

# Effects of Fuel Weathering on RVP, Distillation and Oxygen Content of Ethanol and iso-Butanol Blends

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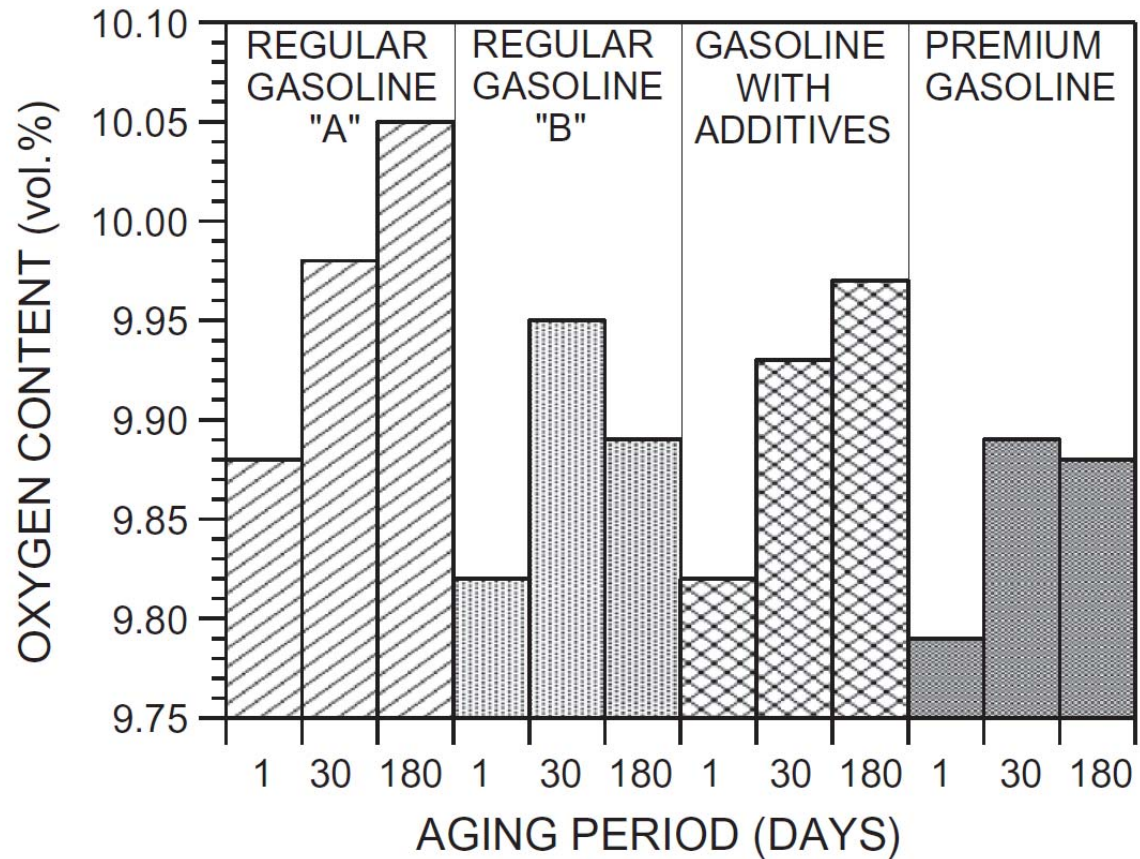
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# Literature review

Average increase in oxygen content [wt%] of four 25 vol% (E25) ethanol blends over a 180 day aging period in automotive fuel tanks

