Shell Global Solutions

Rigorous HDD Emissions Capabilities of Shell GTL Fuel

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Presentation Outline

- Reference Fuels and Candidate Fuels
- Testing Protocol
- Experimental Setup
- Emissions Results
- Summary
- Conclusions
- Acknowledgements

Fuel Description – Reference Fuel

- Reference ULSD (S15) ex Shell Martinez CA Refinery, exhibits
  - < 2 ppm sulfur
  - 43 cetane number (contains no cetane improver)
  - <10%m Aromatics (on a monthly average basis)

- ULSD (S15) fuel is an emissions-reducing enabler in both late-model and current engine technologies, and is the design fuel for advanced HDD engines with exhaust aftertreatment systems for 2007-model year engines with regulated NOx and PM control.

- ULSD (S15) fuel selected is a commercial CARB diesel - already a clean, low-emission fuel compared to LSD fuel available outside California

Fuel Descriptions – Shell GTL Fuel

- Candidate – Shell GTL Fuel
- Shell GTL Fuel
  - is a natural gas-based synthetic liquid fuel, virtually free of sulfur and aromatics.
  - offers government strategic diversification of energy supply as an alternative to petroleum-based fuels.
  - is a cost-effective alternative in reducing emissions compared to CNG, DME, CH_3OH and LPG.
  - can be used cost-effectively within existing diesel infrastructure.
  - can be blended with conventional diesel and used in HDD or LDD engines without modifications.

Fuel Descriptions – Shell GTL Fuel Blends

- Candidate blend of 55% Shell GTL Fuel/45% CARB ULSD (S15)
  - Evaluated to provide an indication of the regulated emissions reduction capabilities of a blend of predominantly Shell GTL Fuel with conventional petroleum-derived ULSD (S15) fuel.
- Blend Study candidates were chosen as blends of 20%, 33%, 55%, and 75% Shell GTL Fuel in ULSD (S15)
  - Evaluated to establish a blend curve to help predict the NO_x emissions reductions achievable with a range of concentrations of Shell GTL Fuel in conventional petroleum-derived ULSD (S15) fuel.

Fuel Properties

Property	Test	"Reference" ULSD (S15)	"Candidate" Shell GTL	"Candidate" 55% GTL 45% ULSD
Density, g/mL	D 4052	0.8314	0.7865	0.8067
Sulfur, mass ppm	D 4053	1.6	0.3	1.0
Nitrogen, mass ppm	D 4629	5.7	< 1.0	3.0
T10, deg F	D 0086	357	474	377
T50, deg F	D 0086	427	568	522
T90, deg F	D 0086	600	627	626
Aromatics, mass %	D 5186	10.8	0.5	4.5
PNA, mass%	D 5186	2.5	0.1	0.8
Cetane Number	D 0613	42.7	~80	65.0

Testing Protocol

- 1991 DDC Series 60 HDD engine installed in a transient-capable test cell
- Hot-start transient emissions
  - Seven days, three consecutive hot-start transient runs with 20-minute engine-off soak between runs was conducted on each fuel (R & C)
- Transient emissions test results for regulated emissions (HC, CO, CO_2, NO_x & PM) run per CFR 40, Part 86, Subpart N

Experimental Setup

- Engine exhaust routed through a full-flow, constant volume sampler utilizing a positive displacement pump
- Tunnel flow was held nominally to 2000 SCFM
- Sample probes for PM, heated NO_x, heated HC, CO and CO_2 connected to main tunnel
  - Individual HC and Aldehyde sample ports also

