OKLAHOMA DEPARTMENT
OF ENVIRONMENTAL QUALITY

Guidance on Estimating Condensate and Crude Oil Loading Losses from Tank Trucks

Section I. Introduction

The purpose of this guidance document is to provide general guidance on estimating condensate and crude oil evaporative emissions from tank trucks during loading operations.

- OAC 165:10-1-2 defines condensate as “a liquid hydrocarbon which: (A) [w]as produced as a liquid at the surface, (B) [e]xisted as a gas in the reservoir, and (C) [h]as an API gravity greater than or equal to fifty degrees, unless otherwise proven.”
- OAC 165:10-1-2 defines crude oil as “any petroleum hydrocarbon, except condensate, produced from a well in liquid form by ordinary production methods.”

The Air Quality Division (AQD) has received permit applications requesting the use of a reduced Volatile Organic Compounds (VOC) loading emission factor for estimating tank truck loading loss emissions. This is to account for methane and ethane entrained in the petroleum liquid that, along with VOC, are released in the vapors as the petroleum liquid is loaded. In some cases, the proposed non-VOC reduction represents a combined methane and ethane vapor concentration of greater than 30 percent by weight.

Permit applications are submitted with loading loss emissions calculated using the methodology outlined in AP-42 (6/08), Section 5.2, using process simulation software, or both. Process simulation software estimates emissions based on all streams reaching equilibrium. The majority of permitted loading losses are calculated assuming negligible concentrations of methane and/or ethane. Due to the high concentrations of methane and ethane proposed in some permit applications, a review of the calculation methodology was conducted and resulted in this guidance document.

Section II. Background Discussion

As stated in AP-42 (6/08), Section 5.2: Transportation and Marketing of Petroleum Liquids:

“Loading losses are the primary source of evaporative emissions from rail tank car, tank truck, and marine vessel operations. Loading losses occur as organic vapors in empty cargo tanks are displaced to the atmosphere by the liquid being loaded into the tanks. These vapors are a composite of (1) vapors formed in the empty tank by evaporation of residual product from previous loads, (2) vapors transferred to the tank in vapor balance systems as product is being unloaded, and (3) vapors generated in the tank as new product is being loaded. The quantity of evaporative losses from loading operations is, therefore, a function of the following parameters:

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(Fact Sheets\AQD\Loading Losses Guidance.indd 8/2017.)

- Physical and chemical characteristics of the previous cargo;
- Method of unloading previous cargo;
- Operations to transport the empty carrier to a loading terminal;
- Method of loading the new cargo; and
- Physical and chemical characteristics of the new cargo."

Variation in these parameters can result in the release of different quantities of actual VOC emissions. For example:

- A tank truck recently cleaned or previously carrying nonvolatile liquids loading a volatile liquid will emit less VOC emissions. This is because the vapors in the tank truck prior to loading contain little to no VOCs.
- A tank truck previously carrying a more volatile liquid than the liquid currently being loaded will emit more VOC emissions. This is due to the higher concentration of VOCs in the vapors of the tank truck prior to loading.
- A tank truck being loaded that had been utilizing a vapor balance system when unloading would result in a greater saturation factor and increased emissions.

Section III. AP-42 Emission Factor Calculation

Emissions from tank truck loading losses are predominantly calculated using Equation 1 of AP-42 (6/08), Section 5.2.

$$L_L = 12.46\frac{SPM}{T}$$

Where:

L_L	=	Loading loss, pounds per 1,000 gallons (lb/10^3 gal) of liquid loaded;
S	=	Saturation factor, dimensionless;
P	=	True vapor pressure (TVP) of liquid loaded, pounds per square inch absolute (psia);
M	=	Molecular weight of vapors, pounds per pound-mole (lb/lb-mol);
T	=	Temperature of bulk liquid loaded, °R (°F + 460); and
12.46	=	Conversion factor which incorporates the ideal gas constant (10.731 ft^3 psia/°R lb-mole) and a conversion to put L_L in terms of lb/1,000 gallons.

The loading loss emission factor calculated by this equation is proportional to the true vapor pressure of the liquid loaded and the vapor molecular weight, and is inversely proportional to temperature of the bulk liquid loaded (EPA-450/3-76-039, Page 10). AP-42 indicates the equation has a probable error of ± 30 percent. Loading operations can be controlled through the use of various control measures and control equipment.

