Emissions from Aboveground Storage Tanks
the basics - 2002

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STORAGE TANKS
Emission Estimates

- Fixed Roof Tank (no floating roof)
  - Standing (Breathing) Loss
  - Working (Filling) Loss
  - ASSUMES STABLE LIQUIDS
- Floating Roof Tank
  - Standing Loss
  - Working (Clingage) Loss
  - ASSUMES THAT THE DECK IS FLOATING

Background on Emission (Loss) Factors

- Developed from over 20 years of testing.

  Research sponsored by API, in cooperation with EPA.

- Published by both API and EPA.

  Chapter 19 of API's MPMS;

  Section 7.1 of EPA's AP-42.

- Encoded in EPA's TANKS software.

  Latest factors in TANKS 3.1 (DOS-version);

  TANKS 4.0X is for Windows, with the same factors.

API Research

- Pilot tank testing in the late 1970’s.
  - Yielded useful info., such as effect of ambient wind.
  - Not feasible for isolating components.
- Wind tunnel and bench scale tests.
  - Testing of individual deck fittings & rim seals.
  - Testing at various wind speeds.
  - ‘Zero wind speed’: frequent air changes (not still air).
  - Bolted deck seams the most difficult to standardize.

API's MPMS, Chapter 19

Manual of Petroleum Measurement Standards

Chapter 19–Evaporative Loss Measurement.

- 19.1 Evaporative Loss from Fixed-Roof Tanks.
- 19.2 Evaporative Loss from Floating-Roof Tanks.
- 19.3 Loss Factor Certification Program.
  - Parts A-E are test methods.
  - Parts F-H are for administration of the tests.
- 19.4 RP for Speciation of Evaporative Losses.

EPA's AP-42

Compilation of Air Pollutant Emission Factors

- Volume I: Stationary Point & Area Sources.
  - Contains emission factors for all sorts of sources.
- Section 7.1 – Organic Liquid Storage Tanks.
  - This is where the TANKS factors are found.
- Fifth Edition, Supplement D – September '97.
  - This version has the TANKS 3.1 & 4.0X loss factors.
  - Major revision of loss factors and equations between TANKS 2 and TANKS 3.0; relatively minor differences between TANKS 3.0 and TANKS 3.1.
  - TANKS 4.0X is a WINDOWS version of TANKS 3.1.

AP-42 vs MPMS 19

The loss factors and equations used are identical, with the following exceptions:

- Liquid surface temperature.

  Both use the same determination for fixed-roof tanks, but differences in the method for floating-roof tanks results in slightly higher vapor pressures from EPA.

- Bolted deck seam loss factor.

  EPA reduced this factor by about 60% (0.14 vs 0.34) in response to data from testing in the late 1990's. API has not changed from the earlier value of 0.34.

Selected Considerations

- Single versus multicomponent liquid.
- Type of tank.
- Special considerations for crude oil.
- Special considerations for low volatility stocks.
- Floating roof landing losses

Single vs Multicomponent

- Single component means only one chemical.
  - e.g., storing only benzene, or only MTBE.
- Multicomponent means a chemical mixture.
  - The crude oil that comes out of the ground may be made up of dozens of chemicals, so most of the fuels made from crude oil are also mixtures of many chemicals. The concentrations of individuals chemicals vary considerably (depending upon what the dinosaurs ate?)

Single Component Liquids

- Individual chemicals.
- Properties are well-defined.
  - Boiling point.
  - Molecular weight.
  - Reid vapor pressure.
  - True vapor pressure at a given temperature.

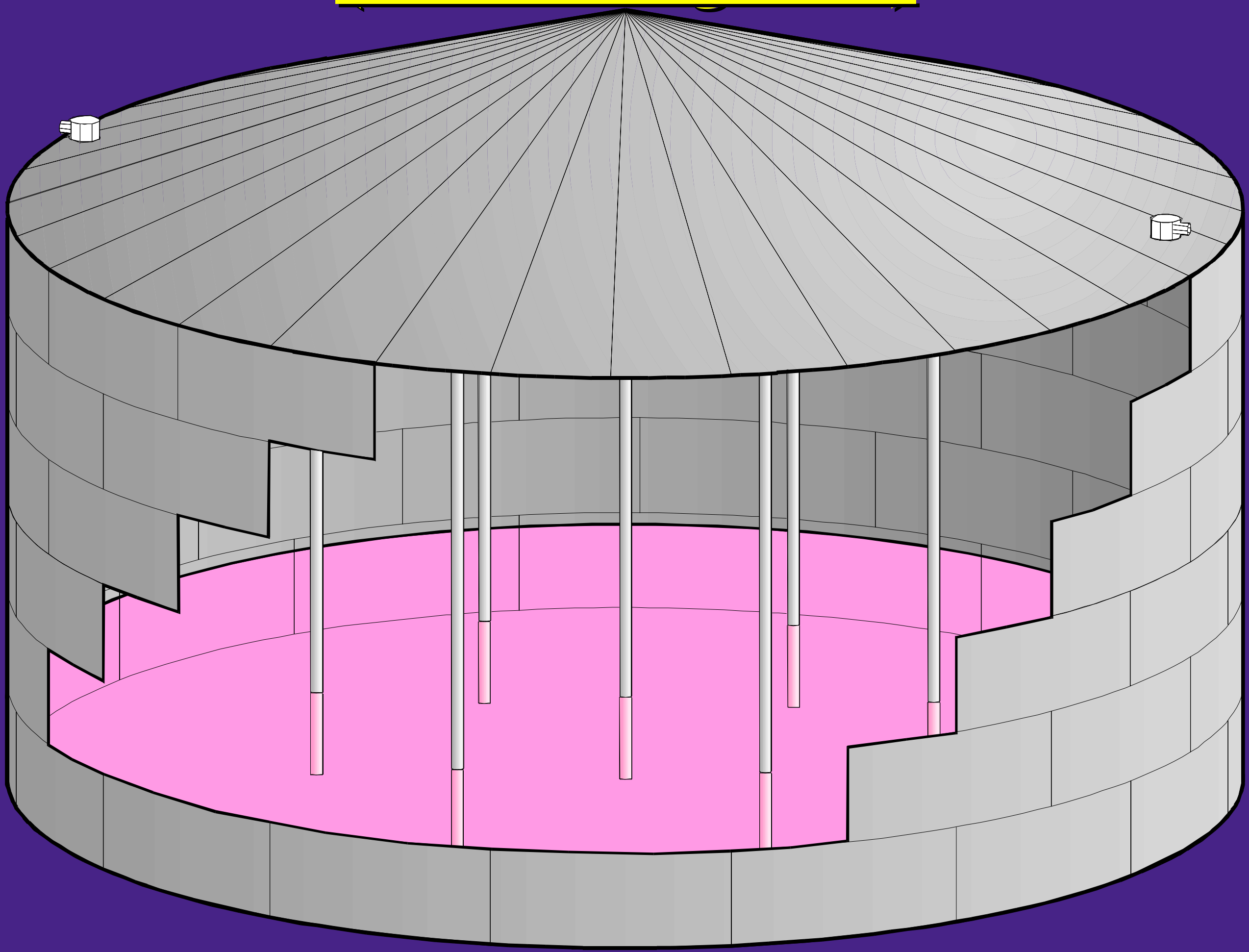
Multiple Component Liquids

- Concentration of each component varies.
  - Stuff that comes out of the ground is not all alike.
- Physical properties vary.
  - Use properties representative of the range.
  - By definition, ‘average’ will be too high or too low for any given tank, but deviations should cancel out for a large number of tanks.

