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Critical Challenges. Practical Solutions.

Energy & Environmental Research Center (EERC)

TANK VAPOR MANAGEMENT

Bakken Production Optimization Program

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April 30, 2021

ABSTRACT

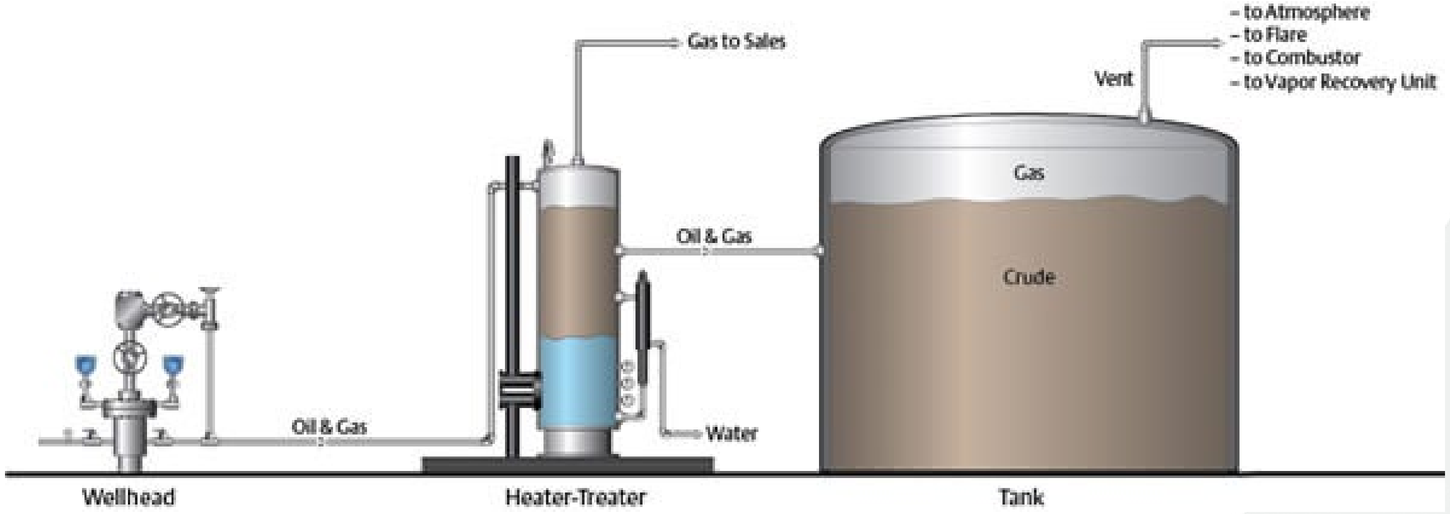
Hydrocarbon vapors, when mixed with air in storage tank headspace, pose a safety risk when compositions reach flammable levels. The presence of air also creates a marketing challenge due in part to the safety risk. In this study, the phase behavior of tank vapors was assessed to better understand and manage tank vapor emissions. Factors influencing the quantity, composition, and phase behavior of the tank vapors were analyzed, and the effect of pressure and air concentration on natural gas liquid (NGL) recovery potential was evaluated. The condensation of tank vapor NGLs was modeled over a range of conditions including pressures of 50 to 500 psia and the presence of air from 0% to 60% on a volume basis. This report provides data illustrating the inhibiting effect nitrogen and oxygen have on NGL recovery.

GOALS AND OBJECTIVES

- Study the factors that influence the quantity and composition of tank vapors.
- Model phase behavior of tank vapors over a range of conditions.
  - Understand factors influencing air entering the tank headspace/tank vapors.
  - Evaluate the impact nitrogen and oxygen have on phase behavior and NGL recovery.
- Assess strategies to reduce tank vapors and emissions.