Experimental Setup

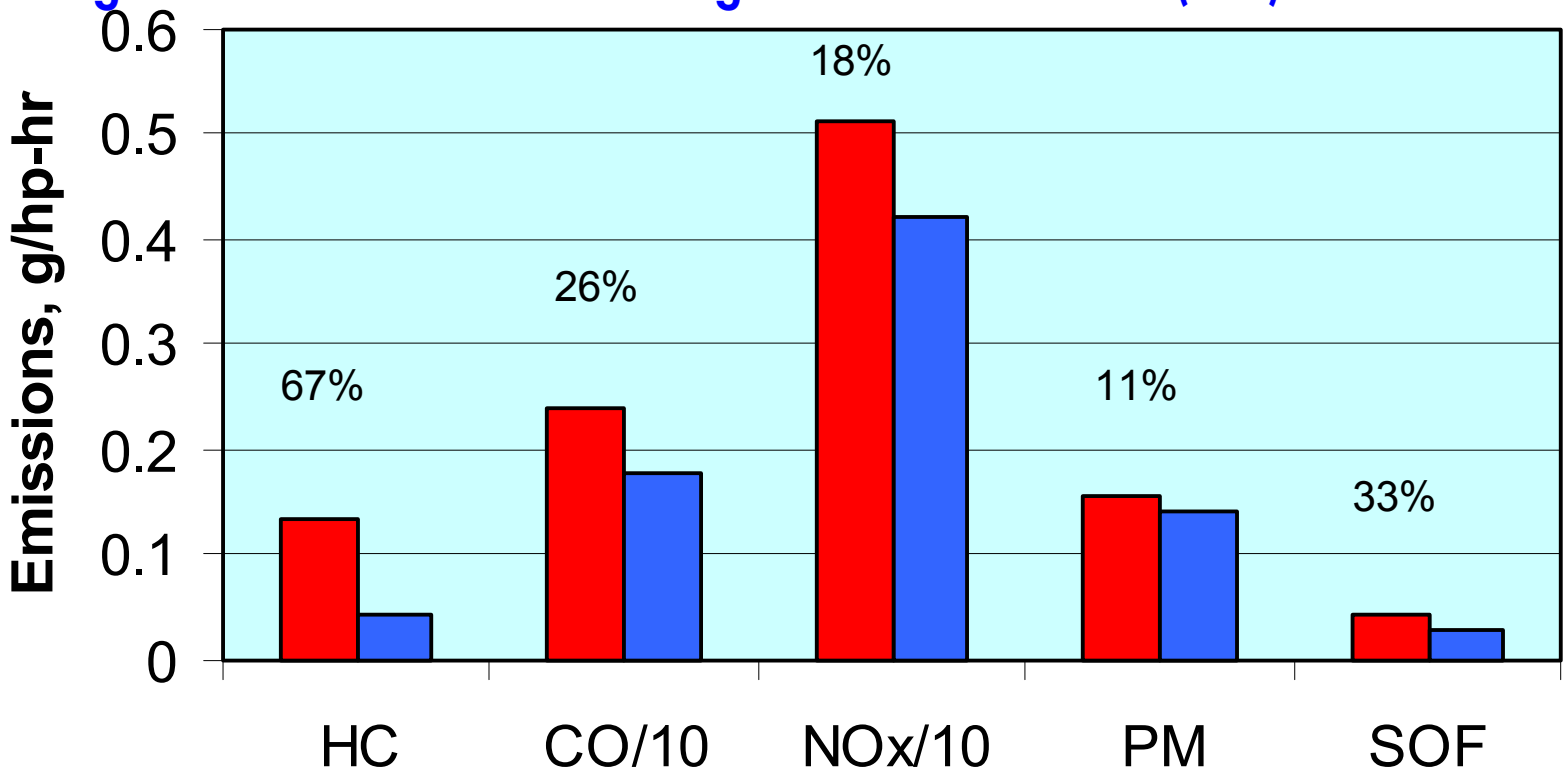
- Probes for background gas measurements were connected to main tunnel between dilution air filter pack and mixing zones
- Particulate and gas phase samples for PAH taken from a double dilution tunnel
  - Particulate phase PAH captured on 20X20 inch Pallflex filter and Gas phase PAH collected downstream using PUF/XAD-2 traps
- PM captured with a pair of 90 mm Pallflex filters
  - 25% for SO4, 25% for SOF, 50% held in reserve

