COMPARISON OF AMMONIA / GASOLINE AND AMMONIA / ETHANOL MIXTURES

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Background and Motivation

- We wish to use ammonia as a primary transportation fuel.
- Ammonia works well at high engine loads but a combustion promoter is needed at lower loads.
- Gasoline has previously been shown to be a good combustion promoter.
- What about ethanol? Ethanol can be grown locally, can be carbon neutral, etc…
- It would be very difficult or impossible to produce enough ethanol to displace all of the gasoline that we use. But we could produce enough to use it as a combustion promoter.
- But is ethanol a good ammonia combustion promoter?

Overview

- Experimental Engine
- Comparison of Ethanol and Gasoline Characteristics
- Ethanol/Ammonia Fuel Mix
- Comparison of Gasoline/Ammonia and Ethanol/Ammonia Fuel Mix Maps
- Comparison of Rough and Knock Limits
- Comparison of Thermal Efficiency
- Conclusions

Comparison of Ethanol Gasoline Properties

Properties	Gasoline	E85
RON	92	101
Density (g/cm^3)	0.74	0.79
Heat of combustion (MJ/kg)	42.4	32.6
Latent heat of vaporization (KJ/kg)	420	845
Stoichiometric Air Fuel Ratio	14.3	9.0

Characteristics of Ethanol

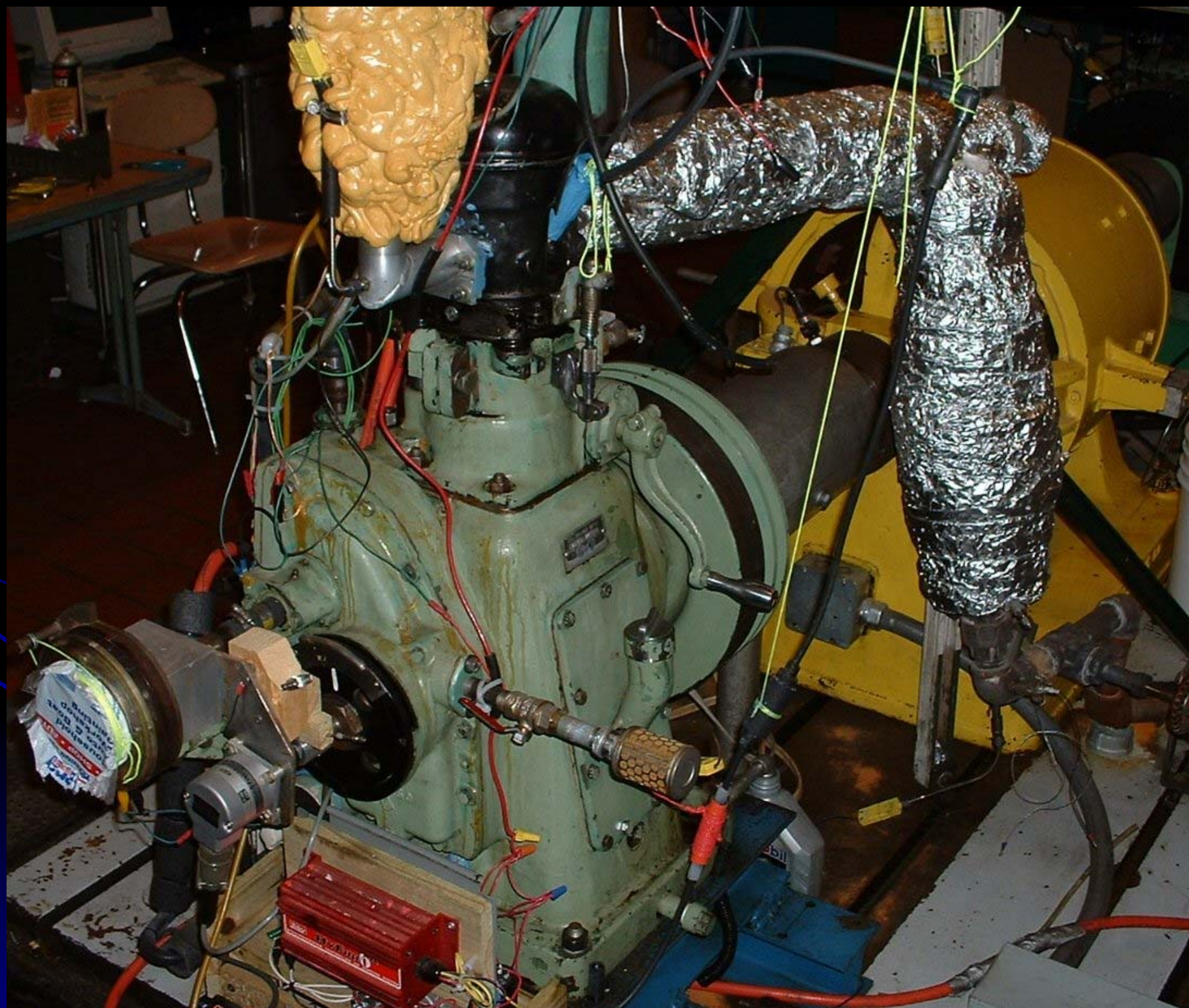
- Ethanol has a high antiknock quality due to its high octane number.
- Ethanol has a high latent heat of vaporization.
  - Advantage: Decreases the compressed gas temperature during the compression stroke.
  - Disadvantage: Property influencing cold start ability.