BACKGROUND

- Oil transferred to tanks from pressurized separators and/or treaters contains lighter hydrocarbons that volatilize when exposed to atmospheric pressure in the tank (e.g., propane and butane).
- This atmospheric flash of light hydrocarbons to the tank headspace generates a gas stream which must be vented to prevent tank pressurization.
- Vented gases are often flared to prevent hydrocarbon emissions to the environment; methane has a greenhouse gas equivalence >80x that of carbon dioxide.
- Flaring also eliminates the potential presence of a flammable mixture of gases on or near the wellsite.

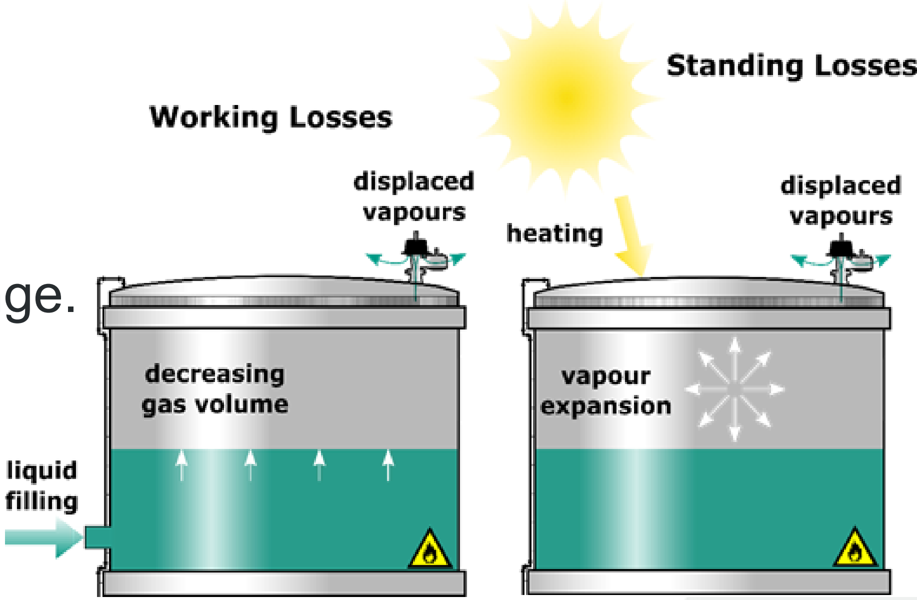


https://www.emersonautomationexperts.com/2014/industry/oil-gas/5-ways-to-maximize-gas-sales-in-oil-production/

