

**OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY
AIR QUALITY DIVISION**

MEMORANDUM

April 6, 2017

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THROUGH: Lee Warden, P.E., Engineering Manager, Engineering Section

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SUBJECT: GP-OGF Modeling of H₂S Sources

SECTION I. INTRODUCTION

[This is an amendment to the previous Memorandum, dated May 16, 2014, to include modeling of storage tanks, dehydration units, tank truck loading, and equipment components (fugitive emissions sources). Additional changes were incorporated into all analyses to include utilization of the updated AERSCREEN model version, use of National Elevation Data (NED) in the place of Digital Elevation Model (DEM) data to accurately account for terrain, the incorporation of a fuel sulfur content limitation of 162 ppmv in place of the previous 343 ppmv, and minor formatting changes.]

AERSCREEN (16216) was used to conduct modeling to demonstrate compliance with the ambient standard for H₂S of OAC 252:100-31-7 for amine units, engines, heaters/boilers dehydration units, storage tanks, tank truck loading operations, and equipment components as follows:

252:100-31-7. Allowable hydrogen sulfide (H₂S) ambient air concentrations for new and existing sources

(b) **Hydrogen sulfide.** Emissions of H₂S from any facility shall not cause an ambient air concentration of H₂S greater than 0.2 ppm at standard conditions, 24-hour average.

(c) **Exceptions.** The standards set in this section shall not apply to ambient air concentrations or impacts occurring on the property from which such emission occurs, providing such property, from the emission point to the point of any such concentration, is controlled by the person responsible for such emission.

AERSCREEN is a screening-level air quality dispersion modeling program. This program was developed by the United States Environmental Protection Agency (USEPA) to conservatively estimate concentrations from a single source. This program estimates the worst-case 1-hr average concentrations based on meteorological data, terrain, and building downwash. AERSCREEN automatically provides impacts for other averaging periods (3-hr, 8-hr, 24-hr, and annual) using scaling ratios or averaging time factors. AERSCREEN is a single source model; therefore, impacts are directly related to emission rates. For purposes of modeling, each scenario was modeled at 1.0 lb/hr. The modeled 24-hr concentrations were then multiplied by the respective emission rates.

Each of the modeling scenarios and cases were modeled in three locations. These locations were selected to be representative of a variety of terrain in the State of Oklahoma. Rough terrain, smooth terrain, and elevation differences within close proximity to the source were considered in the selection of the locations. National Elevation Data (NED) files were used in the AERSCREEN modeling scenarios to accurately account for the terrain. For information regarding the location parameters and default modeling input parameters, refer to Appendix A and Appendix B.

The AERSCREEN modeling conducted to demonstrate compliance with OAC 252:100-31 for all emission sources was based on information obtained from TEAM, AQD's Emission Inventory database.

SECTION II. AMINE UNITS

Amine units are used to remove H₂S and CO₂ from natural gas. Amine units are usually equipped with a flash tank. The natural gas passes through the amine contactor where H₂S and CO₂ are absorbed by the amine. The “rich” amine containing H₂S and CO₂ passes through the flash tank, to recover hydrocarbons that may have dissolved or condensed in the amine solution in the absorber. From the flash tank, the “rich” amine is sent to the amine regenerator/reboiler. The reboiler heats the amine and boils off the H₂S and CO₂ from the amine. The H₂S and CO₂ (acid gas) from the regenerator still vent is typically vented directly to the atmosphere or flared to reduce emissions of H₂S. The amine unit’s flash tank is typically routed to the facility inlet, to a flare, or to the reboiler as fuel, which reduces emissions of VOC and H₂S. Review of emissions from amine units only addresses emissions from the still vent.

In demonstrating compliance with OAC 252:100-31-7 for amine units, different compliance options for OAC 252:100-31-26 were incorporated.

252:100-31-26. Requirements for new petroleum and natural gas processes

Any petroleum and natural gas process that was not in being on or before December 31, 1974 or that is modified after December 31, 1974 shall comply with the following requirements.

(1) Hydrogen sulfide standards and alarm systems.

(A) H₂S contained in the waste gas stream from any petroleum or natural gas process equipment shall be reduced by 95% by removal or by being oxidized to SO₂ prior to being emitted to the ambient air. This requirement shall not apply if a facility's emissions of H₂S do not exceed 0.3 lb/hr, two-hour average.

(2) **Oxides of sulfur.** The following requirements apply to any gas sweetening unit or petroleum refinery process equipment with a sulfur content of greater than 0.54 LT/D in the acid gas stream. Alternatively, any gas sweetening unit or petroleum refinery process equipment with an emission rate of 100 lb/hr or less of SO_x expressed as SO₂, two-hour average, shall be considered to be below this threshold.

The AERSCREEN modeling conducted to demonstrate compliance with OAC 252:100-31 for the different compliance options were based on the following scenarios:

- If H₂S emissions from the amine unit still vent are less than or equal to 0.3 lb/hr, then they are most likely vented directly to the atmosphere without controls. Two cases were developed related to amine units with the still vent routed directly to the atmosphere.
 - The first case is a facility which treats “sweet” natural gas (\leq 4 ppmv H₂S).
 - The second case is a facility which treats “sour” natural gas ($>$ 4 ppmv H₂S).
- If H₂S emissions from the amine unit still vent are greater than 0.3 lb/hr, then they are most likely flared (oxidized). Two cases were also developed related to amine units with the still vent routed to a flare.
 - The first case is based on the de minimis level of H₂S emissions 0.3 lb/hr being flared. Assuming 95% control and 0.3 lb/hr H₂S, this is equivalent to uncontrolled H₂S emissions of 0.015 lb/hr.
 - The second case is based on the maximum amount of SO₂ emissions for a minor source or the major source threshold. Assuming 95% control and 99 TPY (23.79 lb/hr) SO₂, this is equivalent to uncontrolled H₂S emissions of 0.63 lb/hr.

AERSCREEN Amine Unit Modeling Scenario 1

Scenario 1 represents AERSCREEN modeling for amine unit still vents with H₂S emissions routed directly to the atmosphere with emissions of less than 0.3 lb/hr. When modeling an uncontrolled amine unit, the main variables other than the emission rate that affect dispersion are the stack parameters (i.e. stack height, stack diameter, stack temperature, and stack velocity). These variables were established for each case based on review of AQD’s Emission Inventory database, examination of recent site specific modeling, and calculations used to make the modeling representative of the specific scenario or case being modeled. Development of these parameters for each case is discussed below.

The AQD’s Emission Inventory database was reviewed to determine a minimum stack height for the uncontrolled amine unit still vents. Based on the data reviewed, a minimum stack height of 10 feet was used to conduct the modeling review. The default stack temperature was based on 100°F which is the default temperature of lean amine from the AMINECalc© program. The other parameters (stack diameter and stack velocity) are specific to each case reviewed.

The first case represents a facility with an amine unit which is used to treat “sweet” natural gas (\leq 4 ppmv H₂S). This case is the most common. The stack flow for this case was back calculated using the maximum emission rate and assuming that treatment of natural gas for the removal of CO₂ is required when CO₂ reaches a level of 2.5% by volume. Since this case looks at treatment of “sweet” natural gas, the main component of the still vent flow would be CO₂. Assuming a concentration of 4 ppmv H₂S in the inlet gas and a 100% removal efficiency of the amine unit, the facility would have to treat 20 MMSCFD to reach the 0.3 lb/hr emission rate. At 2.5% CO₂ and 90% removal efficiency, the amine unit still vent flow rate would be approximately 18,793 SCFH (332 ACFM). Using this stack flow, the stack velocity which is based on the stack flow and diameter was evaluated for different stack diameters.

