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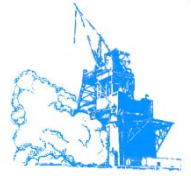
## Stennis Space Center (SSC) LOX Hydrocarbon Issue

Nugent & Hebert

11/07/13



# LOX Hydrocarbon Issue



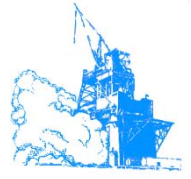
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## Background

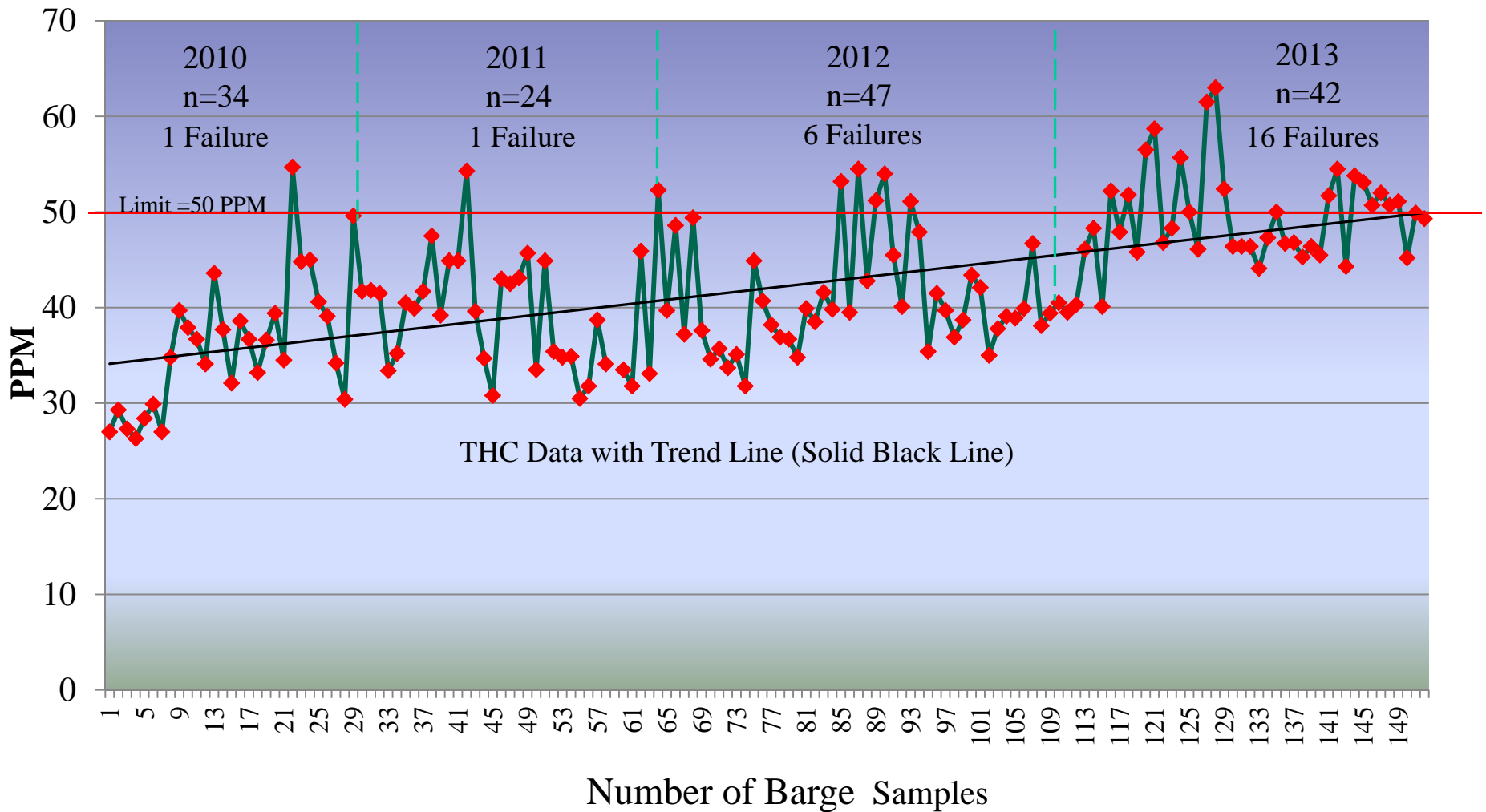
- LOX Vendor is required to provide a Certificate of Analysis with each delivered LOX Trailer:
  - Purity
  - Moisture
  - Total Hydrocarbon Content (THC)
- Recent SSC samples of LOX Barges and Test Stand run tanks indicate elevated Total Hydrocarbon Content (THC): Methane
  - Procurement (per MIL Spec 25508) and Site Limit (per MSFC 3535) THC = 50 PPM Max
  - Customer Limit: J-2X, RS-68, AJ-26, SLS Core Stage THC = 75 PPM Max
  - Barges sampled as high as 63 PPM and E1 run tank as high as 103 PPM