THE PROBLEM WITH AIR

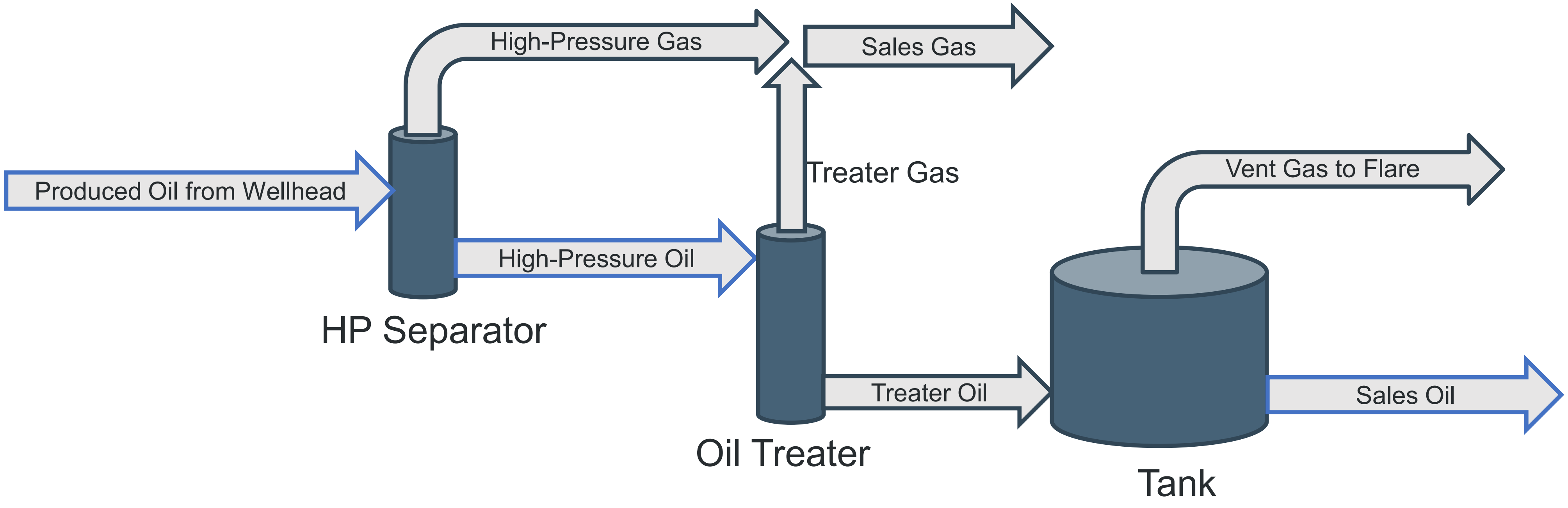
- Under normal wellsite operations, volatilization of light hydrocarbons occurs at a rate sufficient to prevent air from entering the tank.
- However, filling and emptying the tanks and/or changing ambient conditions (temperature, solar irradiation) can contribute to air entering a tank.
- Vacuum relief valves are designed to open when a tank is emptied or cooled to prevent collapse, allowing air and oxygen into the tank.
- Air in a tank headspace introduces a safety hazard.
  - Field data proves flammable levels can exist.
    - ♦ 18.2%–20.2% oxygen in a tank headspace is flammable.
    - ♦ 3.8%–13.4% fuel gas volume in air is flammable.
  - Air in the tank vapor introduces a gas-marketing challenge.
    - ♦ Tank vapors must be scrubbed of oxygen before they are allowed in the gas-gathering system.