Stack Diameter vs. Velocity for Case 1

Stack Diameter (ft)	4"	6"	8"
Stack Velocity (ft/s)	64	29	16

Based on a review of these values and recent modeling submittals, it was determined that representative stack parameters for Case 1 would be a stack flow of 28 ft/sec with a stack diameter of 0.5 ft.

The second case represents a facility with an amine unit which is used to treat “sour” natural gas (greater than 4 ppmv H₂S). The stack flow for this case was back calculated using the maximum emission rate and assuming an H₂S concentration of 10 ppmv and still including a CO₂ concentration of 2.5% by volume. Again, the main component of the still vent flow would be CO₂. Assuming a concentration of 10 ppmv H₂S in the inlet gas and a 100% removal efficiency of the amine unit, the facility would have to treat 8 MMSCFD to reach the 0.3 lb/hr emission rate. At 2.5% CO₂ and 90% removal efficiency, the amine unit still vent flow rate would be approximately 7,519 SCFH (133 ACFM). Using this stack flow, the stack velocity which is based on the stack flow and diameter was evaluated for different stack diameters.

Stack Diameter vs. Velocity for Case 2

Stack Diameter (ft)	4"	6"
Stack Velocity (ft/s)	26	11

Based on a review of these values and recent modeling submittals, it was determined that representative stack parameters for Case 2 would be a stack flow of 26 ft/sec with a stack diameter of 0.33 ft.

Scenario 1 AERSCREEN Input Parameters

Source Parameters	Case 1	Case 2
Type	Point	Point
Emission Rate (lb/hr)	0.3	0.3
Stack Height (ft)	10	10
Stack Diameter (ft)	0.5	0.33
Stack Flow (ACFM)	332	133
Stack Velocity (ft/s)	29	26
Stack Temperature (°F)	100	100

The following table shows the AERSCREEN results for each of the Scenario 1 cases at each of the three locations.

Scenario 1 AERSCREEN 24-hr Average Concentrations (µg/m³)

	Case 1	Case 2
Location 1	384.0	539.4
Location 2	191.9	213.3
Location 3	198.8	231.1

The maximum modeled concentration for both cases is above the 0.2 ppm (283.3 µg/m³ based on EPA standard conditions) ambient air concentration limit.

AERSCREEN Amine Unit Modeling Scenario 2

Scenario 2 represents AERSCREEN modeling for amine unit still vents with H₂S emissions routed to a flare for oxidation. When modeling an amine unit routed to a flare, the main variables other than the emission rate that affect dispersion are the total heat release or heat content of the gas being flared and the stack height. These variables were established for each case based on review of AQD's Emission Inventory database, examination of recent site specific modeling, and calculations used to make the modeling representative of the specific scenario or case being modeled. Development of these parameters for each case is discussed below.

The AQD's Emission Inventory database was reviewed to determine a minimum stack height for the controlled (flared) amine unit still vents. Based on the data reviewed, a minimum stack height of 25 feet was used to conduct the modeling review. Since these units are flared the default flare parameters were used in the modeling for stack temperature (1,273 °K), stack velocity (20 m/s), and heat loss fraction (0.55). The other parameter (total heat release) is specific to each case reviewed.

In order to determine the total heat release, the acid gas flow for each case has to be determined and then using a minimum heat content for the flow of acid gases from the amine unit the total heat release can be calculated. The acid gas flow rate for the first case was based on an H₂S concentration of 10 ppmv and a CO₂ concentration of 1.5%. The acid gas flow for the second case was based on an H₂S concentration of 3,000 ppmv and the same CO₂ concentration (1.5%) as the first case. A removal efficiency of 100% was used for H₂S and 90% was used for CO₂. To be able to flare waste gas, the heat content of the waste gas must be at least 200 BTU/SCF. The total heat content for each case was then calculated using the acid gas flow rate for each case and inclusion of enough auxiliary fuel gas to raise the heat content of the waste gas to 200 BTU/SCF.

Scenario 2 AERSCREEN Input Parameters

Source Parameters	Case 1	Case 2
Type	Flare	Flare
Emission Rate (lb/hr)	0.015	0.63
Stack Height (ft)	25	25
Waste Gas Heat Content (BTUH)	1,127,658	135,788

The following table shows the AERSCREEN results for Scenario 2 at each of the three locations.

Scenario 2 AERSCREEN 24-hr Average Concentrations (µg/m³)

	Case 1	Case 2
Location 1	0.9	246.9
Location 2	0.2	38.3
Location 3	0.2	31.1

The maximum modeled concentration for both cases is below the 0.2 ppm (283.3 µg/m³) ambient air concentration limit. Therefore, all amine unit still vents with emissions routed to a flare will be in compliance with the ambient air concentration limit.

SECTION III. ENGINES

The general permit limits the sulfur content of fuel gas for engines to 162 ppmv. Assuming engines have a combustion efficiency of 99% of the H₂S in the fuel gas, the engine is operating at stoichiometric combustion conditions, and the fuel gas has a heat content of 1,020 BTU/SCF, the resultant concentration in the stack gas is approximately 0.15 ppmvd H₂S at standard conditions. Since the H₂S concentration at the end of the stack is approximately equal to the 0.2 ppm ambient air concentration limit of OAC 252:100-31-7, modeling is required to demonstrate compliance with this limit.

The AERSCREEN modeling conducted to demonstrate compliance with OAC 252:100-31 for engines was based on information obtained from AQD's Emission Inventory database. Due to the variability of engines parameters, three cases were developed using representative emission units from the emission inventory database. These three cases were generated based on the following stack diameters: (a) less than 1 foot, (b) equal to 1 foot, and (c) greater than 1 foot. To determine a representative engine for each of the stack parameters, engines were also split into the following three categories: (1) less than or equal to 100-hp, (2) greater than 100-hp and less than or equal to 1,000-hp, and (3) greater than 1,000-hp. These three categories were then assigned to the specific stack diameter categories. It was determined that engines less than or equal to 100-hp would be used for the less than 1 foot diameter category since it is unusual for small engines to have large stack diameters. Engines in the 100-hp to 1,000-hp category were used for the equal to 1 foot diameter category and engines greater than 1,000-hp were used for the greater than 1 foot diameter category. The emission inventory data for the engines was separated by engines fitting into each of the specific horsepower and stack diameter categories. The data was then sorted by stack velocity and specific engines were selected to be representative for each category. The representative engines used for each category were selected because they had low stack gas exit velocities.

AERSCREEN Engine Modeling Scenario

This modeling scenario represents engines combusting fuel gas with a fuel sulfur content of 162 ppmv with a combustion efficiency of 99%, which results in an emission factor of 1.43×10^{-4} lb/MMBTU. Case 1 is based on an Arrow VRG330, a small engine with a power rating of 68-hp and a heat input of 7,300 BTU/hp-hr (0.50 MMBTUH). Case 2 is based on a White Superior 8G825, a medium engine with a power rating of 800-hp and a heat input of 7,750 BTU/hp-hr (6.20 MMBTUH). Case 3 is based on a Cooper Bessemer GMVA-10, a large engine with a power rating of 2,400-hp and a heat input of 8,000 BTU/hp-hr (19.2 MMBTUH). Actual stack flow was based on stoichiometric combustion using EPA Method 19, the given heat input, and the given stack temperature. If manufacturer's data was not available for the specific engine, the stack temperature was based on the minimum values from the emission inventory database or from stack test data. The stack height for all three cases was based on the minimum values from the emission inventory data.

AERSCREEN Input Parameters

Source Parameters	Case 1	Case 2	Case 3
Type	Point	Point	Point
Emission Rate (lb/hr)	7.08 x 10 ⁻⁵	8.84 x 10 ⁻⁴	2.74 x 10 ⁻³
Stack Height (ft)	7.0	10	15
Stack Diameter (ft)	0.33	1.0	1.5
Stack Flow (ACFM)	238	3,738	8,263
Stack Velocity (ft/s)	45	79	78
Stack Temperature (°F)	970	1,340	825

The following table shows the AERSCREEN results for each engine modeling case at each of the three locations.