Experimental Investigations

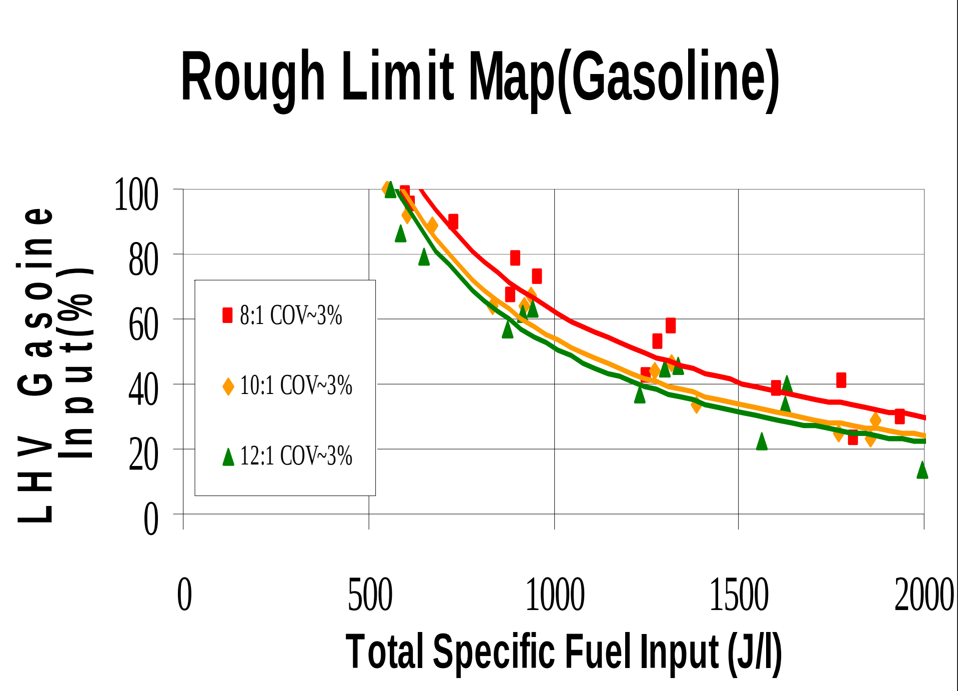
- Roughness Limit
  - There are various methods to determine the cycle to cycle variability which determines the vehicle drivability.
  - Pressure related parameters, burn rate related parameters, flame front position parameters.
  - Pressure related quantities are the easiest and the efficient way to determine the cycle to cycle variability.
  - The IMEPn derived from the pressure data is expressed as Rough Limit= $COV(IMEP_n) = \sigma_{imep}/IMEP_n \times 100$
- Knock Limit
  - The maximum gasoline fraction used to avoid knock
- Efficiency
  - It is the ratio maximum work output to input.

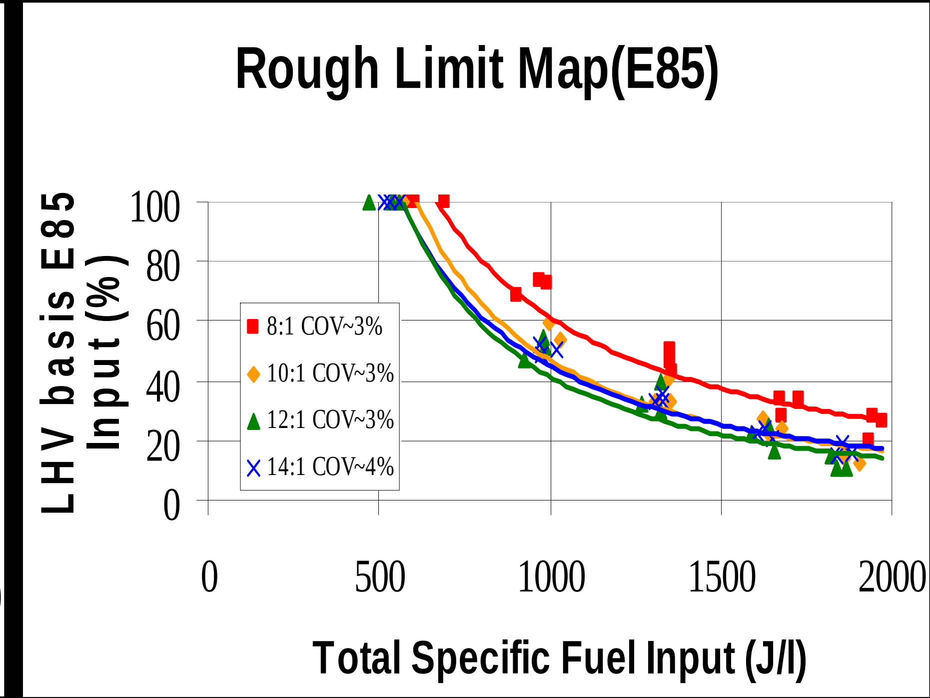
Cooperative Fuel Research Engine (CFR)

