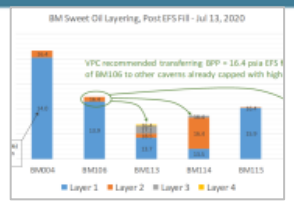
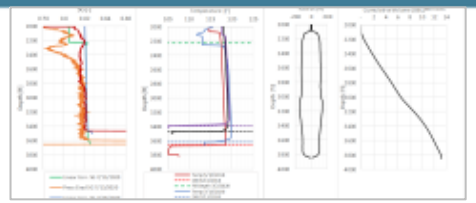
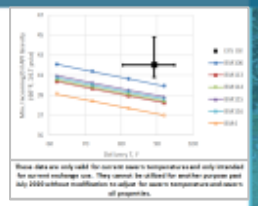
SAND2021-11921C

Sandia National Laboratories

Vapor Pressure Sampling for the U.S. Strategic Petroleum Reserve 2020 Exchange for Storage







David Lord and Joseph Hogge

Sandia National Laboratories

Technical Presentation

Crude Oil Quality Association Fall 2021 Meeting

Sugar Land, TX

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Outline

Description of the U.S. Strategic Petroleum Reserve

Oil Vapor Pressure: Why it Matters at SPR

Oil Layering: Why it Matters at SPR

Exchange for Storage 2020

Vapor Pressure Sampling during Exchange for Storage 2020

Primary Findings from Vapor Pressure Sampling

Utility of Findings for:

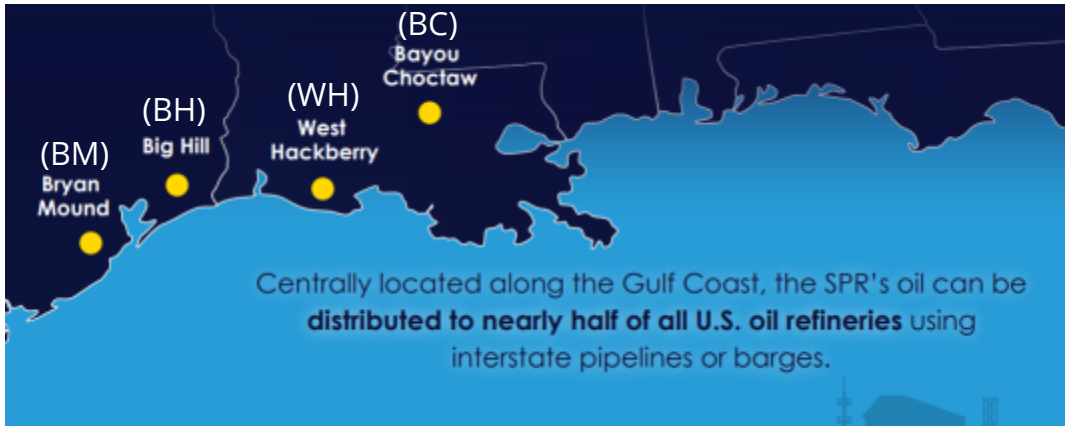
- Sales/exchange operations
- Vapor Pressure Sampling/Analysis Method Development

U.S. Strategic Petroleum Reserve[1]

World's largest supply of emergency crude oil

Administered by the U.S. Department of Energy

Stored in underground salt caverns in TX and LA



Benefits

- Tool used to alleviate the market impacts of both domestic and international crude oil disruptions
- Form of energy insurance, provides a deterrent to threats to cut off oil supplies, and protects the U.S. economy

Uses

- Draw down stocks in an emergency to minimize supply disruption
- Store excess production during demand destruction to minimize production shutoff

[1]https://www.energy.gov/sites/default/files/2021-06/Strategic%20Petroleum%20Reserve%20%28revised%29_1.pdf

Crude Oil Vapor Pressure: Why it Matters at SPR

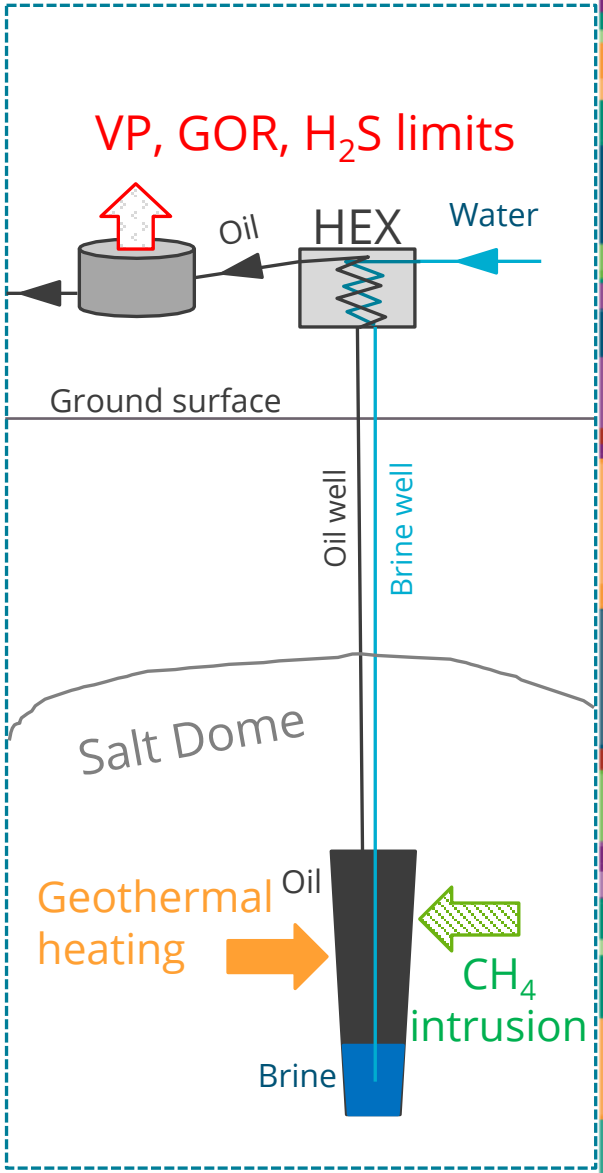
SPR must comply with both DOE/SPR program- and TX/LA/state-required limits for vapor pressure, gas-oil ratio, and H_2S emissions when oil is released to atmospheric pressure tanks

