# GAS MONITORING & CONTROL SYSTEM DRAFT PLAN REVIEW

**NAME OF SITE:** ____________________
**SWIS NO:** __________________________
**REVIEWER:** ____________________
**SECTION:** __________________________
**DATE:** __________________________

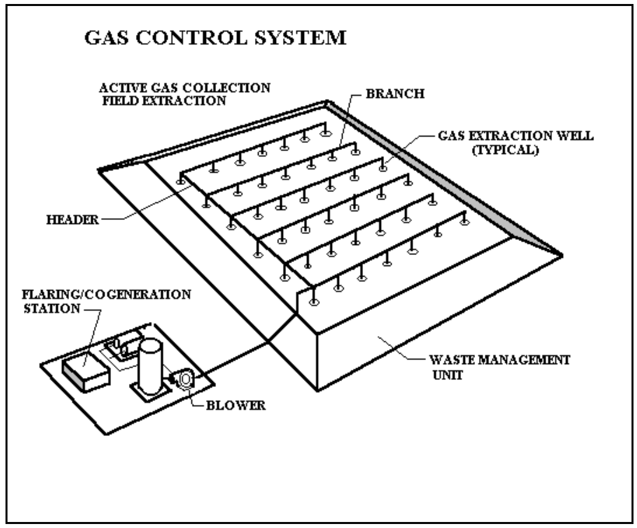


**Figure 1**: GAS CONTROL SYSTEM

**ITEMS NEEDED FOR REVIEW:**

- ☐ **Gas control system drawings**
- ☐ **Gas control system specifications**
- ☐ **Air Solid Waste Assessment Testing**
- ☐ **Gas monitoring data from site characterization report, closure plan, RDSI, or LEA site files**
- ☐ **Waste Discharge Requirements**

## A. GAS MONITORING SYSTEM REVIEW:

Review Air SWAT, Closure Plan Gas Monitoring Section, Environmental Assessments, Site Characterization Reports, Local Enforcement Agency files (pertaining to gas violations) for the following information:

### 1) Factors which effect gas migration:

#### a) methane concentrations in the fill:

| | | % methane | migration potential |
|---|---|---|---|
| i) | ☐ | 0-20% | low |
| ii) | ☐ | 20-30% | medium |
| iii) | ☐ | 30-60% | high |

notes: % methane based of Air SWAT gas monitoring data, or several representative measurements taken across the fill area.

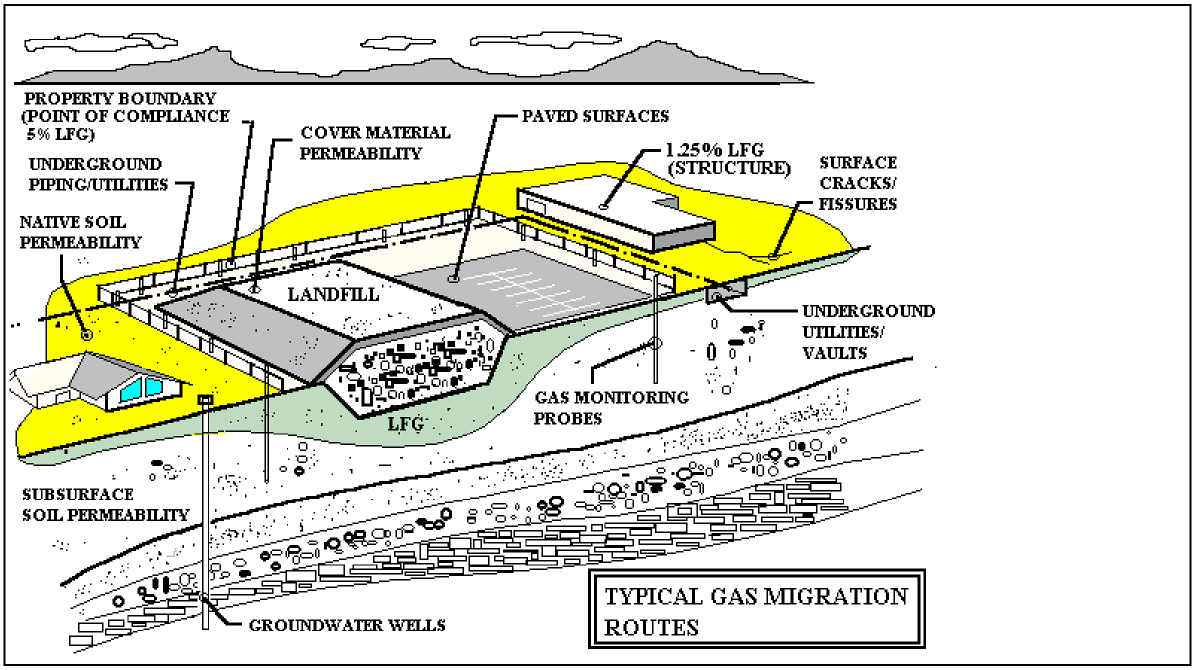


**Figure 2**: **GAS MIGRATION ISSUES**

### b) waste management unit (WMU) type:

| | | WMU type | lateral migration potential |
|---|---|---|---|
| i) | ☐ | gravel mining pit | high |
| ii) | ☐ | exacavation/trench | high |
| iii) | ☐ | canyon or ravine | med |
| iv) | ☐ | waste pile | low-med |
| v) | ☐ | lined unit | low |

### c) surface and subsurface soil conditions:

| **SUBSURFACE SOILS** | Clays | **SURFACE SOILS** Silts | Sands | Gravels |
|---|---|---|---|---|
| Clays | **L-L** | **L-L** | **L-M** | **L-M** |
| Silts | **L-M** | **L-M** | **L-M** | **L-M** |
| Sands | **H-H** | **M-H** | **M-M** | **M-M** |
| Gravels | **H-H** | **H-H** | **M-H** | **M-H** |
| Migration Potential: | **L**-LOW | **M**-MEDIUM | | **H**-HIGH |

**d) land development within 1000 ft or less from the fill area:**

Check plans to determine if any of the following types of building construction, underground structures, utilities or paving are present on or within 1000 ft of the fill area. Note all that apply.