Observation – Non-Emissions Performance

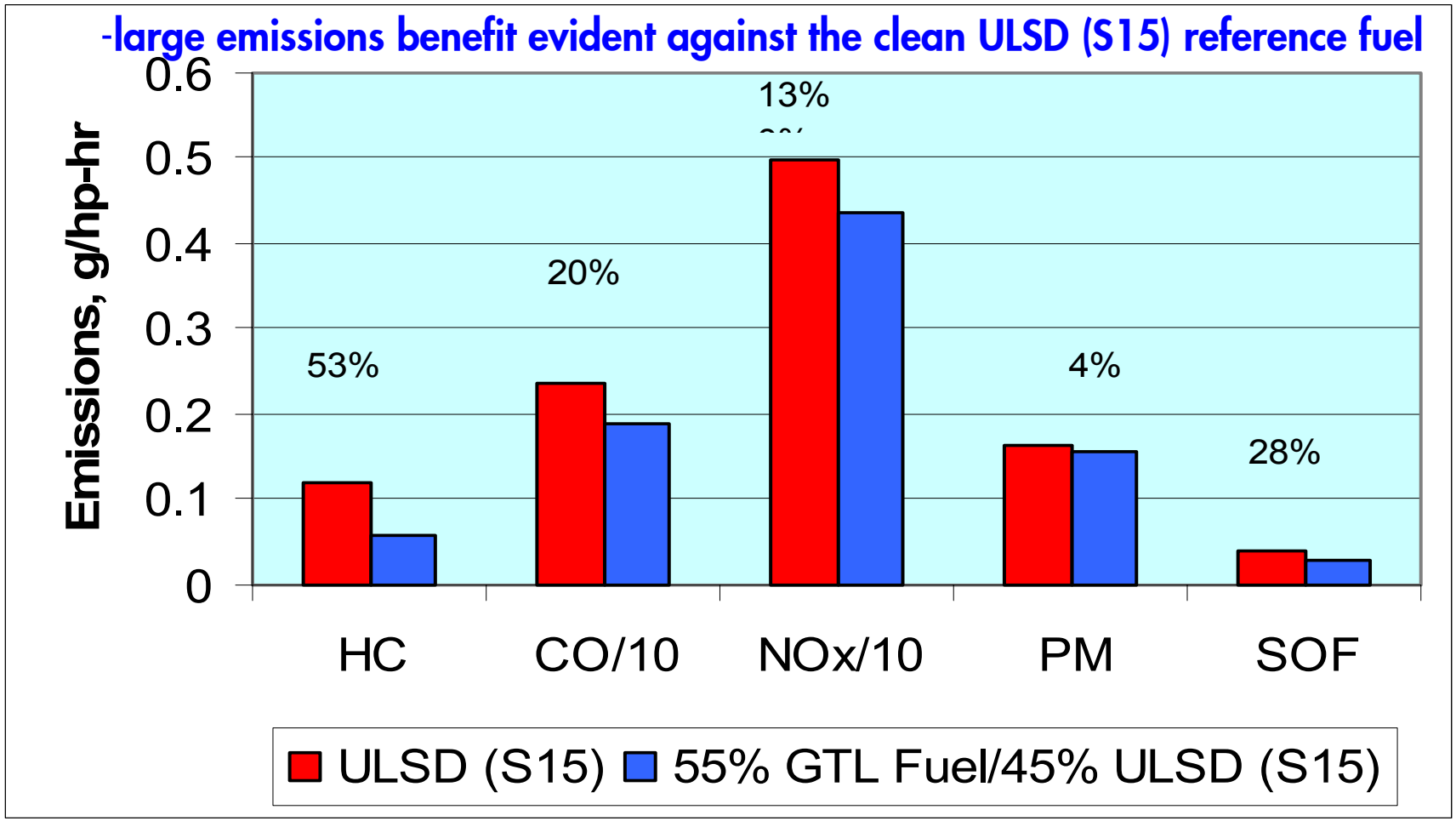
- Transient torque map defined on first run of Reference ULSD (S15) fuel
- This was used as the reference map to generate the transient command cycle for all subsequent hot-start transient runs.
- No non-emissions performance affects were observed regarding engine torque, fuel consumption, or power with the neat or blended Shell GTL Fuel.