Types of Tanks

- Fixed-roof tanks (without a floating roof).
  - There is no cover directly on the liquid surface, but there is a roof on the top of the tank.
- Floating-roof tanks.
  - A raft-like cover floats on the surface of the liquid.

Fixed-Roof Tank
(no floating roof)



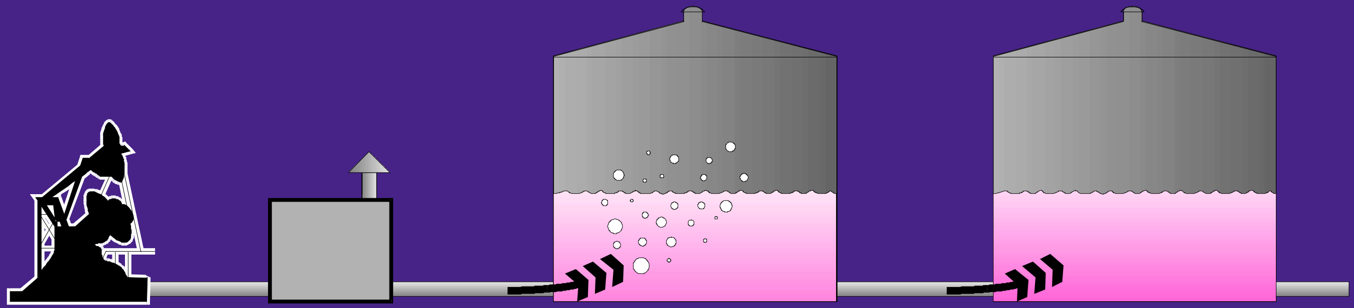
Fixed-Roof Tanks

- API 2518 (& AP-42/TANKS) emission factors:
  - Expressly intended for stable liquids only.
  - Will not account for flashing losses.
- To account for flash losses (unstable liquids):
  - Vasquez-Beggs correlations, or
  - EC/R algorithms, or
  - API/GRI E&P TANK computer model

Stable vs Unstable Liquid

- Stable implies all components are liquid.
  - i.e., none of the components are trying to boil.
- Unstable implies a gaseous component.
  - i.e., one or more components wants to boil.
  - Similar to fizz when opening a soft drink.
  - Gas that was held in by pressure wants to bubble out when the pressure is relieved.
  - Typical of tanks in the oil patch.

Crude Oil Production



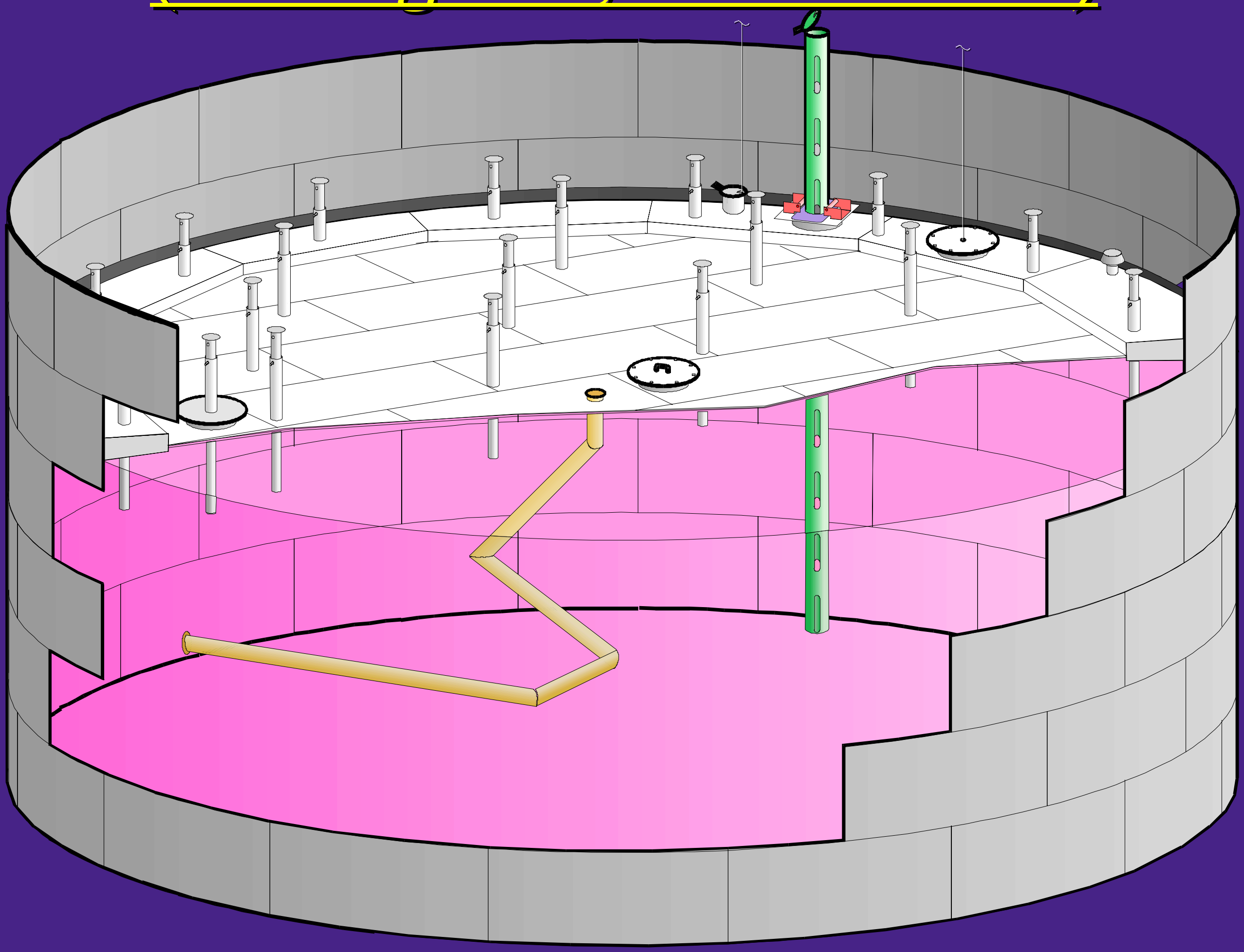
Oil & Natural Gas pumped out of the ground; under pressure until the first tank.