# THC Analyses SSC LOX Barges CY 2010 thru Jul 29, 2013

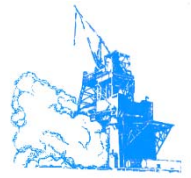


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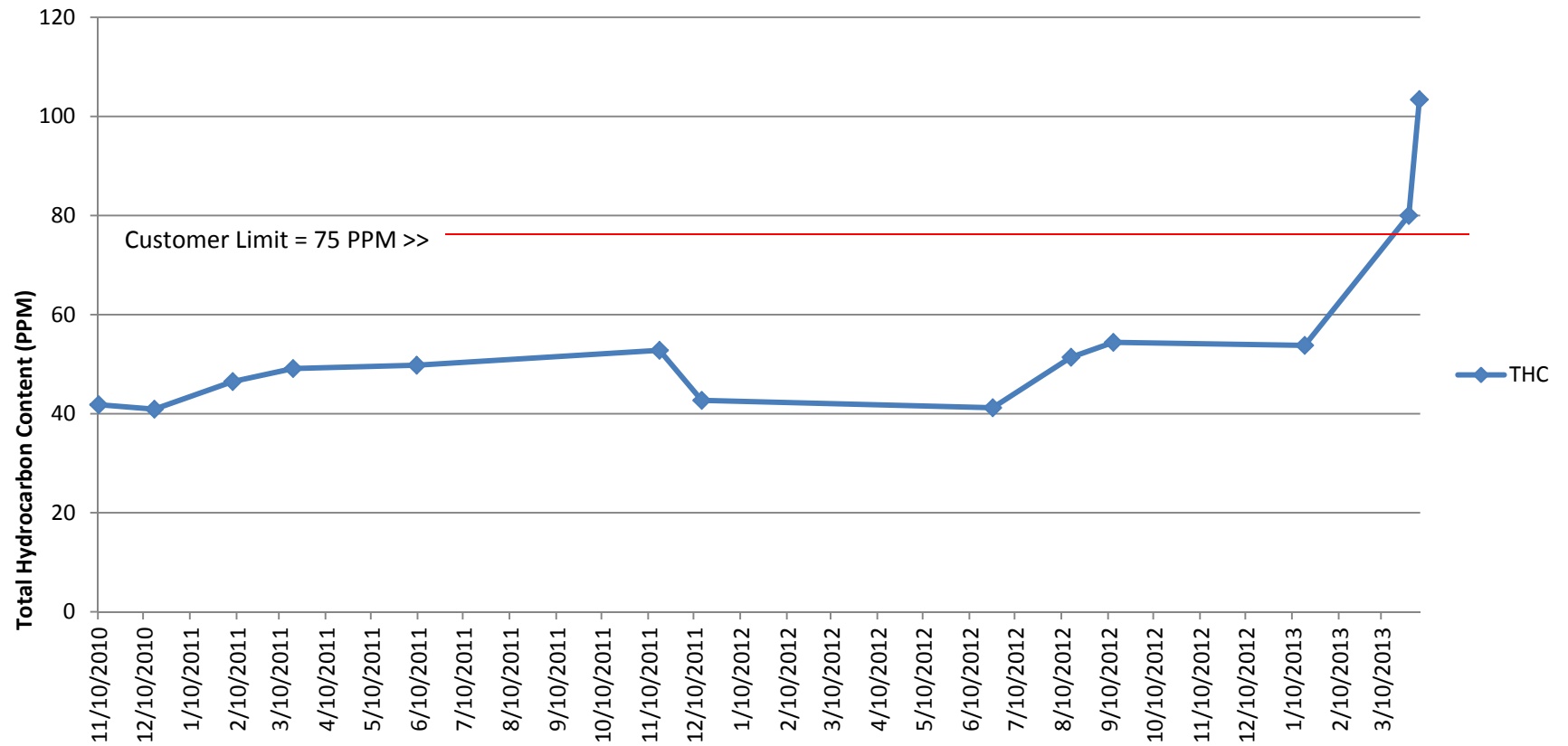