https://cse-institut.de/phd-project-zebra/



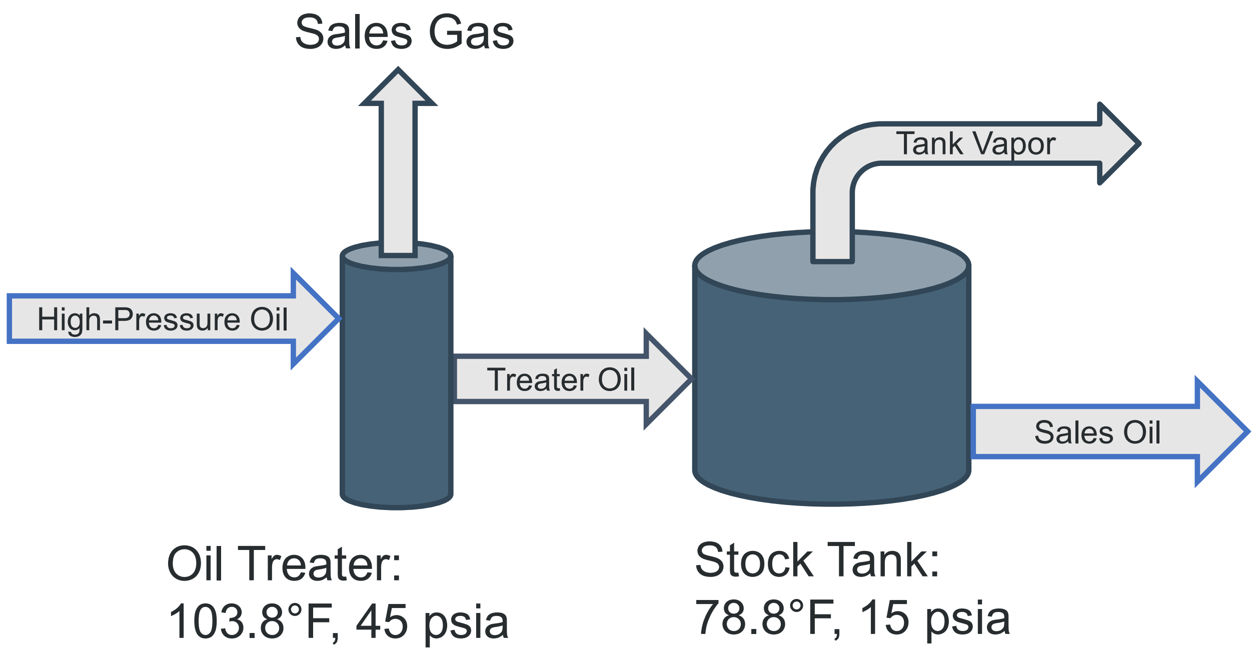
APPROACH/METHODOLOGY: WELLSITE CONFIGURATION

- A wellsite model from prior BPOP studies was applied to this study.
  - Crude oil vapor pressure management (https://undeerc.org/bakken/optimization/Abstract.aspx?id=3)
  - Study of tank headspace O_2 concentration (https://undeerc.org/bakken/optimization/Abstract.aspx?id=214)
- HYSYS model includes wellsite with high pressure (HP) separator, oil treater, and tanks.



TANK VAPOR COMPOSITION FROM ATMOSPHERIC FLASH

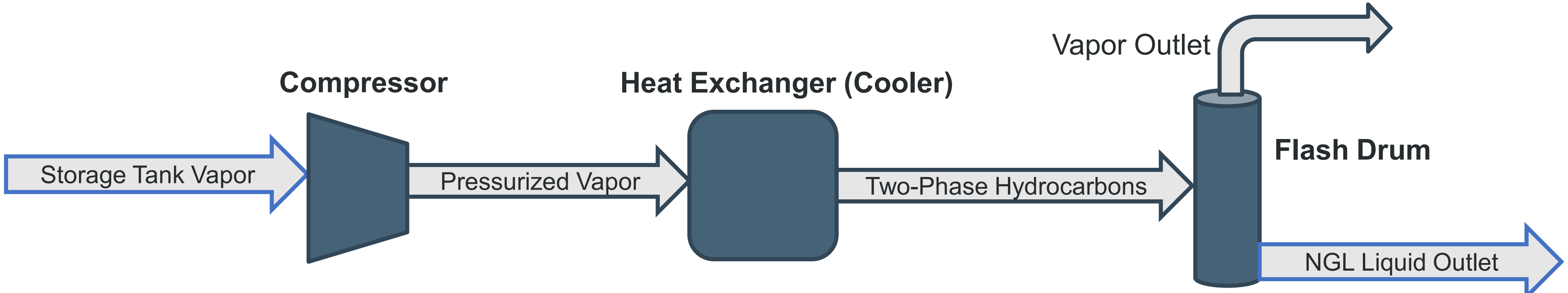
- HYSYS simulations predict tank vapor composition when crude oil is transferred from a pressurized treater to an atmospheric tank.
- Assumed properties for oil entering the tank: 86.5°F, 45 psia, air-free tank headspace.



	Treater Oil	Tank Vapor	Sales Oil
		mol%	
Methane	0.4%	6.6%	0.0%
Ethane	2.0%	24.3%	0.7%
Propane	5.8%	38.5%	3.8%
i-Butane	1.4%	4.9%	1.2%
n-Butane	6.1%	15.8%	5.5%
i-Pentane	2.5%	2.6%	2.4%
n-Pentane	4.6%	3.9%	4.7%
n-Hexane	9.4%	2.4%	9.8%
n-Heptane	8.3%	0.7%	8.7%
n-Octane	9.3%	0.2%	9.8%
n-Nonane	5.4%	0.0%	5.7%
n-Decane	6.3%	0.0%	6.7%
n-C10+	38.5%	-	40.9%