Natural Gas "flashes" (bubbles out)

After flashing is complete, the remaining Crude Oil is stable.

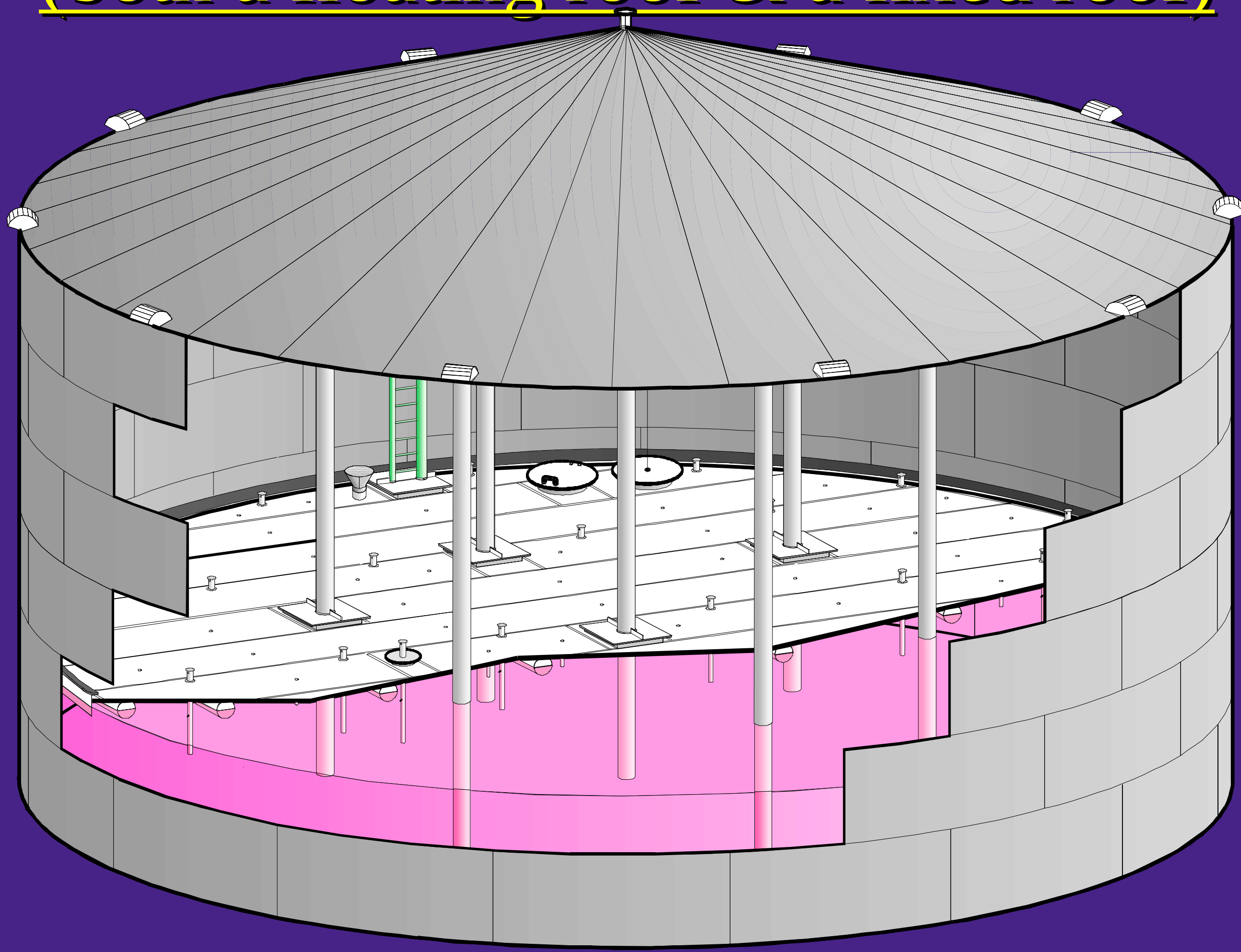
External Floating-Roof Tank

(floating roof, no fixed roof)



Internal Floating-Roof Tank

(both a floating roof & a fixed roof)

