Final Report 2011

Educating the Public and Tomorrow's Engineers Regarding the Benefits & Challenges of Using Ethanol Blended Fuels

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Kettering University pursued the following objectives:

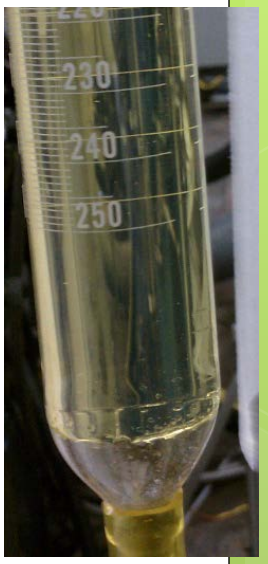
1. **Develop vehicles operating on ethanol blended fuels for the SAE Collegiate Design Series: Clean Snowmobile Challenge & Formula SAE**
2. **Evaluation and Development of Presentation Materials Documenting the Effects of Using Ethanol Blended Fuels in Small Engines**
3. **Flex-Fueled Clean Snowmobile and E85 Formula SAE Car displays and presentations**
4. **Disseminate project results in Technical papers and presentations.**

Some of the Misinformation

Fuel Selection (Mechanic gives this to customers):

"regular" gas may have 10%, or more, alcohol, which attracts and blends with water, causing carburetor problems and the breakdown of lubricating mix-oils in 2-cycle equipment...For best results, avoid Alcohol-blended fuels in 4-cycle lawn equipment and never use high-alcohol blends in your 2-cycle equipment. Premium fuels generally are not blended with alcohol.

The Concerns: Phase Separation



- Water is not readily miscible with gasoline
  - Small amounts of water will cause phase separation
  - Water is the only component located on the bottom
- Ethanol *is* readily miscible in Water
  - Larger amounts of water will cause phase separation
  - The separation layer will be composed of ethanol and water

Ethanol-Water Phase Separation Layer

- Could it combust?
- If so, will it lead to lean combustion, which could damage the engine

Background

- EPA Memo, Originally dated 1995
  - "Water Phase Separation in Oxygenated Gasoline- Corrected version of Kevin Krause memo,"
    - David Korotney, Chemical Engineer, Fuels Studies and Standards Branch, EPA
  - Still Available on Website: http://www.epa.gov/otaq/regs/fuels/rfg/waterphs.pdf
- Widely Referenced in State Environmental Documents: IA, MN, OK…

If Phase Separation Occurs (EPA Memo)

- In the case of conventional and MTBE blended gasolines,
  - when a water phase forms, it will drop to the bottom of the fuel tank, and can therefore be drawn into the engine by the fuel pump. Therefore, large amounts of water will prevent the engine from running, but no engine damage will result.
- Phase separation in ethanol-blended gasoline, however, can be more damaging than in MTBE blends and straight gasoline.
  - When phase separation occurs in an ethanol blended gasoline, the water will actually begin to remove the ethanol from the gasoline.
  - Therefore, the second phase which can occur in ethanol blends contains both ethanol and water, as opposed to just water in MTBE blends and conventional gasoline.

Kettering University Testing

- Is E10 more likely to undergo water phase separation than E0?
  - Store containers in an un-heated shed
- If water-phase separation is present:
  - Will an engine start/run?
  - What level of water-phase?
- Will the engine be damaged?

Ethanol-Water Phase Separation Storage Testing

- 8 samples since 9/7/2011.
- No sign of phase separation.

- Samples checked twice weekly
- 4 samples with E0
- 4 samples with E10

Effect of Ethanol-Water Phase on Small Engines

- Two gasoline-powered pressure washers were acquired for testing
- Phase separation was caused by adding water directly to the fuel: E10 and E0
- Cold start testing was conducted to see what level of phase separation would allow engine starts
- Hot run testing to determine whether engines would operate on ethanol-water phase alone
- Pressure washer performance was compared before and after testing

