

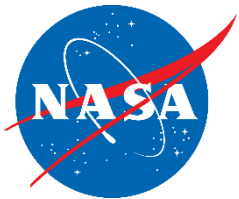
Total Hydrocarbon Content (THC) testing in Liquid Oxygen (LOX)

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THC testing in LOX

- Background
- Test Facility
- Test Hardware
- Test Results
- Conclusions

THC testing in LOX

- Background
 - Limits on THC levels in LOX are based on customer requirements
 - THC levels in LOX delivered to SSC
 - Vendor sample analysis not in agreement with SSC sample analysis
 - SSC analysis showed HIGHER THC values compared to vendor reported data
 - Increased lab analysis of LOX; increased SSC costs
 - THC levels in storage/run tanks
 - Increased over time
 - Consequences
 - LOX losses due to dumping of out of spec commodity
 - Increased commodity costs due to additional sample analysis
 - Program testing delays
 - Mitigation opportunities

THC Testing in LOX





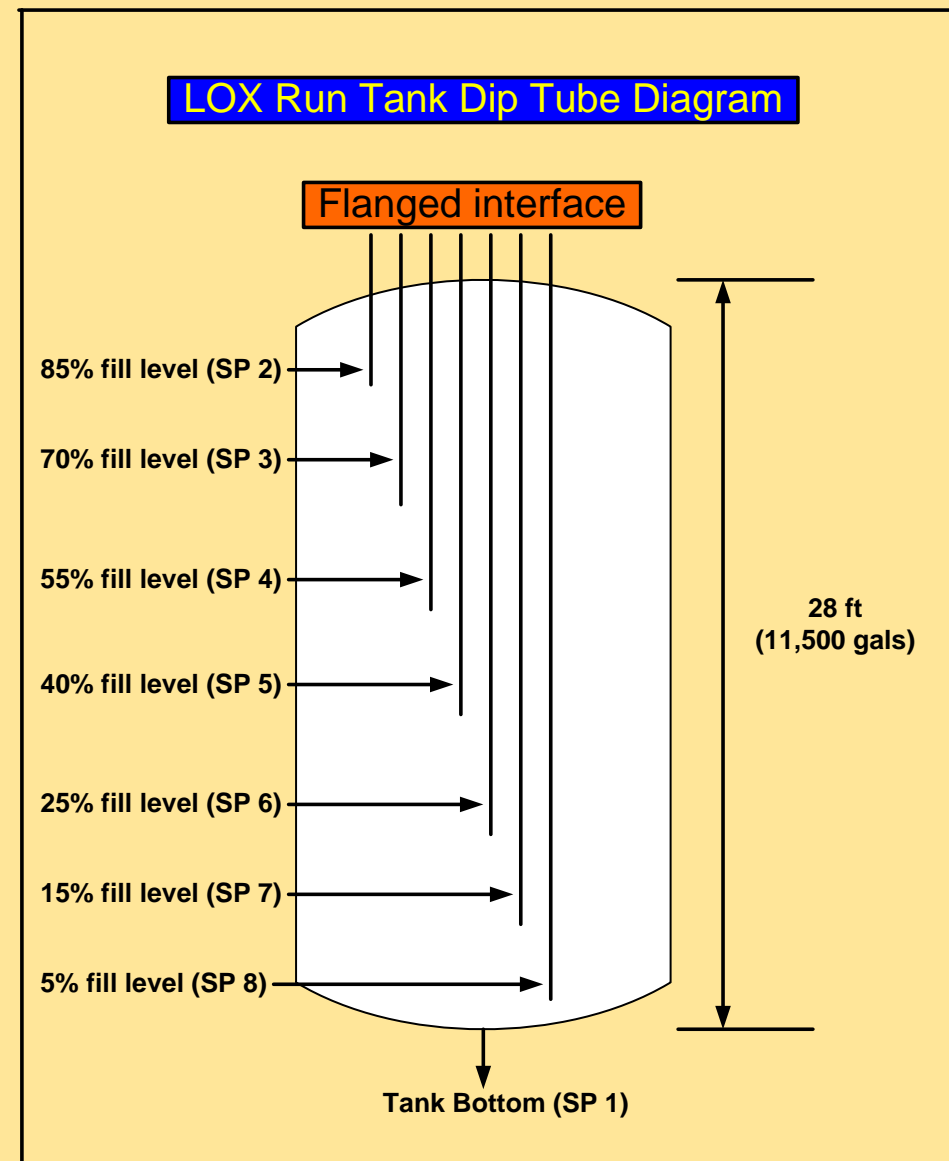