83.4 mm bore diameter, 114.3 mm stroke, 625 cc swept volume displacement



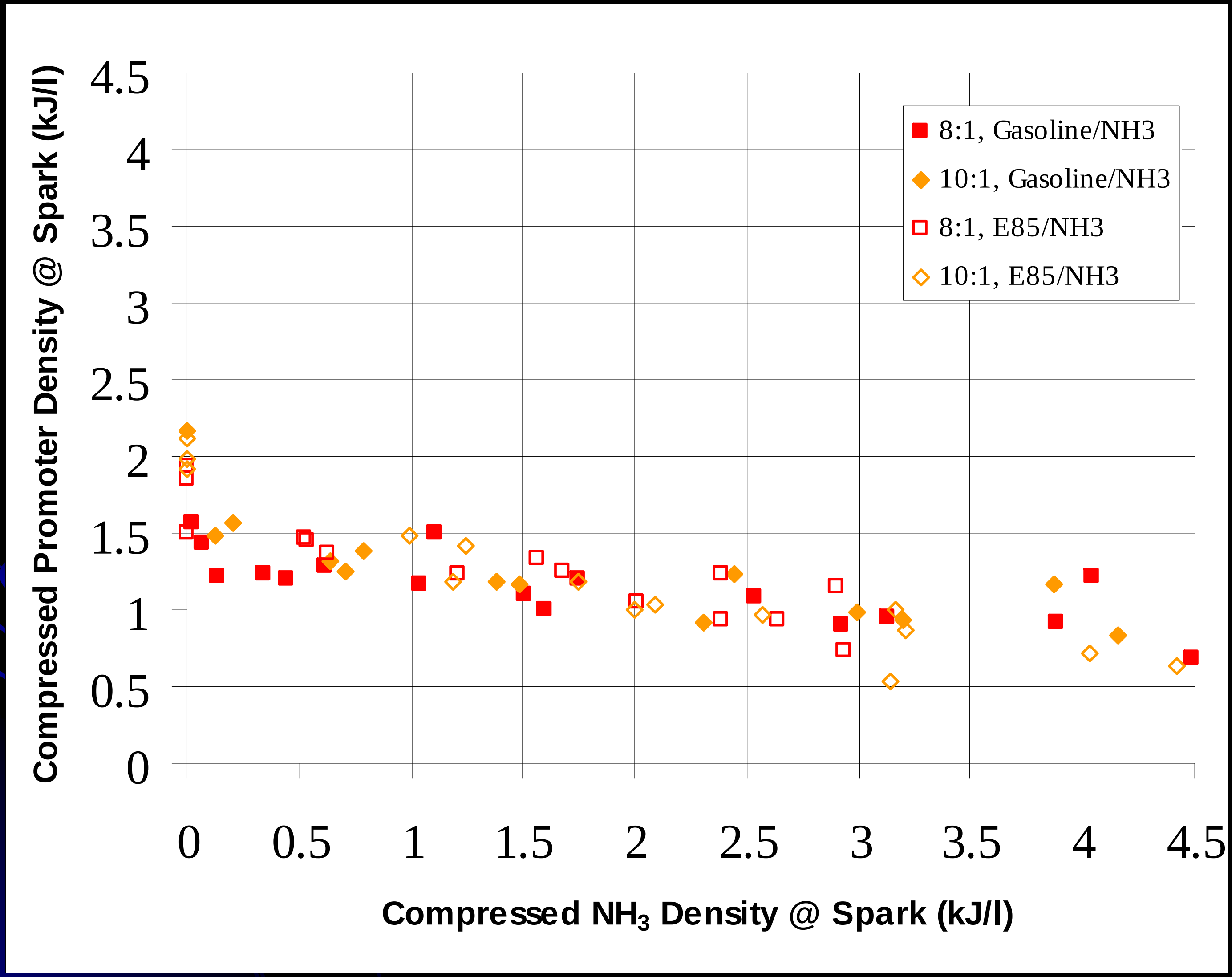
Effect of Compression Ratio & Load on Combustion Promoter Input at Roughness Limit