Saturation Factor (S)

AP-42 (6/08), Section 5.2 defines the saturation factor as representing "the expelled vapor's fractional approach to saturation, and it accounts for the variations observed in emission rates from the different unloading and loading methods." Although several methods of loading tank trucks are described in Section 5.2, it is standard industry practice to conduct submerged fill loading. Most tank trucks are equipped with pumps that pump the liquids into the bottom of the tank truck. AP-42 (6/08), Section 5.2 suggests the following saturation factors:

Typical AP-42 Suggested Saturation Factors

Loading Method	Service Type	S
Submerged Loading	Dedicated Normal Service	0.60
	Dedicated Vapor Balance Service	1.00
Splash Loading	Dedicated Normal Service	1.45
	Dedicated Vapor Balance Service	1.00

A tank truck in dedicated normal service refers to the handling of one product (e.g., crude oil, gasoline, etc.). A tank truck in dedicated vapor balance service (for the purpose of selecting a saturation factor) refers to the handling of one product, in which the vapors displaced during unloading are transported to the tank truck being emptied. As a result, the emptied tank truck will contain saturated organic vapors, which during loading operations, causes more loading losses than a tank truck in dedicated normal service.

True Vapor Pressure (P)

The true vapor pressure of the liquid being loaded should be calculated at the temperature used to calculate emissions. The following table shows the true vapor pressures for a crude oil with a Reid vapor pressure (RVP) of 5 psia over a range of temperatures. Although crude oil with an RVP of 5 psia is the only crude oil presented in AP-42, not all crude oils should be calculated using the values for RVP 5 crude oil.

Crude Oil (RVP 5) True Vapor Pressure at Selected Temperatures [1]

Temperature (°F)	40	50	60	70	80	90	100
True Vapor Pressure (psia)	1.8	2.3	2.8	3.4	4.0	4.8	5.7

1 - AP-42 (11/06), Table 7.1-2.

The true vapor pressure of the liquid may be obtained using:

- The true vapor pressure measured from representative atmospheric liquids;
- The methodologies outlined in AP-42 (11/06), Section 7.1 and representative data; or
- Process simulation software and a representative lab analysis.

Vapor Molecular Weight (M)

The vapor molecular weight can vary depending on the liquid being loaded. For example: the vapor molecular weight given in AP-42 (11/06), Table 7.1-2 for crude oil (RVP 5) at 60°F is 50 lb/lb-mole, and for gasoline (RVP 7) at 60°F is 68 lb/lb-mole. The vapor molecular weight used should be that of the entire vapor composition. An applicant may use a vapor molecular weight obtained from one of the following:

- The methodologies outlined in AP-42 (11/06), Section 7.1 and representative data; or
- Process simulation software and a representative lab analysis.

Note: Some process simulators assume the composition of the loading vapors to be the same as the calculated working and breathing losses from the tank storing the liquid that is loaded. Assuming a truck is in dedicated service, this is an acceptable assumption. If this option is utilized, it is important to ensure the vapor composition does not include any components from the flash gas stream.

Loading Liquid Temperature (T)

The temperature used to calculate loading emissions should be representative of the actual temperature of the liquids as they are loaded into the tank trucks. If the liquid bulk temperature is unknown, it may be calculated using AP-42 (11/06), Section 7.1, Equation 1-28 as follows:

$$T_B = T_{AA} + 6\alpha - 1$$

Where:

T_B = Liquid bulk temperature, °R;

T_{AA} = Daily average ambient temperature, °R; and

α = Tank paint solar absorptance, dimensionless.

Actual local temperature data can be used to calculate the daily average ambient temperature. Additionally, the average ambient temperature for the state of Oklahoma is approximately 60°F as calculated by Tanks 4.0.9d. A list of various tank paint solar absorptance factors are listed in AP-42 (11/06), Table 7.1-6.

Average Ambient and Average Liquid Bulk Temperatures for Crude Oil in Oklahoma

City, State	Average Ambient Temp. [1]	Average Liquid Bulk Temp. for a White Tank [2]	Average Liquid Bulk Temp. for a Black Tank [3]
Oklahoma City, Oklahoma	**59.9ºF**	**59.9ºF**	**64.7ºF**
Tulsa, Oklahoma	**60.3ºF**	**60.3ºF**	**65.1ºF**

1 – This data was generated using Tanks 4.0.9d and crude oil (RVP 5).

2 – Based on a paint solar absorptance factor of 0.17 for a white tank in good condition.

3 – Based on a paint solar absorptance factor of 0.97 for a black tank (both good and poor conditions).

Loading loss emission factors will differ between long-term and short-term based estimates. A long-term emission factor, used to estimate ton per year (TPY) emission rates, should be based on the annual average liquid bulk temperature of the liquid being loaded. As stated previously, the true vapor pressure used to calculate loading losses should be calculated at the temperature used.