A combination of geothermal heating and methane (CH_4) intrusion into the oil in the caverns increase the crude oil vapor pressure

SPR monitors crude oil composition, vapor pressure and temperature in its caverns and uses these with computer models to predict emissions potential

Where calculations show risk against meeting the requirements, mitigation strategies are applied

- Mitigation includes cooling, degasification, H_2S scavenging and cavern to-cavern transfers

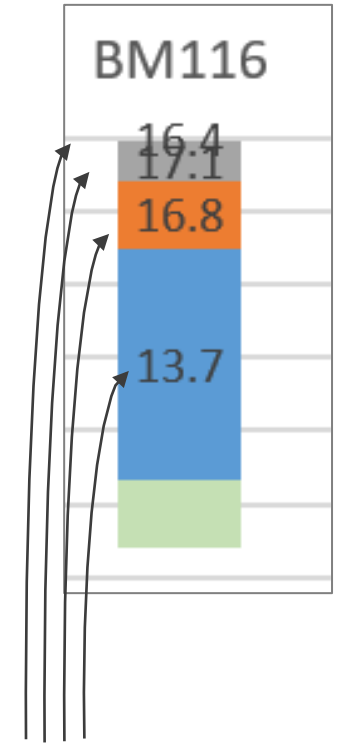


Crude Oil Layering: Why it Matters at SPR

A sale, exchange, or drawdown from SPR injects water into the bottoms and draws oil from the tops of selected caverns leading to a last in → first out effect for oil inventory

Knowledge of cavern layer properties as individual entities as opposed to a volume-weighted fully-mixed slug is important to assuring compliance with the vapor pressure, GOR, and H_2S emissions limits applicable to these operations

This is especially important for sales and exchanges that draw from fewer caverns and are subject to more stringent vapor pressure and emissions requirements than maximum rate drawdowns



Bubblepoint pressure of each oil layer (psia)

Exchange for Storage (EFS)

Definition

- SPR receives oil from an external operator and returns it at a later date. The operators "pays" a small premium of oil to cover the SPR's cost[1].

EFS 2020

- Initiated under presidential order in March 2020 to "…support U.S. oil producers facing potentially catastrophic losses from impacts of Covid-19 and the intentional disruptions to world markets by foreign actors."[2]
- ~21.1 MMB of crude received from the U.S. midstream from April – June 2020 (fill phase)
- ~18.4 MMB of crude returned to the U.S. midstream from Aug-November 2020 (re-delivery phase)

[1]https://www.energy.gov/sites/default/files/2021-06/Strategic%20Petroleum%20Reserve%20%28revised%29_1.pdf
[2]USDOE. (2020). "Announcement of Solicitation to Purchase Crude Oil for the SPR to Provide Relief to American Energy Industry." from https://www.energy.gov/articles/department-energy-executes-direction-president-trump-announces-solicitation-purchase-crude.

Vapor Pressure Sampling During EFS2020

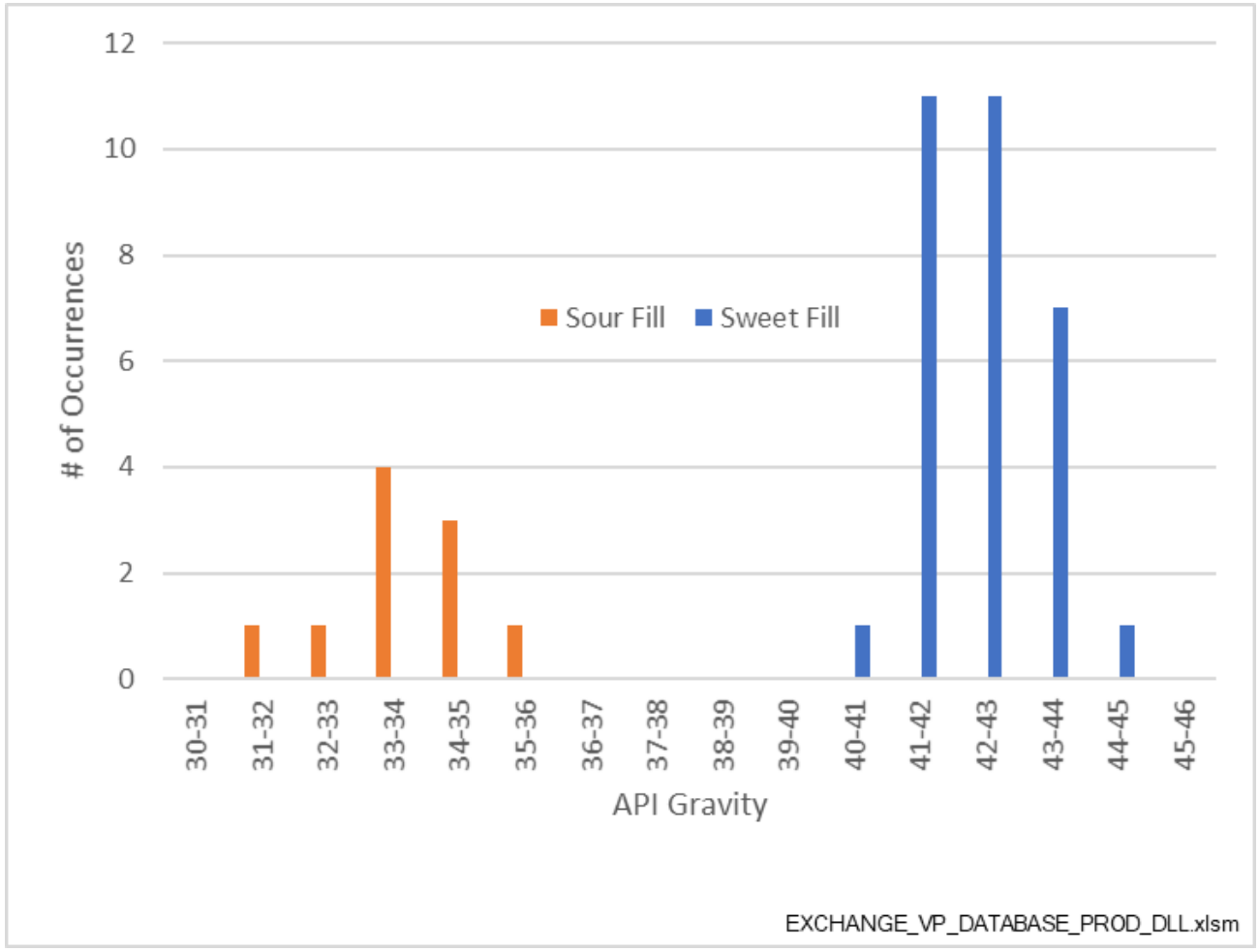
SPR Baseline Monitoring for Vapor Pressure (avg. 6 downhole samples per year)