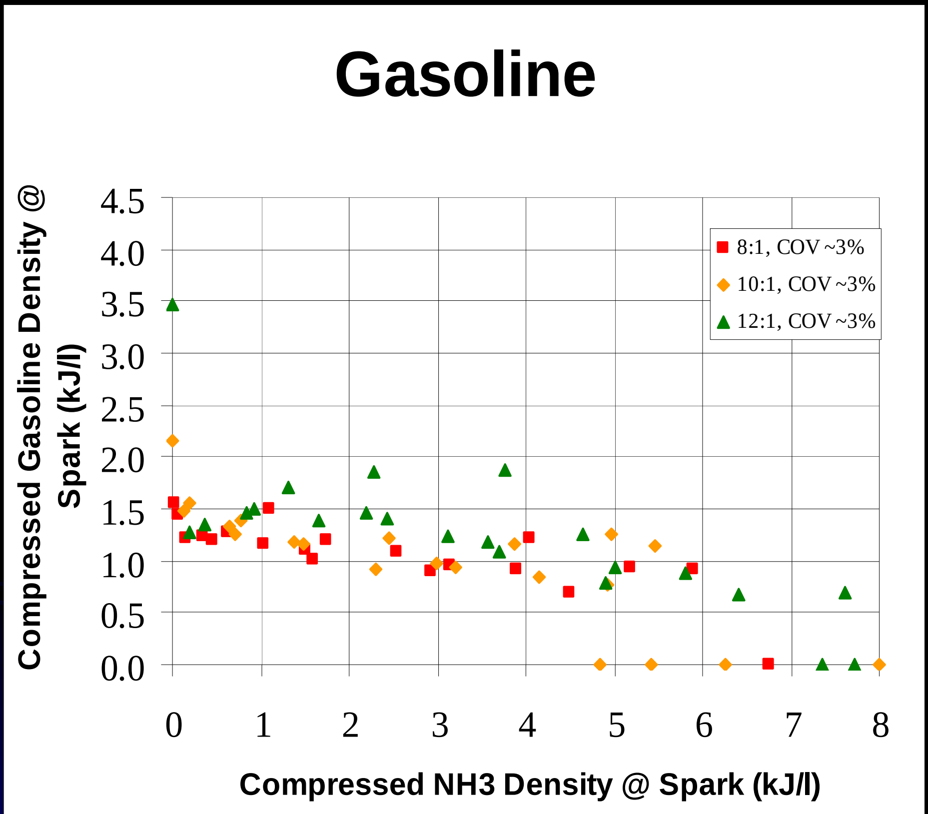


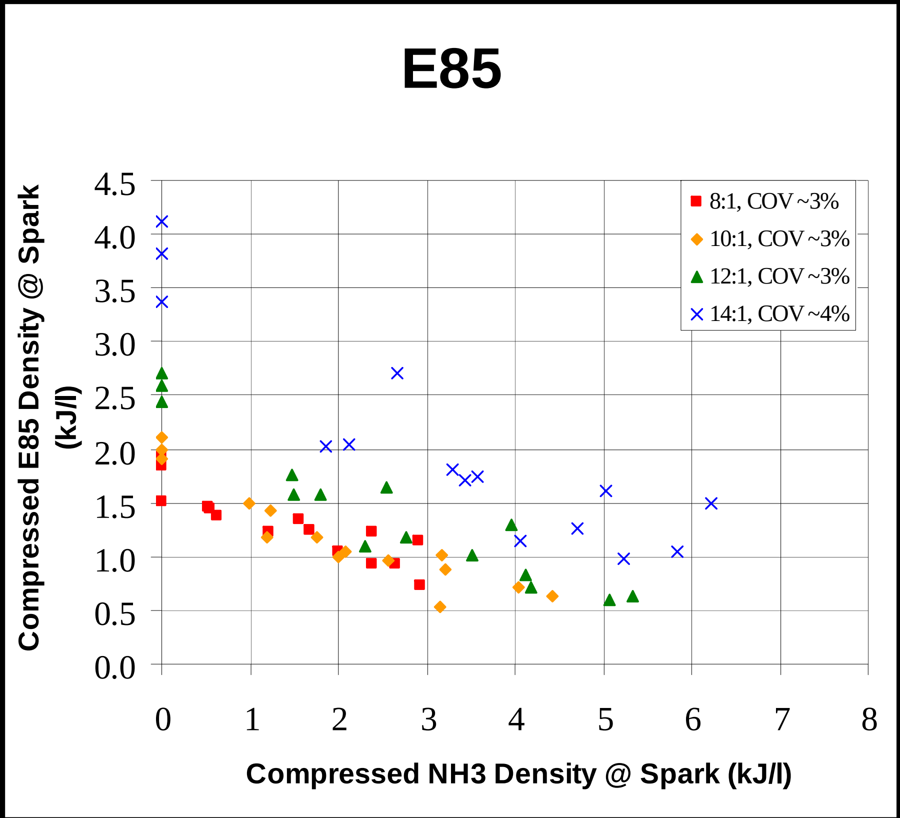
- The fraction of required promoter input decreases drastically as load is increased.
- The required promoter input (%) is the same for both gasoline and ethanol mixtures at the roughness limit.