AERSCREEN 24-hr Average Concentrations (µg/m³)

	Case 1	Case 2	Case 3
Location 1	< 0.1	0.1	0.1
Location 2	< 0.1	< 0.1	0.1
Location 3	< 0.1	0.1	0.1

The modeling results for the engines are all less than 1% of the standard; therefore, all engines combusting fuel with a fuel sulfur content less than 162 ppmv are in compliance with the ambient air concentration limit.

SECTION IV. HEATERS AND BOILERS

The general permit also limits the sulfur content of the fuel gas for heaters and boilers to 162 ppmv. Assuming the heaters and boilers have a combustion efficiency of 95% of the H₂S in the fuel gas, the heaters and boilers are operated at an excess air of 3% O₂ in the exhaust gas, and the fuel gas has a heat content of 1,020 BTU/SCF, the resultant concentration in the stack gas is approximately 0.75 ppmvd H₂S at standard conditions. Since the H₂S concentration at the end of the stack is greater than the 0.2 ppm ambient air concentration limit of OAC 252:100-31-7, modeling is required to demonstrate compliance with this limit.

The AERSCREEN modeling conducted to demonstrate compliance with OAC 252:100-31 for heater and boilers was based on information obtained from AQD's Emission Inventory database. The emission inventory data was separated based on stack flow rates. From these flow rates, three cases were developed. These three cases were then generated base on the following heat input parameters: (a) less than 1 MMBTUH, (b) greater than or equal to 1 MMBTUH and less than 10 MMBTUH, and (c) greater than or equal to 10 MMBTUH and less than 50 MMBTUH. Heaters and boilers with heat input ratings of greater than or equal to 50 MMBTUH were not considered since emission units in this range represent less than 2 percent of the heaters and boilers in the emission inventory database and are not representative of the overall data.

AERSCREEN Heater/Boiler Modeling Scenario

This modeling scenario represents heaters/boilers combusting fuel gas with a sulfur content of 162 ppmv with a combustion efficiency of 95%, which results in an emission factor of 7.13×10^{-4} lb H₂S/MMBTU. Case 1 is based on a low heat input of 0.5 MMBTUH. Case 2 is based on a heat input of 3.2 MMBTUH. Case 3 is based on a heat value 21 MMBTUH. The actual stack flow (ACFM) for each case was calculated based on non-stoichiometric combustion with an excess air of 3% O₂ using EPA Method 19, and the given heat input and stack temperature. Due to the variation in stack temperatures for all of the heat input ranges of heaters and boilers, a standard stack temperature of 370°F was selected based on the geometric mean of the stack temperatures for all of the heaters and boilers in the emission inventory dataset. For Case 1, the stack height was based on the lowest most significantly occurring stack height in the < 1 MMBTUH dataset and the stack diameter was selected based on the geometric mean of the dataset. Stack height and diameter for Case 2 and 3 were selected based on the geometric mean of the stack heights and stack diameters for each of the case specific heat input ranges.

AERSCREEN Input Parameters

Source Parameters	Case 1	Case 2	Case 3
Type	Point	Point	Point
Emission Rate (lb/hr)	3.57×10^{-4}	2.28×10^{-3}	1.50×10^{-2}
Stack Height (ft)	8.0	21.9	33.0
Stack Diameter (ft)	0.50	1.30	2.30
Stack Flow (ACFM)	168	1,072	7,038
Stack Velocity (ft/s)	14	13	28
Stack Temperature (°F)	370	370	370

The following table shows the AERSCREEN results for each heater/boiler modeling case at each of the three locations.

AERSCREEN 24-hr Average Concentrations (µg/m³)

	Case 1	Case 2	Case 3
Location 1	0.2	0.3	0.4
Location 2	0.1	0.1	0.1
Location 3	0.1	0.1	0.1

The modeling results for heater/boilers are all less than 1% of the standard; therefore, all heaters/boilers combusting fuel with a fuel sulfur content less than 162 ppmv are in compliance with the ambient air concentration limit.

SECTION V. GLYCOL DEHYDRATION UNITS

Triethylene glycol (TEG) dehydration units are used to remove water from natural gas. TEG dehydration units are usually equipped with a flash tank and a condenser on the still vent. The natural gas passes through the glycol contactor where water is absorbed by the glycol. The “rich” glycol containing water passes through the flash tank (if so equipped) and is then sent to the dehydration unit reboiler where heat is used to boil off the water. The glycol dehydration

unit's reboiler still vent can be routed to a condenser or through a condenser and a combustion device and then to the atmosphere to reduce emissions of VOC, HAP, and H₂S. The glycol dehydration unit's flash tank can be routed to the atmosphere, the facility inlet, or the reboiler as fuel to reduce emissions of VOC, HAP, and H₂S.

Based on review of GRI-GLYCalc Version 4.0 runs, approximately 3% of the H₂S in the gas being treated is absorbed into the TEG and is emitted from the glycol dehydration unit flash tank or still vent. If there is no flash tank, all of the H₂S is emitted from the still vent. If the dehydration unit is equipped with a flash tank, approximately half (46%) of H₂S will be in the flash tank off-gas. While minimal amounts of H₂S can be absorbed by the liquids produced in a condenser, almost all of the H₂S in the still vent off-gas will remain in the condenser off-gas which will increase the concentration of H₂S in the condenser off-gas. TEG dehydration units treating "sour" natural gas (> 4 ppmv) are ineligible for the general permit.

Flow rates of the dehydration unit still vent/flash tank were calculated assuming 0.56% of the natural gas is adsorbed by the glycol in the dehydration unit with 65% of the throughput routed to the flash tank and 35% routed to the still vent. If a condenser was present, 80% of the still vent off-gases were assumed to be removed as water.

The AERSCREEN modeling conducted to demonstrate compliance with OAC 252:100-31 for dehydration units was based on information obtained from AQD's Emission Inventory database. The glycol dehydration unit still vent was modeled as a point source with a temperature of 212°F, a stack height of 18 feet and a diameter of 2.5 inches. The glycol dehydration unit flash tank was modeled with the same parameters except the stack temperature was set at 90°F. If a condenser was used, the stack temperature was set to ambient temperature by setting the temperature to zero.

Three dehydration unit scenarios were modeled: 1) a 10 MMSCFD throughput with no flash tank, 2) a 30 MMSCFD throughput with a flash tank and a still vent, and 3) a 100 MMSCFD throughput with a flash tank vented to the inlet or reboiler fuel gas system and a still vent vented through a condenser to the atmosphere.

AERSCREEN Input Parameters

Source Parameters	Scenario 1	Scenario 2	Scenario 2	Scenario 3
Type	Point	Point	Point	Point
Source	Still Vent	Still Vent	Flash Tank	Condenser
Emission Rate (lb/hr) ¹	4.49×10^{-3}	7.27×10^{-3}	6.20×10^{-3}	2.42×10^{-2}
Emission Rate (lb/hr) ²	0.182	0.295	0.251	0.982
Stack Height (ft)	18	18	18	18
Stack Diameter (ft)	0.208	0.208	0.208	0.208
Stack Flow (ACFM)	50.26	52.77	80.21	27.75
Stack Velocity (ft/s)	24.58	25.81	39.23	13.57
Stack Temperature (°F)	212	212	90	Ambient

¹ – Emission rate based on a natural gas sulfur content of 4 ppmv.

² – Emission rate based on a natural gas sulfur content of 162 ppmv.

The following table shows the AERSCREEN results for each of the Scenario 1 cases at each of the three locations.