# LOX Hydrocarbon Issue



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## E1 LOX Run Tank THC

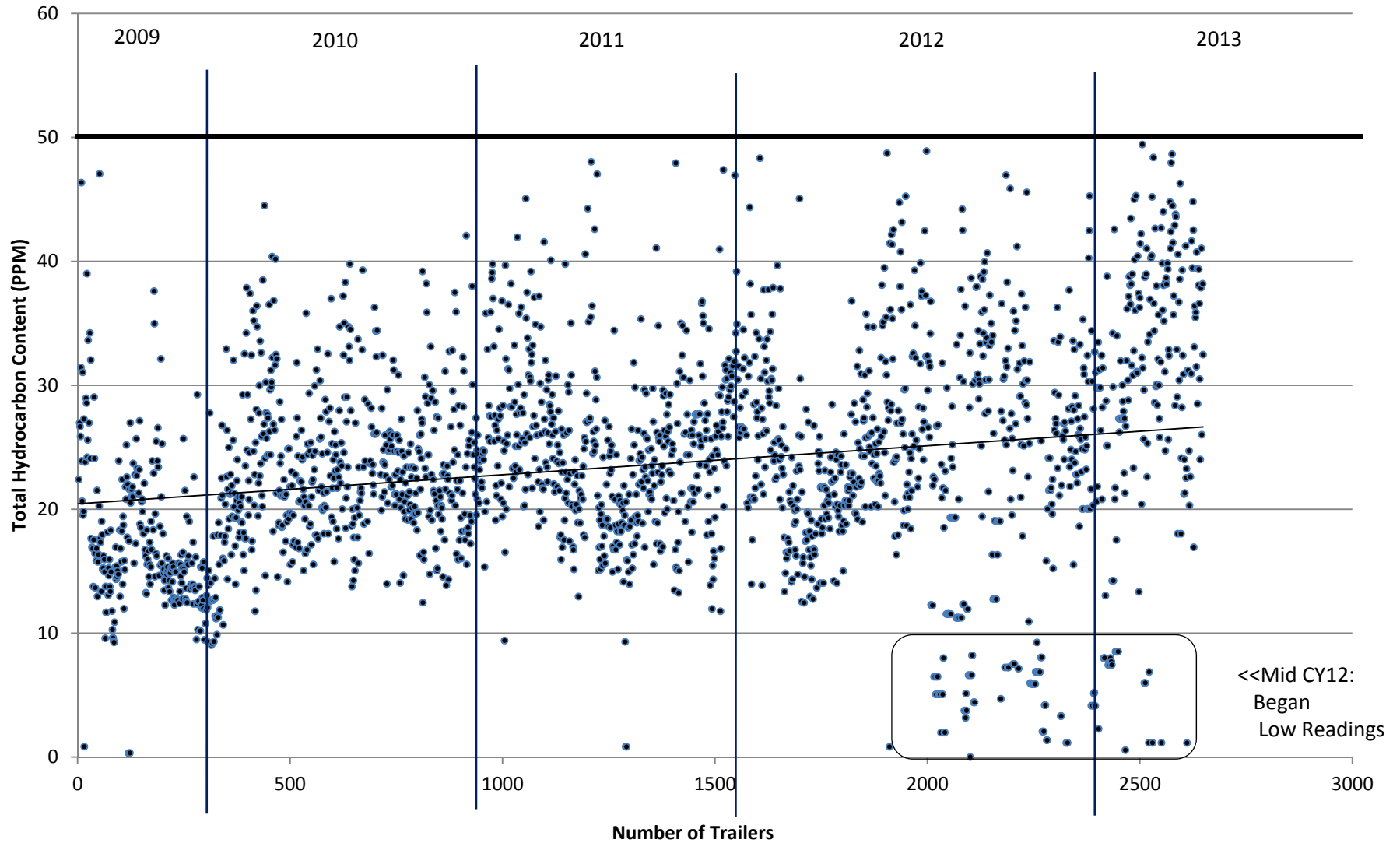




# Vendor Certifications: LOX Trailer THC Contract Start (July, 2009) to Present



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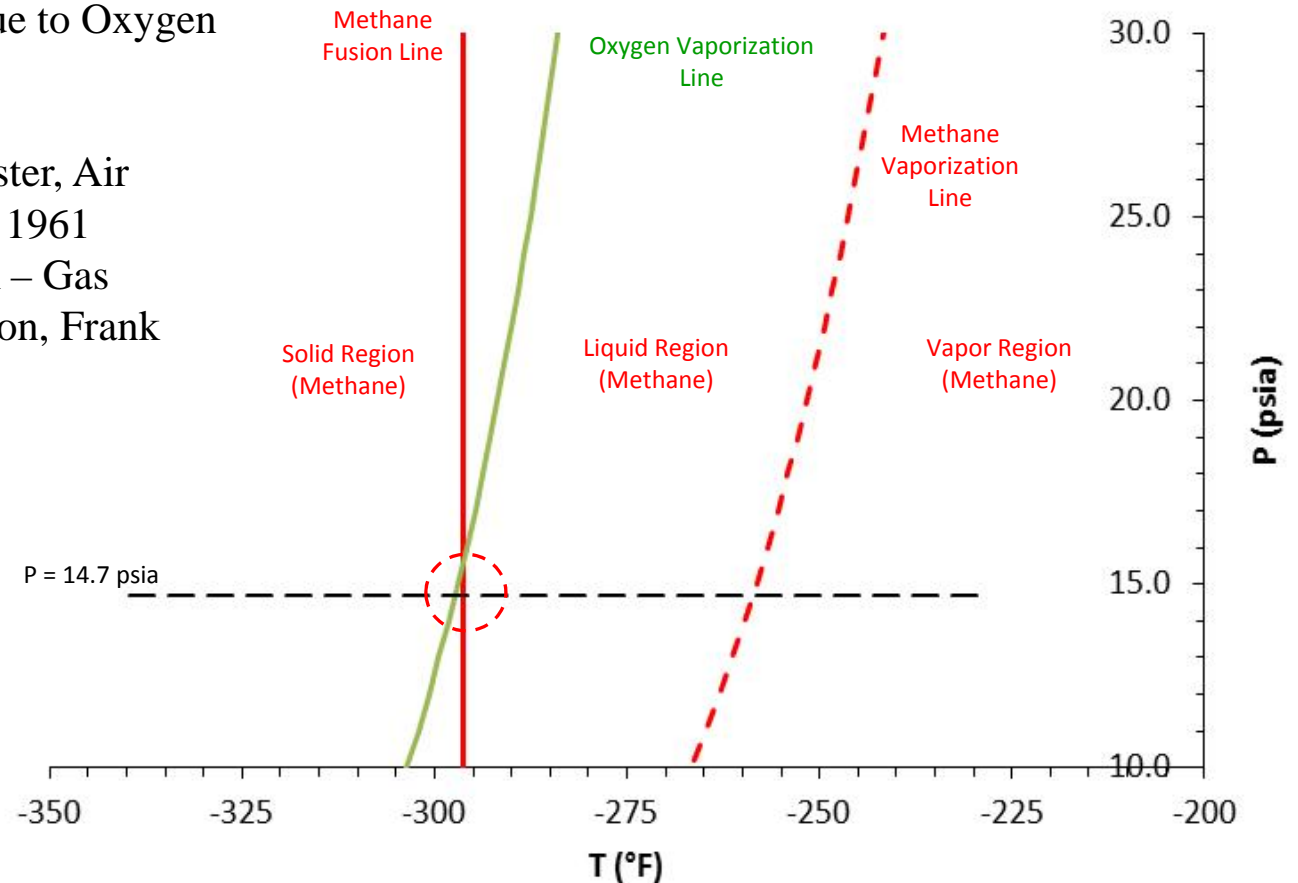
# P-T Diagram for Methane and Oxygen

Figure 4



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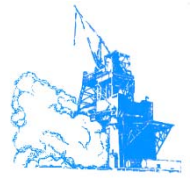
- THC concentration increase due to Oxygen boiloff is documented in:
  - Study of Liquid Oxygen Contamination, R. H. Foster, Air Products and Chemicals, 1961
  - Industrial Gas Handbook – Gas Separation and Purification, Frank Kerry, 2007



- LOX temperature at the normal boiling point (NBP) is  $-297.33^{\circ}\text{F}$  and is lower than the methane fusion temperature of  $-296.38^{\circ}\text{F}$  at 14.7 psia; hence methane may be in the solid state when LOX is at the NBP.