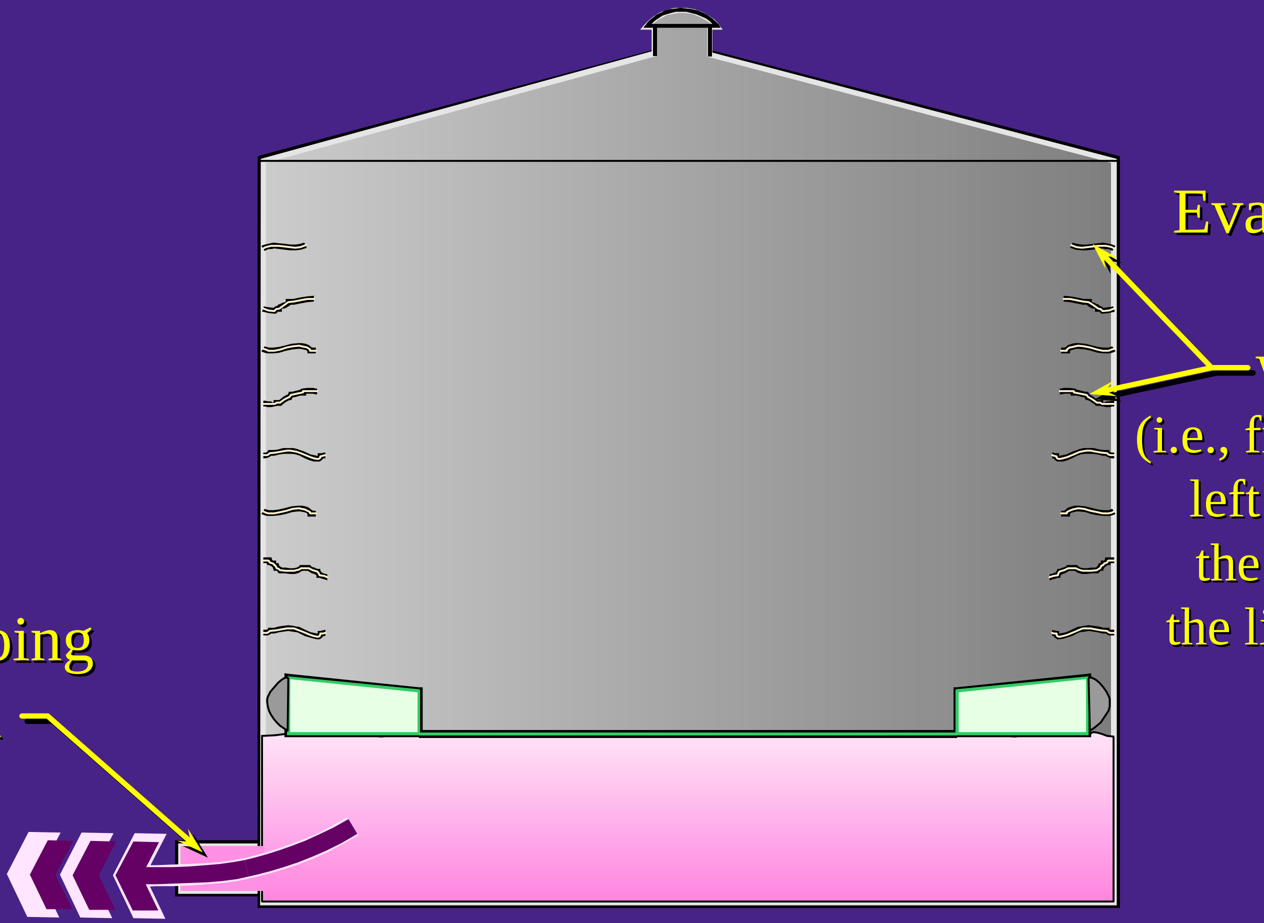


Floating-Roof Tanks

- Only suitable for stable liquids.
  - Minimize evaporation by covering the surface.
  - Unstable liquids would bubble underneath.
    - Vapors would build up under the floating roof until either finding a way out or capsizing the roof.
- Emission factors from 20 years of testing.
  - API 2517 & 2519 and EPA AP-42 & TANKS.
    - Tests sponsored by API; data shared with EPA.

Floating-Roof Tank

Withdrawal Loss



Floating-Roof Tank
Withdrawal (Clingage) Loss

Equation for estimating withdrawal loss, L_W:

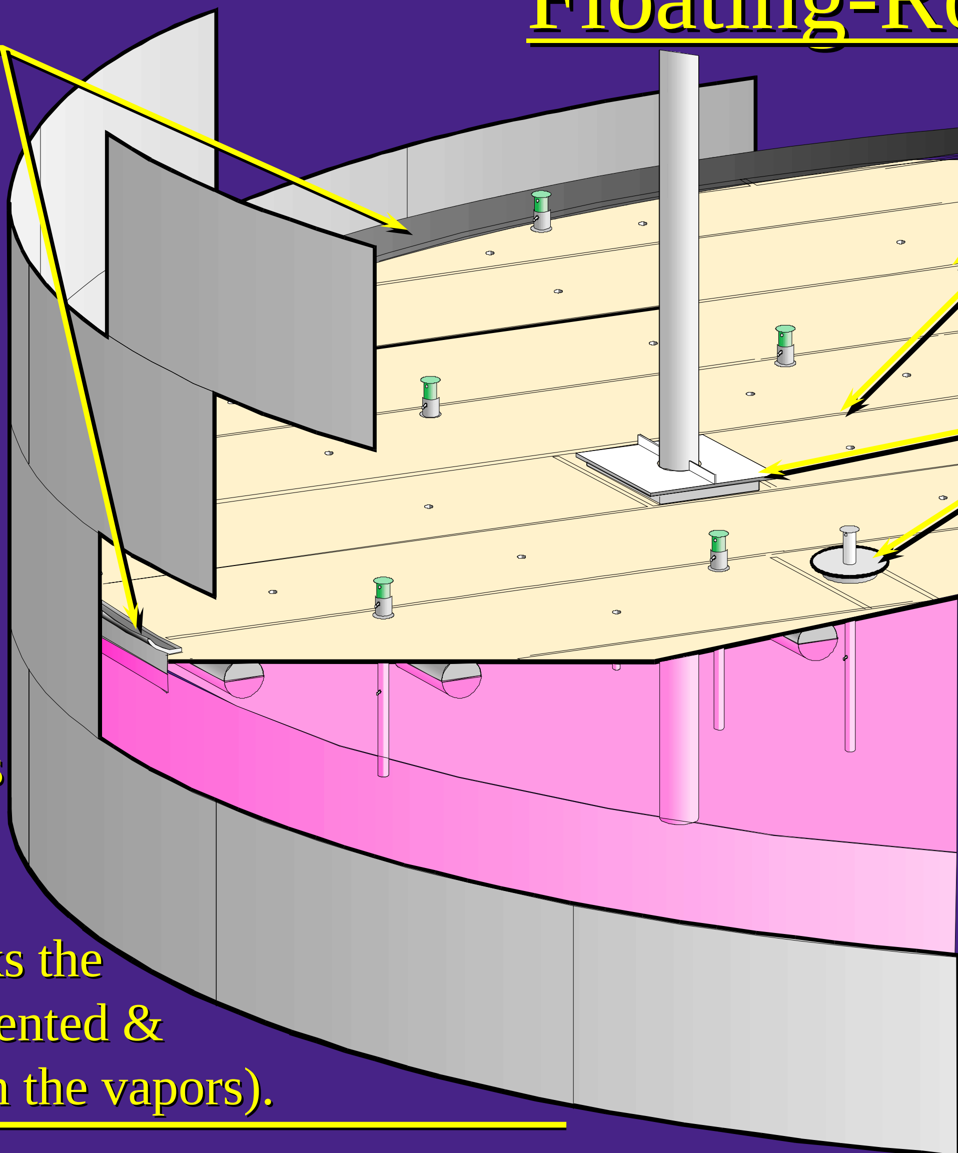
$$L_W = [(0.943\ Q\ C\ W_L\ ) / D]\ [1+(N_{FC}\ F_C\ / D)]$$

Where:

- Q = annual net throughput (barrels/year),
- C = clingage factor (barrels per 1000 square feet),
- W_L = average liquid stock density (pounds/gallon),
- D = tank diameter (feet),
- N_{FC} = no. of fixed-roof support columns (dimensionless),
- F_C = effective column diameter (feet).

Floating-Roof Tank

Rim seal
(closure device between the deck and the tank shell)



Standing Storage Loss

Emissions are based on vapors that get past the floating roof (a fixed roof blocks the wind, but it is vented & does not contain the vapors).

Floating-Roof Tank

Standing Storage Loss

Equation for estimating standing storage loss, L_S:

Equipment-related — Stock-related

$$L_S = [F_R + F_F + F_D]\ P^*\ M_V\ K_C$$

Where:

F_R = total rim-seal loss factor (pound moles/year),

F_F = total deck-fitting loss factor (pound moles/year),

F_D = total deck-seam loss factor (pound moles/year),

P^* = vapor pressure function (dimensionless),

M_V = stock vapor molecular weight (dimensionless),

K_C = product factor (dimensionless).

