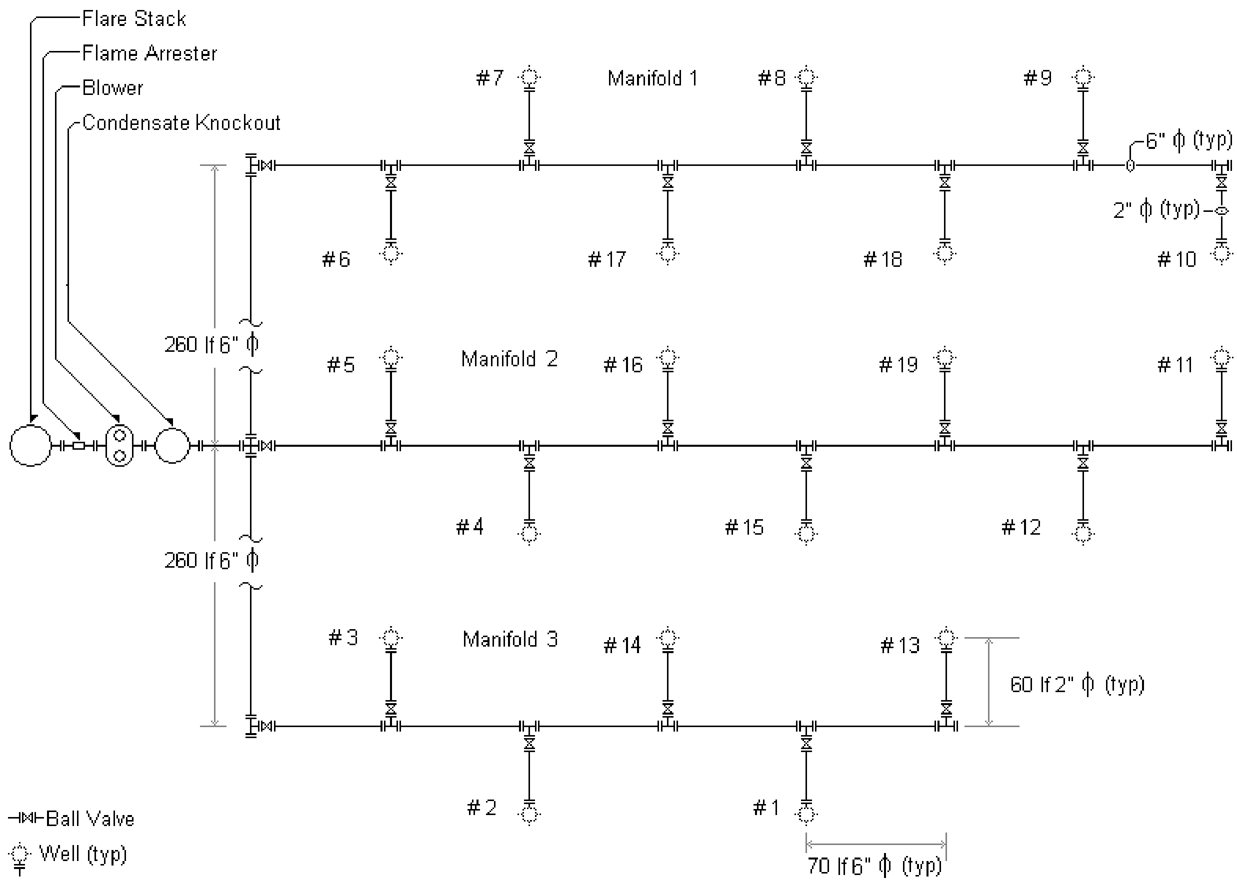


Figure B.2. Landfill Gas Piping Flow Diagram.

B.5.3.5. *Manifold 1 Calculations.* Different flow rates were used for wells installed with different screen lengths: 17.6 scfm for the 25-foot wells, 24.8 scfm for the 35-foot wells, and 31.8 scfm for the 45-foot wells. The wells are connected to a common header. The pressure loss from each well to a common point in the header was calculated to establish the required header vacuum. Following is the example calculation for header # 1. Calculations for headers #2 and #3 are similar.