Emissions Reductions – 100% Shell GTL Fuel

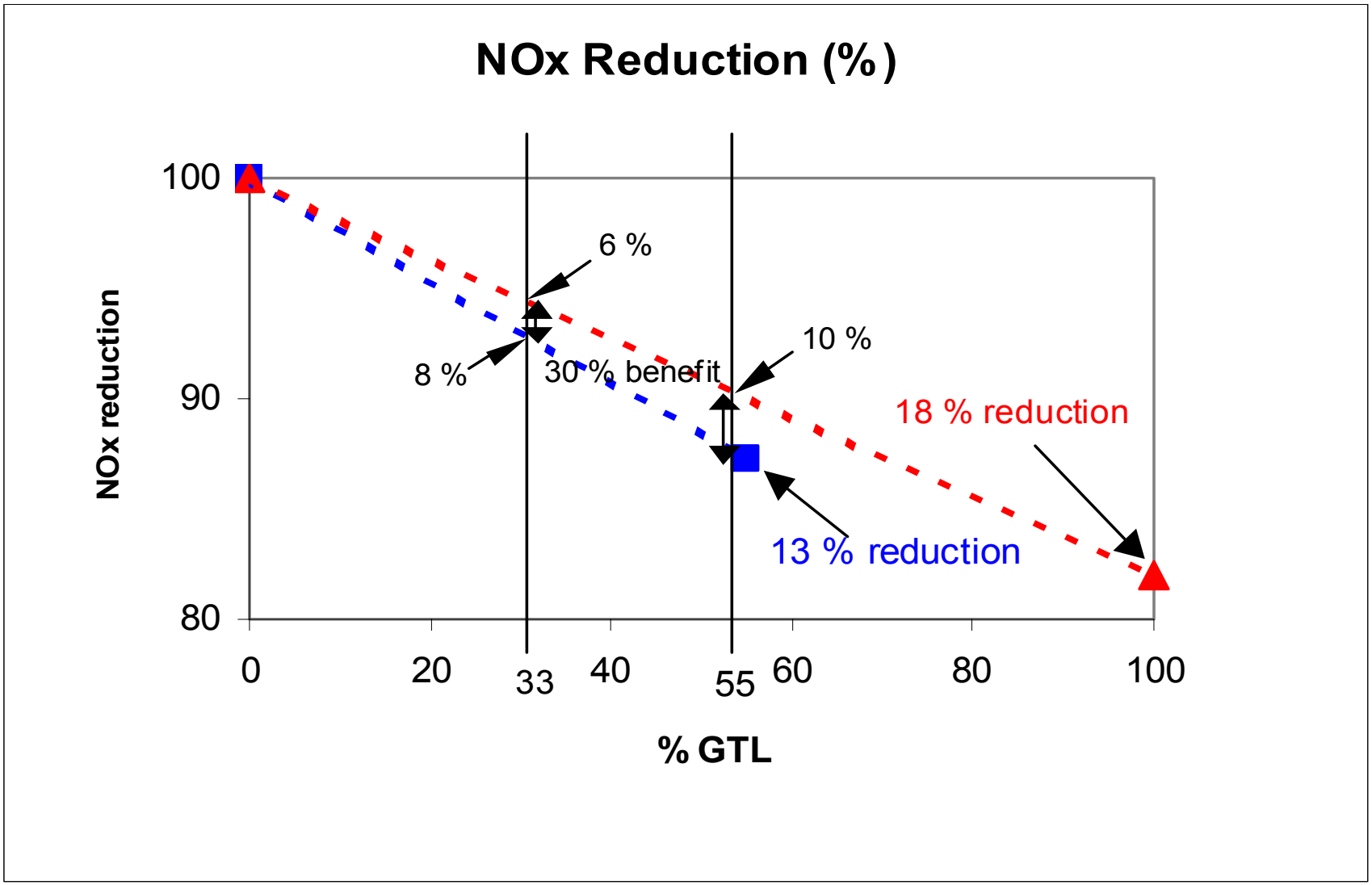
-large emissions benefit evident against the clean ULSD (S15) reference fuel