THC Testing in
LOX

SSC Test Stand

THC Testing in LOX



SSC
Test Stand
LOX Run Tank



THC Testing in LOX

Flanged Interface



Dip Tube Valving



THC Testing in LOX

Cryogenic Properties of Select Fluids at NBP

Property	Units	Parahydrogen	Nitrogen	Oxygen	Methane	Krypton
Normal boiling point (NBP)	°F	-423.18	-320.43	-297.33	-258.67	-244.16
Density	lbm/ft ³	4.42	50.32	71.24	26.37	150.86
Heat of vaporization	Btu/lbm	191.89	85.69	91.66	219.76	46.06
Specific Heat, C _p	Btu/lbm-°R	2.325	0.488	0.406	0.832	0.124
Viscosity	lbm/ft-sec	8.957E-06	1.079E-04	1.308E-04	7.849E-05	2.742E-04
Thermal conductivity	Btu/hr-ft-°F	0.05981	0.0837	0.08717	0.10623	0.06354
Critical temperature	°F	-400.38	-232.52	-181.42	-116.65	-82.61
Critical pressure	psia	186.49	492.52	731.43	667.06	801.33
Temperature at triple point	°F	-434.82	-346.00	-361.82	-296.42	-251.28
Pressure at triple point	psia	1.02	1.82	0.02	1.70	10.67