B.5.3.5.1. *Well Number 10.* The approximate head loss from well #10 (flow rate of 24.8 scfm) including soil head loss (2.57 in. wc) plus wellhead losses (2.00 in. wc) plus discharge piping losses to header 1 at point b (0.668 in. wc) is 5.238 in. wc vacuum.
The following piping head losses are additive to point j:

- 0.005 in. wc vacuum—approximate b–c piping head loss
- 0.017 in. wc vacuum—approximate c–d piping head loss

- 0.039 in. wc vacuum—approximate d–e piping head loss
- 0.062 in. wc vacuum—approximate e–f piping head loss
- 0.090 in. wc vacuum—approximate f–g piping head loss
- 0.099 in. wc vacuum—approximate g–h piping head loss
- 0.132 in. wc vacuum—approximate h–i piping head loss
- 0.454 in. wc vacuum—approximate i–j piping head loss
- The total head loss from well 10 to point j is 6.136 in. wc.

B.5.3.5.2. *Well Number 18.* The approximate head loss from well #18 (flow rate of 31.8 scfm) including soil head loss (2.57 in. wc) plus wellhead losses (3.288 in. wc) plus discharge piping losses to header 1 at point d (1.099 in. wc) is 6.957 in wc vacuum.

The following piping head losses are additive to point j:

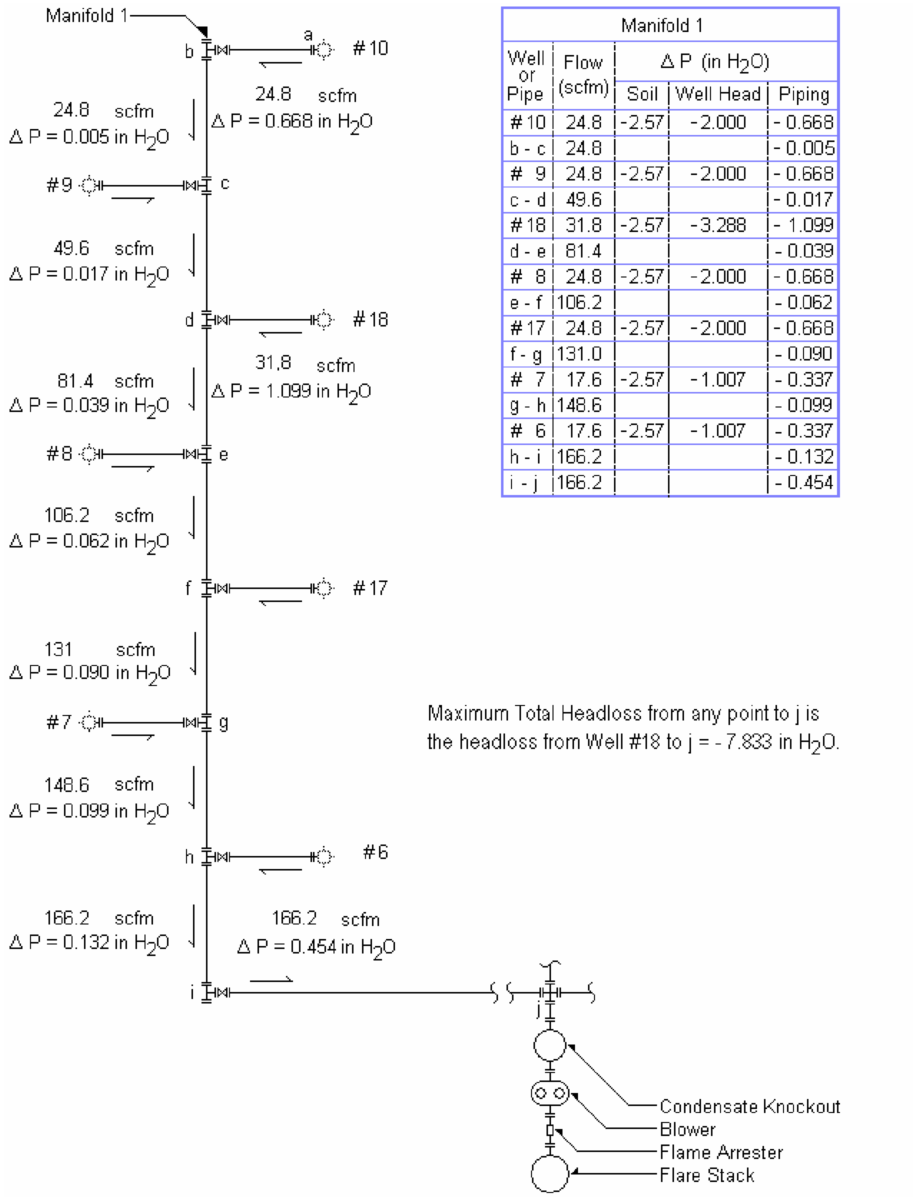
- 0.039 in. wc vacuum—approximate d–e piping head loss
- 0.062 in. wc vacuum—approximate e–f piping head loss
- 0.090 in. wc vacuum—approximate f–g piping head loss
- 0.099 in. wc vacuum—approximate g–h piping head loss
- 0.132 in. wc vacuum—approximate h–i piping head loss
- 0.454 in. wc vacuum—approximate i–j piping head loss
- The total head loss from well 18 to point j is 7.833 in. wc.