MODEL BASIS: TANK VAPOR-PHASE BEHAVIOR

- The air-free tank vapor composition provided the basis for assessing phase behavior and NGL recovery.
- Pressure–temperature diagrams were used to analyze the tank vapor stream for ethane, propane, and n-butane.
- Phase behavior was modeled for tank vapor compositions with varying levels of air dilution: 0%, 5%, 30%, and 60% air.
- Modeled process includes compression, heat exchange, and flash drum.
  - Pressure and tank vapor composition were varied to analyze their effect on NGL recovery.
  - Heat exchanger outlet temperature is fixed at 75°F (future optimization of temperature and pressure is needed).
  - NGL recovery is defined as the liquid outlet from the flash drum.
- The NGL recovery is measured in U.S. gallons of liquid recovered/scf of storage tank vapor.



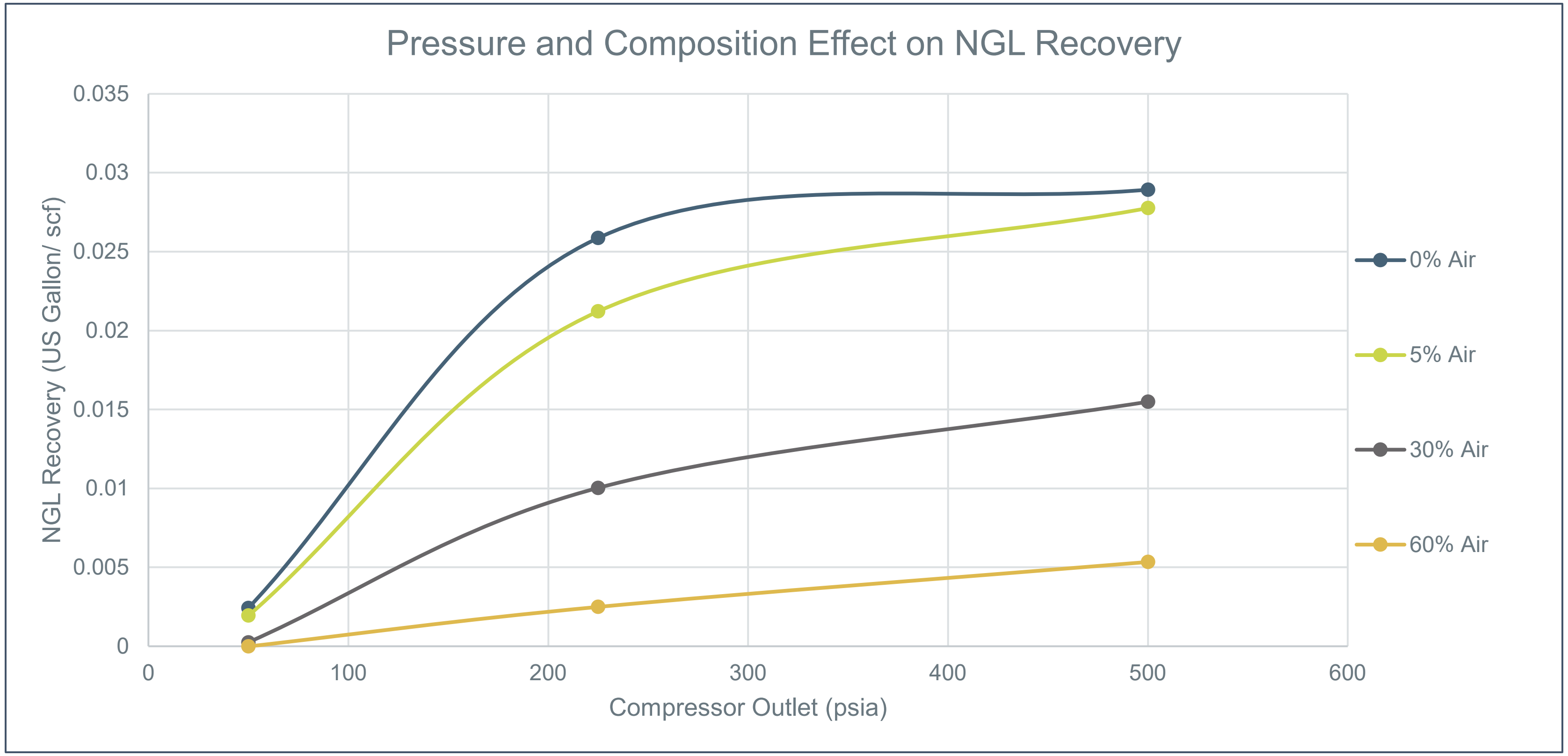
$$NGL\ Recovery = \frac{NGL\ Liquid\ Outlet\ (U.S.Gallons)}{Storage\ Tank\ Vapor\ (scf)}$$