Floating-Roof Tank

Rim Seal Loss Factor

Equation for total rim-seal loss, F_R:

$$F_R = [K_{RA} + K_{RB}\, V^n]\, D$$

Where:

K_{RA} = zero-wind-speed loss factor (lb moles)/(ft yr),

K_{RB} = wind-dependent loss factor (lb moles)/(mph)^n(ft yr),

V = average ambient wind speed (miles per hour) [use $V = 0$ for IFRTs and Domed EFRTs],

n = wind-dependent loss exponent (dimensionless),

D = tank diameter (feet).

Floating-Roof Tank
Deck Fitting Loss Factor

Equation for individual deck-fitting loss, F_{Fi}:

$$F_{Fi} = K_{FAi} + K_{FBi} (K_V V)^{mi}$$

Where, for deck fitting *i*:

K_{FAi} = zero-wind-speed loss factor (lb moles/yr),

K_{FBi} = wind-dependent loss factor (lb moles)/(mph)^m (yr),

K_V = fitting wind-speed correction factor (dimensionless),

V = avg. ambient wind speed (miles per hour) [use $V = 0$ for IFRTs and Domed EFRTs],

mi = wind-dependent loss exponent (dimensionless).

Floating-Roof Tank

IFRT Bolted Deck Seam Loss Factor

Equation for total bolted deck-seam loss, F_D :

$$F_D = K_D S_D D^2$$

Where:

K_D = deck seam loss per unit seam length factor (lb mol/ft yr),

= 0.34 (API MPMS 19.2)

= 0.14 (EPA AP-42 and TANKS)

S_D = deck seam length factor (feet per square feet),

= 0.17 (noncontact deck with 6-ft wide deck sheets)

= 0.28 (contact deck with 5' x 12' rectangular panels)

D = tank diameter (feet).

Ambient Wind Effects

Assumptions in the Equations

- Losses from Internal & Covered (domed external) Floating Roofs are not wind-dependent.
  - Vapor loss past the floating roof is independent of ambient wind speed, (i.e., $V = 0$), but air movement through the vents is adequate to evacuate those vapors that do get past the floating roof.
- Losses from External Floating Roofs are wind-dependent.
  - Full ambient wind speed, V, is applied to rim seal losses.
  - Ambient wind speed, V, is modified by the Fitting Wind-Speed Correction Factor, K_V (= 0.7), for deck fittings losses.

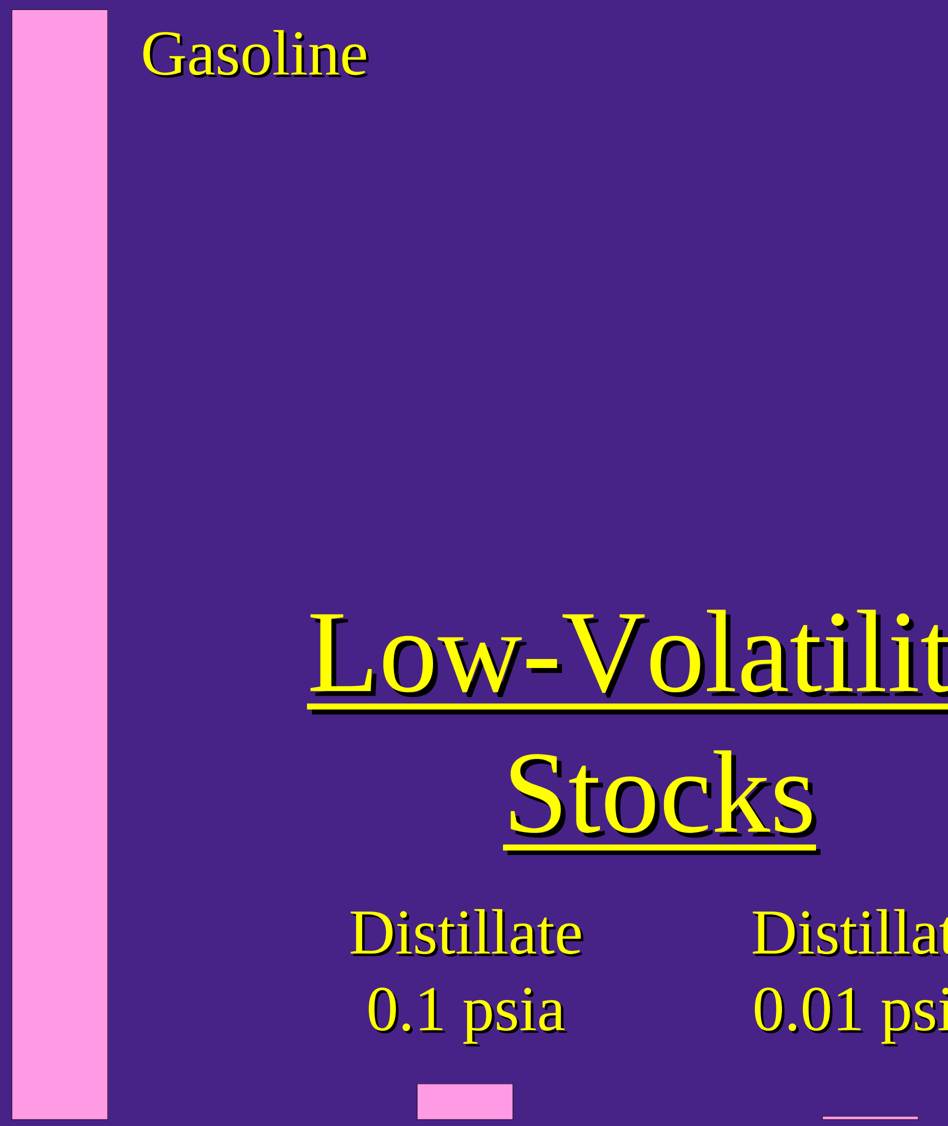
Special Considerations for Crude Oil

- Range of volatility of the components is much greater than for refined products.
- Heavier components may impede migration of lighter components.
  - Thus retarding evaporation rates of stable oils,
  - But also potentially retaining unstable components.

Special Considerations for Low-Volatility Mixtures

- Low volatility means low level of emissions.
- Thus these tanks are typically not regulated.
- Properties have not been well defined.
- Large percent error would still be a small no.
- Nevertheless, better data is being pursued.