AERSCREEN 24-hr Average Concentration (µg/m³) at 4 ppmv

	Scenario 1	Scenario 2*	Scenario 3
Location 1	6.9	24.3	55.2
Location 2	0.7	2.9	9.7
Location 3	0.8	3.2	10.2

*Scenario 2 includes both still vent and flash tank concentrations.

AERSCREEN 24-hr Average Concentration (µg/m³) at 162 ppmv

	Scenario 1	Scenario 2*	Scenario 3
Location 1	280.4	985.0	2,237.2
Location 2	30.0	119.1	394.6
Location 3	32.2	128.2	412.8

*Scenario 2 includes impacts from the still vent and flash tank.

The maximum modeled concentrations for Scenarios 2 and 3 at 162 ppmv H₂S are above the 0.2 ppm (283.3 µg/m³) ambient air concentration limit. The maximum modeled concentration for Scenario 1 at 162 ppmv H₂S is below the ambient air concentration limit. The maximum modeled concentrations for all Scenarios at 4 ppmv H₂S are below the ambient air concentration limit.

SECTION VI. STORAGE TANKS

Storage tanks are located at production facilities, compressor stations, crude oil transfer stations, large storage facilities, and pipeline breakout stations. There are three different types of storage tanks: fixed roof (FR) storage tanks, fixed roof storage tanks with internal floating roofs (IFR), and external floating roof (EFR) storage tanks. A few facilities have storage tanks with no roofs, but these are not usually located at facilities which produce crude oil and condensate or which store VOC. Production facilities and compressor stations do not usually have storage tanks with IFRs or EFRs. Transfer stations with large storage tanks usually have storage tanks which are equipped with IFRs or EFRs to control emissions.

A review of permits for existing facilities in AQD's Emission Inventory database indicate that a typical production facility consists of a tank battery with two (2) to six (6) tanks. The tanks' capacities are generally 210 barrel (8,820 gallons) to 500 barrel (21,000 gallons) fixed roof tanks with a height of 15 feet and diameters of 10 feet to 20 feet. The tanks usually store crude oil/condensate. Large storage facilities or pipeline breakout stations also store crude oil, but the crude oil is usually weathered and can contain "sweet" and "sour" crude oil. These facilities tend to have large (> 500 barrels) IFR or EFR storage tanks. Large storage tanks range from 40 to 50 feet in height with diameters of 50 to 280 feet.

Storage tanks have emissions of VOC and H₂S. The three types of storage tanks have different types of emissions: FR storage tanks have working, breathing (standing), and in some cases flashing emissions. A large majority of them are controlled using an enclosed flare. EFR storage tanks have withdrawal, rim seal, deck fitting, roof landing, and standing idle emissions. IFR storage tanks have withdrawal, rim seal, deck fitting, deck seam, roof landing, and standing

idle emissions. Cleaning emissions related to maintenance of storage tanks are infrequent and will not be addressed further in this memorandum.

The general permit is limited to facilities that produce/store “sweet” crude oil (< 0.5% S). E&P Tanks 2.0, developed by the American Petroleum Institute, was also used to estimate the wt% of H₂S for vapors in equilibrium with crude oil containing H₂S. The ratio of H₂S emissions over total VOC emissions is almost linear over the range of concentrations studied. This is reasonable for flashing losses at atmospheric pressure and ambient temperatures. The H₂S/VOC emissions ratio is slightly higher at lower flashing temperatures. The H₂S/VOC emissions ratio can be used to estimate H₂S emissions from a tank storing crude oil with a given H₂S concentration, based on estimated VOC emissions from the tank. Based on the available speciation data in E&P Tanks 2.0, a “sour” crude oil concentration of 135 ppmw H₂S was used as a maximum concentration for determining compliance with the 24-hour average H₂S ambient air concentration. Additionally, a “sweet” crude oil concentration of 6 ppmw H₂S was used for determining compliance with the 24-hour average H₂S ambient air concentration.

Since H₂S is a gas with high vapor pressure at ambient temperatures, the concentration of H₂S in the vapor space of storage tanks will be substantially higher than the concentration of H₂S in the petroleum liquid. The H₂S concentration by weight in the vapor phase is determined using the ratio of the liquid and vapor molecular weights, the vapor pressures of H₂S, the concentration of H₂S in the liquid by weight, and the methods contained in AP-42 (11/2006), Section 7.1. Using the crude oil default molecular weight and vapor pressure values from AP-42 (11/2006), Section 7.1, the H₂S/VOC emission ratio for “sweet” crude oil (with an H₂S concentration of 6 ppmw) is 1,971 ppmw and the H₂S/VOC emission ratio for “sour” crude oil (with an H₂S concentration of 135 ppmw) is 44,346 ppmw.

The AERSCREEN modeling conducted to demonstrate compliance with OAC 252:100-31 for tanks was based on the following scenarios:

- A fixed roof tank,
- An external floating roof tank,
- An internal floating roof tank, and
- An enclosed flare used to control tank emissions from a fixed roof tank.

Emissions from storage tanks are not typical of most modeled sources, such as engine stacks (point source) and equipment components (fugitives), since they incorporate both point and fugitive sources. The emissions will generally emanate from around the perimeter of the top of the tank wall (EFR tanks) and or from one or more vents, manholes, etc. on the tank roof (FR and IFR tanks). This disperses the emissions from the broader area, but there is not a significant initial velocity for the emissions. FR and IFR tanks were modeled as point sources with no horizontal momentum. The release height was set at the height of the tank plus one foot. EFR tanks were modeled as elevated circular area sources. Enclosed flares were modeled as pseudo point source.

AERSCREEN Storage Tank Modeling Scenario 1

Scenario 1 represents AERSCREEN modeling for a fixed roof tank vented directly to the atmosphere without controls which would be located at a production facility or compressor

station. For FR tanks, emissions are typically released from one or more vents, manholes, etc. on the tank roof. Therefore, the FR tank was modeled as a pseudo point source with no horizontal or vertical momentum. Based on the review of tank dimensions mentioned previously, a worst-case tank of 210 barrels was selected for the model due to its minimal height. To account for a cone or dome roof above the shell height, the release height was assumed to be one foot above the shell height of the tank. Case 1 represents a tank storing “sweet” crude (with a concentration of 6 ppmw H₂S) at a VOC emission rate of 99 TPY. Case 2 represents a tank storing “sour” crude (with a concentration of 135 ppmw H₂S) at a VOC emission rate of 99 TPY.

Scenario 1 AERSCREEN Input Parameters

Source Parameters	Case 1	Case 2
Type	Point	Point
Emission Rate (lb/hr)	4.45×10^{-2}	1.00
Stack Height (ft)	16.0	16.0
Stack Diameter (ft)	0.5	0.5
Stack Flow (ACFM)	0.0	0.0
Stack Velocity (ft/s)	0.0	0.0
Stack Temperature (°F)	Ambient	Ambient

The following tables show the AERSCREEN results for Scenario 1 at each of the three locations.

Scenario 1 AERSCREEN 24-hr Average Concentrations ($\mu\text{g}/\text{m}^3$)

	Case 1	Case 2
Location 1	55.9	1,257.9
Location 2	49.4	1,111.6
Location 3	51.1	1,149.7

The maximum modeled concentration for Case 1 is below the 0.2 ppm (283.3 $\mu\text{g}/\text{m}^3$) ambient air concentration limit. The maximum modeled concentration for Case 2 exceeds the 0.2 ppm ambient air concentration limit.

AERSCREEN Storage Tank Modeling Scenario 2

Scenario 2 represents AERSCREEN modeling for an external floating roof tank vented directly to the atmosphere without controls which could be located at crude oil transfer stations, large storage facilities, or pipeline breakout stations. For EFR tanks, the emissions will generally emanate from around the perimeter of the top of the tank wall. Therefore, the EFR tank was modeled as an elevated circular area source with no initial vertical dimension. Based on the review of tank dimensions mentioned previously, a worst-case tank of 20,000 barrels was selected for the model due to its minimal height and diameter. Case 1 represents a tank storing “sweet” crude (with a concentration of 6 ppmw H₂S) at a VOC emission rate of 99 TPY. Case 2 represents a tank storing “sour” crude (with a concentration of 135 ppmw H₂S) at a VOC emission rate of 99 TPY.