Short-term emission factors, used to estimate lb/hr emission rates, should be based on the maximum loading rate and the worst case loading factor parameters (i.e. highest liquid bulk temperature and associated true vapor pressure).

Although the loading loss emission factor is inversely proportional to the liquid bulk temperature (i.e., as temperature increases, the emission factor decreases), the true vapor pressure of the liquid (to which the loading loss emission factor is directly proportional) has a greater effect on the calculation of the loading loss emission factor than the liquid bulk temperature. Therefore, using a higher liquid bulk temperature and correlating true vapor pressure will result in a higher loading loss emission factor.

For long-term loading loss emission factor calculations, an applicant may use:

- Annual average bulk temperature of the liquids from site-specific data;
- A liquid bulk temperature equal to the API standard temperature (60°F); or

- A liquid bulk temperature calculated from the annual average temperature using the method in AP-42 (11/06), Section 7.1 and:
  – The location data listed in AP-42 (11/06), Section 7.1;
  – The API standard temperature (60°F); or
  – Local temperature data.

For short-term loading loss emission factor calculation, an applicant may use:

- The worst case expected temperature of the liquids being loaded; or
- A liquid bulk temperature calculated from the average highest daily temperature using the methodology provided in AP-42 (11/06), Section 7.1 and:
  – The location data listed in AP-42 (11/06), Section 7.1; or
  – Local temperature data.

Summary of AP-42 Calculation Methodology

Based on the properties presented in AP-42 (11/06), Section 7.1, AP-42 (6/08), Section 5.2 suggests the following loading emission factors for uncontrolled tank trucks:

AP-42 Suggested Loading Loss Factors

Service Type	L_L (lb/10^3 gallons) [1]
Submerged Loading, Dedicated Normal Service (S = 0.60)	
Crude Oil [2]	**2**
Gasoline [3]	**5**
Splash Loading, Dedicated Normal Service (S = 1.45)	
Crude Oil [2]	**5**
Gasoline [3]	**12**
Dedicated Vapor Balance Service (S = 1.00)	
Crude Oil [2]	**3**
Gasoline [3]	**8**

1 – Rounded to nearest whole number.

2 – Based on crude oil with an RVP of 5 psia at 60°F.

3 – Based on gasoline with an RVP of 10 psia at 60°F.

Review of AQD's Emissions Inventory Database indicates that loading loss emission factors used to report emissions for crude oil loading were between 2 and 3 lb/10^3 gallons on average and ranged up to 4.5 lb/10^3 gallons for submerged loading in dedicated normal service. Loading loss emissions factors used to report emissions for condensate loading were between 3 and 4 lb/10^3 gallons on average and ranged up to 7.5 lb/10^3 gallons for submerged loading in dedicated normal service. These loading loss factors are within the range of the referenced AP-42 factors.

Section IV. Load Loss Emission Factor Reductions

Emission Controls

AP-42 identifies several options that are used to control vapors being displaced by the loading of liquids into a tank truck. If utilizing control equipment to control emissions from tank truck loading, AQD will allow the collection efficiencies in AP-42 (06/08), Section 5.2 to be used when calculating the overall control efficiency. Tank truck emission controls (i.e., collection efficiency and control efficiency) cannot be taken into account when calculating potential to emit (PTE) emissions from tank truck loading unless an applicant requests federally enforceable requirements to be incorporated into their permit.

Vapor Composition

As noted in AP-42 (6/08), Section 5.2, "VOC factors for crude oil can be assumed to be 15 percent lower than the total organic factors, to account for the methane and ethane content of the crude oil evaporative emissions. All other products should be assumed to have VOC factors equal to total organics."

Applications have been submitted with various speciated analyses: (1) pressurized separator gas streams, (2) pressurized separator liquids streams, and (3) other various pressurized spot sampling locations for pipeline gas streams. Typical lab analyses of atmospheric hydrocarbon liquids sampled from residual flash lab analyses generally identify non-detectable amounts of methane and minimal amounts of ethane still present in the liquids after flashing has occurred.