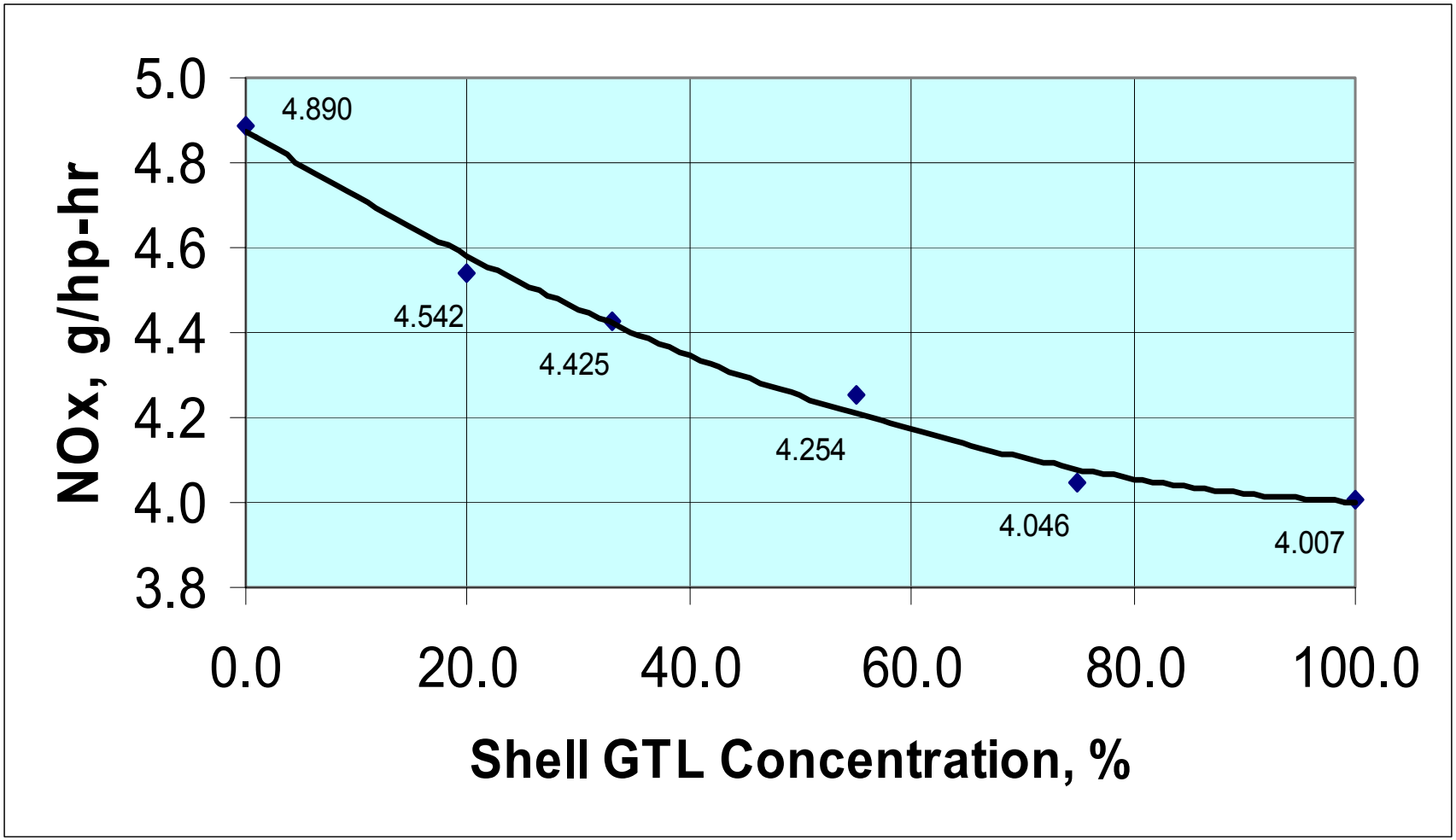
Emissions Reductions
55% Shell GTL Fuel/45% ULSD (S15)