Scenario 2 AERSCREEN Input Parameters

Source Parameters	Case 1	Case 2
Type	Circular Area	Circular Area
Emission Rate (lb/hr)	4.45×10^{-2}	1.00
Height (ft)	45.0	45.0
Diameter (ft)	30.0	30.0
Initial Vertical Dimension (ft)	0.0	0.0

The following table shows the AERSCREEN results for Scenario 2 at each of the three locations.

Scenario 2 AERSCREEN 24-hr Average Concentrations ($\mu\text{g}/\text{m}^3$)

	Case 1	Case 2
Location 1	120.2	2,705.3
Location 2	13.4	301.6
Location 3	13.3	299.3

The maximum modeled concentration for Case 1 is below the 0.2 ppm ($283.3 \mu\text{g}/\text{m}^3$) ambient air concentration limit. The maximum modeled concentration for Case 2 exceeds the 0.2 ppm ambient air concentration limit.

AERSCREEN Storage Tank Modeling Scenario 3

Scenario 3 represents AERSCREEN modeling for an internal floating roof tank vented directly to the atmosphere without controls which could be located at crude oil transfer stations, large storage facilities, or pipeline breakout stations. For IFR tanks, emissions are typically released from one or more vents, manholes, etc. on the tank roof. Therefore, the FR tank was modeled as a pseudo point source with no horizontal or vertical momentum. Based on the review of tank dimensions mentioned previously, a worst-case tank of 1,000 barrels was selected for the model due to its minimal height. To account for a cone or dome roof above the shell height, the release height was assumed to be one foot above the shell height of the tank. Case 1 represents a tank storing “sweet” crude (with a concentration of 6 ppmw H₂S) at a VOC emission rate of 99 TPY. Case 2 represents a tank storing “sour” crude (with a concentration of 135 ppmw H₂S) at a VOC emission rate of 99 TPY.

Scenario 3 AERSCREEN Input Parameters

Source Parameters	Case 1	Case 2
Type	Point	Point
Emission Rate (lb/hr)	4.45×10^{-2}	1.00
Stack Height (ft)	31.0	31.0
Stack Diameter (ft)	0.5	0.5
Stack Flow (ACFM)	0.0	0.0
Stack Velocity (ft/s)	0.0	0.0
Stack Temperature (°F)	Ambient	Ambient

The following table shows the AERSCREEN results for Scenario 3 at each of the three locations.

Scenario 3 AERSCREEN 24-hr Average Concentrations (µg/m³)

	Case 1	Case 2
Location 1	60.6	1,364.2
Location 2	13.5	303.3
Location 3	13.8	310.6

The maximum modeled concentration for Case 1 is below the 0.2 ppm (283.3 µg/m³) ambient air concentration limit. The maximum modeled concentration for Case 2 exceeds the 0.2 ppm ambient air concentration limit.

AERSCREEN Storage Tank Modeling Scenario 4

Scenario 4 represents AERSCREEN modeling for a storage tank with emissions routed to an enclosed flare for control. Enclosed flares are designed with a burner located inside a shell. Therefore, the enclosed flare was modeled as a pseudo point source. The default flare parameters were used in the modeling for stack temperature (1,273 °K) and stack velocity (20 m/s). Based on the review of permitted enclosed flares, a worst-case 2-MMBTUH enclosed flare was selected for the model due to its minimal height. Case 1 represents a tank storing “sweet” crude (with a concentration of 6 ppmw H₂S) at a VOC emission rate of 400 TPY. Case 2 represents a tank storing “sour” crude (with a concentration of 135 ppmw H₂S) at a VOC emission rate of 400 TPY. Both cases assume a control efficiency of 98%.

Scenario 4 AERSCREEN Input Parameters

Source Parameters	Case 1	Case 2
Type	Point	Point
Emission Rate (lb/hr)	3.60×10^{-3}	8.10×10^{-2}
Stack Height (ft)	12.0	12.0
Stack Diameter (ft)	4.0	4.0
Stack Flow (ACFM)	49,474	49,474
Stack Velocity (ft/s)	65.62	65.62
Stack Temperature (°F)	1831.7	1831.7

The following table shows the AERSCREEN results for Scenario 1 at each of the three locations.

Scenario 4 AERSCREEN 24-hr Average Concentrations (µg/m³)

	Case 1	Case 2
Location 1	0.1	1.5
Location 2	< 0.1	1.1
Location 3	< 0.1	1.1

The modeling results for the flared tanks are all less than 1% of the standard; therefore, storage tanks with emissions controlled by a flare/enclosed flare are in compliance with the ambient air concentration limit.

SECTION VI. TANK TRUCK LOADING

Petroleum liquid storage tanks at oil and gas facilities can be emptied by transportation through a pipeline, or by loading the liquids into tank trucks. VOC and H₂S are emitted from tank trucks loaded at oil and gas facilities. The transferred petroleum liquids displace vapors present in the truck tank. These vapors/emissions consist of vapors remaining from the previous cargo and vapors generated from loading of the new cargo. H₂S emissions can be calculated from the VOC emissions using the methods from AP-42 (11/2006), Section 7.1. Emissions from truck loading are typically a fraction of the total facility VOC emissions (in the range of 5 to 10%). Using the crude oil default molecular weight and vapor pressure values from AP-42 (11/2006), Section 7.1, the H₂S/VOC emission ratio for “sweet” crude oil (with an H₂S concentration of 6 ppmw) is 1,971 ppmw and the H₂S/VOC emission ratio for “sour” crude oil (with an H₂S concentration of 135 ppmw) is 44,346 ppmw. The maximum hourly H₂S emissions from loading operations were based on loading a tank truck with a capacity of 11,600 gallons and the default AP-42 (7/2008), Section 5.2, emission factor for submerged loading of crude oil into a tank truck in dedicated normal service of 2 lb/1,000 gallons. The maximum H₂S emissions from loading “sweet” and “sour” crude oil are 0.046 lb/hr and 1.029 lb/hr, respectively. Modeling of a vertical fixed roof tank was used to determine compliance with OAC 252:100-31-7 for loading operations. The following table shows the AERSCREEN results for both cases at each of the three locations.

Vertical Fixed Roof Storage Tank AERSCREEN Results ($\mu\text{g}/\text{m}^3$)

	Case 1	Case 2
Location 1	57.4	1,291.2
Location 2	50.7	1,141.0
Location 3	52.4	1,180.1

The maximum modeled concentration for Case 1 is below the 0.2 ppm ($283.3 \mu\text{g}/\text{m}^3$) ambient air concentration limit. The maximum modeled concentration for Case 2 exceeds the 0.2 ppm ambient air concentration limit.

SECTION VII. FUGITIVE EMISSIONS SOURCES

Equipment components such as pump seals, compressor seals, valves, flanges, connectors, open-ended lines, pneumatic control devices, and other components are the source of fugitive VOC and H₂S emissions. Emissions from fugitive equipment sources are typically a small part of the total facility VOC emissions (in the range of 2 to 5%). The general permit establishes a limit of 162 ppmv in the fuel gas; therefore, this value was used to estimate the amount of H₂S emitted from the equipment in gas/vapor service. For equipment in liquid service, which accounts for approximately 70% of the fugitive emissions, the same methodology used for loading operations was used to determine the H₂S emissions from the leaking liquid components. Using a value of 5 TPY for equipment leaks, the H₂S emissions for a facility processing “sweet” (with an H₂S concentration of 6 ppmw) crude oil would be approximately 0.0003 lb/hr. Fugitive emissions sources were modeled as a volume source covering an area of approximately 22,500 ft² (150 ft by 150 ft) with a height of 10 ft. The release height is half of the vertical dimension of the source. The initial lateral dimension is equal to the side length of the source divided by 4.3. The initial vertical dimension for an elevated source (not on or adjacent to a building) is equal to the vertical dimension of the source divided by 4.3.