SSC Gas & Materials Science

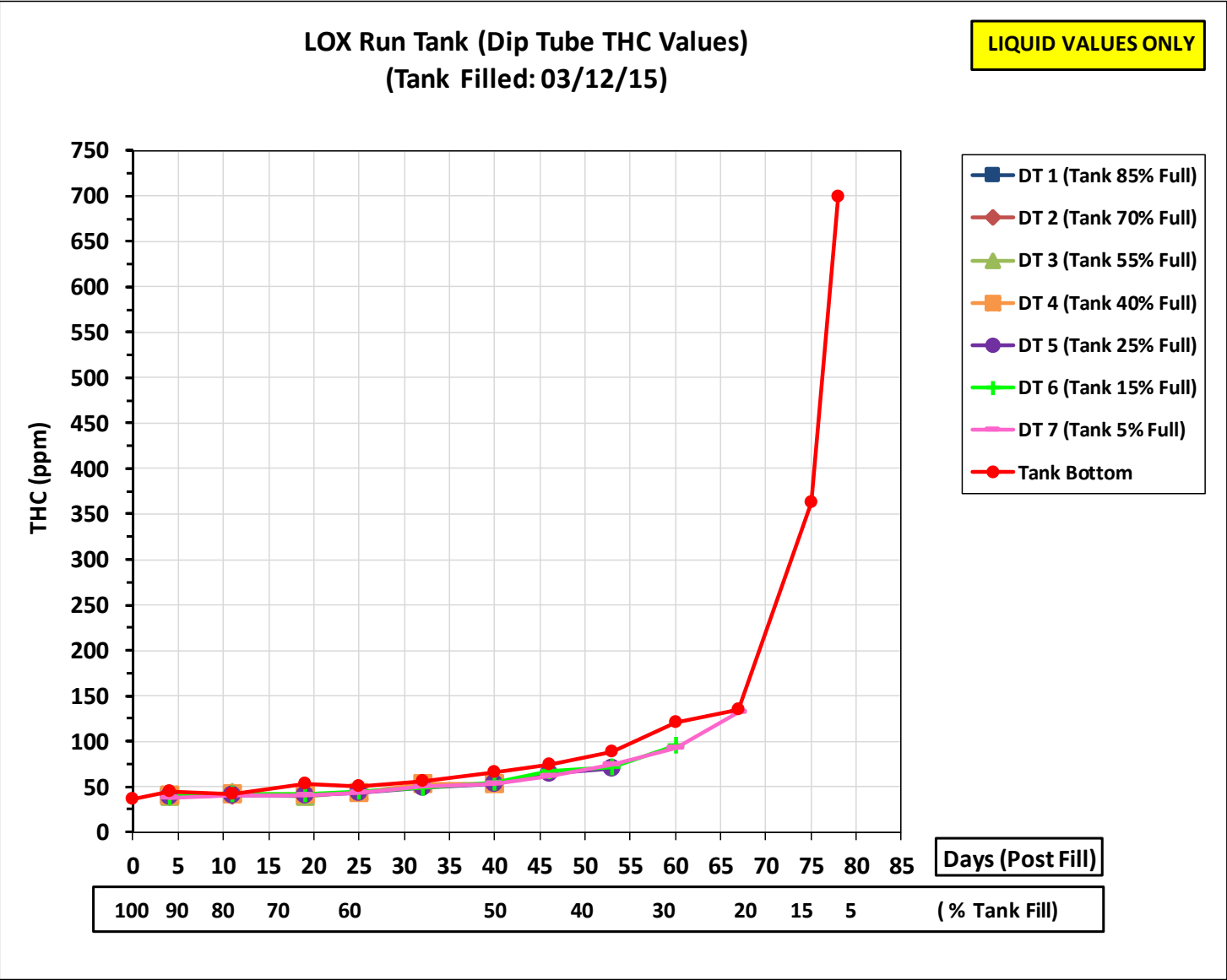
THC Testing in LOX

THC Data (LOX Run Tank)