SUMMARY OF RESULTS

- Increasing compression from 50 to 500 psi increases potential NGL recovery.
- Increasing air concentration from 0%–60% of the tank vapor reduces NGL recovery over the same pressure range.
- When air is present in the tank vapor, lower NGL recovery occurs because of:
  - Dilution – the presence of air reduces the moles of NGL present.
  - Partial pressure – presence of O_2 and N_2 inhibit the condensation of NGL.
- Optimal NGL recovery is achieved on air-free tank vapors at 225 psi. Increasing pressure above this level results in minimal additional NGL recovery.

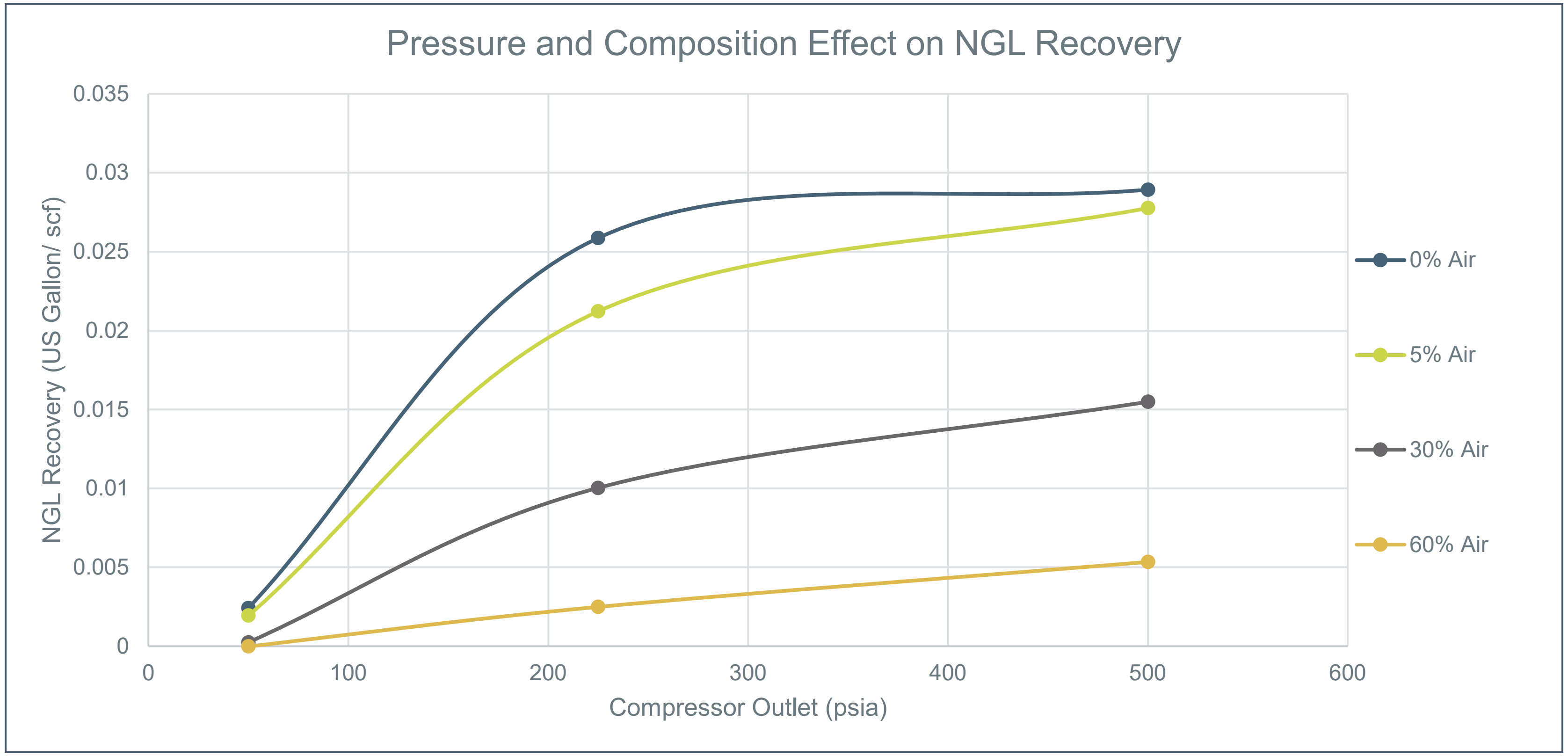
SIMULATION RESULTS: EFFECT OF AIR ON NGL RECOVERY

- **Increasing** air concentration **decreases** NGL recovery at a given temperature/pressure.
  - From 0%–5% air, average NGL recovery drops 14%.
  - From 0%–30% air, average NGL recovery drops 65%.
  - From 0%–60% air, average NGL recovery drops 90%.