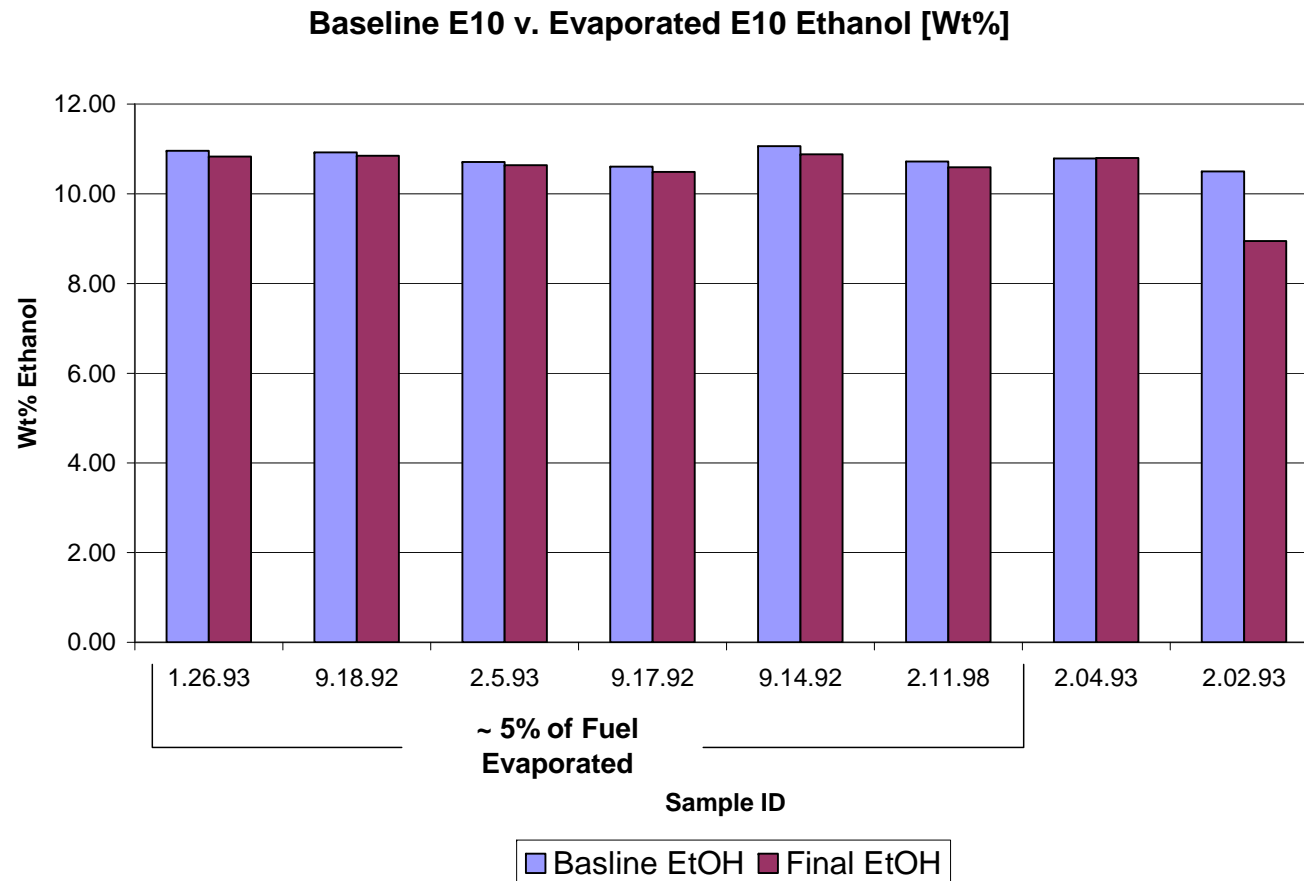


Source: Streva, E., et al, "Aging effects on gasoline-ethanol blend properties and composition" Fuel 90 (2011) pp. 215-219

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# Literature review

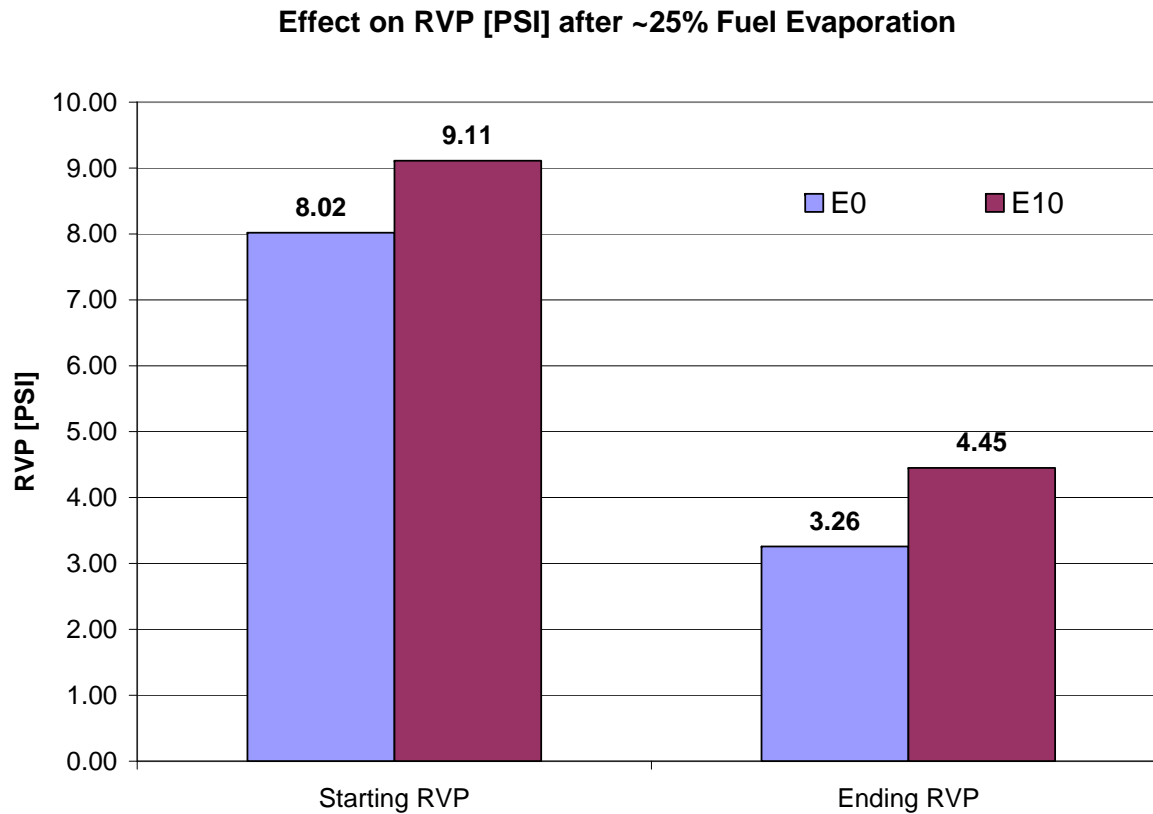
## Loss in vol% ethanol in E10 fuels with approx. 5% total fuel evaporation