- Utilizes a dedicated mobile separator laboratory, TVP-95, capable of retrieving downhole cavern or wellhead/pipeline flowing samples
- Useful for describing current state and long-term trends but will not define the new configuration after 21MMB fill operations in two months

EFS Monitoring for Vapor Pressure (~50 flowing samples in two months)

- Collect data during fill phase necessary to inform EFS re-delivery planning
- 10 TVP-95 flowing samples in incoming oil, weighted toward largest suppliers, tested for bubblepoint pressure, gas-oil ratio, and flash gas composition
- 41 spot samples on incoming oil, averaging one per 0.5 MMB received, tested for ASTM D6377 VPCR and GPA 2103-M pressurized composition

API Gravity of EFS fill



Sour Fill avg °API = 33.8

- Compare to °API = 34-38 in receiving caverns
- New sour fill will likely mix with existing inventory

Sweet Fill avg °API = 44.4

- Compare to °API = 36-41 in receiving caverns
- New sweet fill will likely float on existing inventory

API gravity was sampled at point of custody transfer and measured by **ASTM D5002**, Standard Test Method for Density and Relative Density of Crude Oils by Digital Density Analyzer.

Vapor Pressure for SW and SO Fill @ 100°F

Type		TVP-95 BPP [psia]	$VPCR_{0.2}$ [psia]
SW	avg	16.1	16.2
SW	max	17.5	18.2
SW	min	14.8	14.4
SW	stdev	1.0	0.9
SO	avg	17.4	17.3
SO	max	18.1	19.4
SO	min	16.9	15.8
SO	stdev	0.6	1.3