AERSCREEN Input Parameters

Source Parameters	Scenario 1
Type	Volume
Emission Rate (lb/hr)	9.93 x 10 ⁻⁵
Release Height (ft)	5.0
Initial Lateral Dimension (ft)	34.88
Initial Vertical Dimension (ft)	2.33

The following table shows the AERSCREEN results for Scenario 1 at each of the three locations.

AERSCREEN 24-hr Average Concentrations (µg/m³)	
	Scenario 1
Location 1	0.1
Location 2	0.1
Location 3	0.1

The maximum modeled concentration is less than 1% of the H₂S ambient air concentration limit. Therefore, a gas fuel sulfur content limit of less than or equal to 162 ppmv and a petroleum liquid H₂S content limit of less than or equal to 6 ppmw are in compliance with the ambient air concentration limit.

SECTION VIII. SUMMARY

Amine Units

Uncontrolled amine units with their still vents routed directly to the atmosphere have a potential to exceed the OAC 252:100-31-7 H₂S ambient air concentration limit of 0.2 ppm (283.3 µg/m³) H₂S. Amine units with their still vents routed to a flare are unlikely to exceed the OAC 252:100-31-7 H₂S ambient air concentration limit of 0.2 ppm (283.3 µg/m³) H₂S. However, the ambient impact of Scenario 2, Case 2 at Location 1 has the potential to exceed the H₂S ambient air concentration limit (283.3 µg/m³) when taking into account impacts from other sources.

A limit of less than or equal to 4 ppmv H₂S in the inlet gas for amine units with their still vent routed to a control device will ensure compliance with the H₂S ambient air concentration limit in OAC 252:100-31-7. Uncontrolled amine units and amine units treating “sour” natural gas (> 4 ppmv H₂S) will require case-by-case determinations to demonstrate compliance with the H₂S ambient air concentration limit in OAC 252:100-31-7.

Engines

Engines combusting fuel with a sulfur content of less than 162 ppmv are unlikely to exceed the 0.2 ppm H₂S ambient air concentration limit in OAC 252:100-31-7. A fuel sulfur limit of 162 ppmv will ensure compliance with the H₂S ambient air concentration limit in OAC 252:100-31-7.

Heaters/Boilers

Heaters/boilers combusting fuel with a sulfur content less than 162 ppmv are unlikely to exceed the 0.2 ppm H₂S ambient air concentration limit in OAC 252:100-31-7. A fuel sulfur limit of 162 ppmv will ensure compliance with the H₂S ambient air concentration limit in OAC 252:100-31-7.

Glycol Dehydration Units

The maximum modeled concentrations for Case 2 (“sour” natural gas) of Scenarios 2 and 3 are greater than the 0.2 ppm (283.3 µg/m³) H₂S ambient air concentration limit. The maximum modeled concentrations for Case 1 (“sweet” natural gas) of Scenarios 1, 2, and 3, and Case 2 (“sour” natural gas) of Scenario 1 do not exceed the 0.2 ppm (283.3 µg/m³) H₂S ambient air concentration limit. However, the impacts from Scenario 1, Case 2, when combined with other facility impacts, could potentially exceed the ambient air concentration limit.

A limit of less than or equal to 4 ppmv H₂S in the inlet gas for dehydration units will ensure compliance with the H₂S ambient air concentration limit in OAC 252:100-31-7. Dehydration units treating “sour” natural gas (> 4 ppmv H₂S) will require case-by-case determinations to demonstrate compliance with the H₂S ambient air concentration limit in OAC 252:100-31-7.

Storage Tanks

The maximum modeled concentrations for Scenarios 1, 2, and 3, Case 2 (uncontrolled “sour” crude oil tanks) are greater than the 0.2 ppm (283.3 µg/m³) H₂S ambient air concentration limit. However, the maximum modeled concentrations for Scenarios 1, 2, and 3, Case 1 (uncontrolled “sweet” crude oil tanks) and Scenario 4, Case 1 and 2 (flared crude oil tanks) do not exceed the H₂S ambient air concentration limit. Therefore, crude oil limit of less than or equal to 6 ppmw H₂S or a requirement to route emissions from storage tanks to a flare/enclosed flare will ensure compliance with the H₂S ambient air concentration limit of OAC 252:100-31-7. Facilities handling “sour” petroleum liquid hydrocarbons (> 6 ppmw H₂S) with uncontrolled emissions from the storage tanks will require case-by-case determinations to demonstrate compliance with the H₂S ambient air concentration limit in OAC 252:100-31-7.

Tank Truck Loading

The maximum modeled concentration for Case 2 (uncontrolled loading of “sour” crude oil) is greater than the 0.2 ppm (283.3 µg/m³) H₂S ambient air concentration limit. However, the modeled concentrations for Case 1 (uncontrolled loading of “sweet” crude oil) do not exceed the H₂S ambient air concentration limit. Therefore, a crude oil limit of less than or equal to 6 ppmw H₂S will ensure compliance with the ambient air concentration limit of OAC 252:100-31-7. Facilities handling “sour” petroleum liquid hydrocarbons (> 6 ppmw H₂S) will require case-by-case determinations to demonstrate compliance with the ambient air concentration limit in OAC 252:100-31-7.

Fugitive Emissions Sources

The maximum modeled concentration for fugitive emission sources is less than the 0.2 ppm (283.3 µg/m³) H₂S ambient air concentration limit. With a natural gas sulfur content of less than or equal to 162 ppmv and a crude oil limit of less than or equal to 6 ppmw, impacts from fugitive emission sources are unlikely to exceed the 0.2 ppm H₂S ambient air concentration limit in OAC 252:100-31-7. Facilities treating/combusting “sour” natural gas (> 162 ppmv) and handling “sour” petroleum hydrocarbons liquids (> 6 ppmw H₂S) will require case-by-case determinations to demonstrate compliance with the ambient air concentration limit in OAC 252:100-31-7.

Facility Wide Compliance

The H₂S ambient air concentration of OAC 252:100-31-7 is applicable to each facility as a whole. Since not each type of oil and gas facilities will have all of the emission sources which have been evaluated, a number of representative oil and gas facility types were established to evaluate the impacts from the whole facility for the types of emission sources usually located at those facilities.

Typical Emission Units Located at Specific Types of Facilities

Emission Units	Production Sites	Tank Battery	Compressor Station ¹	Transfer Station	Storage Facility
FR Storage Tank	X	X	X ²	X	
IFR Storage Tank				X	X
EFR Storage Tank				X	X
Loading Operation	X	X	X ²		
Combustion Equipment	X	X	X		
Dehydration Unit	X ³		X		
Amine Unit	X ³		X ³		
Fugitive Sources	X	X	X	X	X

¹ - Compressor stations also represents gas plants since similar equipment is located at both.

² - Even though compressor stations will have FR storage tanks and loading operations, the liquids handled at compressor stations do not contain significant amounts of H₂S.

³ - Most facilities will not have multiple dehydration units or amine units so the evaluation only takes into account impacts from a single dehydration unit or amine unit.