Source: Aulich, T., He, X., et al, "Gasoline Evaporation – Ethanol and Nonethanol Blends" Air and Waste Management Vol. 44 pp. 1004-1009

# Literature review

Greater change in RVP with E0 (non-oxygenated) fuel compared to E10 fuel after approximately 25% fuel evaporation



Source: Aulich, T., He, X., et al , “Gasoline Evaporation – Ethanol and Nonethanol Blends” Air and Waste Management Vol. 44 pp. 1004-1009

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# Literature review

## Summary

- Limited data and mixed results were found on O<sub>2</sub> content of weathered ethanol blends
- No data available on O<sub>2</sub> content of weathered iso-butanol fuel blends
- No direct comparison under the same conditions between E10 and iB16 weathered fuels

# Severe Fuel Weathering Experiment Overview

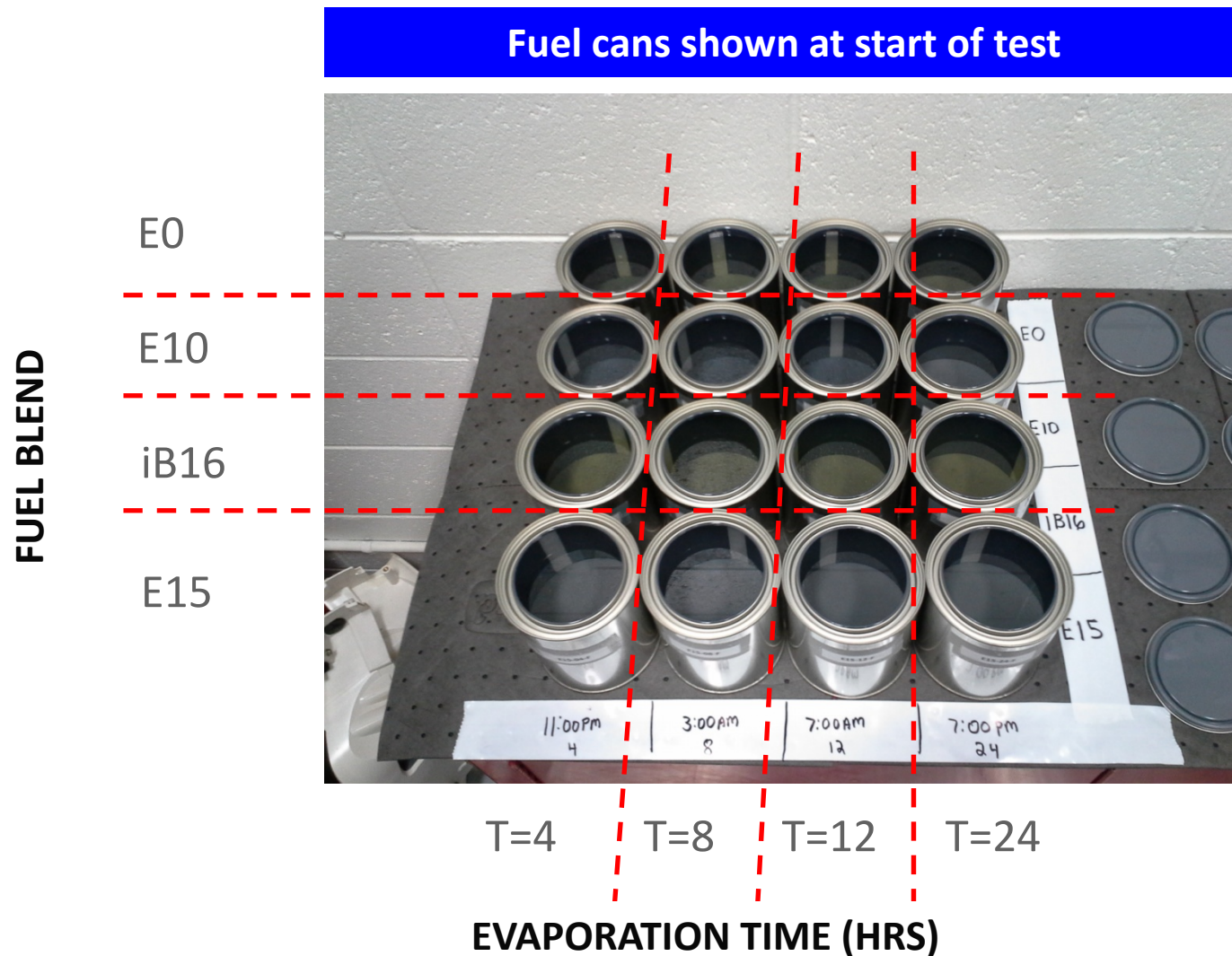
- **Input from BP/Butamax on fuel blending and experiment design**
- **Fuel analysis performed at Intertek Laboratory in Romeoville, IL**
- **Fuel blends tested:**
  - E0 (non-oxygenated)
  - E10 (3.5 wt% O<sub>2</sub>)
  - E15 (5.3 wt% O<sub>2</sub>)
  - iB16 (3.5 wt% O<sub>2</sub>)
- **Fuel blend stocks:**
  - Neat bio-isobutanol
  - Fuel grade ethanol
  - Indolene certification fuel 8.5 RVP (non-oxygenated)
  - Winter fuel 13 RVP (non-oxygenated)
- **BP/Butamax recipes were followed to blend 5-gallons of four unique finished test fuels:**
  - E0, E10, E15, iB16