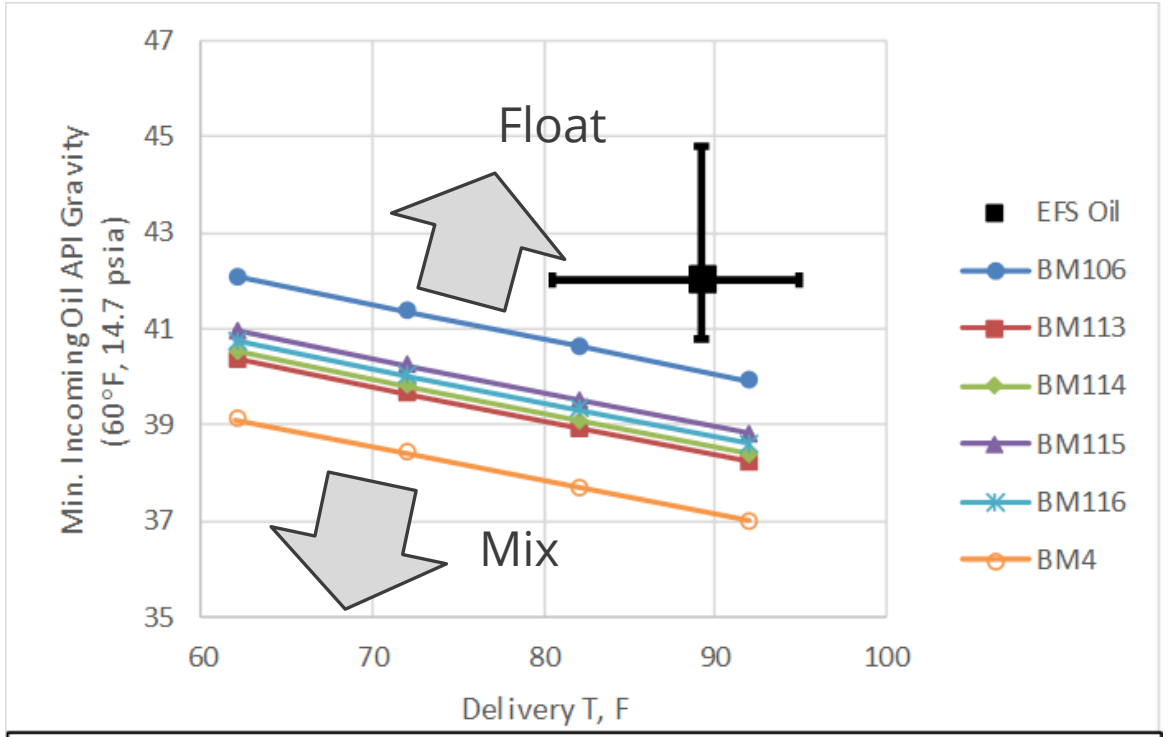
Summary Points

- Sweet fill avg BPP = 16.1 psia (@ 100°F)
- Sour fill avg BPP = 17.4 psia (@ 100°F)
- TVP-95 BPP vs. $VPCR_{0.2}$ methods give comparable results
- BPP of EFS fill is generally higher than the blendstock (BPP < 15 psia @ 100°F) in many of the receiving caverns

Notation

- TVP-95 BPP [psia] = Bubblepoint pressure measured by TVP-95 separator method
- VPCR0.2 [psia] = Vapor pressure of crude $VPCR_{0.2}$(100°F) by ASTM D6377-16

Float vs. Mix Predictions: Sweet Fill



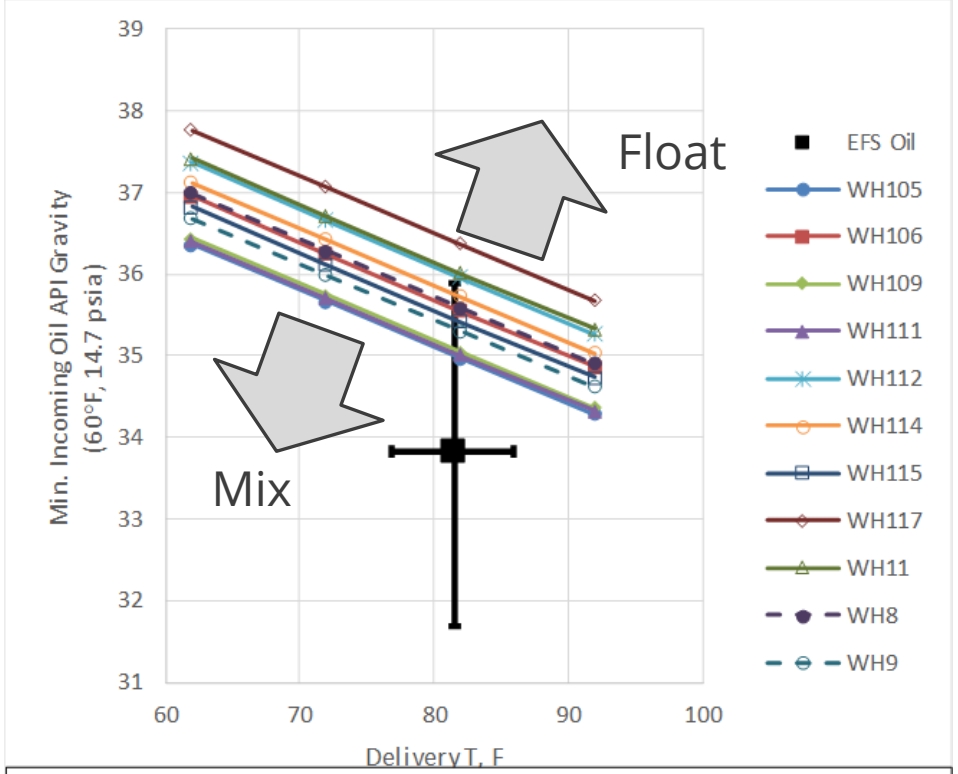
These data are only valid for current cavern temperatures and only intended for current exchange use. They cannot be utilized for another purpose past July 2020 without modification to adjust for cavern temperature and cavern oil properties.

A simple pressure-temperature-density model was run to predict in-situ density where the EFS fill oils met the existing oils at the roofs of each receiving cavern.

The example at left indicates EFS fill was predicted to float on all of the BM sweet caverns.

Figure Reproduced from: Lord, D. L., J. W. Hogge and L. Eldredge (2021). "Overview of Oil Distribution and Properties at Completion of the 2020 Exchange for Storage Fill at the U.S. Strategic Petroleum Reserve." *Unlimited Release* ***SAND2021-5498. Sandia National Laboratories. May-2021.***

Float vs. Mix Predictions: Sour Fill



These data are only valid for current cavern temperatures and only intended for current exchange use. They cannot be utilized for another purpose past July 2020 without modification to adjust for cavern temperature and cavern oil properties.

EFS sour fill was predicted to mix in most of the WH sour caverns as it was more dense at in-situ conditions