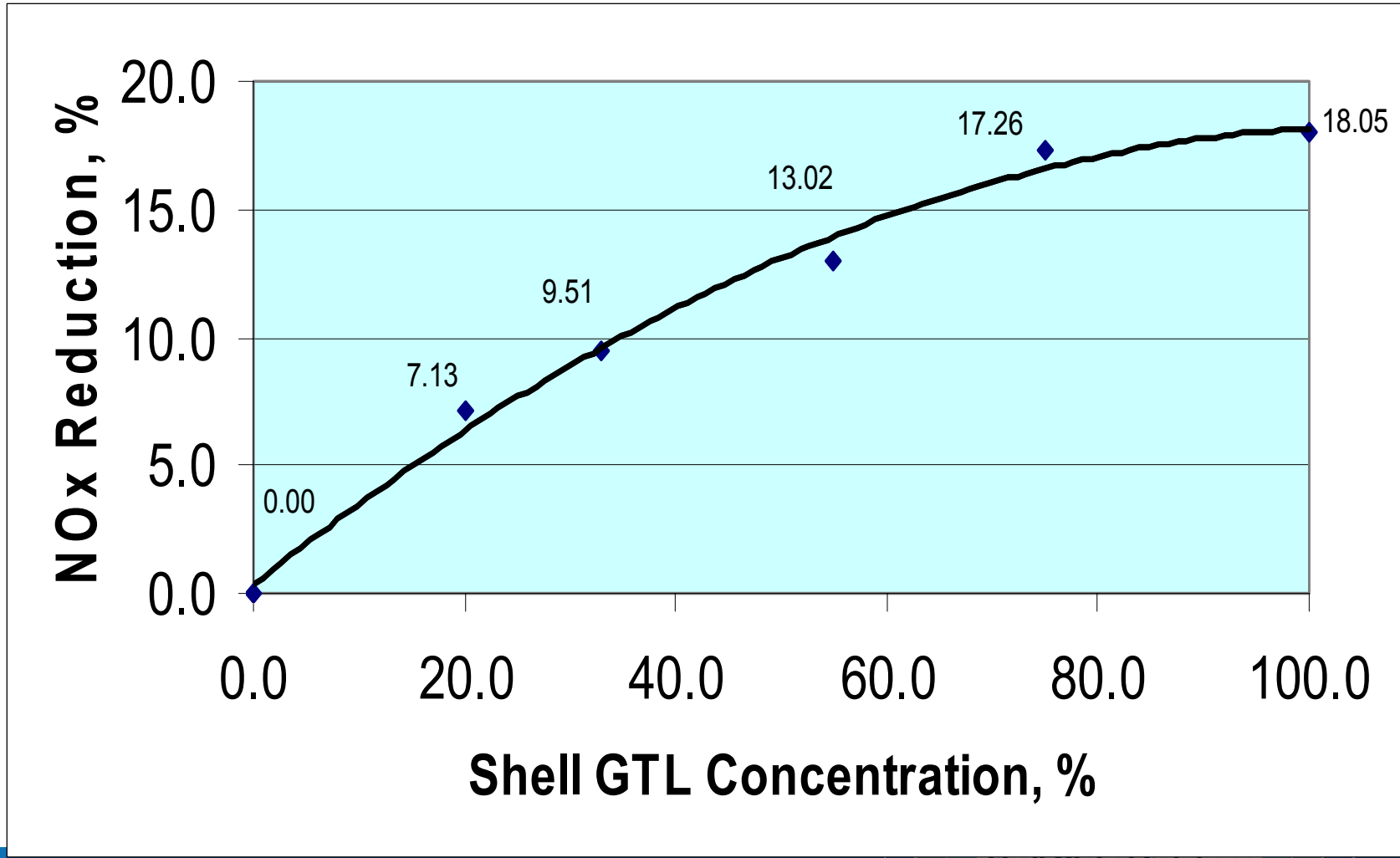
NOx Emissions Reductions



Blend Study – NOx Emissions



Blend Study – NOx Reductions



Summary

- The vastly improved low-emissions NOx & PM capabilities of Shell GTL Fuel was demonstrated relative to an already clean commercial ULSD (S15) diesel fuel.

- We suspect that even greater emissions benefits may be achieved with Shell GTL Fuel relative to conventional LSD fuels.

- Improved low emissions capabilities achievable with Shell GTL Fuel are aligned with legislation aimed at increasing energy security and diversification of supply by demonstrating the emissions reducing capabilities of alternative fuel sources.

Conclusions

- Shell GTL Fuel has been rigorously proven in a recognized, external protocol to demonstrate significant regulated emissions benefits:
  - exhibits18% reduction in NO_x and 11% reduction in PM relative to a very clean ULSD (S15) fuel
  - 55% Shell GTL Fuel/45% ULSD(S15) blend exhibits 13% reduction in NO_x and 4% reduction in PM relative to ULSD (S15) fuel
  - 33% Shell GTL Fuel/67% ULSD (S15) blend exhibits 9.5% reduction in NO_x relative to ULSD(S15) fuel
  - exhibits emissions benefits over and above other clean alternative fuels.

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