# Severe Fuel Weathering Experiment Setup and Process

- Finished fuel blends were dispensed into 24 quart sized wide-mouth metal cans
- Each can was carefully weighed and the starting weight recorded for each fuel can
- After initial weighing, each fuel sample was covered to prevent evaporation until all cans were ready for start of test
- At the start of the test, all covers were removed from the fuel cans.
- Each fuel weathered for a specific period of time
- Cans were weighed then sealed after 4, 8, 12 and 24 hours of evaporation
- Cans were stored on ice until fuel analysis completed



# Severe Fuel Weathering Experiment Setup

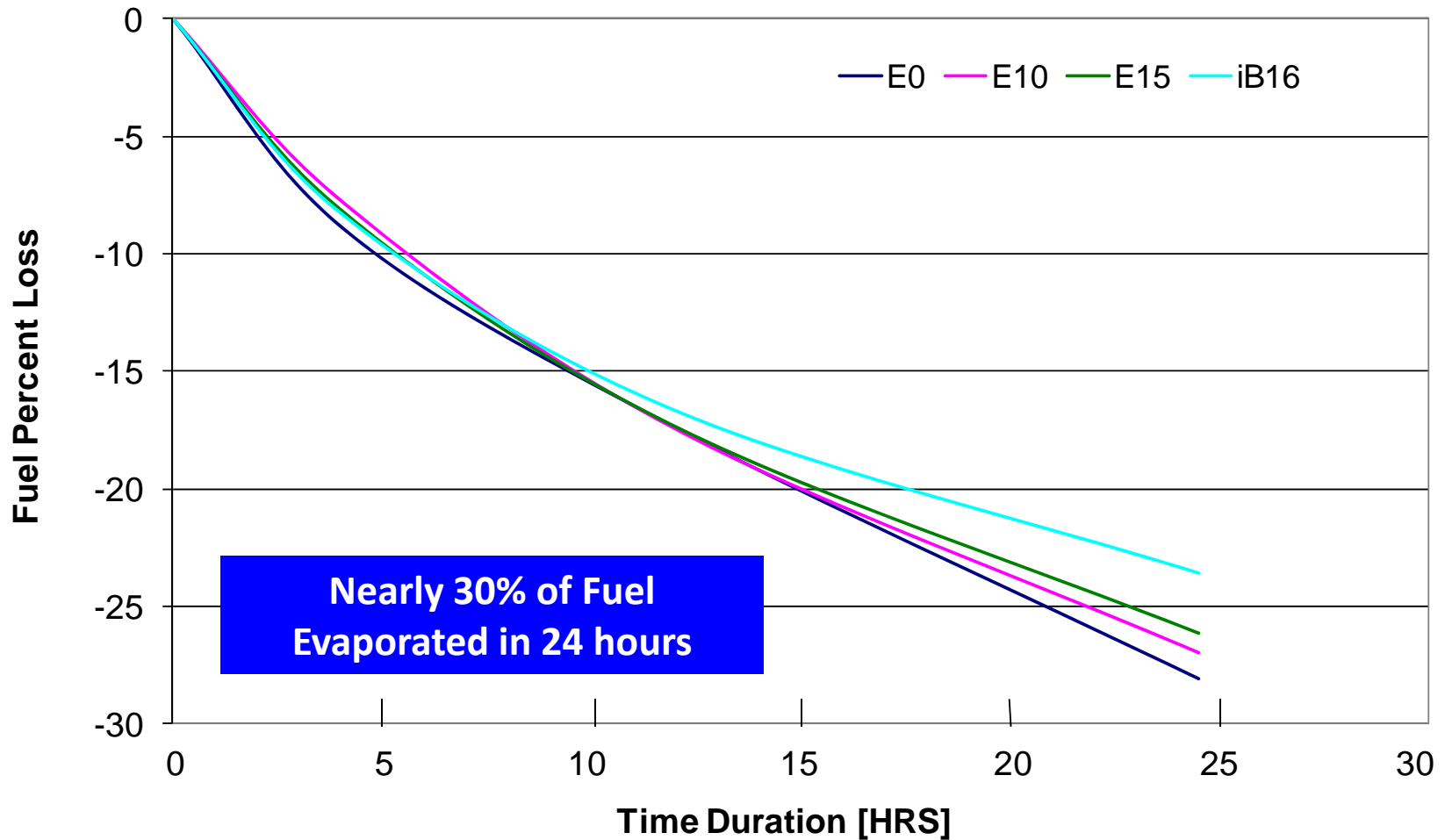


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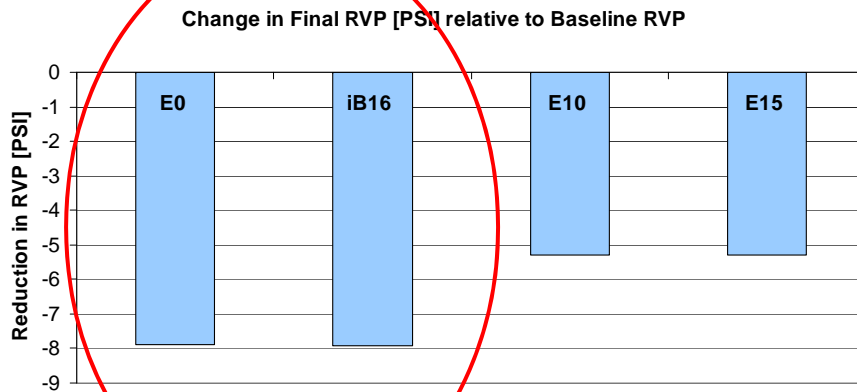