Low-Volatility Stocks



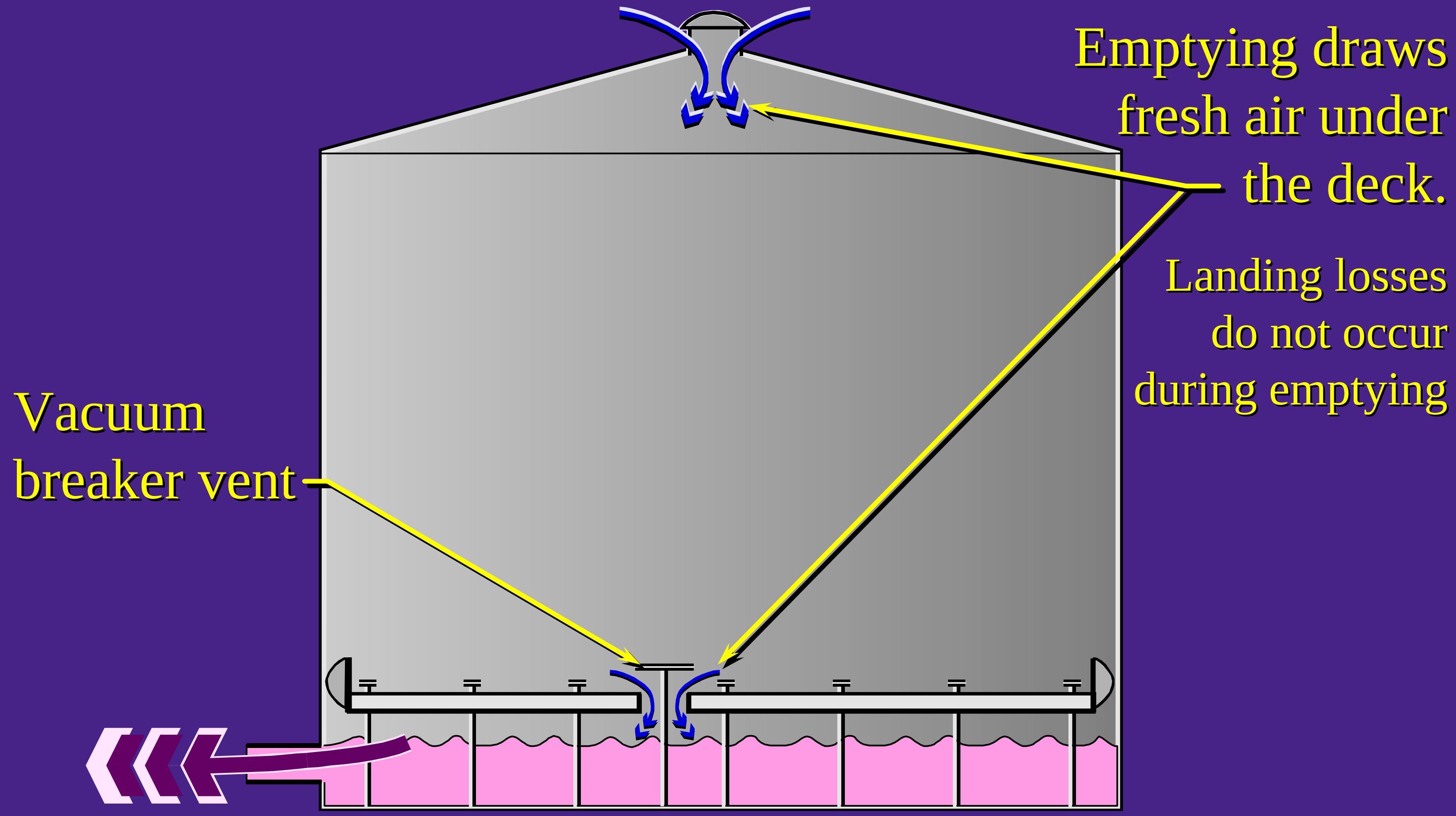
Floating Roof
<u>Landing Losses</u>

- Not a special event for fixed-roof tanks.

  Emptying & refilling is accounted for in working loss.

- Landing a floating roof:
  - Opens the vacuum breaker vent.
  - Tank subsequently has losses while standing idle.
  - Refilling expels vapors from under the deck.

Landing a Floating Roof



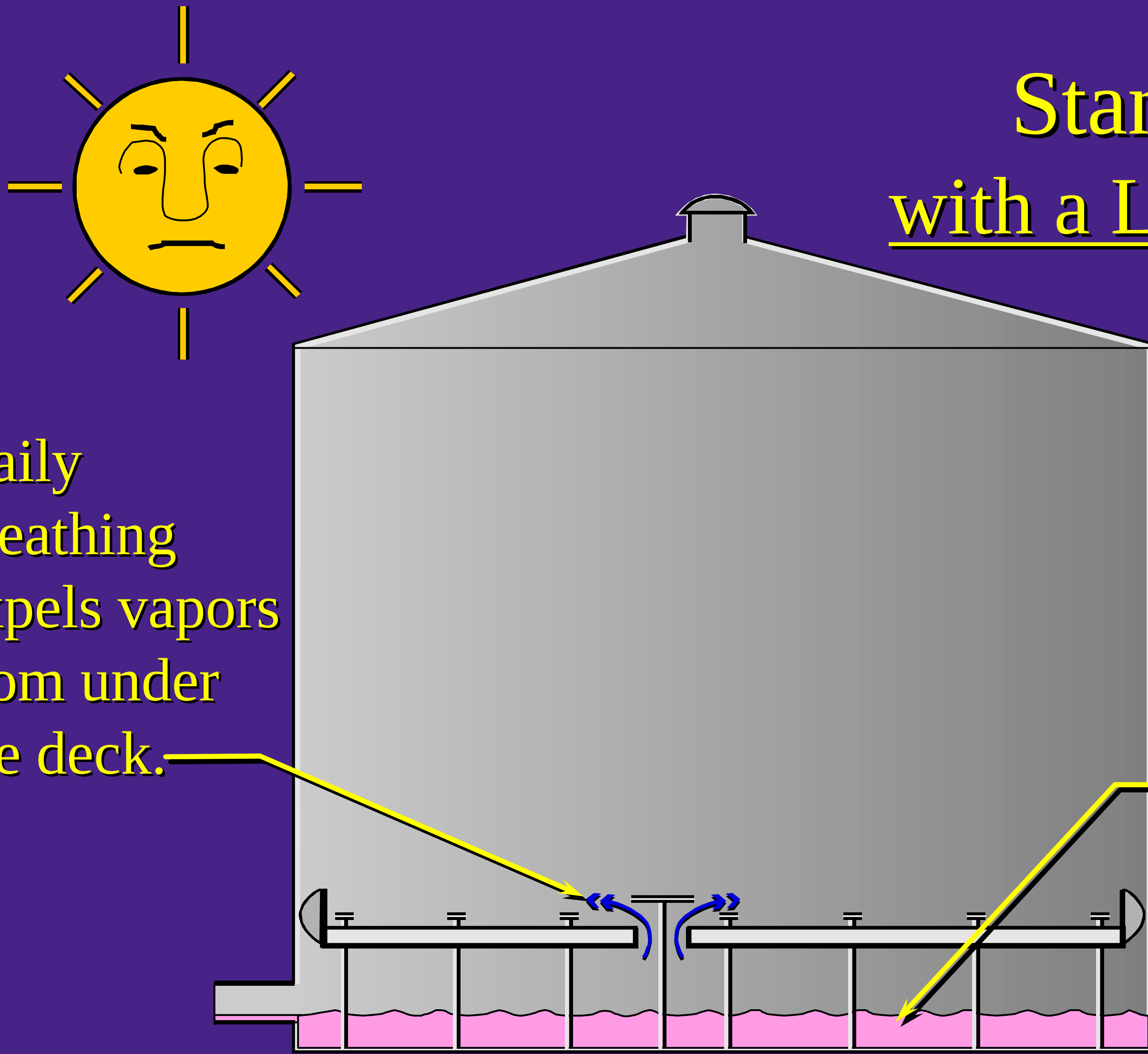
Standing Idle Losses <u>for a Landed Floating Roof</u>

- Emissions occur while the tank stands idle after landing the floating roof.
- Modeling these emissions depends upon:
  - Liquid heel vs drain dry condition.