B.5.3.5.3. *Well Number 7.* The approximate head loss from well #7 (flow rate of 17.6 scfm) including soil head loss (2.57 in. wc) plus wellhead losses (1.007 in. wc) plus discharge piping losses to header 1 at point g (0.337 in. wc) is 3.914 in. wc vacuum. The following piping head losses are additive to point j:

- 0.0099 in. wc vacuum—approximate g–h piping head loss
- 0.0132 in. wc vacuum—approximate h–i piping head loss
- 0.454 in. wc vacuum—approximate i–j piping head loss
- The total head loss from well 7 to point j is 4.39 in. wc.

B.5.3.6. *Head Losses to the Blower Intake.* The total head loss from well #18 to point j exceeds the losses from well #10 and also well #7 to point j (Table B-1 and Figure B.3). Therefore the head loss in well #18 and associated piping determines the required the header vacuum. Control valves at the other wells will have to be throttled to maintain the required flow rates at those wells. The blower vacuum required is equal to the head losses to point j (7.833 in. wc) + point k–l (0.888 in. wc) + the condensate tank (2.00 in. wc) + point m–n (0.335 in. wc) = 11.076 in. wc.

B.5.3.7**.** *Calculations for Combined Flow to the Flare Stack.* Refer to the flow sheet (Figure B.4 and Table B-2) for piping from point j through the condensate knock out tank, blower, flame arrestor, and stack. The 12.444 in. wc blower discharge head requirement is the sum of head losses from point o to the stack discharge at ambient atmospheric pressure. The 12.444 in. wc represents the pressure exerted on the discharge side of the blower resulting from the various pieces of equipment attached to the discharge side of the blower.



Manifold 1				
Well or Pipe	Flow (scfm)	Δ P (in H_2O)		
		Soil	Well Head	Piping
# 10	24.8	-2.57	- 2.000	- 0.668
b - c	24.8			- 0.005
# 9	24.8	-2.57	- 2.000	- 0.668
c - d	49.6			- 0.017
# 18	31.8	-2.57	- 3.288	- 1.099
d - e	81.4			- 0.039
# 8	24.8	-2.57	- 2.000	- 0.668
e - f	106.2			- 0.062
# 17	24.8	-2.57	- 2.000	- 0.668
f - g	131.0			- 0.090
# 7	17.6	-2.57	- 1.007	- 0.337
g - h	148.6			- 0.099
# 6	17.6	-2.57	- 1.007	- 0.337
h - i	166.2			- 0.132
i - j	166.2			- 0.454

Figure B.3. Piping Head Loss Diagram

Table B-1. Piping Head Loss Calculations

Landfill Gas Piping System - Manifold 1

Dimensions of Schedule 40 HDPE Pipe

Nom	I. D.	Cross-Sectional Area.	
in.	**in.**	**in.^{2}**	**ft^2**
2	2.067	3.356	0.02331
3	3.068	7.393	0.05134
4	4.026	12.730	0.08840
6	6.065	28.890	0.20063
8	7.981	50.030	0.34743
10	10.020	78.850	0.54757