# Severe Fuel Weathering Experiment Results - Evaporation Loss

Evaporation Loss [%] vs. Time Duration [hrs]

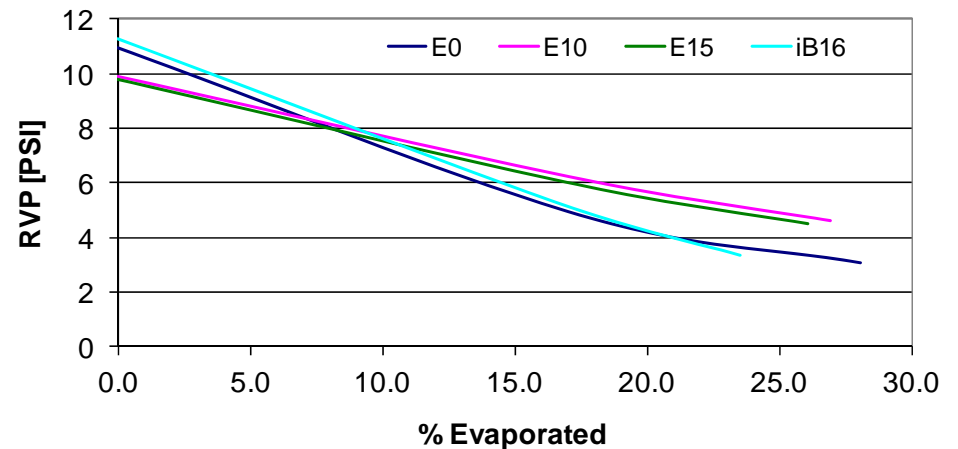


# Severe Fuel Weathering Experiment Results - Final Measured RVP [PSI]



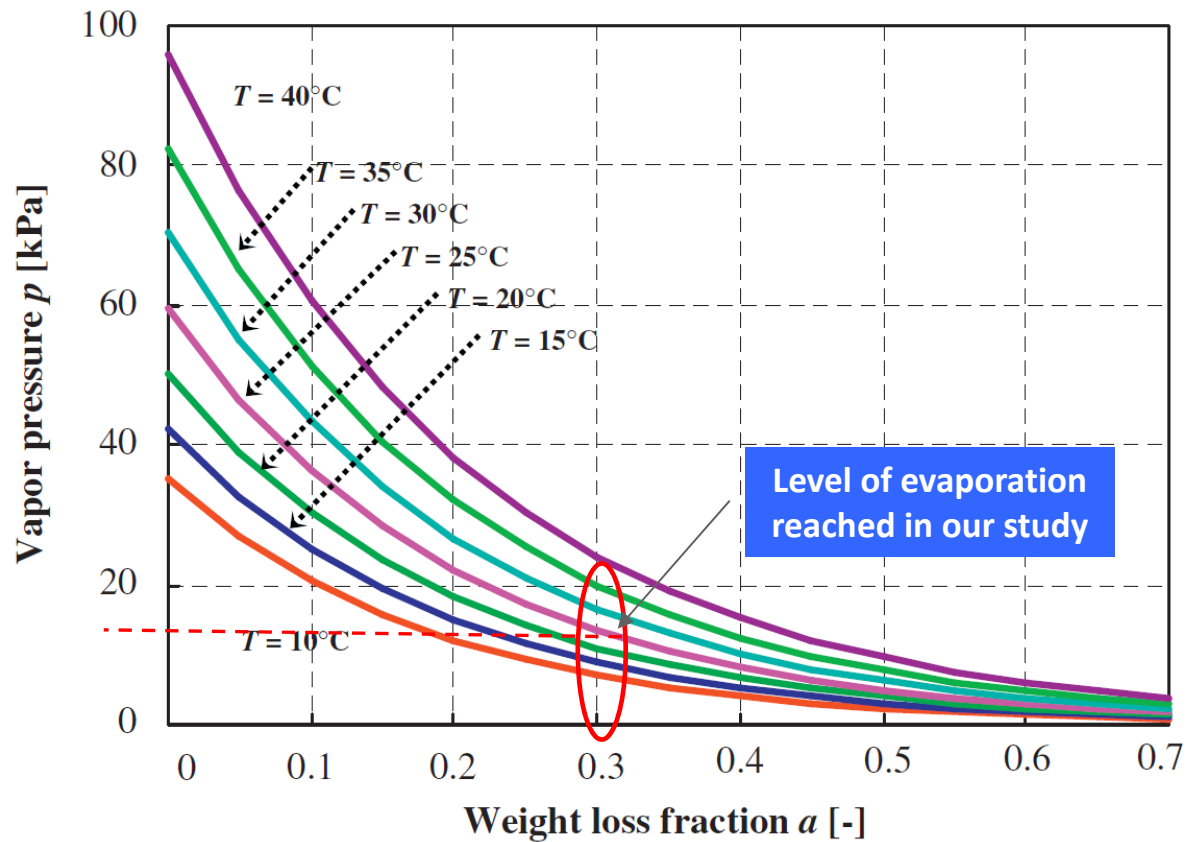
iB16 has nearly identical reduction in RVP as E0  
~3.4RVP