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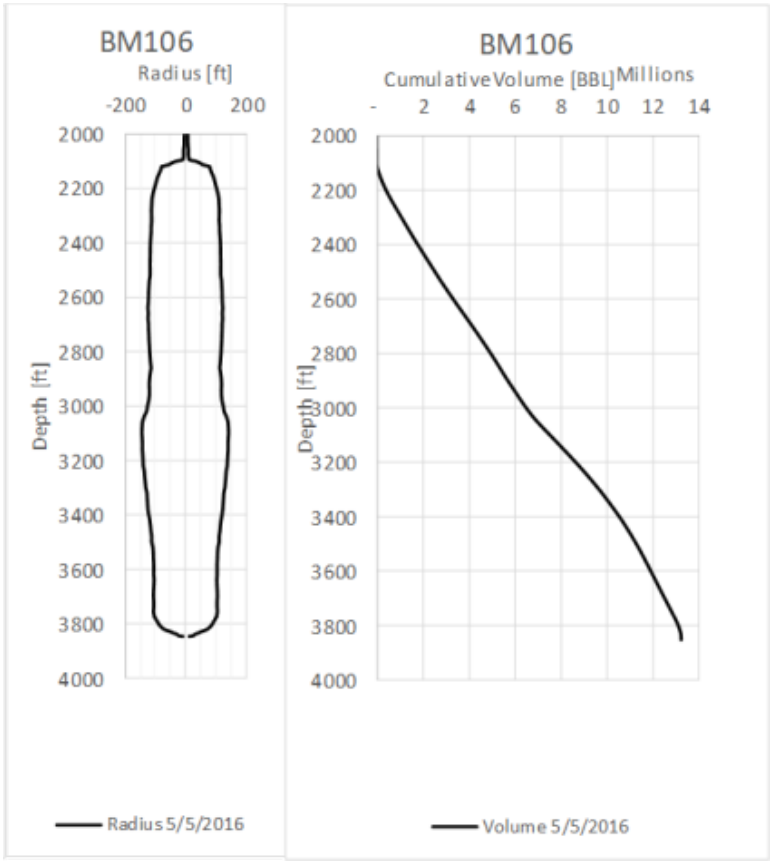
Bryan Mound Layering Example: BM106 (1)



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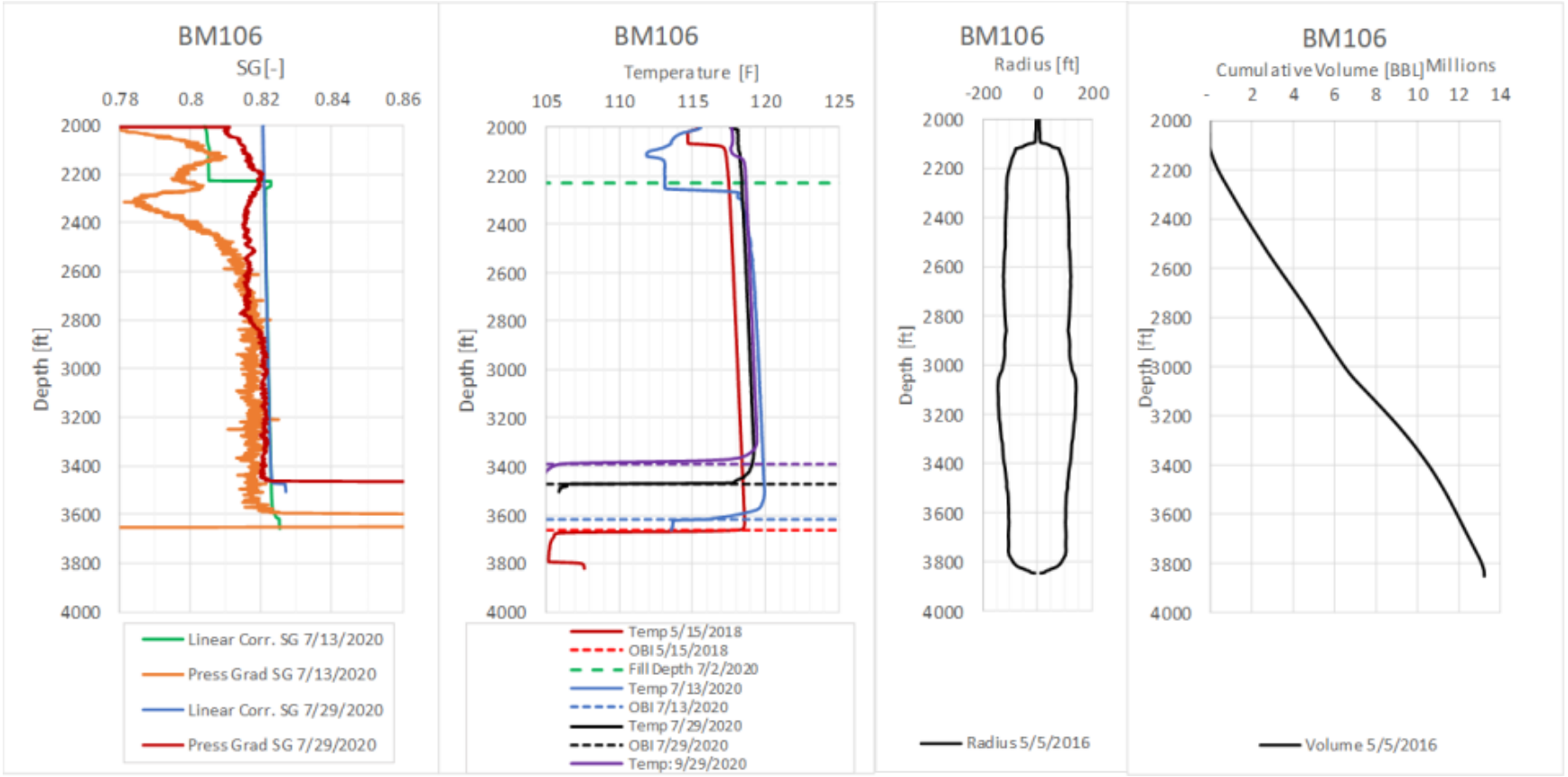
Bryan Mound Layering Example: BM106 (2)