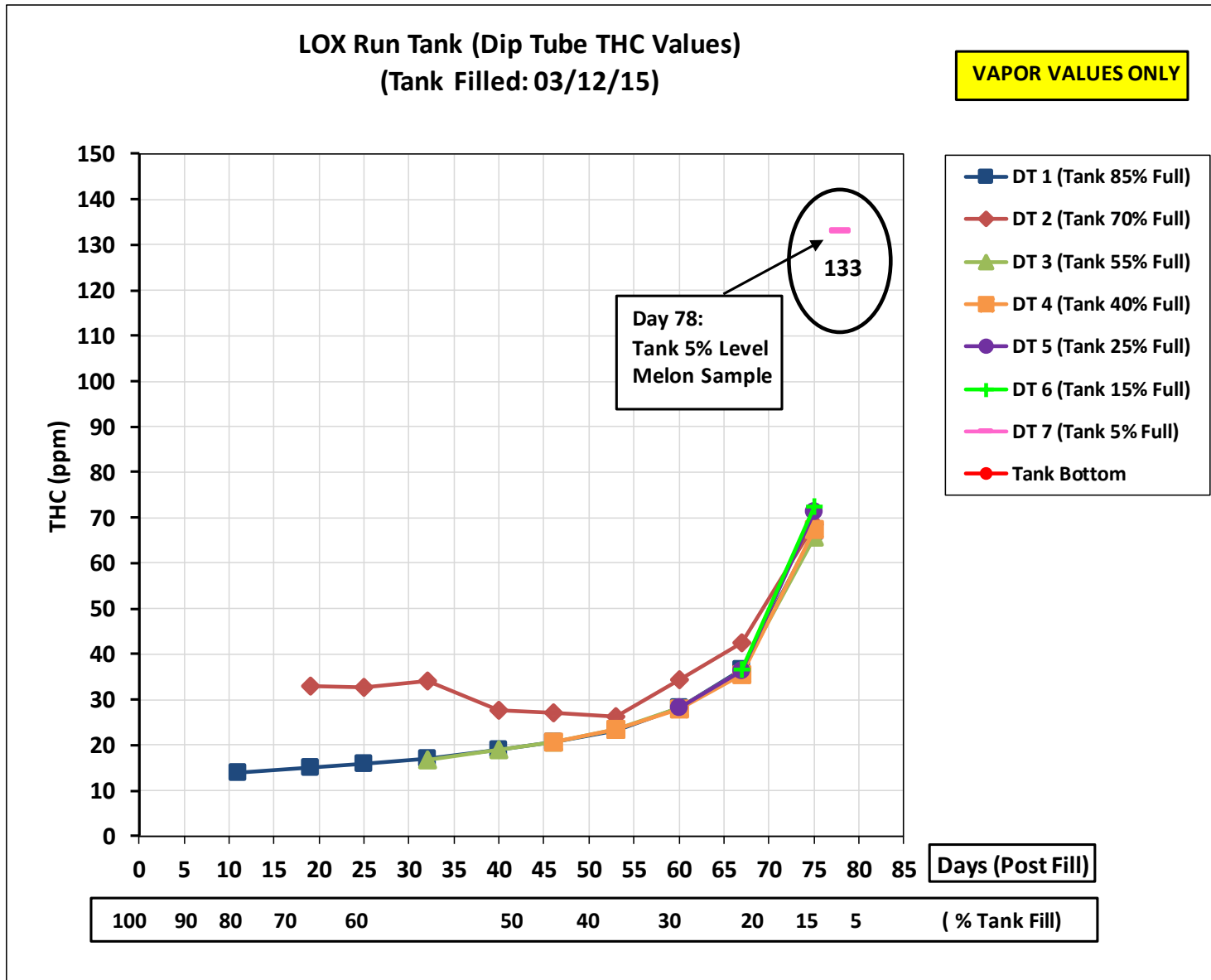
Sample Date	Elapsed Time From Initial Fill (Days)	THC Values (ppm) - ALL VALUES							
		DT 1 (85% Full)	DT 2 (70% Full)	DT 3 (55% Full)	DT 4 (40% Full)	DT 5 (25% Full)	DT 6 (15% Full)	DT 7 (5% Full)	Tank Bottom
03/12/15	0								35.4
03/16/15	4	39.3	38.5	39	40.6	39.1	39.2	37.9	43.9
03/23/15	11	13.9	40.1	43.1	41.3	40.9	41.1	40.3	41.6
03/31/15	19	14.97	33.12	39.3	41.7	40	42.2	40.1	52.4
04/06/15	25	15.9	32.7	44.9	43.1	43.7	43.8	43.7	50.2
04/13/15	32	17	34.1	16.8	52.3	48.7	48.9	50	55.5
04/21/15	40	18.9	27.7	19	52.7	52.8	54.4	52.8	65.5
04/27/15	46	20.8	27.1	20.8	20.6	64.2	66.8	61.7	74.4
05/04/15	53	23.2	26.3	23.4	23.4	69.6	71.2	73.7	88.7
05/11/15	60	28.3	34.3	28.1	28	28.2	95.3	92.3	120
05/18/15	67	36.7	42.6	36.3	35.6	36.3	36.7	132.4	135.1
05/26/15	75	66.9	68.64	65.59	67.46	71.3	72.46		362.3
05/29/15	78							133	699