Promoter Density at Spark at Rough Limit



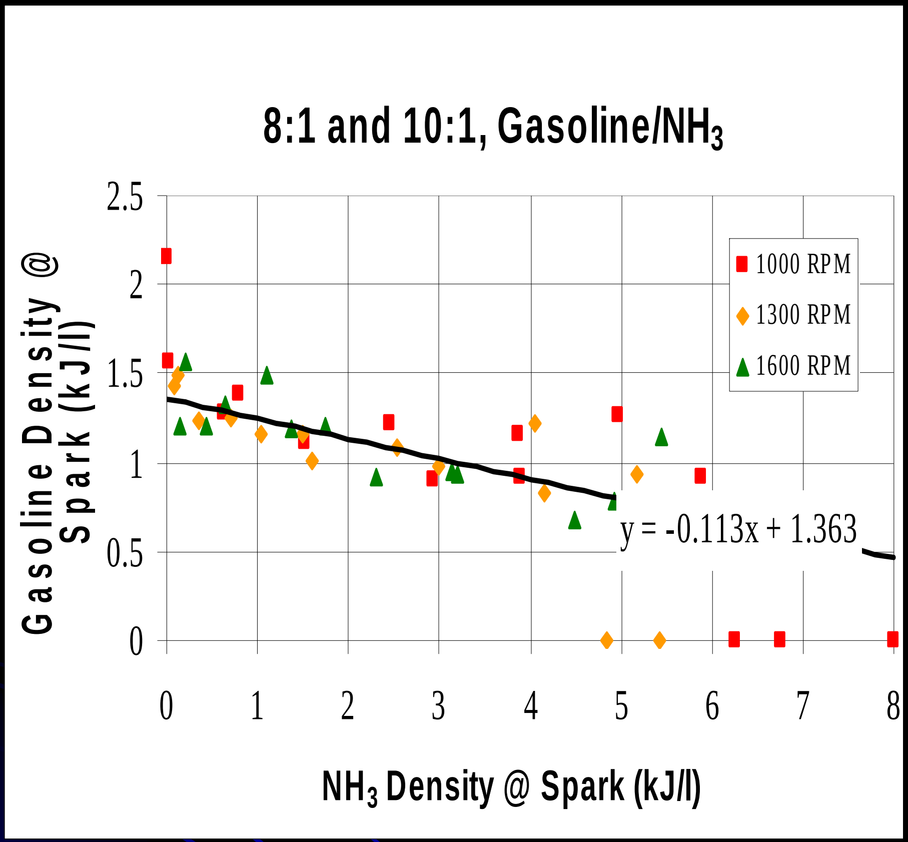
Promoter Density at Spark at Rough Limit

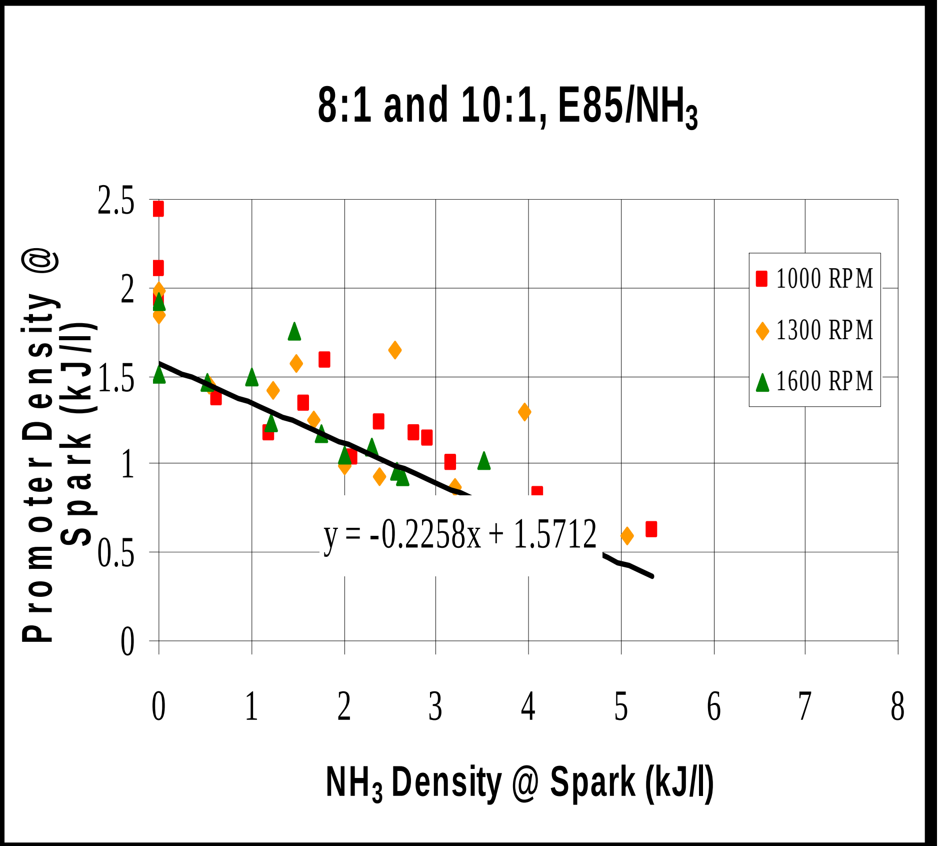




The promoter input (%) decreases as compressed NH_3 density at spark increases.