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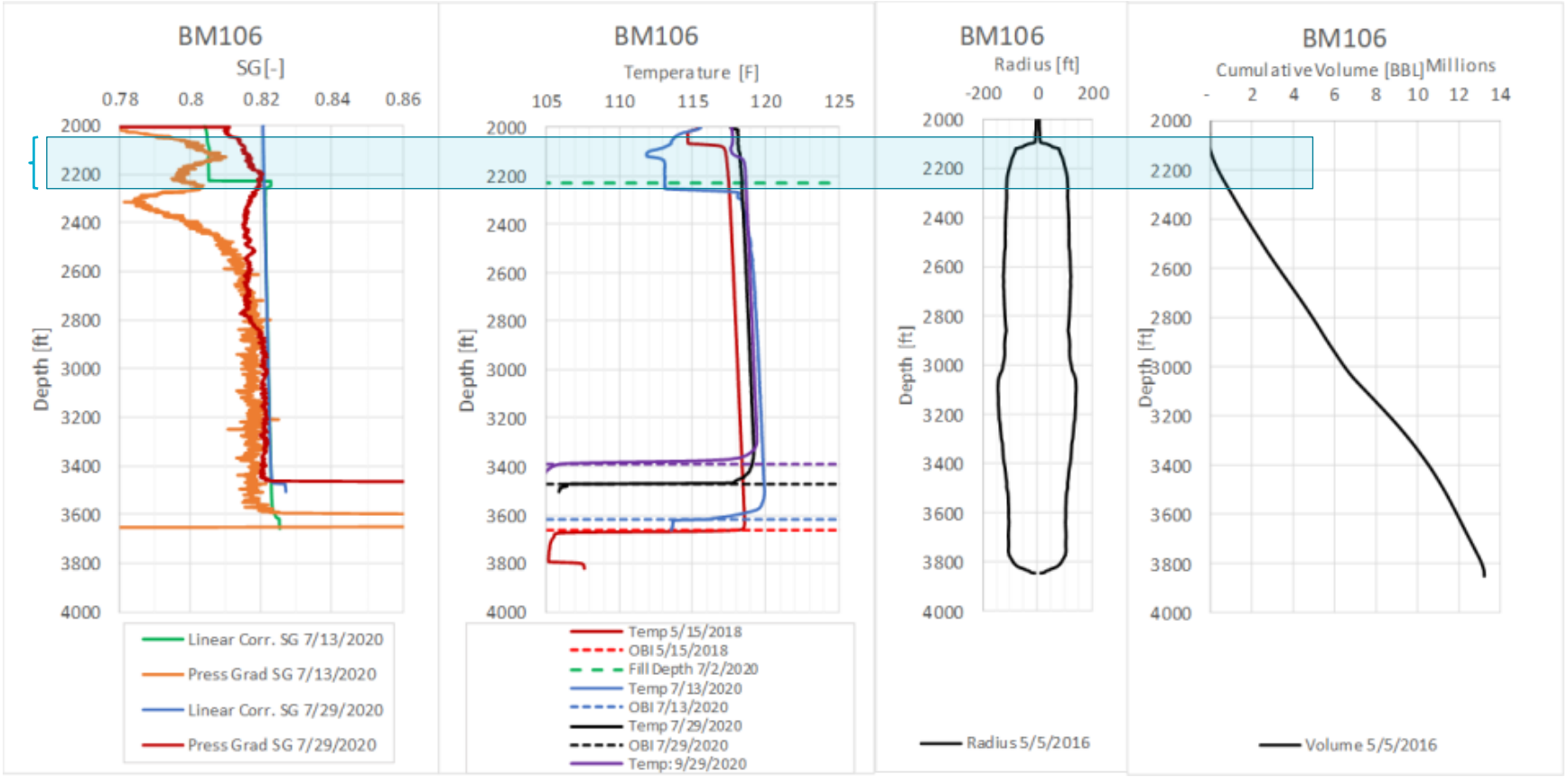
Bryan Mound Layering Example: BM106 (3)

EFS fill floating

Wirelines taken in July 2020 indicated that EFS sweet fill was floating on all receiving sweet caverns.



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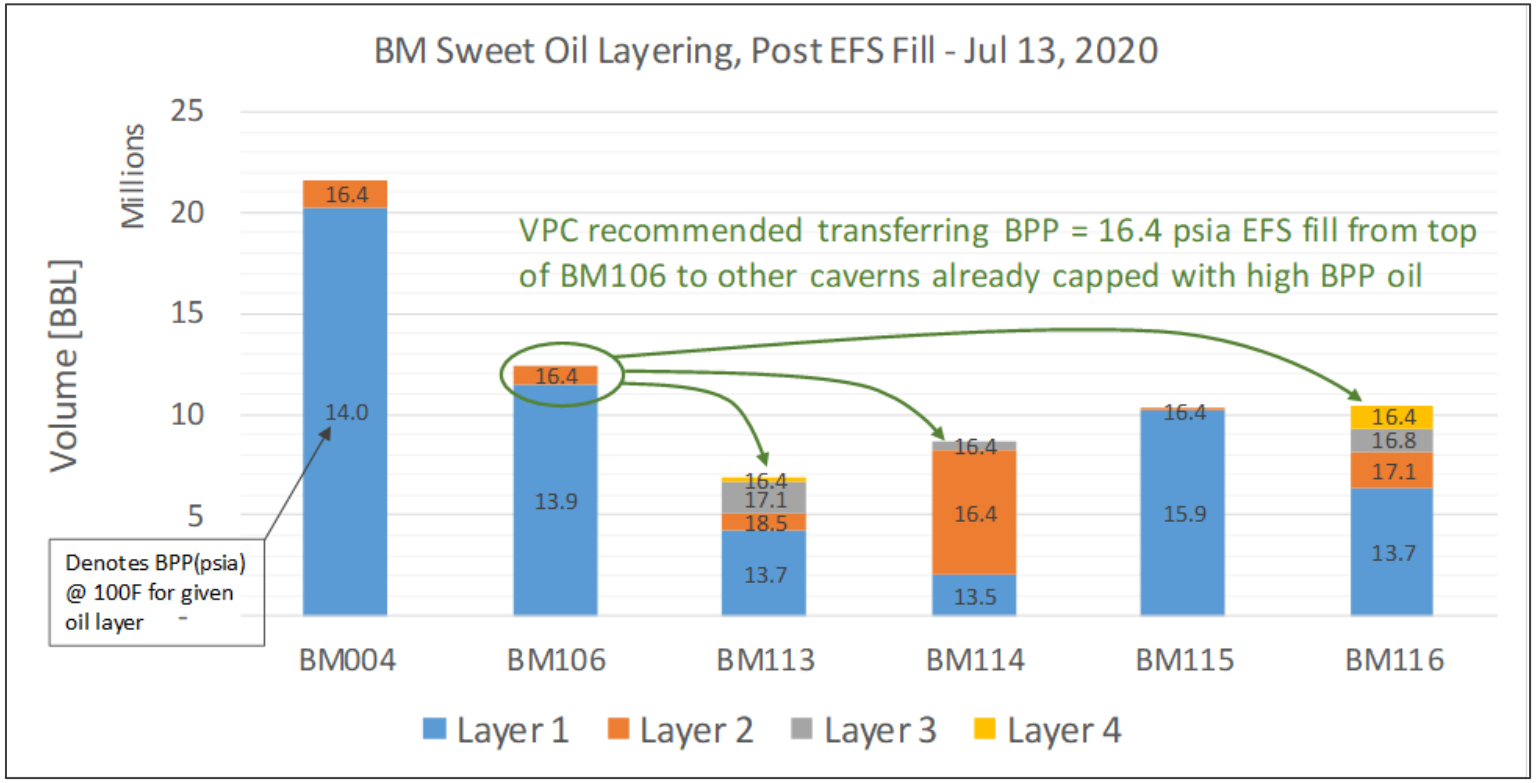
Operational Implications of Floating EFS Sweet