NOTE: Values in Yellow are from Vapor samples

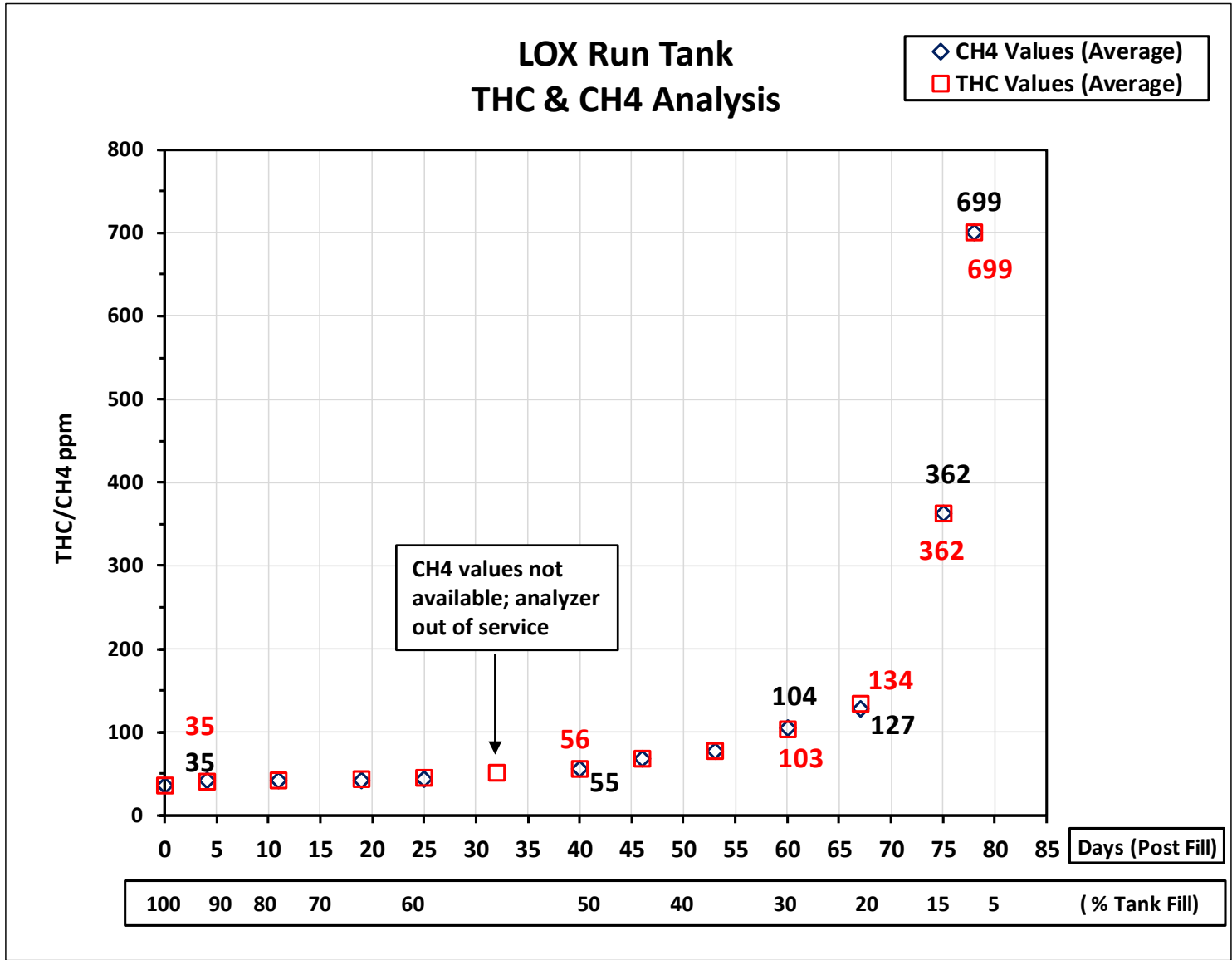
THC Testing in LOX



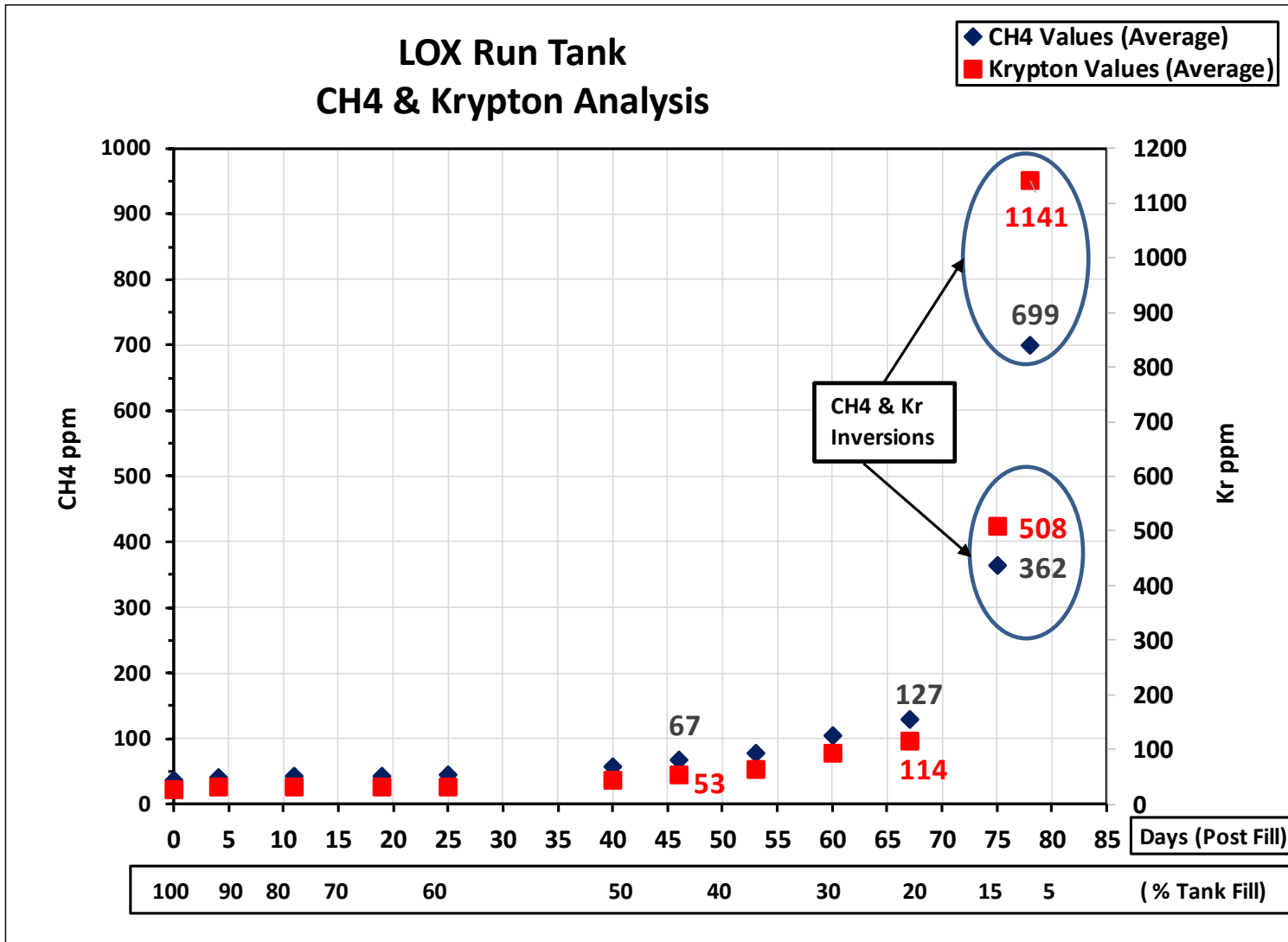
THC Testing in LOX



THC Testing in LOX

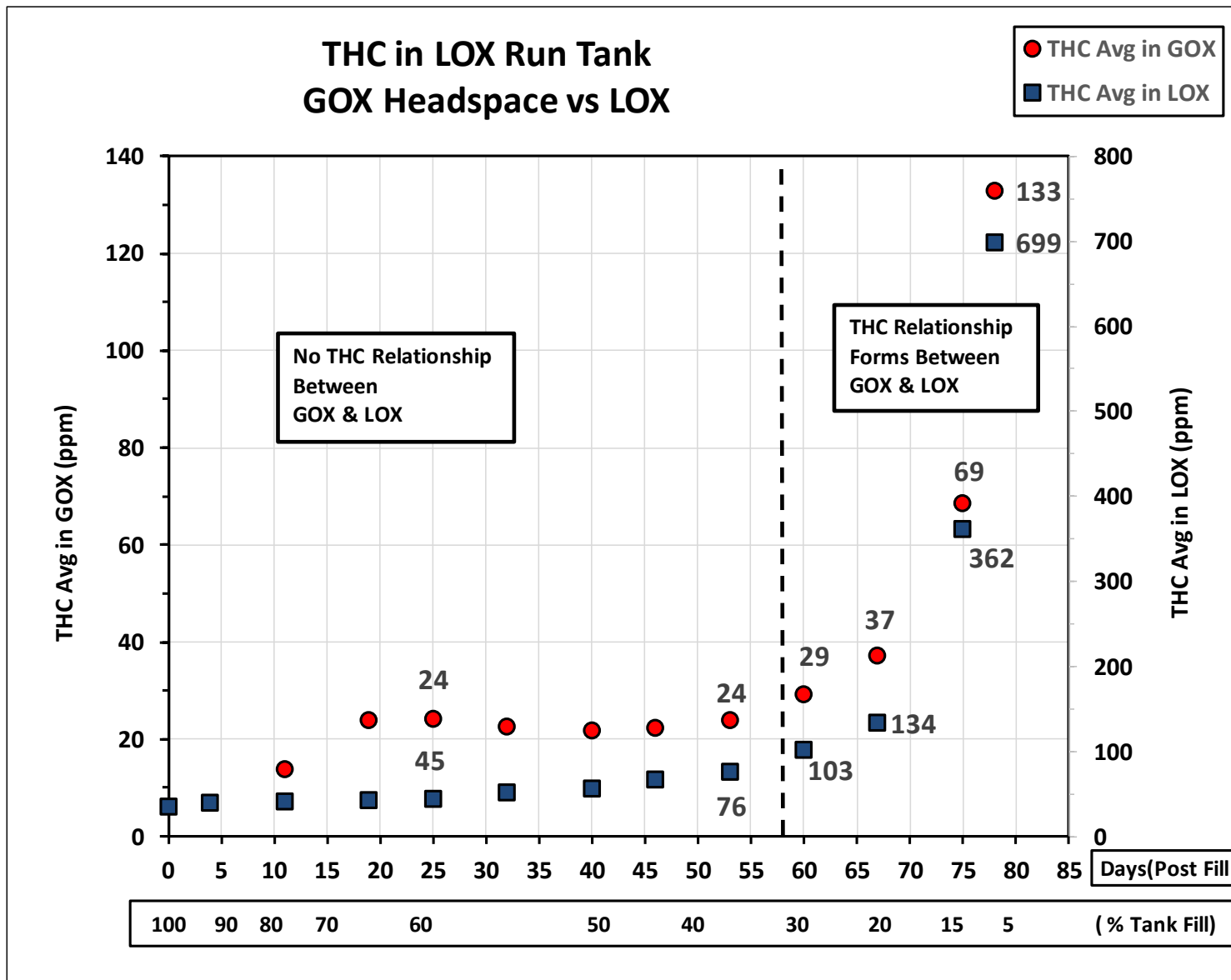


THC Testing in LOX



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THC Testing in LOX



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THC Testing in LOX

- Mitigation of THC values
 - Dilution method developed
 - Based on simple chemistry of solutions
 - Does not account for potential transfer losses or boil-off

	Initial Volume (gallons)	Initial Volume THC (ppm)	Added Volume (gallons)	Added Volume THC (ppm)	Final Volume (gallons)	Final Volume THC (ppm)	Final Volume THC (ppm) [PREDICTED]	% Diff (Predicted vs Measured)
Tank 1 (Horizontal)	9800	55.6	12300	18	22100	34.1	34.7	1.8
Tank 2 (Horizontal)	35400	112.4	12200	57.1	47600	101.7	99	-2.7