# Multiple Methane Samples of LOX Tank During Boiloff (Factor of ~8 decrease in Volume = Factor of ~3 Increase in CH<sub>4</sub>) (From 1961 Air Products Report)



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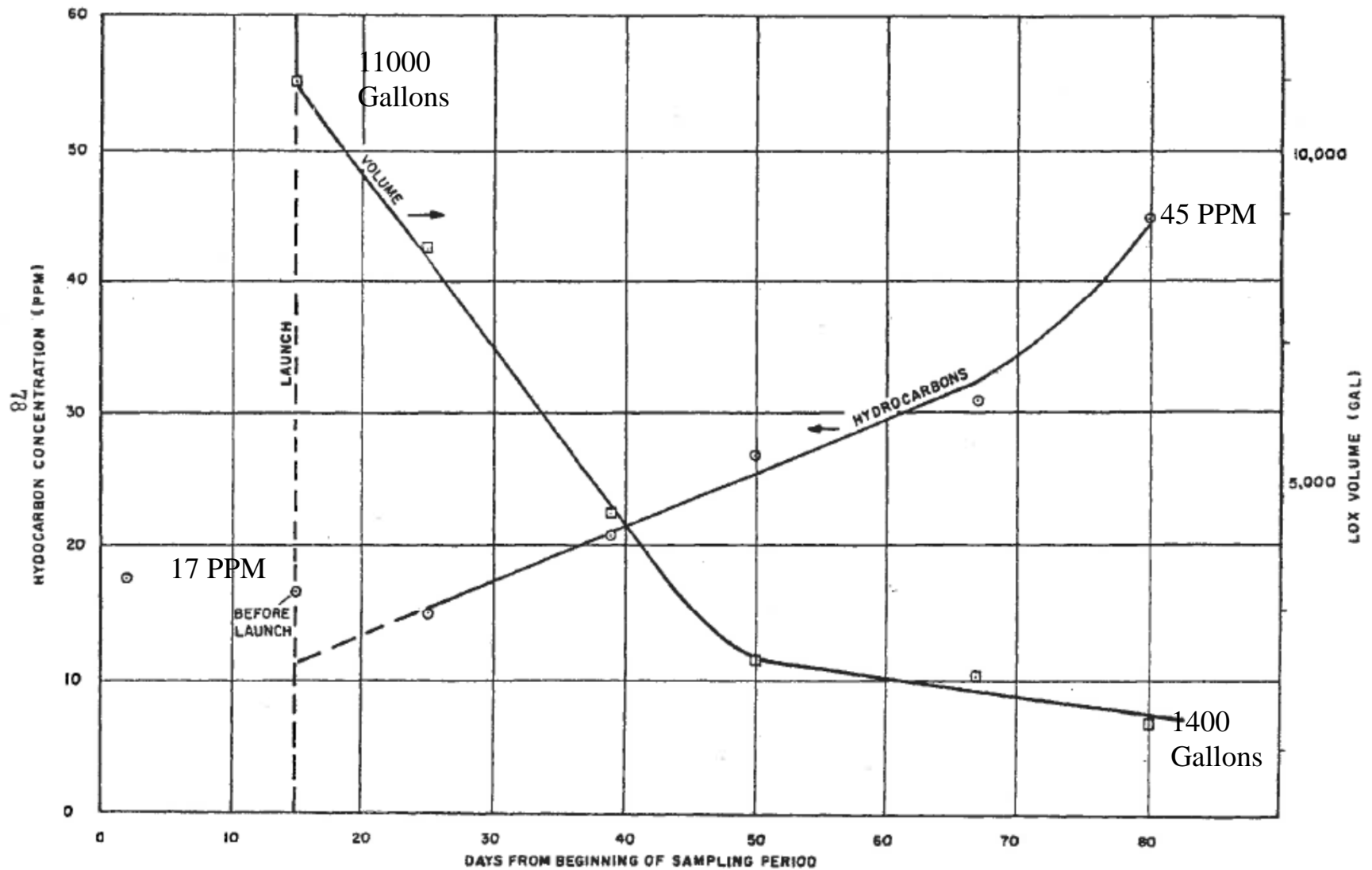
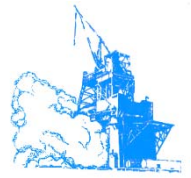