### RVP [PSI] vs Percent Fuel Evaporated



- iB16 fuel closely followed the RVP of E0

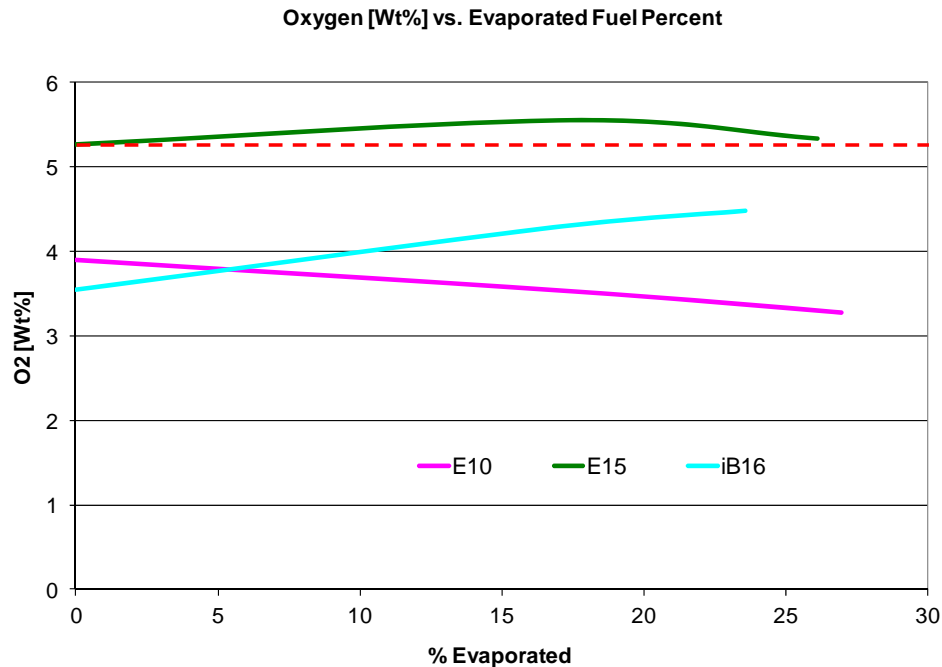
# Severe Fuel Weathering Experiment Results - RVP versus Weight Loss Fraction



Source: Okamoto, K., Watanabe, N., et al, "Changes in evaporation rate and vapor pressure of gasoline with progress of evaporation" Fire Safety Journal 44 (2009) 756-763

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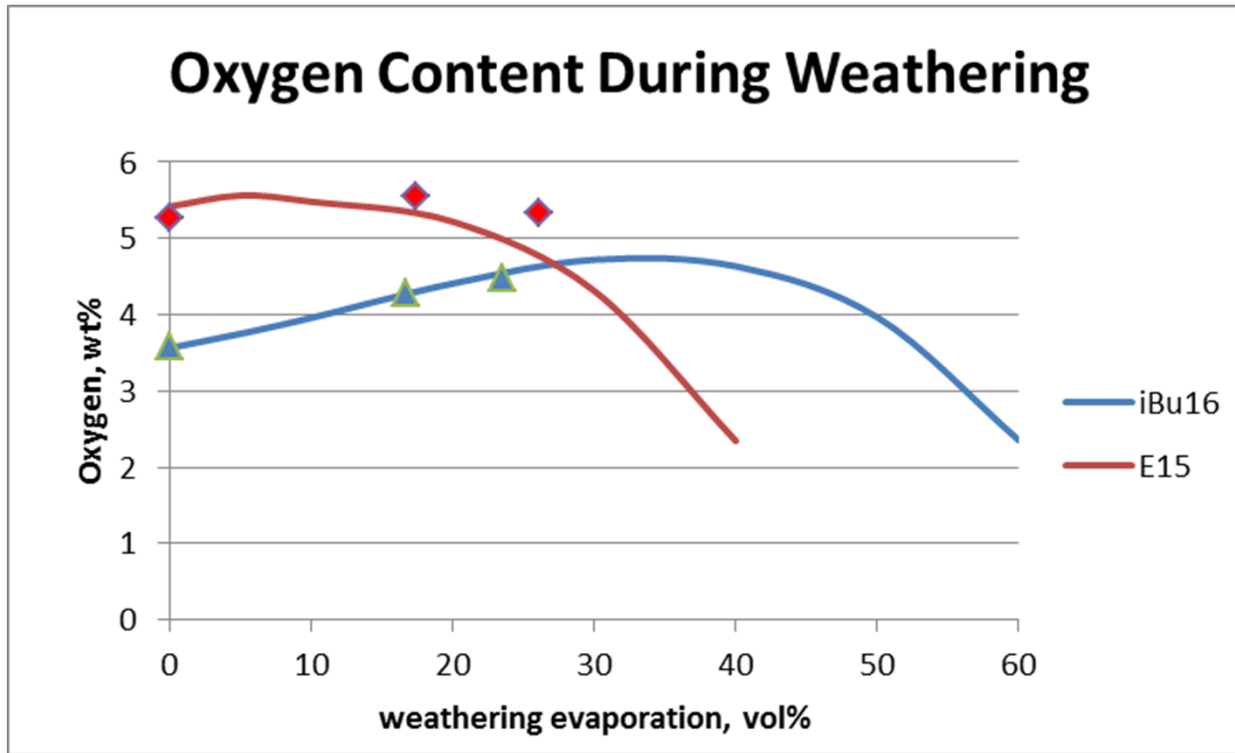
# Severe Fuel Weathering Experiment Results - Oxygen Content