Utilizing a limited number of speciated analyses, the speciation calculation methodology presented in AP-42 (11/06), Section 7.1, and calculated vapor pressures (Perry 2-50), AQD estimated the non-VOC content of the data to be approximately 15 percent by weight. A review of speciated analyses from production site atmospheric storage tank vapors indicates a concentration of up to 15 percent by weight for methane and ethane combined. The boiling point of methane and ethane are -258.52°F and -127.5°F, respectively (Perry 2-37 and 2-40). Therefore, it is assumed that most of the methane and ethane in the petroleum liquids is released when the liquid exits the pressurized stream into a storage tank and reaches atmospheric temperature and pressure. However, some small amount of the methane and ethane may still remain dissolved in the liquids after flashing has occurred. The amount of methane and ethane in the petroleum liquids after flashing is dependent on the specific composition, temperature, and pressure of the stored liquids. Stored petroleum liquids containing methane and ethane will have a higher true vapor pressure and vapors with a lower vapor molecular weight.

Condensate and crude oil from production facilities will generally contain more volatile components (i.e., methane and ethane). Over time, the petroleum liquids stored in atmospheric tanks will evaporate and more volatile components will be lost to evaporation. Liquids being loaded at non-production sites will have negligible concentrations of methane and ethane. The retention time of liquids in a tank prior to being loaded into a tank truck has an effect on the amount of methane and ethane in the liquid when it is loaded.

Section V. Produced Water Loading Loss Emission Factors

In addition to crude oil, condensate, and natural gas, oil and gas wells will also produce significant quantities of water. This water is separated from the crude oil, condensate, and natural gas by various means throughout the various stages of processing to improve the quality of the hydrocarbons produced. This water is commonly referred to as produced water. Trace amounts of hydrocarbons will be present in the produced water. The amount of hydrocarbons present in the produced water can be affected by equipment operation.

For the purpose of calculating emissions from produced water tank truck loading operations, an applicant should use the same methods used for calculating loading losses for crude oil and condensate. After a review of select process simulation model outputs, the loading loss emission factor calculated for produced water consistently appears to be less than one percent (1 percent) of the loading loss emission factor calculated for crude oil or condensate. Therefore, an applicant may conservatively assume the produced water loading loss emission factor to be 1 percent of the calculated crude oil or condensate loading loss emission factor as an acceptable alternative calculation method.

Section VI. Conclusion

Based on AQD's review of the AP-42 calculation methodology and additional considerations for estimating evaporative emissions from petroleum liquids loaded into tank trucks, AQD will allow the assumptions and calculation methodologies presented in this section to be used to determine an appropriate loading loss emission factor.

New Facilities – Prior to Startup

Estimating emissions prior to the construction of a new facility represents an obvious challenge, because there is no facility-specific data on the composition and characteristics of the gas and hydrocarbon liquids that will be produced and/or processed. DEQ's policy is to provide the owner/operator considerable latitude in predicting the composition of various process streams and in estimating emissions prior to first construction, provided that the applicant provides a complete description of the assumptions used and the methods employed. In addition, it is essential that, when using data from a similar facility, the applicant indicate the location of the reference facility, the date the sample was collected, and a justification why the data set used is considered likely to be representative of the new facility. Loading loss emission factor calculations for new facilities may include data from nearby representative facilities, or from the information provided in AP-42 (6/08), Section 5.2 and Section AP-42 (11/06), 7.1.

Facilities Currently Operating

For existing facilities, the owner/operator will have access to additional site-specific data. Therefore, loading loss emission factors for currently operating facilities shall be calculated based on the following:

- Tank trucks may be considered to be in dedicated normal service (i.e. they handle petroleum liquids with similar component compositions).
- The vapors from working and breathing losses may be considered to be representative of the vapors displaced from the tank truck during loading operations. Vapors in the atmospheric storage tank headspace resulting from flashing are not representative of the vapors from truck loading operations.
- The appropriate saturation factor (S) from AP-42 (6/08), Section 5.2 should be utilized, i.e.:
  - For submerged fill, dedicated normal service, S = 0.60.
  - For splash fill, dedicated normal service, S = 1.45
  - For dedicated vapor balance service (during unloading operations), S = 1.00.
- The true vapor pressure (P) of the liquid being loaded should correspond to the temperature being utilized (long-term or short-term) in the emissions calculation. The true vapor pressure may be obtained using:
  - The true vapor pressure measured from atmospheric liquids;