LFG Composition: 50% Methane, 50% Carbon Dioxide

MW LFG : 0.5(16) + 0.5(44) = 30

Density LFG	0.067183 lb/ft^3	
Temperature LFG	110ºF	
Absolute Viscosity LFG	2.58×10^{-7}	lb(force) s/ft2
Absolute Viscosity LFG	8×10^{-6}	lb(mass)/ft s

$Re = Dvp/u$

Head Loss, in. wc = (0.0.0002007)$fL(v^2)/D$

Node From	Node Thru	Component Type	Flow Rate CFM	Nom I.D. In.	I.D.,ft	X-Sect Vel FPS	Pipe L, ft	Ftg Loss Coef	Ftg Equiv ft pipe	Reynolds Number *Re*	Friction Factor *f*	Well h.l. in wc	Pipe h.l. in. wc	Ftg h.l. in. wc	Total h.l. in. wc
a	b	well 10	24.8									2.57			2.570
		well head	24.8	2								2			2.000
		piping	24.8	2	0.1723	17.74	60			2.47×10^4	0.0270		0.5937		0.594
		ball valve	24.8	2											0.000
		2x6	24.8	2				43	7.4					0.0732	0.073
		Tee(branch)	24.8	6	0.5054	2.06		60	30	8.42×10^3	0.0302			0.0015	0.002
		Sub-Total													5.238
18	d	well 18	31.8									2.57			2.570
		well head	31.8	2								3.288			3.288
		piping	31.8	2	0.1723	22.74	60			3.17×10^4	0.0270		0.9762		0.976
		ball valve	31.8	2				0	0.0					0.00000	0.000
		2X6	31.8	2				43	7.4					0.12051	0.121
		Tee(branch)	31.8	6	0.5054	2.64		60	30.0	1.08×10^4	0.0300			0.00249	0.002
		Sub-Total													6.958
7	g	well 7	17.6									2.57			2.570
		well head	17.6	2								1.007			1.007
		piping	17.6	2	0.1723	12.59	60			1.75×10^4	0.0270		0.2990		0.299
		ball valve	17.6												0.000
		2x6	17.6	2				43	7.4					0.03688	0.037
		Tee(branch)	17.6	6	0.5054	1.46		60	30.0	5.98×10^3	0.0350			0.00089	0.001
		Sub-Total													3.914
b	c	piping	24.8	6	0.5054	2.06	70			8.42×10^3	0.0302		0.0036		0.004
		Tee(run)	24.8	6	0.5054	2.06		20	10.0					0.00051	0.001
		Sub-Total													0.004

Node From	Node Thru	Component Type	Flow Rate CFM	Nom I.D. in	I.D.,ft	X-Sect Vel FPS	Pipe *L*, ft	Ftg Loss Coef	Ftg Equiv ft pipe	Reynolds Number *Re*	Friction Factor *f*	Well h.l. In. wc	Pipe h.l. In. wc	Ftg h.l. In. wc	Total h.l. In. wc
c	d	piping	49.6	6	0.5054	4.12	70			1.68×10^4	0.0276		0.0130		0.013
		Tee(Run)	49.6	6				20	10.0					0.00372	0.004
		Sub-Total													0.017
d	e	piping	81.4	6	0.5054	6.76	70			2.76×10^4	0.0270		0.0343		0.034
		Tee(Run)	81.4					20	10.0					0.00490	0.005
		Sub-Total													0.039
e	f	piping	106.2	6	0.5054	8.82	70			3.61×10^4	0.0251		0.0543		0.054
		Tee(Run)	106.2					20	10.0					0.00776	0.008
		Sub-Total													0.062
f	g	piping	131	6	0.5054	10.88	70			4.45×10^4	0.0240		0.0791		0.079
		Tee(Run)	131					20	10.0					0.01129	0.011
		Sub-Total													0.090
g	h	piping	148.6	6	0.5054	12.35	70			5.05×10^4	0.0230		0.0975		0.097
		Tee(Run)	148.6					20	10.0					0.00139	0.001
		Sub-Total													0.099
h	I	piping	166.2	6	0.5054	13.81	70			5.64×10^4	0.0218		0.1155		0.116
		Tee(Run)	166.2					20	10.0					0.01650	0.017
		Sub-Total													0.132
i	j	ell	166.2	6	0.5054	13.81		30	15.0	5.64×10^4	0.0218			0.02476	0.025
		piping	166.2	6	0.5054	13.81	260			5.64×10^4	0.0218		0.4292		0.429
		Sub-Total													0.454