Promoter Density at Spark at Rough Limit



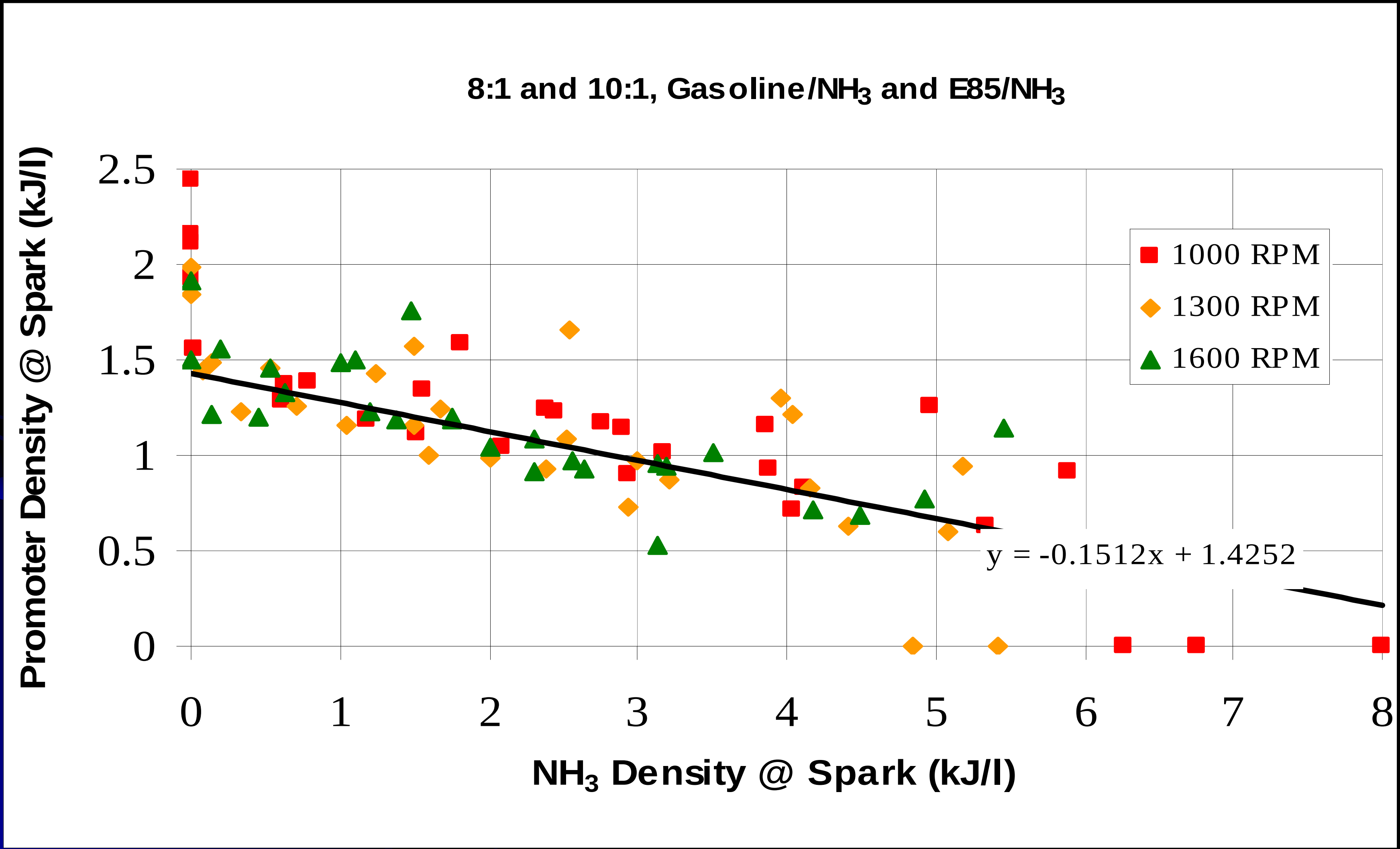


Minimum gasoline requirement at spark= 1.36

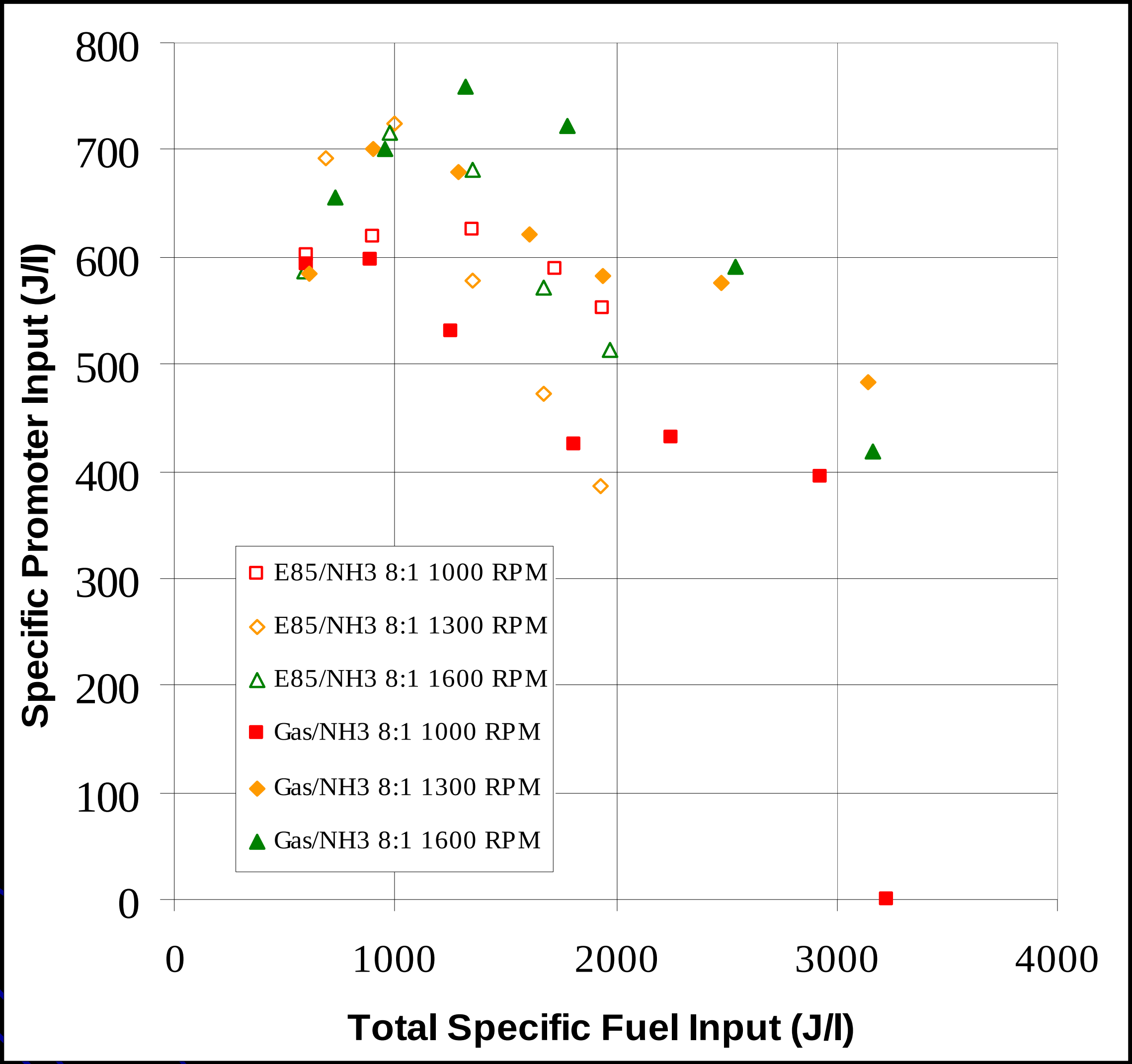
Minimum E85 requirement at spark=1.57

Both the fuels require almost the same energy/volume at the spark!!