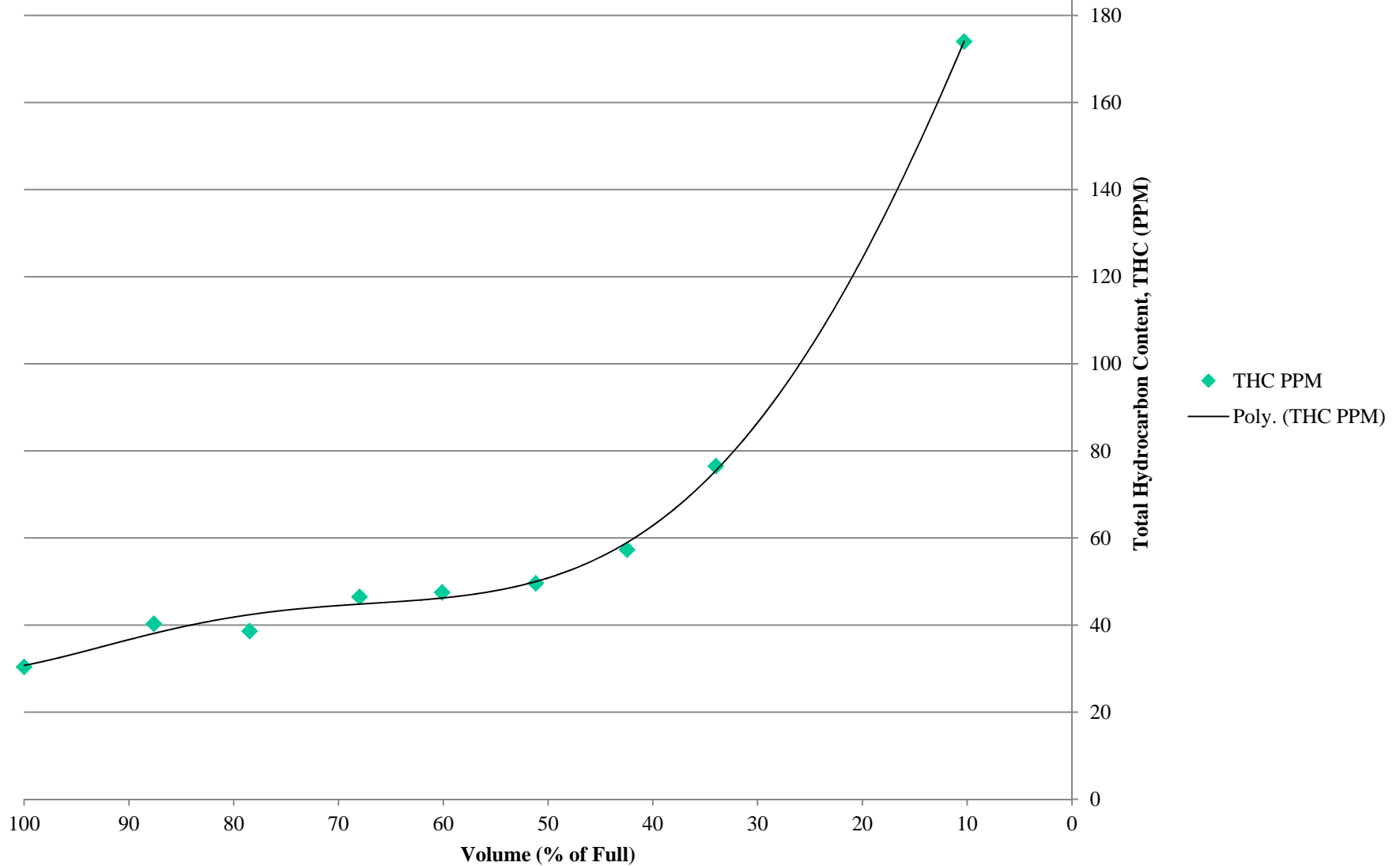
FIGURE 22. HYDROCARBONS & VOLUME PAD 12



# E1 LP LOX Run Tank (11,500 Gallon) Total Hydrocarbon Content (THC)



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# LOX Hydrocarbon Issue



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## Sampling

- Initial SSC sampling of 48 vendor delivered trailers indicated THC consistently above vendor provided certification:
  - SSC samples of trailers indicated ~42 PPM average, Max = 59.5 PPM (3 trailers > 50 PPM Max Allowed)
  - Vendor Certifications indicated ~ 27 PPM, Max = 39 PPM, Multiple identical readings
- After discussions with vendor, an internal audit was performed at the LOX production plant in mid July, 2013.
- Also, site audit at vendor performed by NASA KSC/SSC on 8/20/13.
  - Found issues with sampling:
    - No notification for THC Analyzer off line
    - Calibration gas not manually valved off
- Some improvement as results of audits:
  - LOX deliveries post audits have reduced THC by ~ 40%
    - Now ~25-30 PPM)
  - Vendor certs more accurate:
    - 6 PPM average delta
    - 12 PPM Max delta