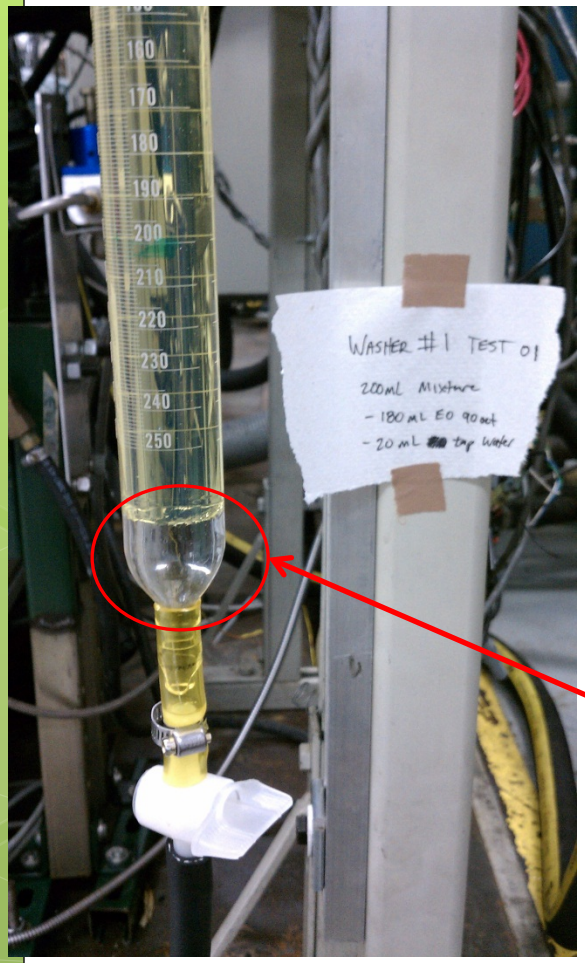
Engines and Equipment

- 2 - 2400 PSI PowerWasher gasoline pressure washers
  - 140cc Ducar Engine
  - 3.75 HP
- Identical testing performed on both engines
- Switch instrumentation between engines for consistency

Cold Start Testing Procedure

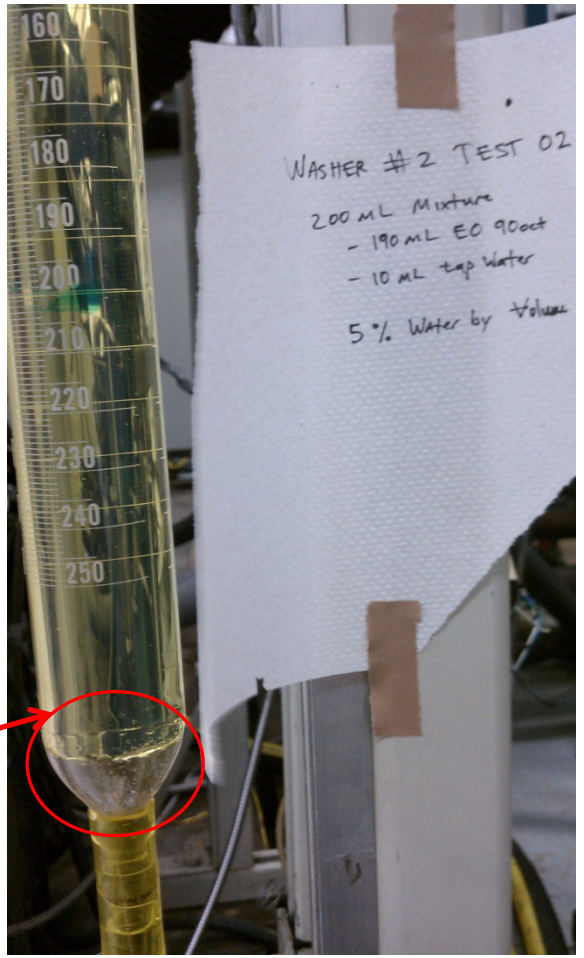
- Created separated fuel blends-200 mL
  - Approx. 2.5mL, 5mL, 10mL, 20mL separation layer
  - Ranging 1.25% to 10% by volume
- Recorded engine cold-start ability for each blend
- Repeated for E0 and E10
- Follow fuel clearing procedures between blends