	Unit	Flow (scfm)	Δ P (in H_2O)
j	Manifold Vacuum	463.2	- 7.833
k - l	Pipe and Fittings	463.2	- 0.888
l - m	Condensate Knockout	463.2	- 2.00
m - n	Pipe and Fittings	463.2	- 0.355
n	Blower Inlet Vacuum	463.2	- 11.076
o - p	Pipe and Fittings	463.2	+ 0.355
p - q	Flame Arrestor	463.2	+ 2.000
q - r	Pipe and Fittings	463.2	+ 0.089
s	Stack	463.2	+ 10.000
o	Blower Discharge Pressure	463.2	+ 12.444

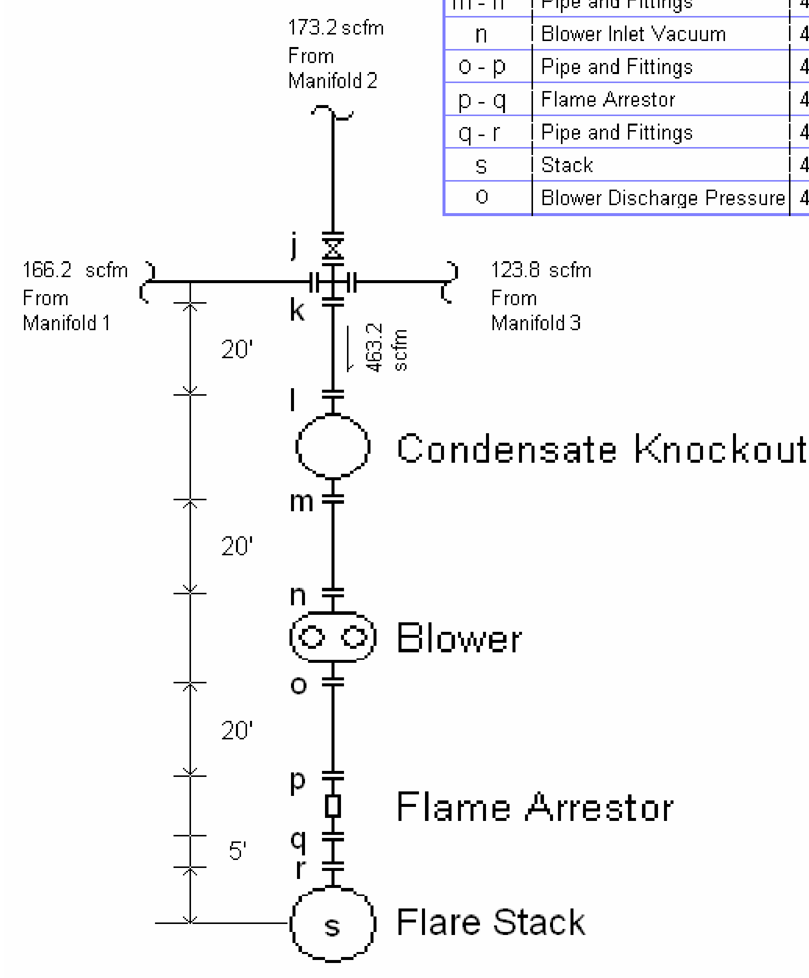


Figure B.4. Discharge Pressure Diagram

Table B-2.
Blower Discharge Pressure Calculations

Landfill Gas Piping System - Combined flow to stack

Dimensions of Schedule 40 HDPE Pipe

Nominal	**I. D.**	**Cross-Sectional Area.**	
in.	**in.**	**in.^{2}**	**ft^2**
2	2.067	3.356	0.02331
3	3.068	7.393	0.05134
4	4.026	12.730	0.08840
6	6.065	28.890	0.20063
8	7.981	50.030	0.34743
10	10.020	78.850	0.54757

LFG Composition: 50% Methane, 50% Carbon Dioxide

MW LFG : 0.5(16) + 0.5(44) = 30

Density LFG	0.067183 lb/ft^3	
Temperature LFG	110 deg F	
Absolute Viscosity LFG	2.58×10^{-7}	lb(force) s/ft2
Absolute Viscosity LFG	8.31×10^{-6}	lb(mass)/ft s