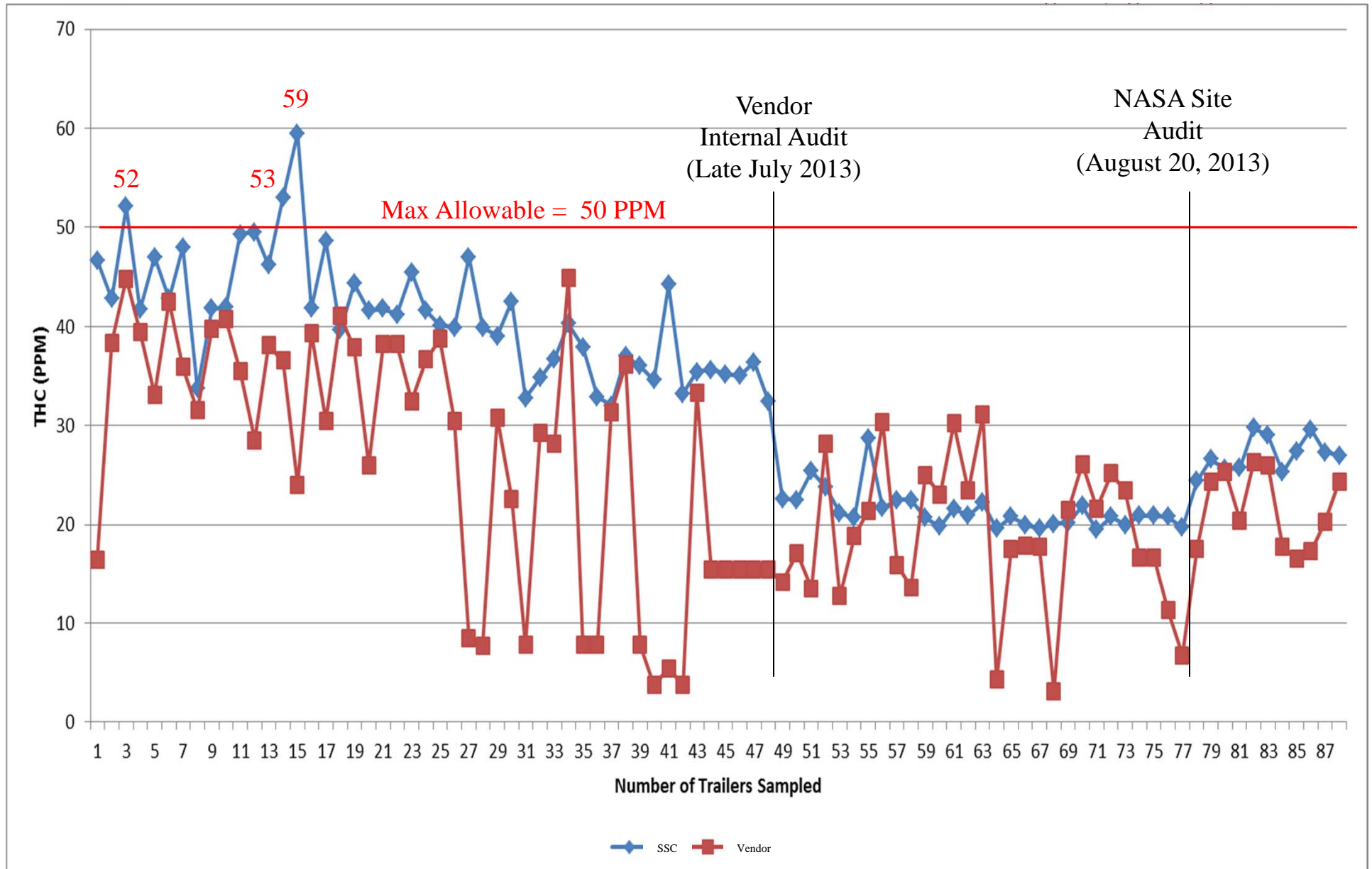
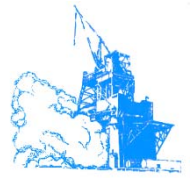


Cosmodyne Sampler



# THC Analyses of Vendor LOX Trailers

## NASA SSC Samples vs Vendor Samples





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## Recommendations

- Reduce SSC sampling of vendor trailers:
  - Sample trailer if Vendor Cert > 35 PPM (margin to protect from > 50 PPM)
    - Reject trailer if > 50 PPM
  - Sample 1 Trailer/week (continue to monitor for THC increase)
- NASA SSC considering increasing Site Limit (i.e., SSC Barges) from 50 to 55 PPM to allow for hydrocarbon concentration due to Oxygen boiloff as documented in numerous studies:
  - MIL Spec limit based on least soluble hydrocarbon (isobutylene), not Methane which is highly soluble
  - SSC data indicates 55 PPM Barge limit will satisfy customer 75 PPM limit with sufficient margin.
- To better understand E1's THC increase, NASA SSC considering a test project to understand operational mitigations:
  - Various sampling techniques, long term boiloff, transfer operations, prechill warm tanks/lines, sampling static vs stirred tank, subcooled LOX, etc
- Include requirements in next LOX Delivery Contract
  - THC analysis accuracy and verification