Cumulative H₂S Impact at a Production Site

Emission Units	Source Impact ($\mu\text{g}/\text{m}^3$)
FR Storage Tank ¹	55.9
Loading Operation ¹	57.4
Combustion Equipment ²	1.0
Dehydration Unit ³	55.2
Amine Unit ⁴	0.9
Fugitive Sources	0.1
Total H₂S Impact	170.5

¹ - Based on “sweet” crude oil.² - Based on maximum impact for engines and heaters/boilers and two engines and two heaters/boilers.³ - Based on maximum impact for a dehydration unit treating “sweet” natural gas.⁴ - Based on controlled amine unit treating “sweet” natural gas.**Cumulative H₂S Impact at a Tank Battery**

Emission Units	Source Impact ($\mu\text{g}/\text{m}^3$)
FR Storage Tank ¹	55.9
Loading Operation ¹	57.4
Combustion Equipment ²	0.8
Fugitive Sources	0.1
Total H₂S Impact	114.2

¹ - Based on “sweet” crude oil.² - Based on maximum impact for heaters/boilers and two heaters/boilers.**Cumulative H₂S Impact at a Compressor Station**

Emission Units	Source Impact ($\mu\text{g}/\text{m}^3$)
FR Storage Tank ¹	55.9
Loading Operation ¹	57.4
Combustion Equipment ²	2.2
Dehydration Unit ³	55.2
Amine Unit ⁴	0.9
Fugitive Sources	0.1
Total H₂S Impact	171.7

¹ - Based on “sweet” crude oil.² - Based on maximum impact for engines and heaters/boilers and ten engines and three heaters/boilers.³ - Based on maximum impact for a dehydration unit treating “sweet” natural gas.⁴ - Based on controlled amine unit treating “sweet” natural gas.

Transfer Station/Storage Facility

Emission Units	Source Impact ($\mu\text{g}/\text{m}^3$)
FR Storage Tank ¹	55.9
EFR Storage Tank ¹	120.2
IFR Storage Tank ¹	60.6
Fugitive Sources	0.1
Total H₂S Impact	236.8

¹ - Based on “sweet” crude oil.

Based on the modeling, the cumulative impact of the facilities is below the H₂S ambient air concentration limit. To ensure compliance with OAC 252:100-31-7, the general permit should exclude the following:

- Facilities that produce or handle “sour” crude oil;
- Facilities with uncontrolled amine units;
- Facilities with controlled amine units treating “sour” natural gas;
- Facilities with multiple amine units; and
- Facilities with glycol dehydration units treating “sour” natural gas.

These facilities may be eligible for coverage under an Authorization to Operate if they first obtain an individual minor source construction permit, where all relevant requirements and limitations demonstrate compliance with OAC 252:100-31-7.

LOCATION MODELING PARAMETERS

Three locations were used to account for a variety of terrain differences throughout the state of Oklahoma. The following table shows location coordinates (NAD83), source base elevations, and seasonal average moisture surface characteristics.

Location Average Moisture Surface Characteristics

Location 1	UTM Coordinates:		15S 267061mE 3,881,725mN	
	Source Base Elevation:		205 m⁽¹⁾	
Season	Winter	Spring	Summer	Autumn
Albedo	0.17	0.15	0.17	0.17
Bowen Ratio	0.83	0.47	0.39	0.83
Surface Roughness Length	0.141	0.244	0.518	0.518
Location 2^b	UTM Coordinates:		14S 749,527mE 4,083,926mN	
	Source Base Elevation:		288 m⁽²⁾	
Season	Winter	Spring	Summer	Autumn
Albedo	0.18	0.16	0.18	0.18
Bowen Ratio	0.90	0.47	0.52	0.90
Surface Roughness Length	0.022	0.055	0.148	0.148
Location 3^c	UTM Coordinates:		14S 620,321mE 3,814,118mN	
	Source Base Elevation:		326 m⁽³⁾	
Season	Winter	Spring	Summer	Autumn
Albedo	0.19	0.17	0.18	0.18
Bowen Ratio	0.91	0.44	0.58	0.91
Surface Roughness Length	0.030	0.070	0.184	0.184

⁽¹⁾ – The terrain of Location 1 varies from 199.34 meters above MSL to 281.33 meters above MSL.

⁽²⁾ – The terrain of Location 2 varies from 261.30 meters above MSL to 305.09 meters above MSL.

⁽³⁾ – The terrain of Location 3 varies from 298.70 meters above MSL to 345.72 meters above MSL.

ADDITIONAL MODELING PARAMETERS

The following default AERSCREEN modeling parameters were used uniformly throughout each of the modeling runs.

DEFAULT MODELING PARAMETERS

Source Parameters	
Pollutant	Other (H ₂ S)
Land Type	Rural
Building Parameters	
Building Selection	No Building Downwash
Met Data Parameters	
Minimum Temperature (K)	250.0
Maximum Temperature (K)	310.0
Minimum Wind Speed (m/s)	0.5
Anemometer Height (m)	10.0
Land Use Type	From AERSURFACE Values (See Appendix A)
Receptor Parameters	
Maximum Receptor Distance (m)	1000.0
Distance to Fence Line (m)	1.0
Flagpole Height (m)	0.0
Discrete Receptors	None
Terrain Parameters	
Include Terrain	See Appendix A for location source base elevations and locations

EXAMPLE CALCULATIONS

Calculation of inlet gas flow rate based on a given H₂S emission rate and a fixed concentration of H₂S in the inlet gas.

$$Q = 0.3 \frac{lb}{hr} \div 34.08 \frac{lb}{lb-mole} \times 379.5 \frac{SCF}{lb-mole} \times 24 \frac{hr}{day} \div 4 \frac{SCF}{MMSCF} = 20 MMSCFD$$

Where:

Q is the flow rate of inlet gas;

$0.3 \frac{lb}{hr}$ is the given H₂S emission rate;

$34.08 \frac{lb}{lb-mole}$ is the molecular weight of H₂S;

$379.5 \frac{SCF}{lb-mole}$ is the molar volume of a gas @ 60°F; and

$4 \frac{SCF}{MMSCF}$ is the given concentration of H₂S in the inlet gas (4 ppmv).

Calculation of the amine unit flow rate based on a given CO₂ concentration in the inlet gas:

$$Q = 0.025 \frac{SCF}{SCF} \times 20 \frac{MMSCF}{day} \div 24 \frac{hr}{day} \times 90\% \times \frac{1E6}{MM} \times \frac{(460 + 100)R}{520 R} = 20,238 ACFH$$

Where:

Q is the flow rate of waste gas from the amine unit still vent;

$0.025 \frac{SCF}{SCF}$ is the given concentration of CO₂ in the inlet gas (2.5%);

$20 \frac{MMSCF}{day}$ is the flow rate of inlet gas; and

90% is the capture and removal efficiency of the amine unit.

$\frac{(460+100)R}{520 R}$ is the correction from 60°F to stack temperature of 100°F; and

Calculation of the velocity of the based on a given stack diameter and stack flow:

$$V = 20,238 \frac{ACF}{hr} \div 60 \frac{min}{hr} \div 60 \frac{sec}{min} \div \left(\frac{\left(\frac{4}{12} ft\right)^2 \times \pi}{4} \right) = 64 \frac{ft}{sec}$$

Where:

V is the stack velocity;

$20,238 \frac{ACF}{hr}$ is the stack flow rate;

$\frac{\left(\frac{4}{12} ft\right)^2 \times \pi}{4}$ is the calculation of the area of the stack given the diameter (4 inches).

Calculation of the amount of auxiliary fuel gas needed to get a heat content of 200 BTU/SCF based on a given waste gas flow rate and taking into account the heat added by the H₂S in the waste gas stream:

$$Q = \left(200 \frac{BTU}{SCF} \times 4,509 \frac{SCF}{hr} \right) - \left(\left(646 \frac{BTU}{SCF} - 200 \frac{BTU}{SCF} \right) \times 3 \frac{SCF}{hr} \right) \Big/ \left(1,000 \frac{BTU}{SCF} - 200 \frac{BTU}{SCF} \right) = 1,125 \frac{SCF}{hr}$$

Where:

Q is the flow rate of auxiliary fuel gas needed (SCFH);

$4,510 \frac{SCF}{hr}$ is the flow rate of waste gas minus the amount of H₂S;

$3 \frac{SCF}{hr}$ is the flow rate of H₂S;

$646 \frac{BTU}{SCF}$ is the heat content of H₂S;

$200 \frac{BTU}{SCF}$ is the required heat content of the waste gas stream; and

$1,000 \frac{BTU}{SCF}$ is the heat content of natural gas.