- ☐ Concrete slab-on-grade ______________________________
- ☐ Raised foundation ______________________________
- ☐ Piling foundation ______________________________
- ☐ Basement/cellar ______________________________
- ☐ Water wells ______________________________
- ☐ Underground vaults/tanks ______________________________
- ☐ Utility lines/trenches ______________________________
- ☐ Parking lots _____________________________
- ☐ Roads ______________________________

Note: The presence of any of these features, which could be potential receptors for landfill gas should trigger the following actions:

1) if applicable, an initial gas monitoring survey of the receptor space using a combustible gas indicator (CGI) instrument.

2) placement of sensors or monitoring probes to check for explosive gas concentrations.

**e) Other migration factors:**

1) Seasonal variations, which will predominantly cause moisture conditions within the fill to change, can effect gas generation.

2) Atmospheric conditions, predominantly changes in barometric pressure conditions, temperature and humidity can effect lateral migration of landfill gas.

**f) Considering the discussed factors gas migration has (high/medium/ low) potential to occur due to the following:** ____________________

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
[1]

[1]**LandTec Landfill Gas Control System Engineering Manual LandTec Corporation. Copyright 1994.**

## 2) Placement of Monitoring Probes

Monitoring probes are typically placed using the following guidelines[1]:

a) ☐ Multi-level (shallow, medium, deep) probes are typically constructed.

b) ☐ Probes are typically installed to the depth of refuse around the perimeter of the fill at the property boundary in native soil.

c) ☐ Ideally, there should be a buffer zone between the refuse fill boundary and the property boundary (100 ft or greater), especially where native subsurface soils near the fill are permeable, e.g. sands and gravels.

d) ☐ Common probe spacing is 100 to 500 feet, althought Title 14, Section 17783 specifies a minimum spacing of 1000 ft.

e) ☐ Probes are often required for any new structure built within 1000 feet of fill or existing structures within 100 feet or less from the fill.

f) ☐ Well boring logs from previous investigations or domestic wells should be consulted to determine most likely depth to place monitoring probes screening intervals.

g) ☐ Screened intervals can also be determined based on gas monitoring data taken during well construction, i.e. annotation in log showing depth at which gas is encountered.

h) ☐ Probes' screened intervals should sample permeable geologic layers such as sands & gravels and not impermeable materials such as clays & mudstone.

i) ☐ Probes should be placed between and not immediately opposite LFG extraction wells

j) **Remarks and Comments on Gas Monitoring Probe Placement.**

Gas monitoring probe placement is (inadequate/adequate/good).
Recommend the following: ____________________________________

_____________________________________________________________

_____________________________________________________________

_____________________________________________________________

_____________________________________________________________

_____________________________________________________________

4) Construction of Monitoring Probes

The following figure respresents typical features of a multi-level gas monitoring probe.

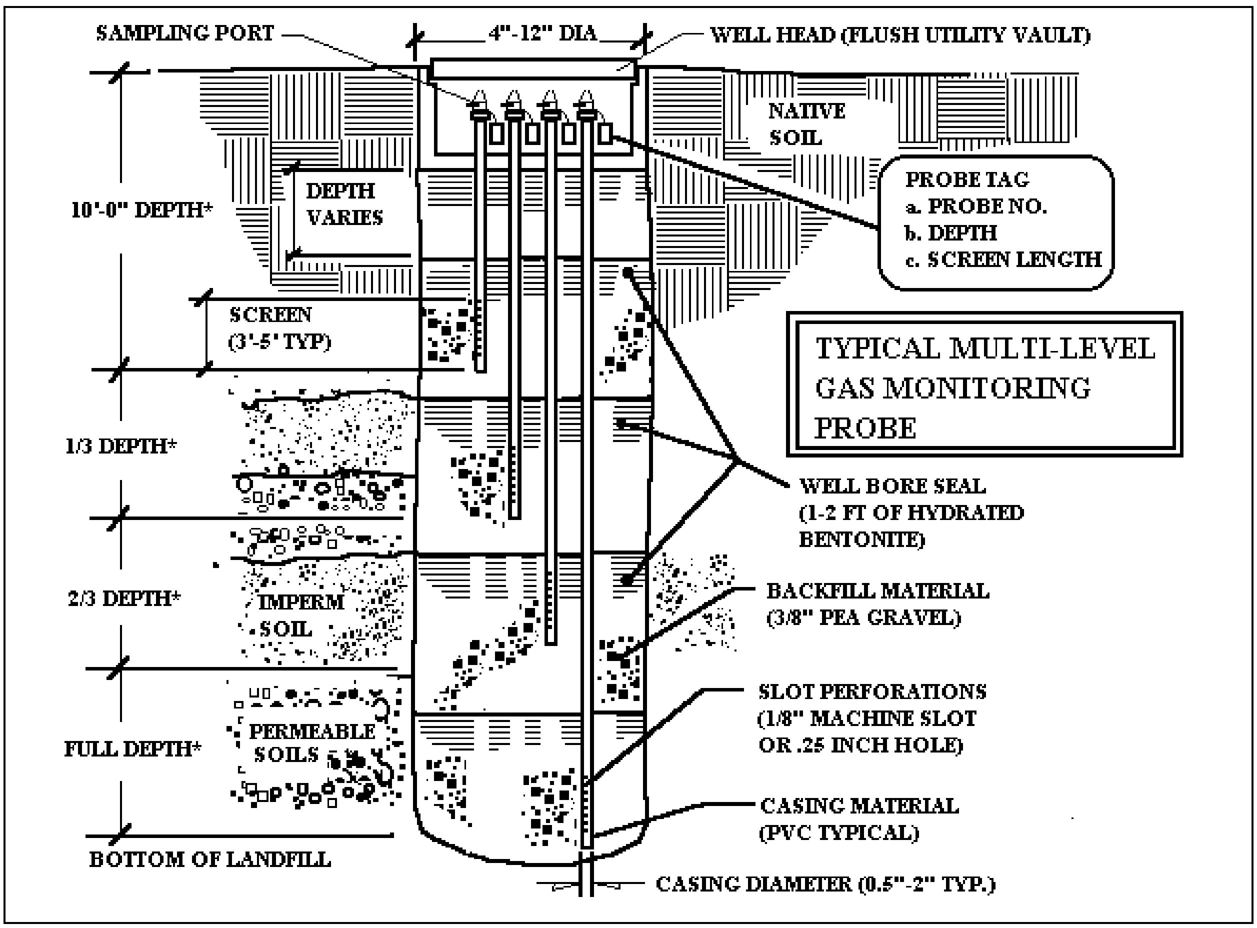


**Figure 3**: **TYPICAL GAS MONITORING PROBE CONSTRUCTION**

The following guidelines[1] are provided for reviewing the adequacy of gas monitoring probe design and construction specifications.