    If drained dry, available liquid is limited to clingage.
  - IFRT vs EFRT.

    The vapor space under a landed IFR will behave in a manner similar to a fixed roof tank, but an EFR will additionally have wind effects.

Standing Idle
with a Liquid Heel

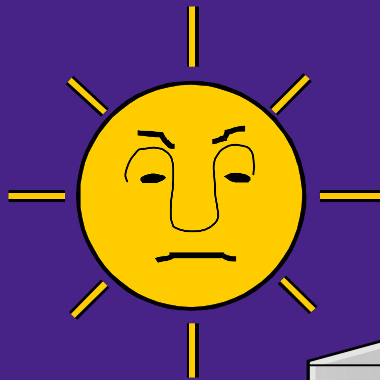


Daily breathing expels vapors from under the deck.

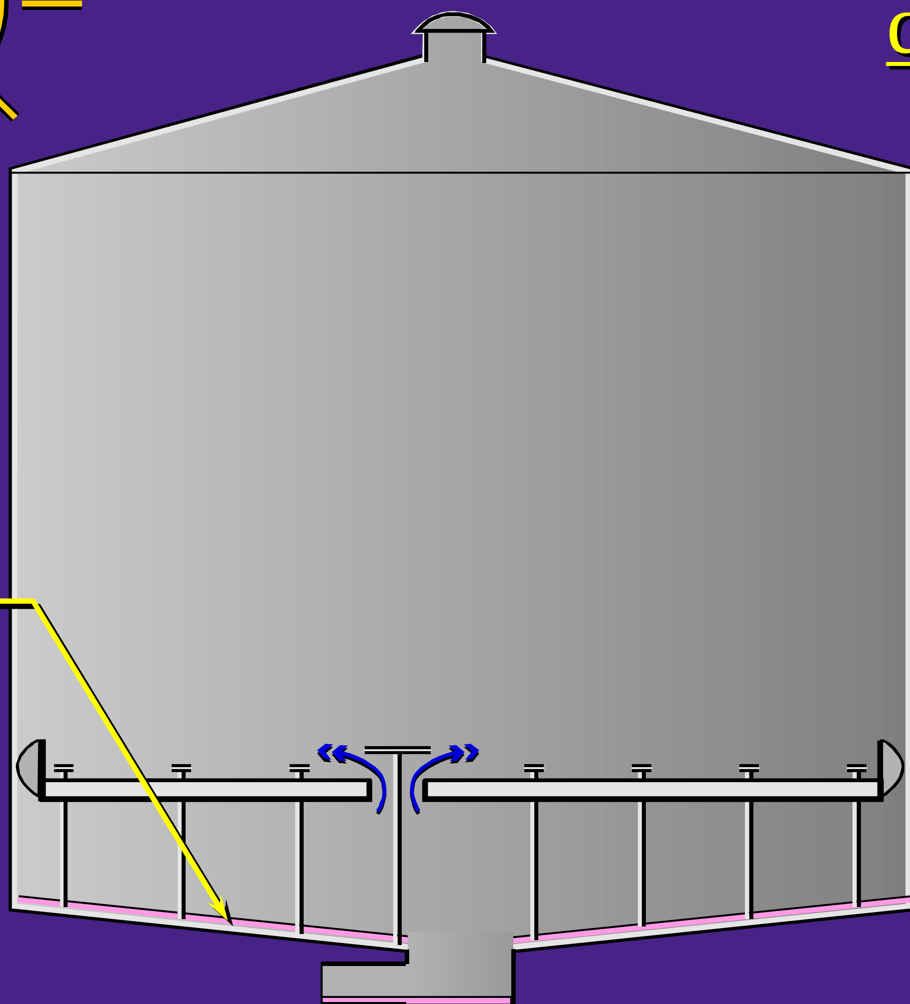
Depth of liquid heel is sufficient to continue to support breathing loss