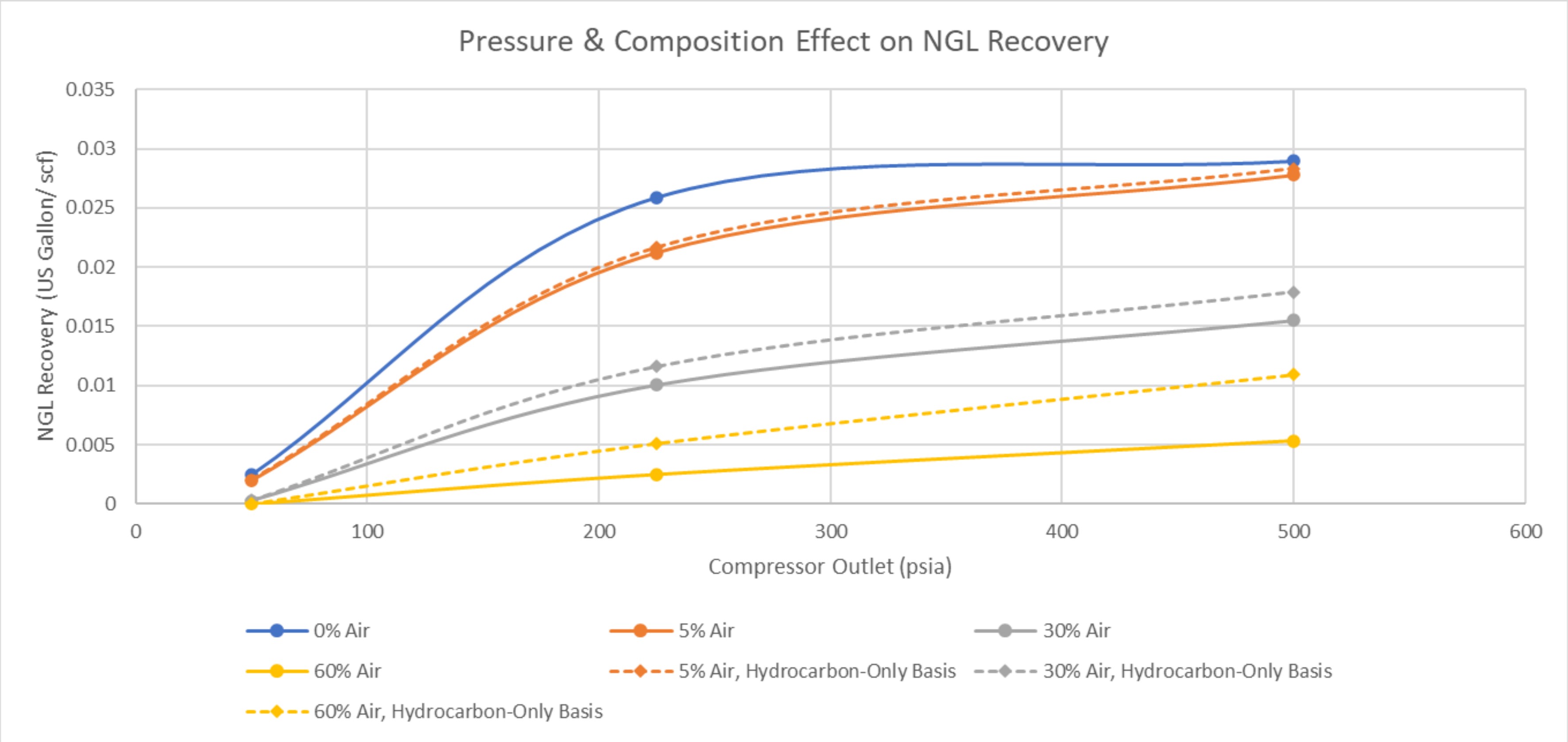
SIMULATION RESULTS: EFFECT OF PRESSURE ON NGL RECOVERY

- **Increasing** pressure **increases** NGL recovery at a given temperature/air concentration.
  - From 50–225 psi, average NGL recovery increases 93%.
  - From 50–500 psi, average NGL recovery increases 94%.
  - Optimal NGL recovery occurs at 225 psi with an air-free tank vapor.



SIMULATION ANALYSIS: ACCOUNTING FOR AIR DILUTION

- Normalizing the data to eliminate the impact of dilution on NGL recovery illustrates the impact O_2 and N_2 have on NGL condensation.
- Solid lines represent NGL recovery on a gallon/scf of total tank vapor basis (hydrocarbon and air).
- Dashed lines represent NGL recovery on a gallon/scf of hydrocarbon only basis (subtracting air fraction).
- Minimizing tank vapor air improves safety and enables NGL recovery at relatively low pressure.



CONCLUSIONS

- Avoiding air ingress to tanks can eliminate the flammability risk and create opportunities for beneficial use of tank vapors.
  - Compression to gas-gathering system if pipeline capacity allows.
  - Tank vapor processing for NGL recovery reduces low-pressure flare volume.
- Tank blanketing with hydrocarbon vapor (methane, treater gas, etc.) could enhance options for tank vapor management. Additional study needed to ensure fugitive emissions are mitigated.
- Alternate tank vapor management strategies should be explored.

FUTURE STUDY

- Detailed characterization of the emission benefits associated with NGL recovery from tank vapors prior to low-pressure flare.
- Economic analysis of the tank vapor uses:
  - Compression to gathering.
  - NGL recovery.
  - Methane/ethane fraction for on-site use (treater, electrical generation, boiler operation for cold conditions).
- Field studies to validate and improve process model.
  - Compare
  - Modeled tank vapor composition and volumetric output compared to real sampling data.
  - Additional hydrocarbon volatilization within subsequent tanks before the stock tanks?

PRODUCT OF BPOP 3.0

Led by the Energy & Environmental Research Center (EERC), the highly successful Bakken Production Optimization Program (BPOP), funded by its partners and the North Dakota Industrial Commission through its Oil and Gas Research Program, conducts research to provide the state and industry with science-based insight to maintain the economic and environmental sustainability of the Bakken play in North Dakota.

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For more information, please visit: https://undeerc.org/bakken/Optimization/

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