| | REVIEW ITEM | | TYPICAL |
|---|---|---|---|
| a) | **Bore-hole Dia.** | _______(in) | 4-8 inches |
| b) | **Casing Diameter:** | _______(in) | 0.5-2 inch PVC pipe<br>Schedule 40 or 80 |
| c) | **Depth of Hole:** | _______(ft) | Depth of fill |
| d) | **Well Bore Seal:** | _______ | 1-2 ft hydrated<br>bentonite |
| e) | **Filter Pack:** | _______ | 3/8 inch pea gravel |
| f) | **Screened Length:** | _______(ft) | 3-5 feet |
| g) | **Perforation Sizes:** | _______(in) | 1/8 inch machine<br>slot .25 inch perforation |
| i) | **No. of Screens** | _______ | 1 screen/probe |
| h) | **GrndWater Depth** | _______(ft) | Should not be above<br>screened interval |
| i) | **ID Tags/Depth** | | Attached to each probe |
| j) | **Locking Well Head Cover** | | 1 per hole |
| k) | **Anti-Vehicular Barrier** | | Well head flush with ground |

## 5) Remarks and Comments on Gas Monitoring Probe Construction

The gas monitoring system is (well-designed/adequate/inadequate) due to the following: ____________________________________________

____________________________________________________________
____________________________________________________________
____________________________________________________________
____________________________________________________________
____________________________________________________________
____________________________________________________________

## B. GAS GENERATION/GAS CHARACTERISTICS DATA REVIEW:

**1) Review Air Solid Waste Assessment Testing (SWAT) or gas monitoring data for site and review and record the following information:**

a) Landfill Gas Chemical/Physical Characteristics:

Methane:______% $CO_2$:_______% $O_2$:_______%
Nitrogen:______% $H_2S$:_______ppm CO:______ppm
Other constituents:____________________________________________
Dry Bulb Temp ______°F Wet Bulb Temp: ______°F
Relative Humidity: ______% Pressure:______psi

b) Integrated Surface Sample (ISS) data:___________________________
______________________________________________________________

c) Non-Methane Organic Compounds (NMOC) constituents:
______________________________________________________________
______________________________________________________________

**2) Calculate gas generation rate for blower/flare sizing based on following equation[1]:**

$$Q_{CH}4(t) = m_o L_o (1 - e^{-lt})$$

| | | | |
|---|---|---|---|
| Where: | **$Q_{CH4}(t)$** | = | Total methane generated from $t_o$ to t ($ft^3$) |
| | **$L_o$** | = | Methane generation potential ($ft^3$/lb) |
| | l | = | Decay constant (1/yr) |
| | **t** | = | Time (years) |
| | **$m_o$** | = | Mass of refuse (lb) |

**a) Calculate decomposable waste mass ($m_o$) in place at year t**

**Area** of fill (estimate from topographic maps): ______________**($ft^2$)**
Averaged **depth** of fill (historical records): ______________**(ft)**
**Volume** of waste in place (calculated): ______________**($yd^3$)**

*note 1: density of waste = 800-1400 lbs/CY avg: 1100 lb/CY*
*note 2: consider fraction of daily cover (soil) or burn ash in determining "decomposable waste mass"*
*note 3: if daily tonnages (or annual tonnages) are available $m_o$ can be calculated from these figures*

**$m_o$ = ________________________lbs**

**b) Choose decay constant ($\lambda$): __________**

For: Wet Conditons: $\lambda$ = 0.1-0.35
Medium Moisture Conditions: $\lambda$ = 0.05-0.15
Dry Conditions: $\lambda$ = 0.02-0.10

if no waste moisture data is available, consider the following factors to determine if $\lambda$ is high, medium or low value based on:

- i) type of wastes disposed of, i.e. liquids, "green" waste, food wastes, agricultural wastes, etc.
- ii) presence of leachate (is leachate being generated?)
- iii) sources of moisture: annual precipitation, drainage,
- iv) hydraulic gradients between fill area and surface and/or ground water, i.e. landfill intersects ground water table or surface water.
- v) climate: desert, mountains, coastal, foothills or central valley.

**c) Choose gas generation rate ($L_o$): ___________**

| | | |
|---|---|---|
| high: | $L_o$ = | 2.88 |
| medium: | $L_o$ = | 2.55 |
| low: | $L_o$ = | 2.25 |

gas generation rate should be selected as high, medium or low value based on the following factors:

- i) data from gas monitoring or Air SWAT (high: 40-60% methane, medium: 20-40% methane, low: 0-20% methane)
- ii) amount of degradable wastes, i.e. presence of yard wastes, green wastes, food wastes, animal waste, etc.
- iii) moisture content of waste (see $\lambda$ above)
- iv) age of waste (high: 0-15 yrs, med: 15-30 yrs, low: >30 yr)

**d) Choose year of total gas produced from first placement of waste to that year, i.e. age of waste.**

t = _____________yrs;

Calculate: ______(t) yrs x 365 day/year x 24 hrs/day x 60 min/hr
No. of minutes:__________________________________________

**10) Calculate gas quantity:**

$$Q_{CH}4(t) = m_o L_o (1 - e^{-lt})$$

**$Q_{CH4}$ = ________________________ $ft^3$**

**11) Calculate gas flow rate (cfm) = $Q_{CH4}$ /No. of minutes in t years**

**PREDICTED GAS FLOW RATE AT YEAR t:**

***____________cfm's**

**3) GAS GENERATION REMARKS AND COMMENTS:**

The total flow for the gas collection system is (over-designed/well-designed/adequate/under-sized) for the following reasons: ___________________________________

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

## C. Gas Control System:

This section provides useful design and construction information for reviewing gas control system designs and specifications. Useful calculations for sizing blowers, pumps, piping and storage vessels are included to verify specified equipment and material sizes for the purpose of estimating construction costs. The following guidelines[1] are provided for reviewing the adequacy of specific gas control system design parameters:

### 1) Well-field Layout

The following table provides information for reviewing gas extraction system well-field layout:

| | REVIEW ITEM | | CONSIDERATIONS |
|---|---|---|---|
| a) | **Conveyance Routing:** | | |
| | ☐ Branched | | +Less piping; greater area coverage<br>-Less flow & pressure redundancy |
| | ☐ Looped | | +Better flow & pressure distr.<br>+Easier to maintain & trouble shoot<br>+Easier to locate condensate sumps<br>-More piping; higher expense |
| | ☐ Above Ground | | +Reduced installation cost<br>+Ease of maintenance & repair<br>+System expansion easier<br>-Exposure to UV degradation<br>-Accomodate for surface run-off<br>-Minimizes vehicular access<br>-Increased condensate |
| | ☐ Below Ground | | +Protected from surface activity<br>+Less susceptible to temp changes<br>-Higher capital installation costs<br>-Access vaults needed<br>-Difficult to maintain; settlement |
| b) | **Extr. Well Spacing:** | ________(ft) | Interior wells 200-500 ft<br>Perimeter wells 100-250 ft<br>Shallow or wet fills : 100-300 ft<br>Deeper or dryer fills: 200-600 ft |
| c) | **Well-Field Density:** | ________(well/acre) | One well per 0.5-2 acres;<br>0.75-1.5 acre is typical |
| d) | **Well Flow Rate:** | prod._______(cfm)<br>migr._______(cfm) | Production: 20-40 cfm<br>Migration: 5-20 cfm |
| e) | **Well Vaccum:** | ______(in of W.C.) | 5-10 in w.c. |
| f) | **Piping Slopes:** | ______(%) | 3% or greater |
| g) | **Well Schedule:** | | Should include following info:<br>☐ Well Number<br>☐ Well Depth<br>☐ Casing Diameter & Length<br>☐ Perforated Length<br>☐ Non-Perf. Length<br>☐ No. of Slip Couples<br>☐ No. of Caps |

## 2) Extraction Well Contruction

The following guidelines[1] can be used to review the construction of gas extraction wells:

| | REVIEW ITEM | | | TYPICAL |
|---|---|---|---|---|
| a) | **Vert. Well-bore Diameter:** | | ______(in) | 12"-36" standard<br>24", 30" and 36" typical |
| b) | **Horiz. Well Depth:** | | ______(ft) | In active fill, trenched into refuse or layed on top and filled around later; 2-3 ft wide and 4 ft deep<br><br>Closed fill: install deep as practical |
| c) | **Well Depth** | **(Vertical)** | ______(ft) | 60 ft or 5 ft from fill bottom, whichever occurs first<br><br>EPA minimum in proposed (draft) MSW NSPS is 75% of LF depth or to W.T., whichever occurs first. |
| | | **(Horizontal)** | ______(ft) | Deeper the better; minimum of 25 ft or depth of backhoe reach or use membrane to seal surface and extend for distance equal to influence desired. |
| d) | **Perforations** | **(Vert. Wells)** | ______(ft) | Bottom 1/3 to 2/3 of extraction well |
| e) | **Slot Area** | | ______($in^2$) | Total area roughly 10 X casing dia. |
| f) | **Casing** | **(Size)**<br>**(Materials)** | ______(in)<br>______(type) | 3"-8" nom. (approx. 40-600 cfm)<br>PVC; polyethylene (HDPE);<br>>125 ft depth use steel or telescoping well joint |
| g) | **Wellbore Seal** | | ______(type) | Down-Hole: hydrated bentonite<br>Surface: LandTec Membrane WBS |
| h) | **Well-Head Construction** | | | Well-Head should have following components:<br><br>❑ sampling port<br>❑ shut-off valve<br>❑ temperature sensor<br>❑ flex connection<br>❑ quick disconnect unions |

The following figure shows typical features of a gas extraction well:

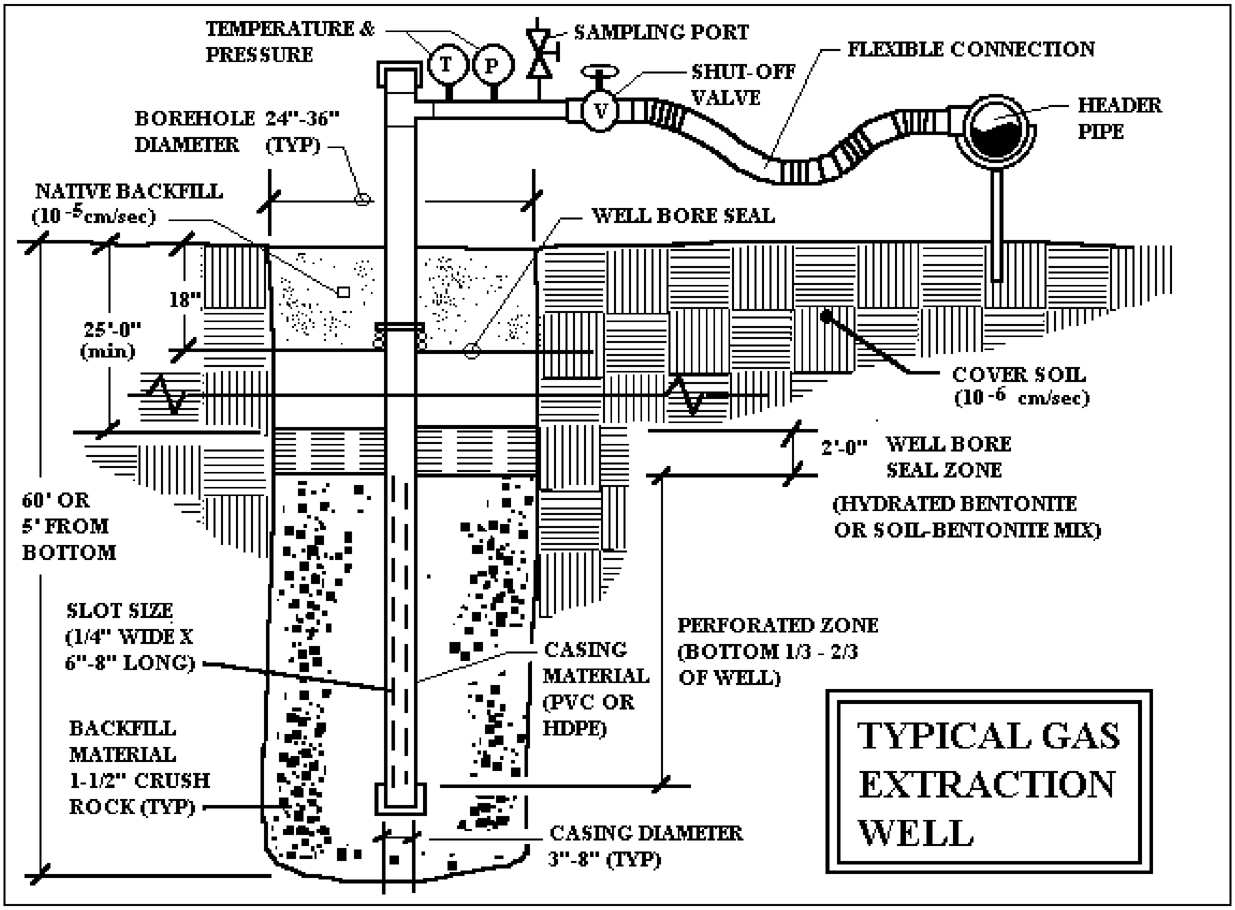

**Figure 4: TYPICAL GAS EXTRACTION WELL CONSTRUCTION**

**3) Well Field Layout Comments:**

The well-field layout is (well designed/adequately designed/poorly designed) due to the following:________________________________________________________

**Extraction Well Construction Comments**:

The extraction wells are (well designed/adequately designed/poorly designed) due to the following: ______________________________________________________________

## 4) Gas Conveyance System

The following procedures and calculations[1] can be used to determine if the gas collection piping system is adequately sized for the blower selected.

a) From the construction drawings and specifications fill in the following:

**Total System Flow** _______(cfm)
**Fan Pressure**** _______(in w.c.)

b) Based on the specified flow and pressure of the gas collection system, select the "longest" pipe run (or path with highest resistance to gas flow) and calculate the Total Pressure Drop (TPD) from blower to extraction well:

**Total pressure Drop or Fan Pressure Required =**

**Pipe Friction + Fitting Losses + Applied Head losses**

c) **Calculate Pipe Friction Losses:**

Pipe friction can be calculated by multiplying the effected length of pipe (feet) times the Darcy friction factor (in w.c./100 ft of pipe) which is derived from the Moody Diagram. The following equation represents Darcy's Friction Loss:

$$\Delta P = \frac{(\rho)(f)(100)(v)^2(27.7)}{(144)(D)(64.4)}$$

| | | | |
|---|---|---|---|
| **Where:** | $\Delta P$ | = | **Press. Drop/100 ft pipe (in w.c.)** |
| | $\rho$ | = | **Fluid Density ($lb_m/ft^3$)** |
| | $f$ | = | **Darcy Friction Factor (in w.c./100 ft)** |
| | $v$ | = | **Fluid Velocity** |
| | **D** | = | **Pipe Diameter** |

**Total $\Delta P_{friction}$ = Header Friction Loss + Branch Friction Loss**

## DETERMINE HEADER PIPE FRICTION LOSS

1. Select length ________ (ft) of Effected Header Pipe (L)

2. Obtain specified blower flow rate (Q) _________(cfm)

3. Determine pipe internal diameter as _______ in or (_______ ft)

4. Use Continuity Equation ($Q = vA$) to calculate velocity as ________ (linear ft/min) or _________ (ft/sec)

5. Calculate Reynolds Number ($N_{RE}$) using the following equation:

$$N_{RE} = \frac{Dvr}{m_e}$$

| where: | D | = | **Pipe Diameter (ft)** |
|---|---|---|---|
| | **v** | = | **Fluid Velocity (ft/sec)** |
| | r | = | **Fluid Density ($lb_m/ft^3$)** |
| | $m_e$ | = | **Absolute Viscosity ($lb_m/ft \cdot sec$)** |

Reynolds Number =__________ Verify that flow is turbulent.

6. Calculate relative roughness ($\varepsilon/D$) as _____________

7. Use Moody Chart to determine the Darcy friction factor by calculating relative roughness, and referring to a Moody Chart.

*f* = _______________(approximately)

Substituting into Darcy:

$$\Delta P = \frac{(r)(f)(100)(v)^2(27.7)}{(144)(D)(64.4)}$$

$\Delta P$ = _______ (or psi) per 100 ft of pipe

**Total friction loss for header pipe section**

**= (______100's) x _______DP ( in W.C.) = _______in W.C.**

## DETERMINE BRANCH PIPE FRICTION LOSS

1. Select length ________ (ft) of Effected Branch Pipe (L)

2. Obtain specified branch flow rate (Q) _________(cfm)

3. Determine pipe internal diameter as _______ in or (_______ ft)

4. Use Continuity Equation ($Q = vA$) to calculate velocity as ________ (linear ft/min) or _________ (ft/sec)

5. Calculate Reynolds Number ($N_{RE}$).

   $N_{RE}$ = ___________ Verify that flow is turbulent.

6. Calculate relative roughness ($\varepsilon$/D) as ______________

7. Use Moody Chart to determine the Darcy friction factor by calculating relative roughness, and referring to a Moody Chart.

   $f$ = _______________(approximately)

   Substituting into Darcy:

$$\Delta P = \frac{(r)(f)(100)(v)^2(27.7)}{(144)(D)(64.4)}$$

   $\Delta P$ = _______ (or psi) per 100 ft of pipe

   **Total friction loss for branch pipe section**

   **= (______100's) x ________$\Delta$P ( in W.C.) = _______in W.C.**

   **TOTAL FRICTION LOSS = HEADER ______ + BRANCH ______**

   **= ____________________(in W.C.)**

d) **Calculate Valve and Fitting Losses:**

Locate all valves (ball, globe, angle etc.) and fittings (elbows, tees, reducers, etc.), which are in the "longest run" of piping and are points of resistance against flow from the extraction well to the blower.