- EFS fill "capped" every sweet cavern at BM site.
- This created an operational issue that required cavern-to-cavern transfers prior to EFS returns to expose low BPP oils (<14.7 psia) in some caverns to enable re-delivery of the blended stream within VP specifications (stream BPP≤14.7 psia).



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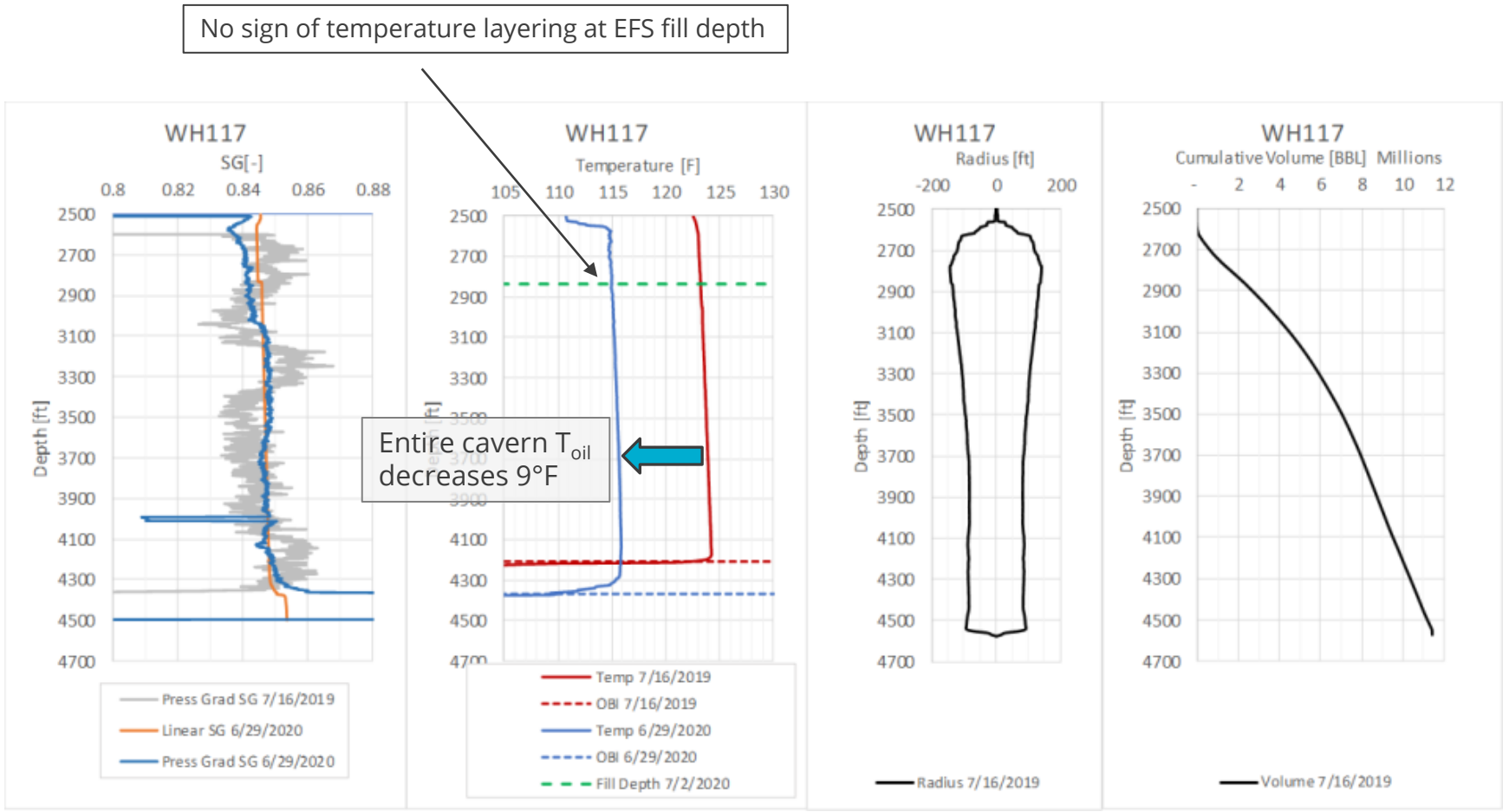
West Hackberry Mixing Example: WH117

Wirelines taken in July 2020 indicated that EFS sour fill mixed in all receiving sour caverns.