  - The methodologies outlined in AP-42 (11/06), Section 7.1 and representative data; or
  - Process simulation software and a representative lab analysis.
- The molecular weight (M) of the vapors being expelled during loading should be representative of the entire vapor composition and can be obtained using:
  - The methodologies outlined in AP-42 (11/06), Section 7.1 and representative data; or
  - Process simulation software and a representative lab analysis.
- The liquid bulk temperature (T) can be:
  - For long term calculations:
    - ➢ The annual average bulk temperature of the liquids from site-specific data;
    - ➢ A liquid bulk temperature equal to the API standard temperature (60°F); or
    - ➢ A liquid bulk temperature calculated from the annual average temperature using the method in AP-42 (11/06), Section 7.1 and:
      - ▪ The location data listed in AP-42 (11/06), Section 7.1;
      - ▪ The API standard temperature (60°F); or
      - ▪ Local temperature data.
  - For short-term calculations:
    - ➢ The worst case expected temperature of the liquids being loaded; or
    - ➢ A liquid bulk temperature calculated from the average highest daily temperature using the methodology provided in AP-42 (11/06), Section 7.1 and:
      - ▪ The location data listed in AP-42 (11/06), Section 7.1; or
      - ▪ Local temperature data.
- Emissions controls may be applied based on the following:
  - The collection efficiency shall be selected based on the appropriate suggested value from AP-42 (6/08), Section 5.2;
  - The overall control efficiency shall include the collection efficiency and the control efficiency and any downtime of the control device; and
  - The applicant must request federally enforceable requirements be incorporated into their permit when calculating PTE emissions in order to account for tank truck loading emissions controls.
- VOC content of loading loss vapors:
  - The applicant may exclude the non-VOC components from the emissions calculation by multiplying the calculated loading loss emission factor by the percent of VOC components (by weight) in the vapors only if site-specific data is used to calculate the speciated breakdown of the loading loss vapors;
  - Otherwise, the following shall be assumed:
    - ➢ For condensate and crude oil, a loading loss vapor VOC content of 85 percent by weight (i.e., 15 percent by weight methane and ethane) may be assumed at wellhead facilities only as long as the loading loss emission factor (calculated in accordance with Section III) is equal to or greater than the AP-42 loading factor of 2 lb/10^3 gallons.
    - ➢ Condensate and crude oil being loaded at a facility other than a wellhead facility should assume a vapor VOC content of 100 percent.
    - ➢ All other petroleum liquids being loaded should assume a vapor VOC content of 100 percent.

- Produced water loading loss emission factors can be obtained using:
  - The same calculation methodology used to calculate the condensate or crude oil emission factor and appropriate produced water parameters; or
  - By multiplying the calculated condensate or crude oil emission factor by 1 percent.

Additional Considerations

Regardless of the calculation methodology chosen or the type of data used, the applicant shall adhere to the following requirements:

- If an applicant uses a lab analysis (from representative or site-specific samples) to calculate any of the loading loss emission factor parameters (using process simulation software, AP-42 calculation methodologies, etc.), the lab analysis shall not be older than three (3) years. Additionally, if the facility is a wellhead site, the facility shall be sampled after the last time the well was refractured.
- When using process simulation software to calculate loading loss emissions, the software shall be used as intended by conforming to the software user guidance provided by the developer. Upon request, the applicant shall provide a copy of the process simulation computer files for AQD review. The applicant shall submit a detailed report which identifies the following:
  - All user-defined inputs (values, calculations, formulations, relationships, etc.);
  - All assumptions made;
  - Equation of state used;
  - Stream flowsheet(s);
  - Stream composition and properties; and
  - Resulting emissions.
- When using representative samples with a process simulator to calculate any of the loading loss emission factor parameters, the sample must meet the following criteria:
  - For wellhead facilities, the sample shall be taken from a site that produces from the same reservoir/formation as the actual site;
  - For non-wellhead facilities, the sample shall be taken from a site with similar inlet properties;
  - The sample shall be from a site having a sales oil with similar API gravity as the actual site;
  - The sample shall be taken from a stream that is processed in a similar manner as the actual site; and
  - The sample shall be taken from a stream similar in temperature and pressure to the actual site at the point of sampling.
- When using representative data, the applicant must include a description that identifies how the sample is representative of the facility.
- If an applicant claims a loading loss vapor VOC content other than allowed as mentioned previously, the applicant will be required to submit site-specific documentation for the operating permit application.
- Alternative calculations that have been proven to be equivalent to the methods indicated in the guidance may be approved by the Air Quality Division Director.

Section VII. References

Oklahoma Administrative Code, Title 165: Corporation Commission, Chapter 10: Oil and Gas Conservation, Subchapter 1, OAC 165:10-1, August 25, 2016.

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U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, "Fifth Edition Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources," Publication AP-42, Research Triangle Park, North Carolina, January 1995.

https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emission-factors

U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, "Revision of Evaporative Hydrocarbon Emission Factors" Publication EPA-450/3-76-039, Research Triangle Park, North Carolina, August 1976.

Who Can I Contact for More Information?

For assistance, contact the Air Quality Division at (405) 702-4100 and ask to speak with a permit writer.

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