Final weathered iB16  
oxygen content was  
equivalent to E12

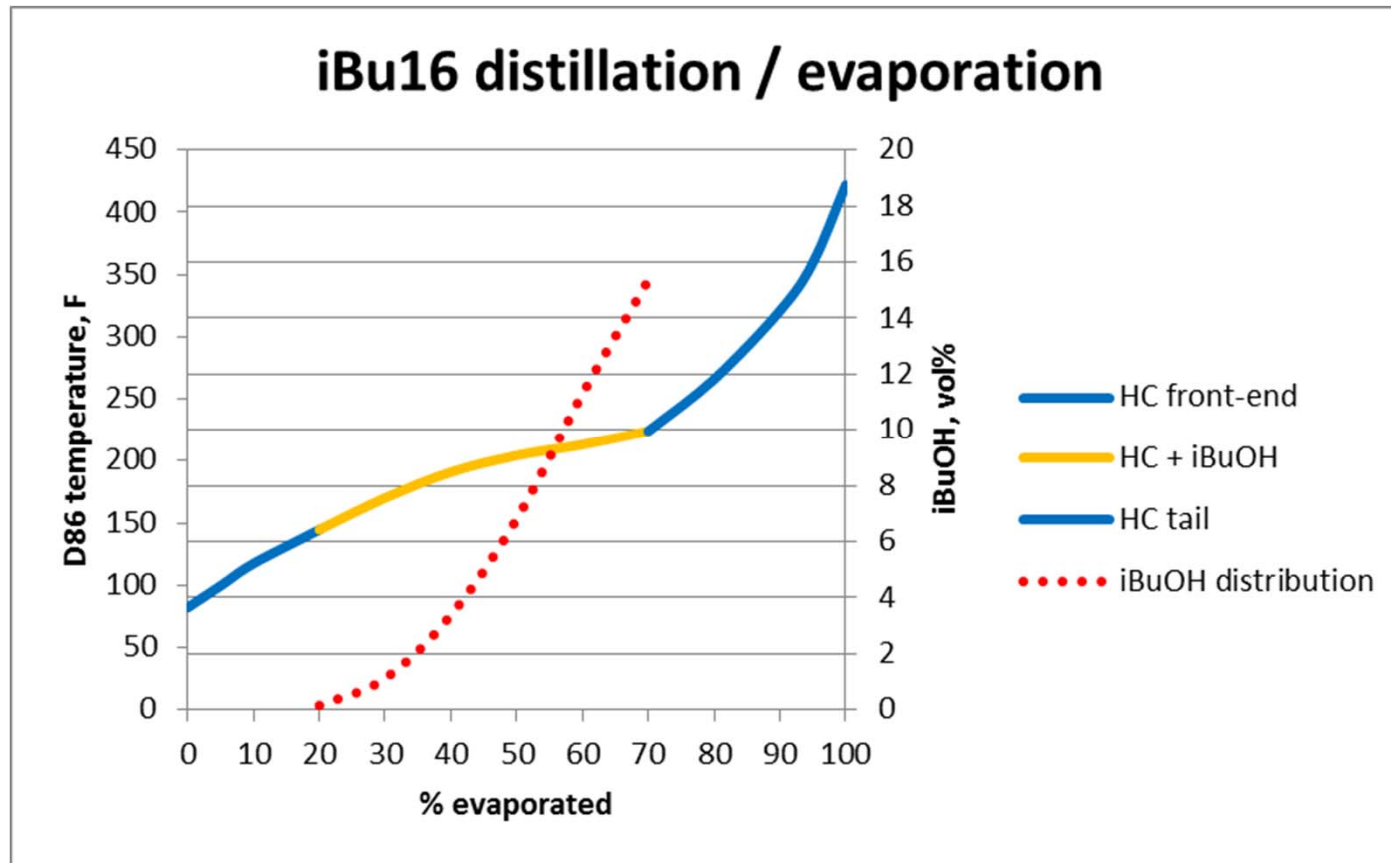
- E10 Oxygen content Wt% decreased with increasing evaporation
- E15 Oxygen content Wt% increased/maintained with increasing evaporation
- iB16 Oxygen content Wt% increased with increasing evaporation, but never reached the E15 equivalent Wt%