Standing Idle

<u>drained dry</u>

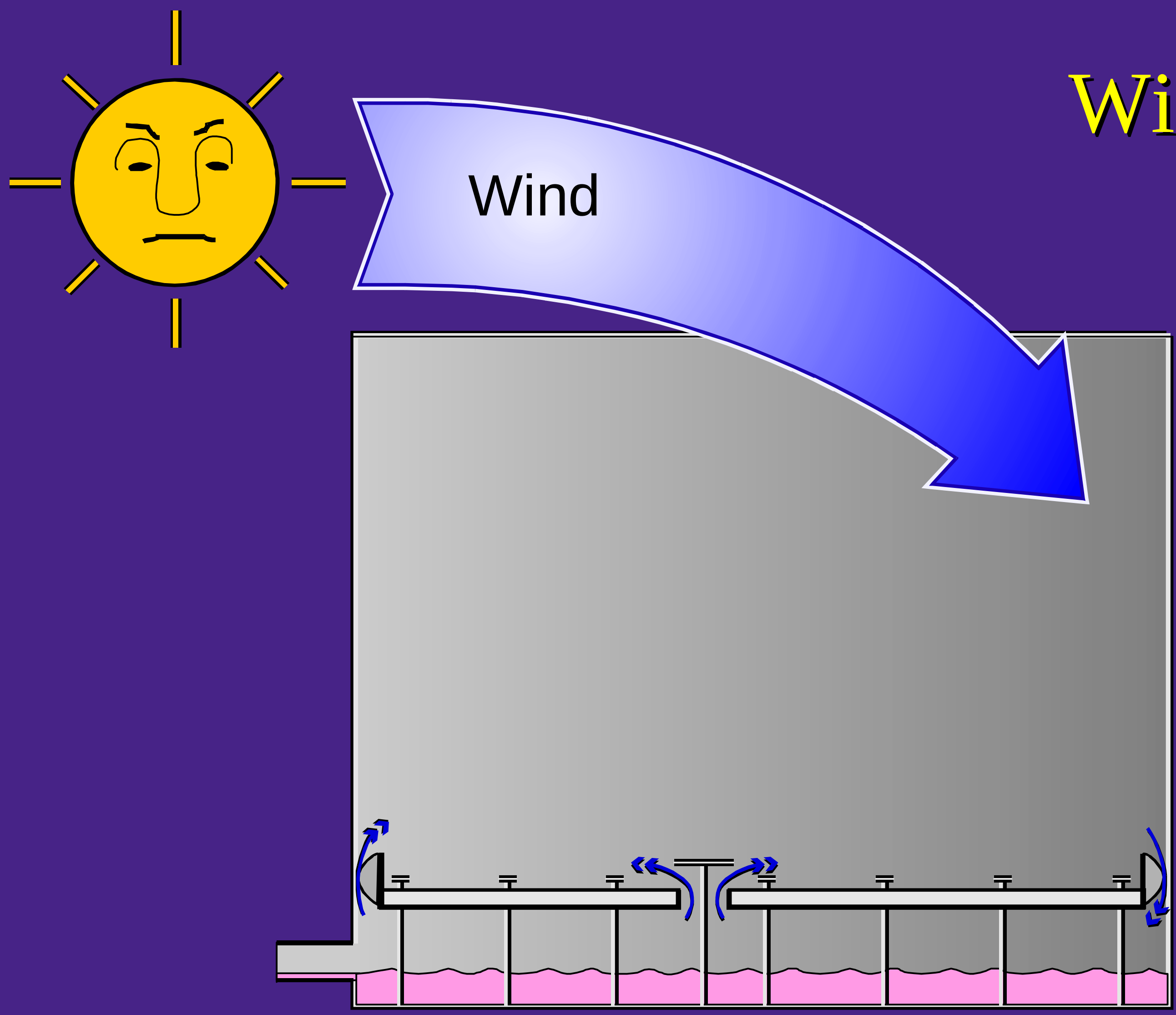


The only remaining liquid is clingage that didn't drain.



Breathing loss ends when the wetted areas become dry.

Wind Effect on EFRT



Standing idle loss from an EFRT with a liquid heel is accelerated by wind.

Filling Loss
for a Landed Floating Roof

- Refilling expels vapors from under the deck.

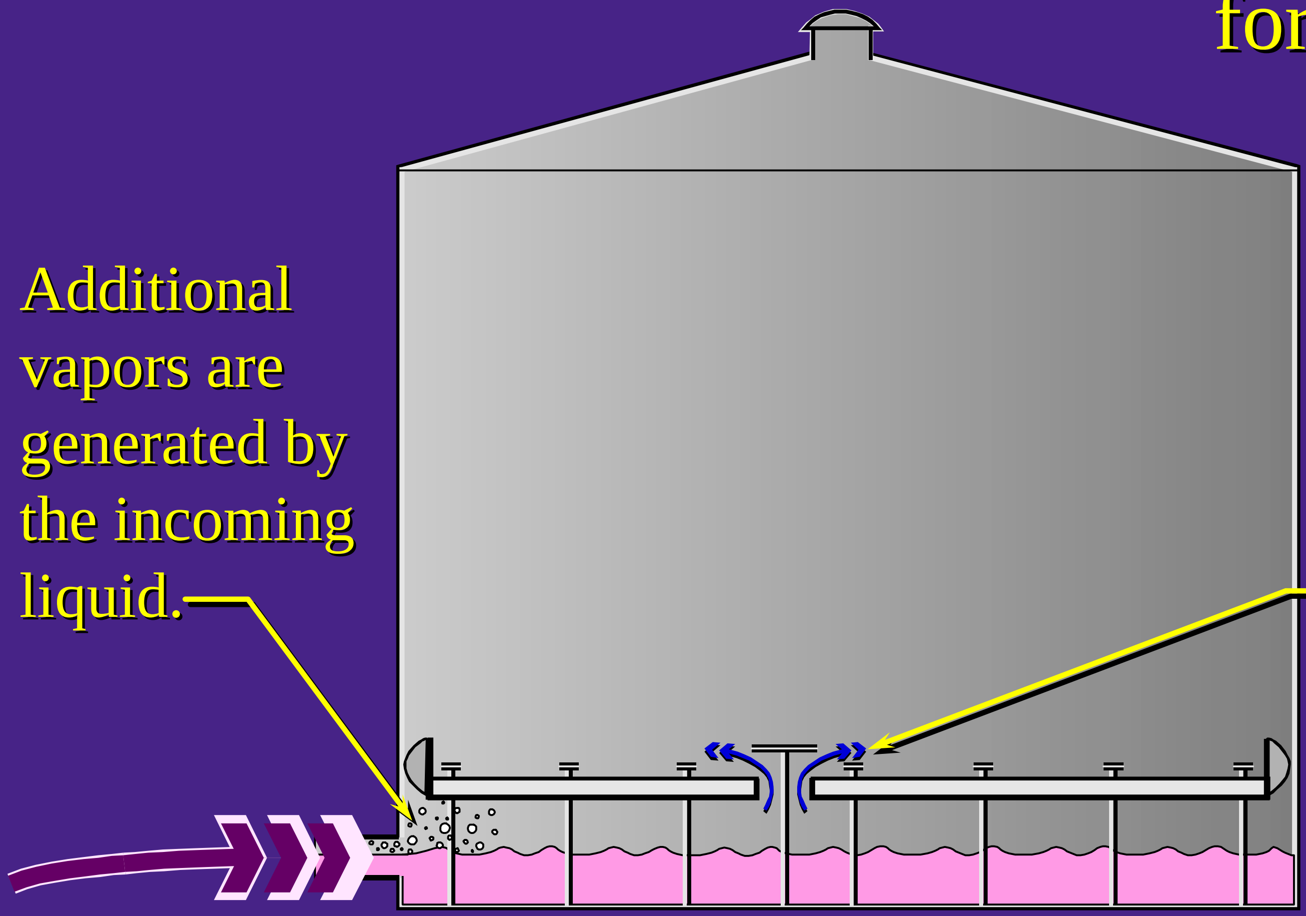
  The quantity of vapors residing under the deck prior to refilling depends upon the standing idle condition.

- Incoming liquid generates additional vapors.

  Thus even a completely vapor-free tank will have vapors in the air displaced from under the deck.

Filling Loss for a Landed Floating Roof

Additional vapors are generated by the incoming liquid.



Incoming liquid displaces vapors from under the deck.

Landing Loss Summary

Each scenario has a critical parameter that is not well quantified.

- IFRT w/liquid heel: the critical parameter is the saturation level (concentration of vapors) of the air-vapor mixture expelled from under the deck.
- EFRT w/liquid heel: the effect of wind is an additional critical parameter for this case.
- Drain-dry tanks (IFRT or EFRT): the effective depth (thickness) of the layer of liquid left behind on the tank bottom is the critical parameter.

Status of Landing Loss Estimation Methods

- API has developed a theoretical model.

  Accounting for all the phenomena identified.

- API has conducted limited field testing.

  Which improved understanding of the theoretical model.

- Critical parameters remain elusive.

  If you have to come up with a number, the present state of the practice is to make a good faith effort using sound engineering judgment – with lots of caveats.