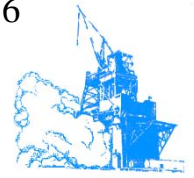
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**Backup**



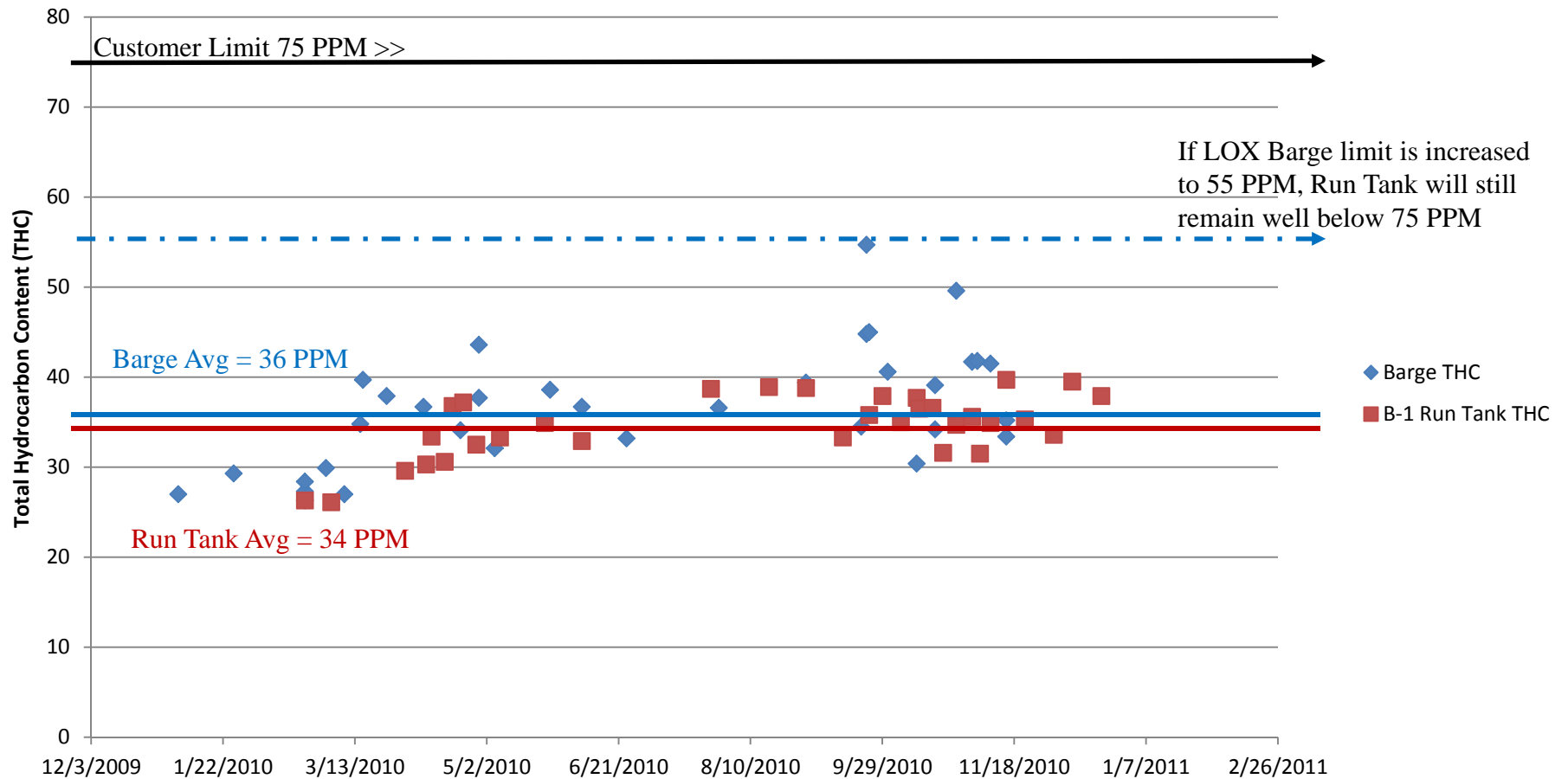
Figure 6

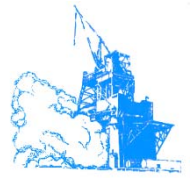


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## LOX Barges THC vs B-1 LOX Run Tank THC





## Vendor LOX Trailer Certifications vs SSC LOX Barge Samples Total Hydrocarbon Content (THC) - April 2012 to Present