E0 Water Phase Separation

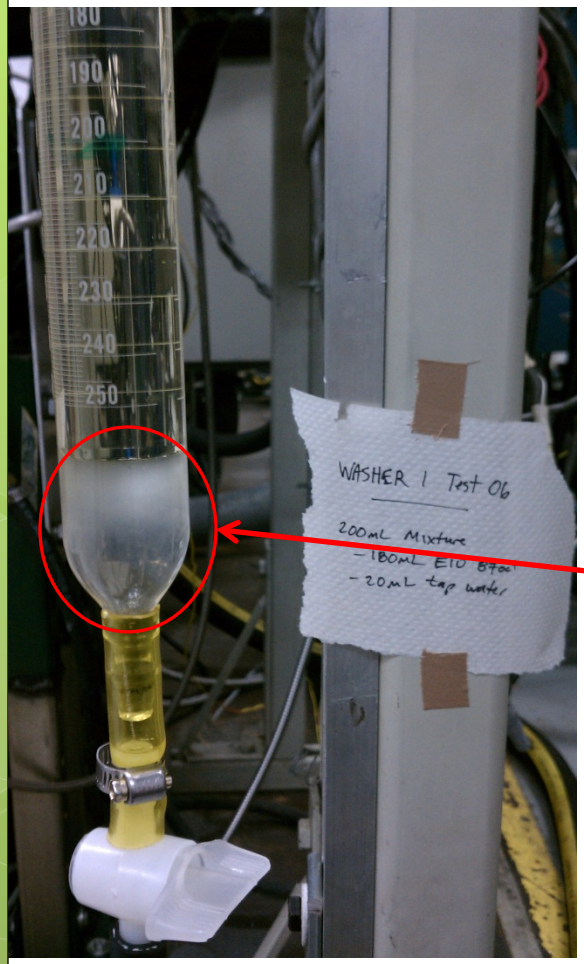


- Clearly defined phase separation

- Top – gasoline
- Bottom - water

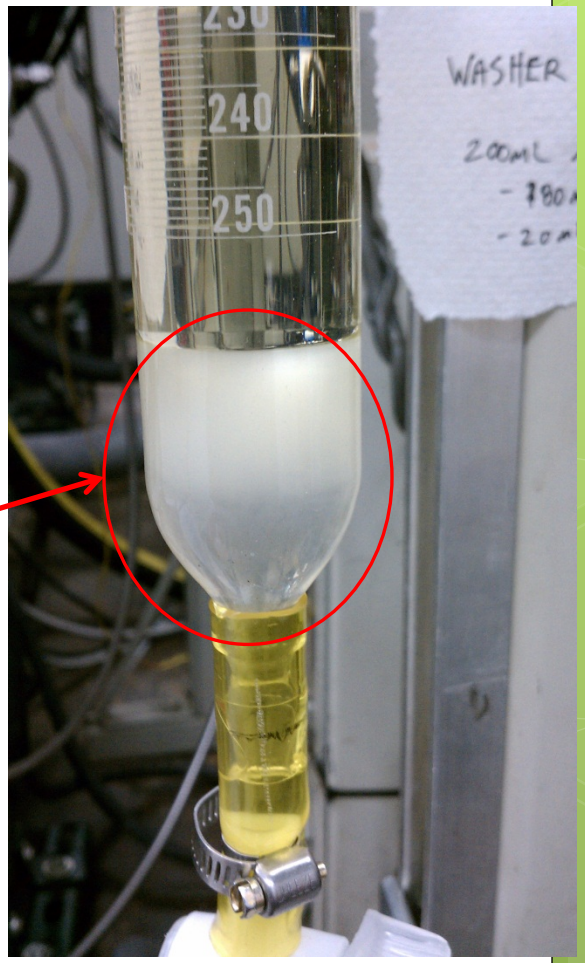


E10 Ethanol-Water Phase Separation



- Clearly defined phase separation

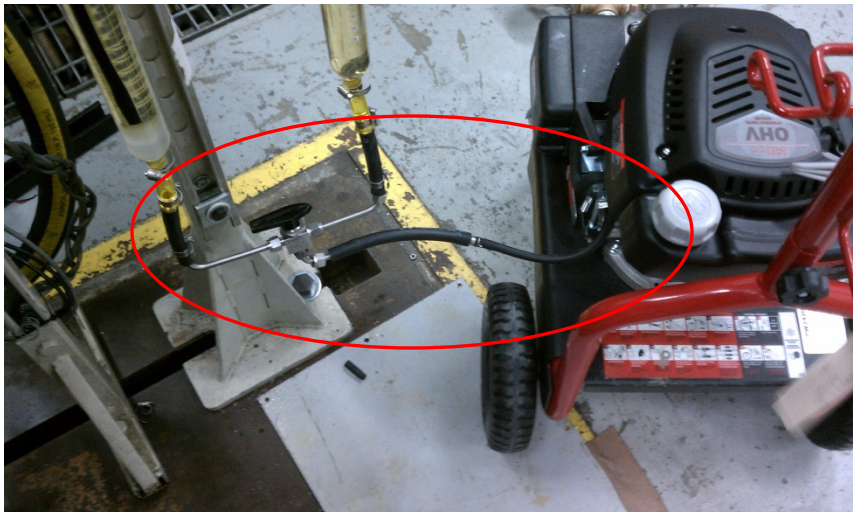
- Top – gasoline
  - Bottom – water/ethanol blend



Engine 1 Cold-Start Summary

	Test #	Tap Water V (mL)	Fuel Type	Total Mixture V (mL)	% Water by Volume	Cold Start Achieved?
ENGINE 1	Engine 1 Test 1	20	E0	200	10.0%	No
	Engine 1 Test 2	10	E0	200	5.0%	No
	Engine 1 Test 3	5	E0	200	2.5%	No
	Engine 1 Test 4	2.5	E0	200	1.3%	Yes
	Engine 1 Test 5	0	E0	200	0.0%	Yes
	Engine 1 Test 6	20	E10	200	10.0%	No
	Engine 1 Test 7	10	E10	200	5.0%	No
	Engine 1 Test 8	5	E10	200	2.5%	No
	Engine 1 Test 9	2.5	E10	200	1.3%	Yes
	Engine 1 Test 10	0	E10	200	0.0%	Yes

Running Engine Fuel Switch



- Ensure direct feed into carburetor
- Using 3 way valve, switch fuel reservoir to feed separated blend into engine