THC testing in LOX

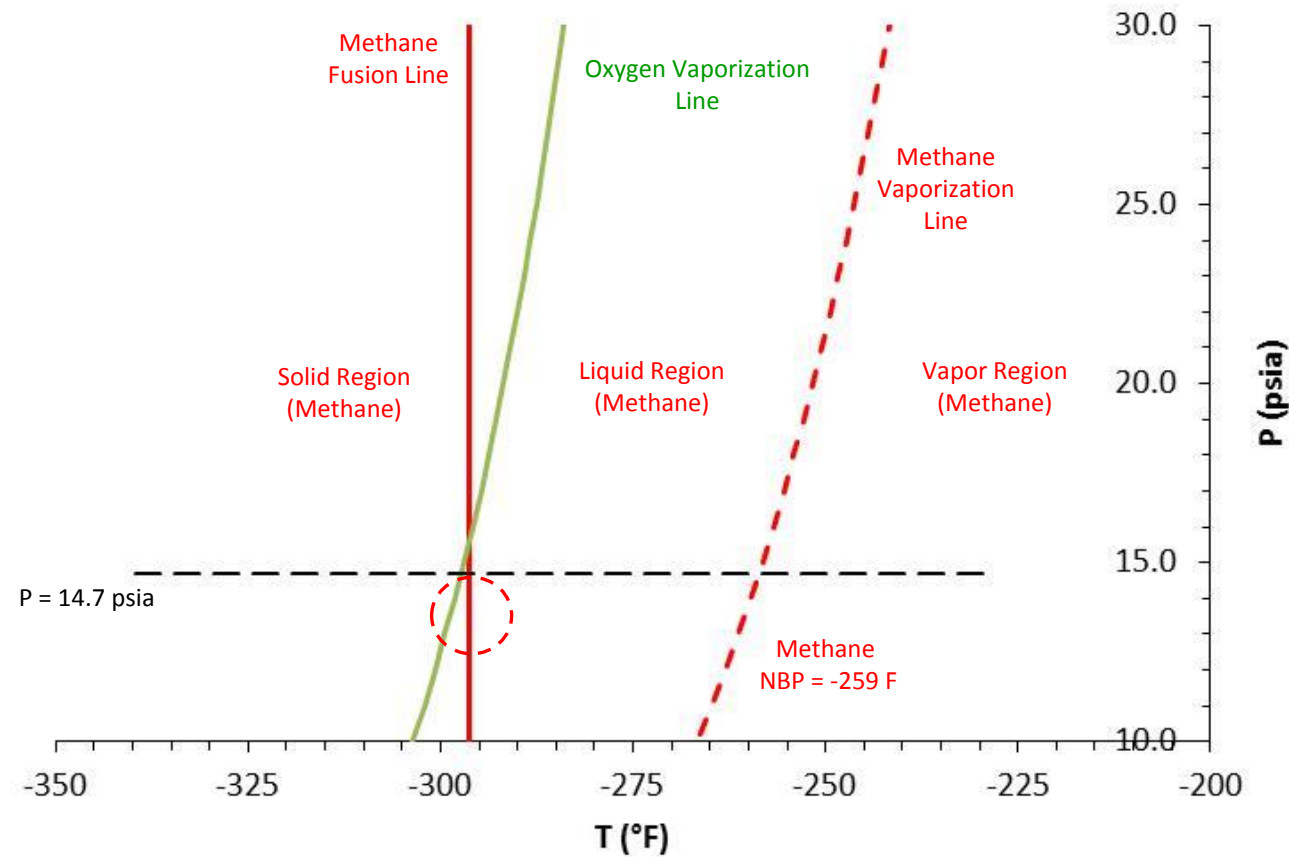
- SUMMARY
 - THC values increase over time in tanks due to boil-off
 - Stratification of THC in tanks may be present
 - May occur when tank volume is less than 50%
 - Mitigations
 - Work with vendor to consistently obtain LOX with lower THC
 - Dumping of some LOX from tanks and/or dilution with low THC LOX
 - Using LOX with a high THC value to chill run lines followed by tank dilution with low THC LOX
 - Modeling of THC rise in tanks and projected THC levels over time can assist engine test programs
 - Replicate testing of LOX Run Tank in progress

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 - Eric Dirschka
 - Jared Sass
 - Claire Offer

Backup Information

P-T Diagram for Methane and Oxygen



- LOX temperature at the normal boiling point (NBP) is -297.33°F and is lower than the methane fusion temperature of -296.38°F at 14.7 psia; hence methane may be in the solid state when LOX is at the NBP. Also, Methane NBP = -259°F so LOX will boil first.

Cosmodyne TYPE TTU-131 Cryogenic Sampler