In this example, addition of sour EFS fill gave no indication of temperature layering to expected fill depth (---).

Instead, the entire cavern T_{oil} **decreased by about 9 °F**, consistent with a simple volume-weighted temperature estimate



Utility of Findings for Re-delivery Phase

Knowing the configurations (floating versus mixed) and vapor pressures of the EFS fill enabled an informed re-delivery phase

EXAMPLES

- Cavern transfers were implemented at Bryan Mound sweet to expose blendstock in BM 106
- Cavern selections for re-delivery used optimal amounts of valuable blendstock to meet vapor pressures specs, avoiding under- or over-use due to lack of data
- Re-delivery at Bayou Choctaw was scheduled for fall/winter to leverage cooler ambient raw water temperatures

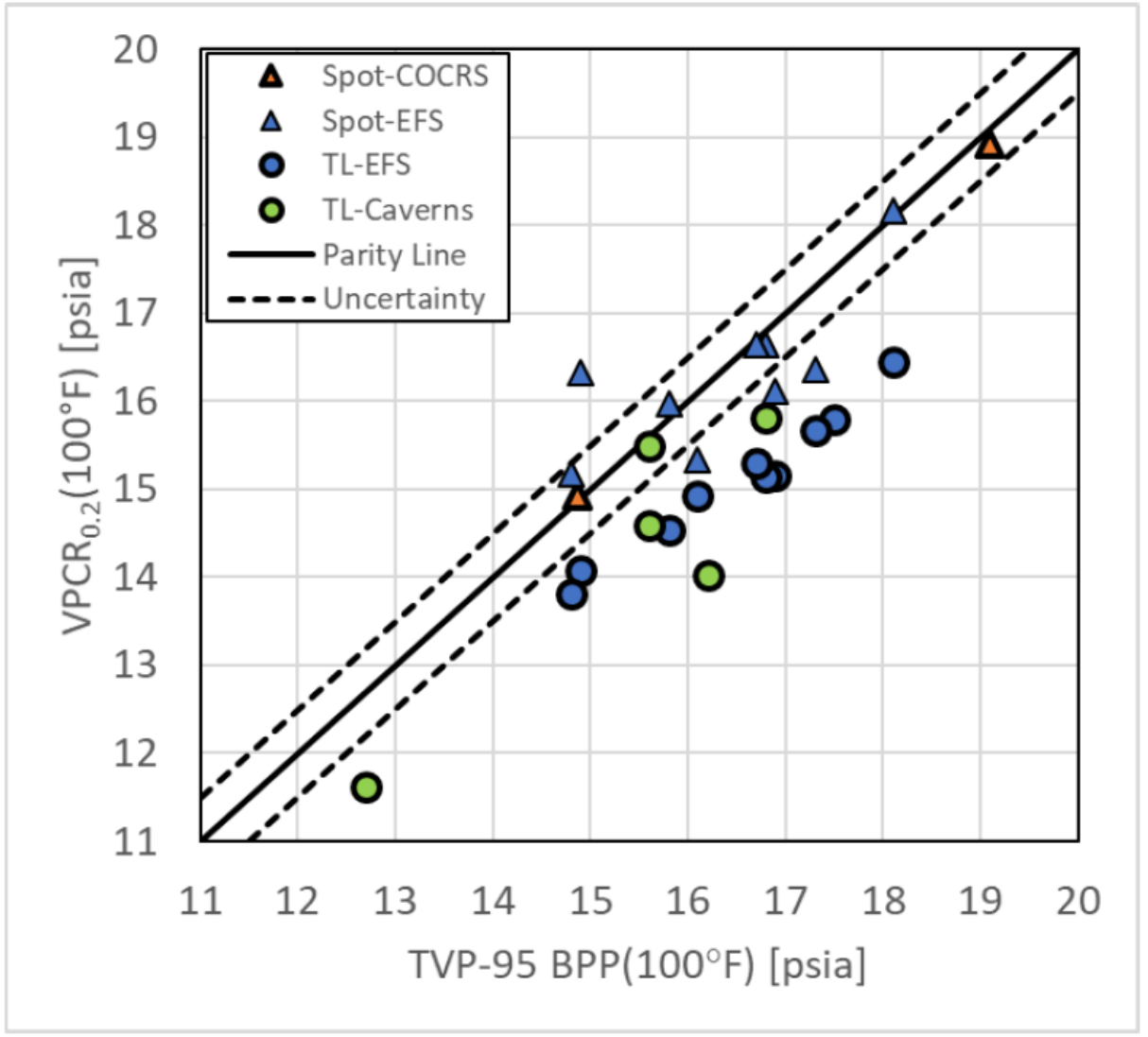
Utility of Findings in Methods Research

Nine vapor pressure samples taken during EFS fill (**Spot-EFS** series at right) were obtained in parallel between TVP -95 and spot sampling

These add to a growing body of parallel data that are being used to assess alternatives to the TVP-95

Parity plot at right summarizes findings from 2017 to-date for TVP-95 BPP vs $VPCR_{0.2}$ at T = 100°F

Research at SPR and Sandia in this area is ongoing



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