Header Pipe Section (Darcy $\Delta P$ = _______in w.c./100 ft of pipe):

| | FITTING TYPE | NO. | SIZE | EQ. LENG. | $\Delta p$ |
|---|---|---|---|---|---|
| ☐ | Gate Valve | ____ | ____ | __________ | ________ |
| ☐ | Ball Valve | ____ | ____ | __________ | ________ |
| ☐ | Check Valve | ____ | ____ | __________ | ________ |
| ☐ | $90^o$ Standard Elbow | ____ | ____ | __________ | ________ |
| ☐ | $45^o$ Standard Elbow | ____ | ____ | __________ | ________ |
| ☐ | Standard Tee | ____ | ____ | __________ | ________ |

Branch Pipe Section (Darcy $\Delta P$ = _______in w.c./100 ft of pipe):

| | FITTING TYPE | NO. | SIZE | EQ. LENG. | $\Delta p$ |
|---|---|---|---|---|---|
| ☐ | Gate Valve | ____ | ____ | __________ | ________ |
| ☐ | Ball Valve | ____ | ____ | __________ | ________ |
| ☐ | Check Valve | ____ | ____ | __________ | ________ |
| ☐ | $90^o$ Standard Elbow | ____ | ____ | __________ | ________ |
| ☐ | $45^o$ Standard Elbow | ____ | ____ | __________ | ________ |
| ☐ | Standard Tee | ____ | ____ | __________ | ________ |

**Total $\Delta P_{fittings + valves}$ =** ________

Compute the pressure drop from these sources using the following methods:

**Pressure Drop Due to Fittings**

Using PVC or HDPE pipe manufacturing data, obtain "equivalent length of straight pipe" data for fitting types and sizes used in the "longest run".
By multiplying the Darcy Friction Factor for the effected section of piping,

i.e. the header or the branch, times the effected fitting's "equivalent length of straight pipe", the pressure drop across the fitting can be computed.

For example:

Given: $\Delta P$ = .654 in w.c./100 ft of pipe*

*note: computed using Q = 800 cfm, D = .665 ft, $\rho$ = .065 $lb_m/ft^3$, $\mu_e$ = 8.14 x $10^{-6}$ $lb_m/ft°$ sec, for smooth plastic pipe

Find: Pressure Drop due to two 8" 90$^o$ elbows and three 8" tees in the header pipe section.

Solution:

1. Obtain pipe manufacturer's "equivalent length of straight pipe" data for 8 inch elbow and 8 inch tee:

   for 8", 90$^o$ elbow, equivalent length = 33.3 ft

   for 8" tee, with flow through run, equivalent length = 16.5 ft.

2. Using $\Delta P$ = .654 in w.c./100 ft of pipe

   $\Delta p_{elbows}$ = (.654 in w.c.) x (33.3 ft/100 ft) x 2
   = .436 in w.c.

   $\Delta p_{tees}$ = (.654 in w.c.) x (16.5 ft/100 ft) x 3
   = .323 in w.c.

3. Compute $\Delta p_{fittings} = \Delta p_{elbows} + \Delta p_{tees}$

   $\Delta p_{fittings}$ = (.436 in w.c.) + (.323 in w.c.) = .759 in w.c.

**Pressure Drop Due to Valves**

The previous method used for fittings can also be used for valves if equivalent length data is available. If equivalent length data is not available pressure drop due to valves can be computed using the following equation:

$$\Delta P_{valve} = (\frac{r}{62.4})\_(\frac{7.48\_Q}{C_v})^2$$

| | | | |
|---|---|---|---|
| **Where:** | r | = | **fluid density ($lb_m/ft^3$)** |
| | **Q** | = | **flow through valve ($ft^3$/min)** |
| | **$C_v$** | = | **valve or fitting coefficient** |

$C_v$ can usually be obtained from the valve manufacturer's data. If the fitting coefficient must be computed the following may be used:

$$C_v = \frac{29.9\_d^2}{\sqrt{K}}$$

| | | | |
|---|---|---|---|
| **Where:** | **$C_v$** | = | **valve or fitting coefficient** |
| | **d** | = | **pipe diameter (in)** |
| | **K** | = | **Resistance Coefficient*** |

***note: normally provided by fitting/valve manufacturer**

For example:

| | | | |
|---|---|---|---|
| Given: | Q | = | 800 cfm |
| | ρ | = | .065 $lb_m/ft^3$ |
| | d | = | 8 inch |
| | K | = | 106.5 |

Find: $\Delta P_{valve}$

Solution:

$$\Delta P_{valve} = (\frac{.065\,lb_m/ft^3}{62.4})\_(\frac{7.48\_800\,ft^3/min}{\frac{29.9\_8\,inch^2}{\sqrt{106.5}}})^2$$

$\Delta P_{valve}$ = 1.09 in w.c.

e) **Calculate/Determine Applied Head Losses:**

Applied head losses for gas control systems usually consist of the following:

- ☐ Extraction Well Vacuum: _______ in w.c. (typical: 5-10 in w.c.)
- ☐ Flare Backpressure: _______ in w.c. (typical: 10 in w.c.)
- ☐ Inlet Scrubber Vessel _______ in w.c. (typical: 2-5 in w.c.)

**TOTAL APPLIED HEAD LOSS _______ IN W.C.**

f) Compute Total Head Loss from Extraction Well to Flare:

- ☐ Pipe Friction Head Losses _______ in w.c. (from "c" above)
- ☐ Fitting & Valve Losses _______ in w.c. (from "d" above)
- ☐ Applied Head Losses _______ in w.c. (from "e" above)

**TOTAL PRESSURE DROP _______ IN W.C.**

g) **Remarks and comments on blower sizing**

Blower flow rate is (undersized/adequate/oversized) based on the fact that computed gas generation (</=/>) specified blower flow rate. Recommend the following:______________________________________________________

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

Blower fan pressure is (undersized/adequate/oversized) based on the fact that computed total pressure drop (</=/>) specified fan pressure. Recommend the following:______________________________________________________

______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________
______________________________________________________________________

**5) Condensate Collection/Recovery/Treatment System**

a) Calculate total amount of condensate expected from fill, in gallons per MMcf (million cubic feet) of LFG, using the following[1] :

$$V_{cond} = 5{,}694\_(\frac{10^b}{P_s})$$

| | | | |
|---|---|---|---|
| **Where:** | $V_{cond}$ | **=** | **Volume of condensate (water) produced** |
| | b | **=** | **6.32 - (3081/(T + 385))** |
| | **T** | **=** | **Maximum gas temperature (°F)** |
| | $P_s$ | **=** | **System pressure (psia)** |

1. Obtain the following information from the gas control system specifications or Air SWAT data:

   Max. Gas Temp. (T) = _____°F    Typical: 110°F
   System Pressure ($P_s$) = _____psia    Typical:

2. Compute the total amount of condensate for the system:

   $V_{cond}$ _______________ = 5,694 • ($10^{\beta}$_______ / $P_s$ ________ )

3. Determine condensate storage capacity required:

   Duration of Storage period: __________ hrs
   Volume flow of gas during period (Q) __________ cfm

   Compute Storage Capacity:

   Storage Capacity = ((Q_________($ft^3$/min))/(1 x $10^6$ cf)) x
   Storage period_______hrs x 60 min/hr x
   $V_{cond}$ ___________(gal/MMcf)

   Storage Capacity Required = __________________

4. Obtain the following information from the gas control system drawings and specifications:

Condensate Sump/Tank Information:

| Sump Size (gallons) | No. of Sumps | Storage Capacity (gallons) |
|---|---|---|
| __________ | ____________ | ______________ |
| __________ | ____________ | ______________ |
| __________ | ____________ | ______________ |

**TOTAL STORAGE CAPACITY** **_____________gal**

b) Remarks and Conclusions comparing expected with total specified condensate storage capacity.

Gas condensate storage capacity is ( </=/>) the computed storage capacity. Recommend the following:______________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________

c) Review pump specifications for sump with the longest run.

1. Obtain the following information:

Condensate Pump Specifications: Flow: ______gpm
Pressure: ______ psi

2. Minimum pump flow rate is based on:

flow rate required to empty sump within specified period, e.g. a 500 gallon tank that must be emptied in 4 hours requires at minimum a 2 gpm pump. Typical condensate sump pumps are rated from 10-30 gpm.

d) **Remarks and conclusions on specified pump capacities.**

Condensate sump pump sizes are (undersized/adequately-sized/over-sized) for the condensate management system. Recommend the following: ______________________________________________________

______________________________________________________

______________________________________________________

e) Determine if longest run of condensate pipe is adequately sized, such that total head loss $\Delta h_{total}$ is 10% of the condensate sump pump's specified pressure.

1. Use the following equation (Hazen-Williams) to compute head loss per 100 ft of pipe:

$$h_f = 0.2083\_(\frac{100\_Q}{C})^{1.852}\_(\frac{1}{d})^{0.48655}$$

| | | | |
|---|---|---|---|
| **Where:** | $\mathbf{h_f}$ | = | **frictional head loss (ft/100 ft pipe)** |
| | **C** | = | **Hazen-Williams roughness coeff.*** |
| | **Q** | = | **Flow (gallons per minute)** |
| | **d** | = | **Inside diameter of pipe (inches)** |

*note: typical value recommended for C is 150 for HDPE or PVC.

$h_f$ _____ft/100 ft of pipe =

0.2083 • ((100 • Q _____ gal/min)/C)$^{1.852}$• (1/d ____in)$^{0.48655}$

2. Compute the Total Head Loss From Pump to Receiver Tank (assume 20% loss due to fittings):

$\Delta h_{total}$ =

($h_f$ _____ ft/100 ft of pipe) X (Total Length of Run (ft) + 20%)

3. Determine if $\Delta h_{total}$ is approximately 10% of specified pump pressure.

$\Delta h_{total}$ ______ psia < / = / > .10 X $h_{pump}$ _________ psia

f) **Remarks and conclusions on specified condensate pipe size:**

Condensate pipe size for the longest run appears to be (undersized/ adequately sized/oversized), based on the specified pump pressure. Recommend the following:___________________________________

___________________________________________________________

___________________________________________________________

___________________________________________________________

g) Other general review items:

1. Sump placement should be located at lowest elevation with respect to gas header and branches from which condensate will be collected.

2. All condensate pipe should have at least 3% slope (if possible) to promote drainage.

3. Condensate pipe should be run with air supply lines and gas collection lines to provide better access for maintenance and protection of pipe (if PVC or HDPE is used).

4. Most condensate collection system sump pumps use compressed air versus electric powered. If compressed air system is used, air lines and air compressors will need to be sized as part of design process.

5. Condensate collection systems are normally discharged to regional waste water treatment systems with an amendment to the operator's NPDES or sewer use permit. However, depending on the amount of condensate and its characteristics, pretreatment may be necessary prior to discharge (to a sewer system or navigable waterway). Several skid mounted treatment systems are commercially available with the following capabilities:

| | PROCESS | REMOVES |
|---|---|---|
| ☐ | Reverse Osmosis | contaminants |
| ☐ | Sand Filtration | suspended solids |
| ☐ | Carbon Absorption | organics |
| ☐ | Anion & Cation Exchange | inorganics |
| ☐ | Air Stripping Column | volatiles |
| ☐ | Chemical Oxidation | inorganics |
| ☐ | Precipitation | inorganics |
| ☐ | Neutralization | pH adjustment |
| ☐ | Chlorination | disinfect |
| ☐ | Biological Digestion | certain organics |

h) **Remarks and Comments on Condensate Management Systems:**

6) Flaring/Blower Station Review

a) Review flare/blower station layout for components. The following diagram[1] shows the typical components of a flare/blower station:

The following list[1] are typical components of the blower/flare station

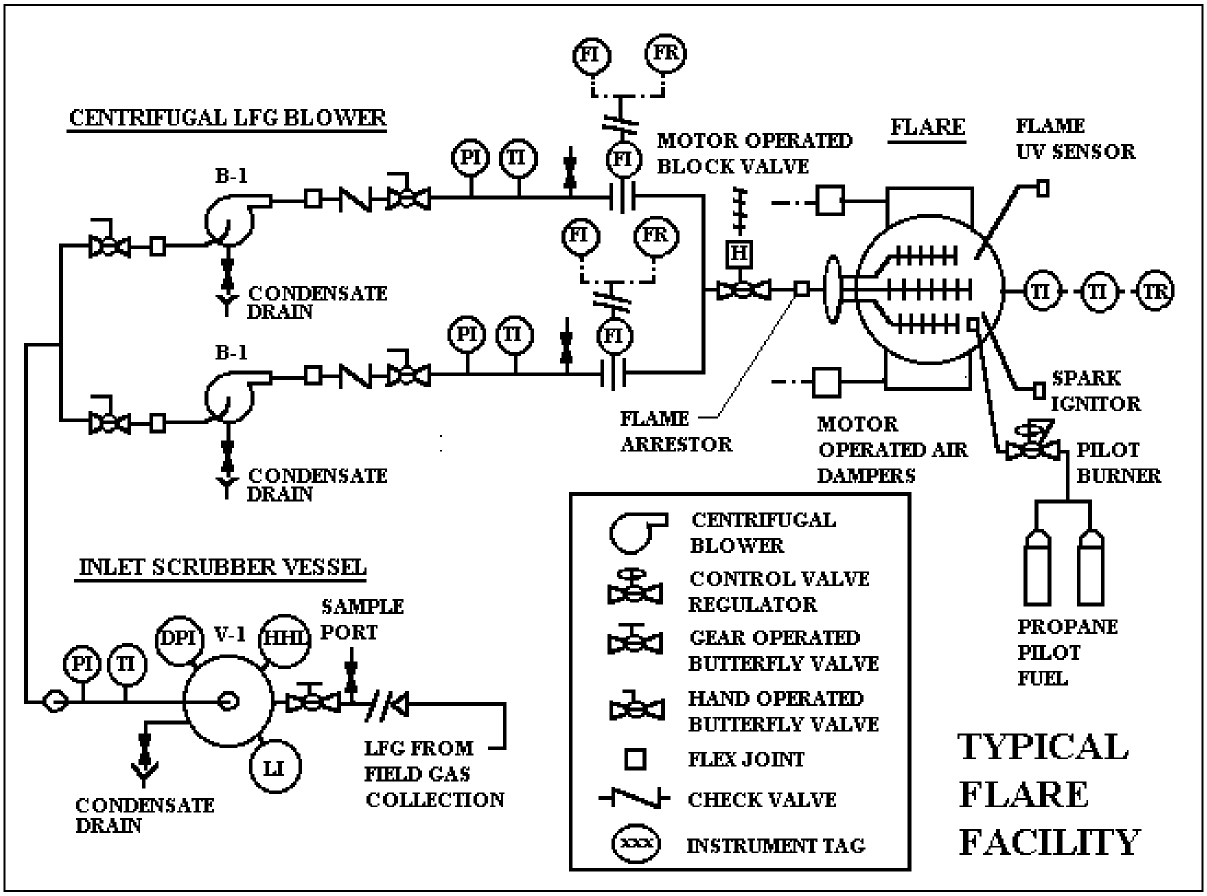


**Figure 5**: **TYPICAL FLARE/BLOWER STATION LAYOUT**

facility and their purpose:

| | FLARE STATION COMPONENT | PURPOSE |
|---|---|---|
| ☐ | **Inlet demister or scubber vessel** | Dehumidy gas stream to improve combustion efficiency. |
| ☐ | **Valve (check, butterfly, ball)** | Shut-off or vary flow to control combustion process/isolate major component for repair |
| ☐ | **Temperature/Pressure/Flow Sensors/Meters** | Measure gas stream characteristics to control efficiency of combustion process |
| ☐ | **Sampling Port** | Provide access to gas stream for sampling to determine gas quality |
| ☐ | **Blower/compressor Unit** | Provide system vacuum for extracting gas from well field |
| ☐ | **Flare Unit (ground/candlestick)** | Combust LFG at optimal temperatures and retention times to destroy LFG constituents and minimize stack emissions |
| ☐ | **Flame Arrestor** | Valve which prevents flare "backflash" by by automatically constricting flow to gas manifold at specific pressure or temp. |
| ☐ | **Pilot Burner** | Provides "safe" ignition source for burner tip or flare's gas manifold |
| ☐ | **Propane Pilot Fuel** | "Make-up" gas system used to ignite Pilot burner and provide fuel if LFG quality is insufficient for combustion |
| ☐ | **Automatic Block Valve** | Isolates gas stream from blower and upstream flare station piping |
| ☐ | **Electrical Controls** | Provide automatic control of electric-driven motors, solenoids, sensors, etc. to control gas extraction & combustion process |
| ☐ | **Condensate Drains** | Provide conveyance of condensation from major components to main storage vessel. |
| ☐ | **Condensate Storage Tank** | Provide temporary storage capacity for all condensation "knocked-out" of wellfield and flare/blower station components. |
| ☐ | **Condensate Treatment** | Remove contaminants from condensate to meet discharge or permit requirements. |

b) **Remarks and Comments on Flare/Blower Station:**

The flare/blower station is (inadequate/adequate) for the following reasons: ______________________________________________________
______________________________________________________________
______________________________________________________________
______________________________________________________________
______________________________________________________________
______________________________________________________________
______________________________________________________________
______________________________________________________________
______________________________________________________________
______________________________________________________________
______________________________________________________________
______________________________________________________________

c) Blower/Flare Station Operations & Maintenance Manual Review

The following is a typical table of contents for a landfill blower/flare station facility:

**Section 1** **Introduction**

General
Use of this Manual
Notice & Warnings
Control System General Description

Description of Landfill and Operations
Description of Facility
Gas Collection System Description
Gas Condensate Handling System Description

**Section 2** **Design and As-built Conditions**

Basis of Design
Blower-Flare Station
Gas Collection System
Condensate Handling System
Specifications
Drawings

| | | |
|---|---|---|
| **APPENDIX D** | **-** | **Facility Equipment and Controls Listings** |
| **APPENDIX E** | **-** | **Facility Equipment & Device Set Point List** |
| **APPENDIX F** | **-** | **Master List of Shutdown Devices** |
| **APPENDIX G** | **-** | **Facility Short Form Start-up Checklist** |
| **APPENDIX H** | **-** | **Collection System Inspection Checklist** |
| **APPENDIX I** | **-** | **Facility & Wellfield Reading Sheets** |
| **APPENDIX J** | **-** | **Trouble-Shooting Chart** |
| **APPENDIX K** | **-** | **Facility Maintenance Checklists** |
| **APPENDIX L** | **-** | **Equipment Vendor List** |

**GLOSSARY**

d) **Remarks and Comments on Operations & Maintenance Manual**

The operations and maintenance manual is (deficient/sufficient) for the following reasons: ________________________________________

________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________
________________________________________________________________

## D. COST ESTIMATES FOR GAS MONITORING AND CONTROL SYSTEMS

### 1) Gas Monitoring Probes

a) single probe
b) multi-level probe

### 2) Gas Control System

a) extraction wells
b) conveyance system
c) flare & blower station
d) condensate management system