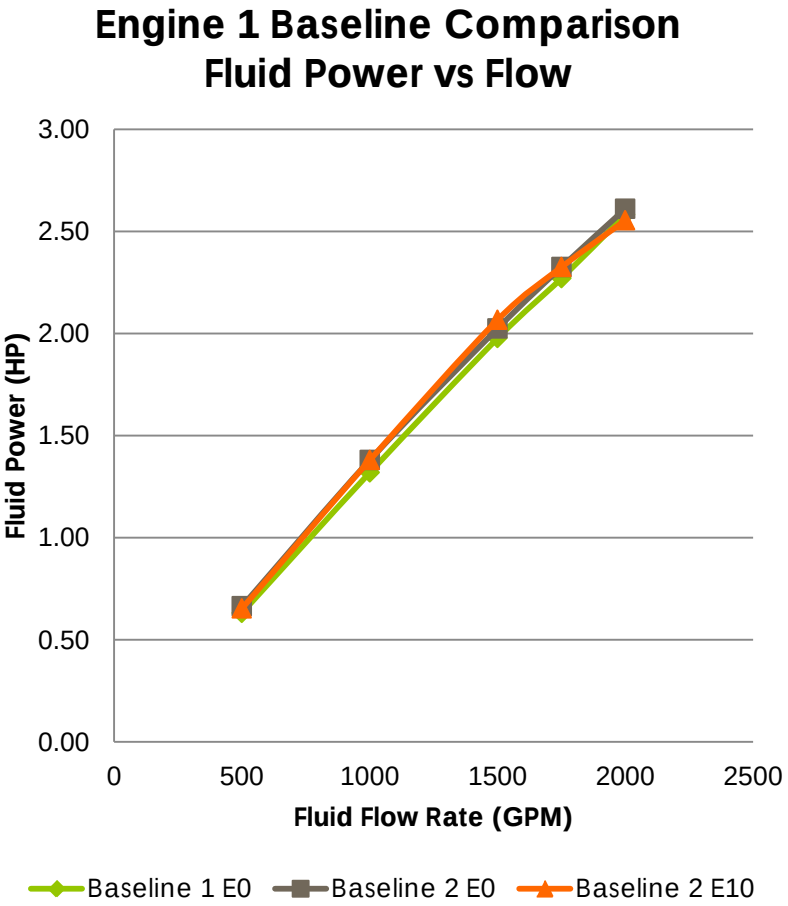
Running Engine Fuel Switch Results

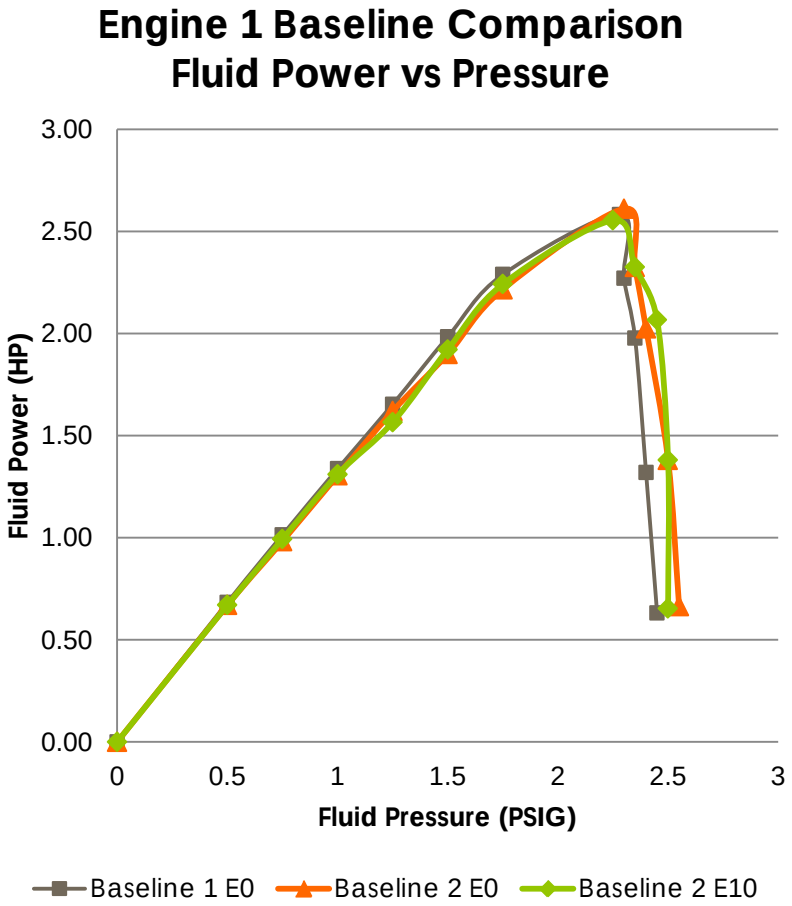
- On all attempts, the engines would **cease operation** around 6-10 seconds later.
  - E0 water phase layer
  - E10 ethanol-water phase layer
- Both water and/or ethanol-water phase liquids are **NOT** suitable for combustion.

Final Pressure Washer Performance Testing

- Repeat initial performance testing using E0 and E10 fuels with no separation layer
- Look for any degradation in performance

Engine 1 Comparison





- Baseline 2 testing conducted at completion of other testing

Results

- E10 has not caused phase separation to occur during fuel storage in an un-heated, vented location
- Ethanol-water phase did not burn in a small 4-stroke engine (caused engine to stall)
- Engines did not cold start on fuel mixtures with >~2.5% ethanol-water phase by volume
- Engines difficult to cold start on fuel mixtures of ~1.2% ethanol-water phase by volume
- Testing did not demonstrate any reduction in engine power

Thank You!!!!!

- Corn Marketing Program of Michigan

MICHIGAN CORN

- Kettering University
  - Mr. Clark Richardson, Student
  - Mr. Ray Rust, Senior Engineering Technician