$Re = Dvp/u$

Head Loss, in. wc = $(0.0.0002007)fL(v^2)/D$

Node		**Component**	**Flow**	**Nom**	**I.D.**	**X-Sect**	**Pipe**	**Ftg**	**Ftg**	**Reynolds**	**Friction**	**Well**	**Pipe**	**Ftg**	**Press**
		Type	**Rate**	**Dia**	**ft**	**Vel**	***L*, ft**	**Loss**	**Equiv**	**Number**	**Factor**	**h.l.**	**h.l.**	**h.l.**	
From	**Thru**		**CFM**	**In.**		**FPS**		**Coef**	**ft pipe**	***Re***	**f**	**in. wc**	**in. wc**	**in. wc**	**in. wc**
j	j														–7.833
k	l	piping	463.2	6	0.5054	38.48	20			1.57×10^5	0.0302		0.3552		–0.355
		Tee(Branch)	463.2		0.5054	38.48		60	30.0					0.53271	–0.533
		Sub-Total													–0.888
l	m	condensate tank													–2.000
m	n	piping	463.2	6	0.5054	38.48	20			1.57×10^5	0.0302		0.3554		–0.355
n	n	blower inlet vacuum													–11.076
o	p	piping	463.2	6	0.5054	38.48	20			1.57×10^5	0.0302		0.3554		0.355
p	q	flame arrestor													2.000
q	r	piping	463.2	6	0.5054	38.48	5			1.57×10^5	0.0302		0.0888		0.089
r	s	stack													10.000
n	o	blower discharge pressure													12.444

B.5.4**.** *Blower Selection Considerations.* Three criteria are used to size the blower: flow (463 SCFM), head loss on the suction side of the blower (11.076 in. wc), and discharge head on the outlet side of the blower (12.444 in. wc). Based on these criteria, manufacturer's catalogs are used to select a blower that can meet these criteria. It is important to select a blower that only minimally exceeds the calculated requirements to avoid exceeding the capacity of any of the in-line treatment processes.

It is a difficult task to select a blower that will remain in an efficient operating range over the long-term because gas production varies during the life of the landfill. Consideration should be given to selection of a variable frequency blower motor drive for energy conservation and greater operating flexibility as the generation of landfill gas decreases over time.

B.5.5. *Condensate Production Rate.* Assume air is extracted at 100% relative humidity and remains at 100% relative humidity as it travels from the extraction well to the blower. Determine the amount of condensate removed as a result of the temperature drop of the gas. The gas is assumed to be at its maximum temperature as it exits the well. The gas will drop in temperature as it travels through the header piping. The length of travel, location of the header pipe, and the ambient temperature will determine the magnitude of the temperature drop over the section of header piping for which condensate generation is being computed.

A rough estimate of the amount of condensate generated can be determined using psychrometric charts for air. The following assumptions were made in order to compute the amount of condensate produced.

B.5.5.1. *Flow Rate.* The flow rate was determined to be 463 ft^3/min (218 L/s) in the above calculations.

B.5.5.2. *Temperature.* The temperature of the gas exiting the landfill is 110^{o}F (316.3 K) and drops 20^o to 90^{o}F (305 K) as it travels to the blower system.

B.5.5.3. *Potential Condensate Generated.* Psychrometric charts can be used to estimate saturated water vapor concentration at different temperatures:

Conc. of water vapor = 0.059 kg water/kg landfill gas (at 316.3 K)

Conc. of water vapor = 0.031 kg water/kg landfill gas (at 305 K)

Subtracting:

Potential Condensate = 0.028 kg water/kg landfill gas

Note that most psychometric charts are created for higher pressures than are typically found in the header pipes of a LFG collection system. However, using these charts will generally not introduce large error when estimating condensate generation.

Density of landfill gas = 1.074×10^{-3} kg/l = .067 lbs/ft^3

The flow rate times the concentration of the condensate yields the following condensate generation rate:

(0.028 kg water/kg LF gas) × (1.074×10^{-3} kg/L) × (218 L/s) × (86,400 s/day) × (1 L/kg) = 566 L/day = 150 gal/day.