Calculation of the total heat release of the waste gas with a given heat content:

$$H = \left[\left(1,125 \frac{SCF}{hr} \times 1,000 \frac{BTU}{SCF} \right) + \left(3 \frac{SCF}{hr} \times 646 \frac{BTU}{SCF} \right) \right] \times \frac{1 MM}{10^6} = 1.13 \frac{MMBTU}{hr}$$

Where:

H is the total heat release of the waste gas;

$1,125 \frac{SCF}{hr}$ is the flow rate of the auxiliary fuel (natural gas);

$1,000 \frac{BTU}{SCF}$ is the heat content of natural gas;

$3 \frac{SCF}{hr}$ is the flow rate of H₂S; and

$646 \frac{BTU}{SCF}$ is the heat content of H₂S.

Calculation of the stack concentration with a given fuel gas concentration and combustion efficiency (99%).

$$C = 162 \frac{SCF}{MMSCF} \times (1 - 0.99) \div 1,020 \frac{BTU}{SCF} \div 10,610 \frac{WSCF}{MMBTU} \times 1E6 \frac{SCF}{MMSCF} = 0.15 \frac{SCF}{MMSCF}$$

Where:

C is the concentration in the stack gas (ppmvd);

$162 \frac{SCF}{MMSCF}$ is the concentration of H₂S in the fuel gas (ppmv);

0.99 is the combustion efficiency;

$1,020 \frac{BTU}{SCF}$ is the heat content of the fuel gas; and

$10,610 \frac{WSCF}{MMBTU}$ is the Fw factor for natural gas from Method 19.

Calculation of the glycol dehydration unit still vent flow rate based on a given processing rate:

$$Q = 10 \frac{MMSCF}{day} \times \frac{1E6}{MM} \times 0.56\% \times \frac{(460 + 212)R}{520 R} \div 24 \frac{hr}{day} \div 60 \frac{min}{hr} = 50.26 ACFM$$

Where:

Q is the flow rate of waste gas from the amine unit still vent (actual ft³/min);

$10 \frac{MMSCF}{day}$ is the dehydration unit processing rate;

0.56% is the amount of natural gas adsorbed by the glycol in the dehydration unit; and
 $\frac{(460+212)R}{520 R}$ is the correction from 60°F to stack temperature of 212°F.

Calculation of the glycol dehydration unit still vent H₂S emissions based on a given processing rate and H₂S concentration:

$$E = 10 \frac{MMSCF}{day} \times 162 \frac{SCF}{MMSCF} \div 379.5 \frac{SCF}{lb - mole} \times 34.08 \frac{lb}{lb - mole} \times 3\% \div 24 \frac{hr}{day} = 0.1818 \frac{lb}{hr}$$

Where:

- E is the emissions of H₂S from the glycol dehydration unit (lb/hr);
- $10 \frac{MMSCF}{day}$ is the dehydration unit processing rate;
- $162 \frac{SCF}{MMSCF}$ is the given concentration of H₂S in the inlet gas (162 ppmv);
- $379.5 \frac{SCF}{lb - mole}$ is the molar volume of a gas @ 60°F;
- $34.08 \frac{lb}{lb - mole}$ is the molecular weight of H₂S; and
- 3% is the amount of H₂S adsorbed by the glycol in the dehydration unit.

Calculation of the H₂S/VOC emissions ratio in the vapor released from petroleum liquids based on a given petroleum liquid H₂S concentration:

$$Z_{V_i} = 6 \frac{lb}{10^6 lb} \times 207 \frac{lb}{lb - mole} \div 50 \frac{lb}{lb - mole} \times 237.07 psia \div 2.98 psia = 1,971 \frac{lb}{10^6 lb}$$

Where:

- Z_{V_i} is the weight fraction of H₂S in the vapor emitted (ppmw);
- $6 \frac{lb}{10^6 lb}$ is the weight fraction of H₂S in the liquid (6 ppmw);
- $207 \frac{lb}{lb - mole}$ is the molecular weight of the liquid;
- $50 \frac{lb}{lb - mole}$ is the molecular weight of the vapor stock;
- 237.07 psia is the vapor pressure of H₂S at the daily average surface temperature (61.98°F); and
- 2.98 psia is the total vapor pressure of the liquid mixture.

Calculation of emissions from tank truck loading operations based on a given H₂S concentration of the liquids loaded:

$$E = 1,971 \frac{lb}{10^6 lb} \times 2 \frac{lb}{1000 gal} \times 11,600 gal \times 1 hr = 0.046 \frac{lb}{hr}$$

Where:

- E is the emissions of H₂S from tank truck loading (lb/hr);
- $1,971 \frac{lb}{10^6 lb}$ is the weight fraction of H₂S in the vapor emitted (1,971 ppmw);
- $2 \frac{lb}{1000 gal}$ is the emission factor for submerged loading of crude oil into a tank truck in dedicated normal service;

11,600 gal is the capacity of a tank truck; and

1 hr is the time required to fill a tank truck.

Calculation of emissions from fugitive emissions sources based on a given H₂S concentration in the gases and liquids:

$$E_T = E_L + E_V$$

Where:

E_T is the total emission rate from fugitive emission sources;

E_L is the emission rate from fugitive components in liquid service; and

E_V is the emission rate from fugitive components in gas/vapor service.

$$E_L = 5 \frac{\text{tons}}{\text{yr}} \times 2000 \frac{\text{lb}}{\text{ton}} \div 8,760 \frac{\text{hr}}{\text{yr}} \times 70\% \times 6 \frac{\text{lb}}{10^6 \text{ lb}} = 4.79 \times 10^{-6} \frac{\text{lb}}{\text{hr}}$$

Where:

$5 \frac{\text{tons}}{\text{yr}}$ is the total VOC emissions from fugitive equipment leaks;

70% is the percentage of VOC emissions from components in liquid service; and

$6 \frac{\text{lb}}{10^6 \text{ lb}}$ is the weight fraction of H₂S in the liquid (6 ppmw).

$$E_V = 5 \frac{\text{tons}}{\text{yr}} \times 2000 \frac{\text{lb}}{\text{ton}} \div 8,760 \frac{\text{hr}}{\text{yr}} \times 30\% \times 162 \frac{\text{SCF}}{\text{MMSCF}} \div 379.5 \frac{\text{SCF}}{\text{lb-mole}}$$

$$\times 34.08 \frac{\text{lb}}{\text{lb-mole}} \times 379.5 \frac{\text{SCF}}{\text{lb-mole}} \div 20 \frac{\text{lb}}{\text{lb-mole}} \times \frac{1 \text{ MM}}{10^6} = 9.45 \times 10^{-5} \frac{\text{lb}}{\text{hr}}$$

Where:

$5 \frac{\text{tons}}{\text{yr}}$ is the total VOC emissions from fugitive equipment leaks;

30% is the percentage of VOC emissions from components in gas/vapor service; and

$162 \frac{\text{SCF}}{\text{MMSCF}}$ is the weight fraction of H₂S in the fuel gas (162 ppmv).

$379.5 \frac{\text{SCF}}{\text{lb-mole}}$ is the molar volume of a gas @ 60°F;

$34.08 \frac{\text{lb}}{\text{lb-mole}}$ is the molecular weight of H₂S; and

$20 \frac{\text{lb}}{\text{lb-mole}}$ is the molecular weight of vapors released.