# Severe Fuel Weathering - Oxygen Content



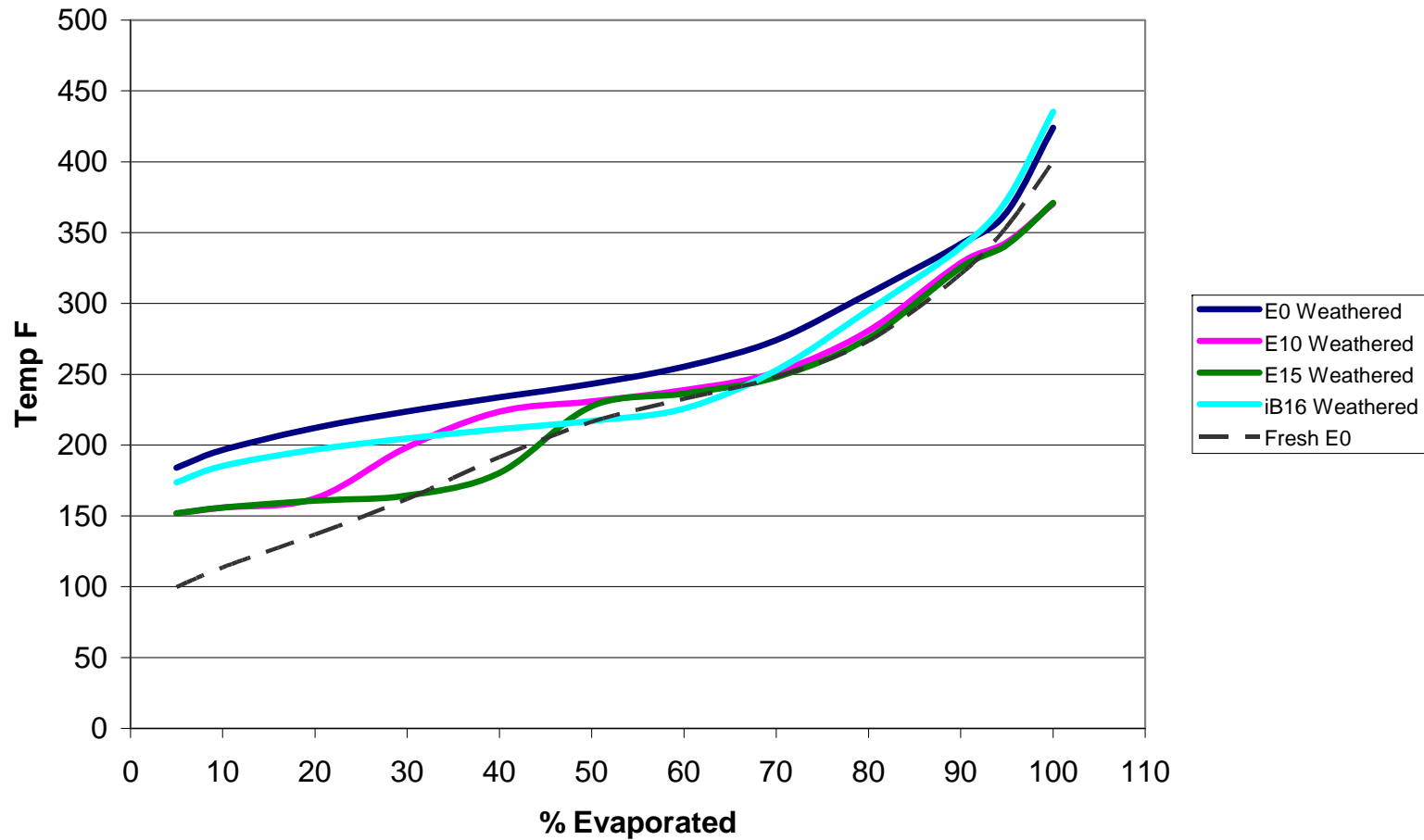
- BP/Butamax vapor-liquid equilibrium model for E15 & iBu16
- Calculates fuel composition during simulation of evap experiment
- E15 and iBu16 oxygen increase on initial weathering, then decrease as weathering continues
- Maximum iBu16 oxygen is lower than initial E15 concentration

# Severe Fuel Weathering - Oxygen Content



- iBuOH and its HC azeotropes evaporate in the fuel's mid-range
- Initial weathering evaporates only HC, concentrating the alcohol
- Continued weathering begins to evaporate iBuOH as well, until by 70% evaporated only HC remains

# Severe Fuel Weathering Experiment Results - Distillation of Weathered Fuels



• **iB16 maintains a better drivability index compared to E0**

# Conclusions

- No comprehensive data available in the literature on fuel weathering behavior of ethanol compared to isobutanol
- Study was designed to evaluate worst case scenario fuel property changes due to weathering for E0, E10, E15 and iB16
- Evaporation loss and evaporation rate reduced with iB16 compared to E10
- RVP reduction due to weathering is lower for E10/E15, iB16 equivalent to E0
- Distillation curves shift significantly for all weathered fuels, changes for ethanol and butanol blends less critical than E0
- **Overall all alcohol blends show improvements in weathering behavior compared to neat gasoline**
- **Oxygen content Wt% of iB16 never reaches E15 O2 content**