Promoter Density at Spark at Rough Limit

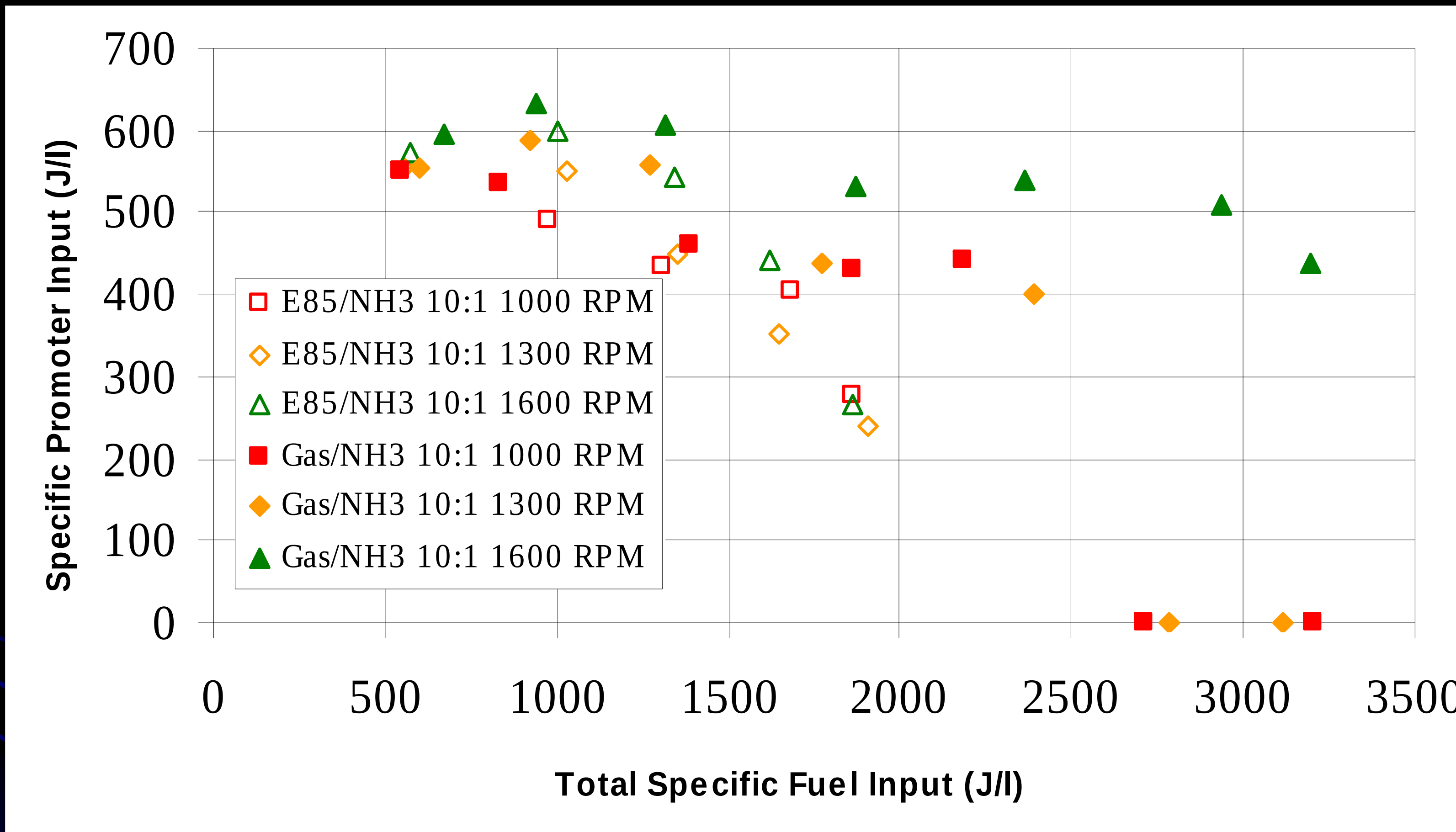


Is Ammonia a Good Fuel ?

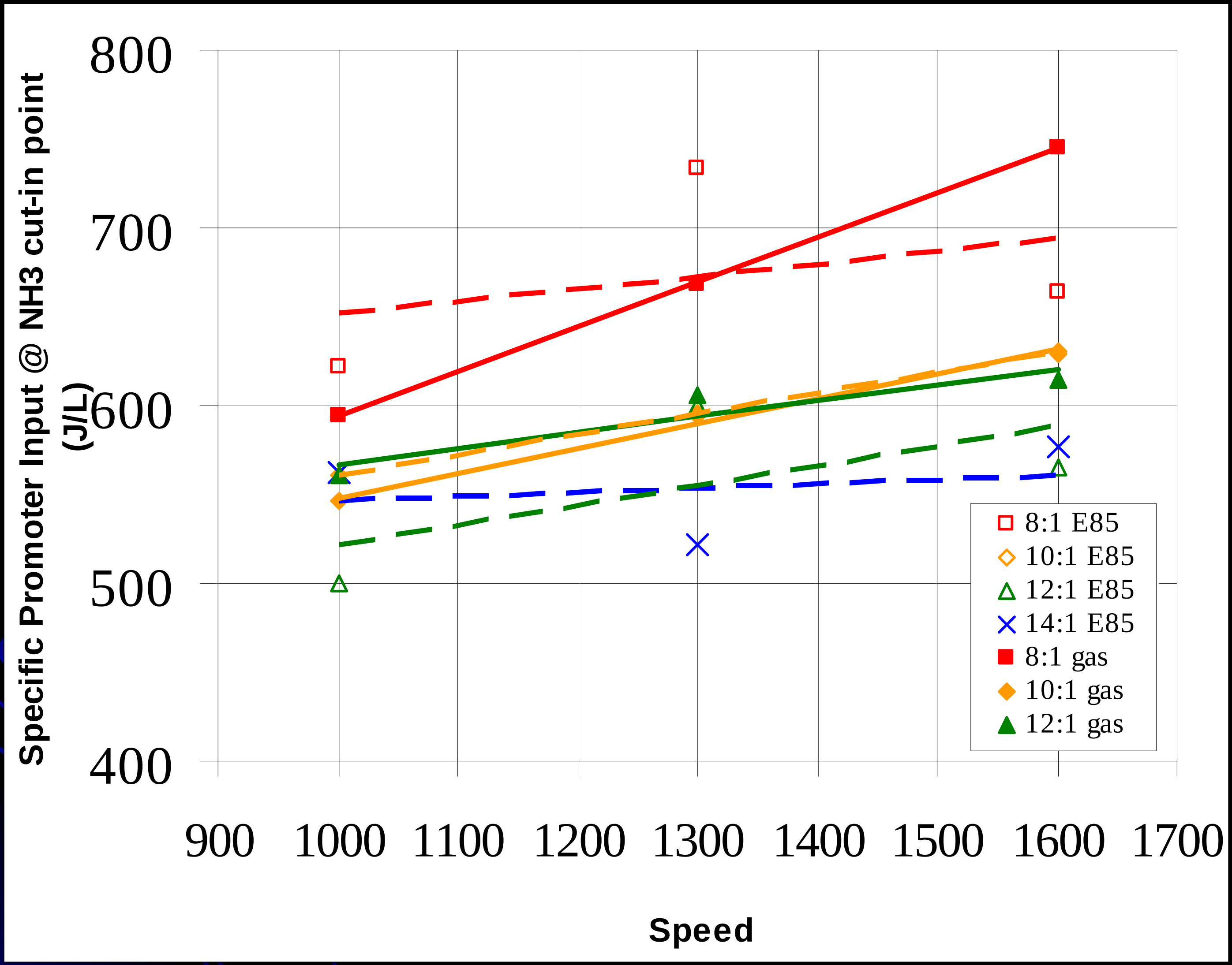


- The required promoter input decreases slightly as load is increased., showing that ammonia as a fuel having a slighter positive or neutral effect when used with both gasoline and ethanol at the rough limit.

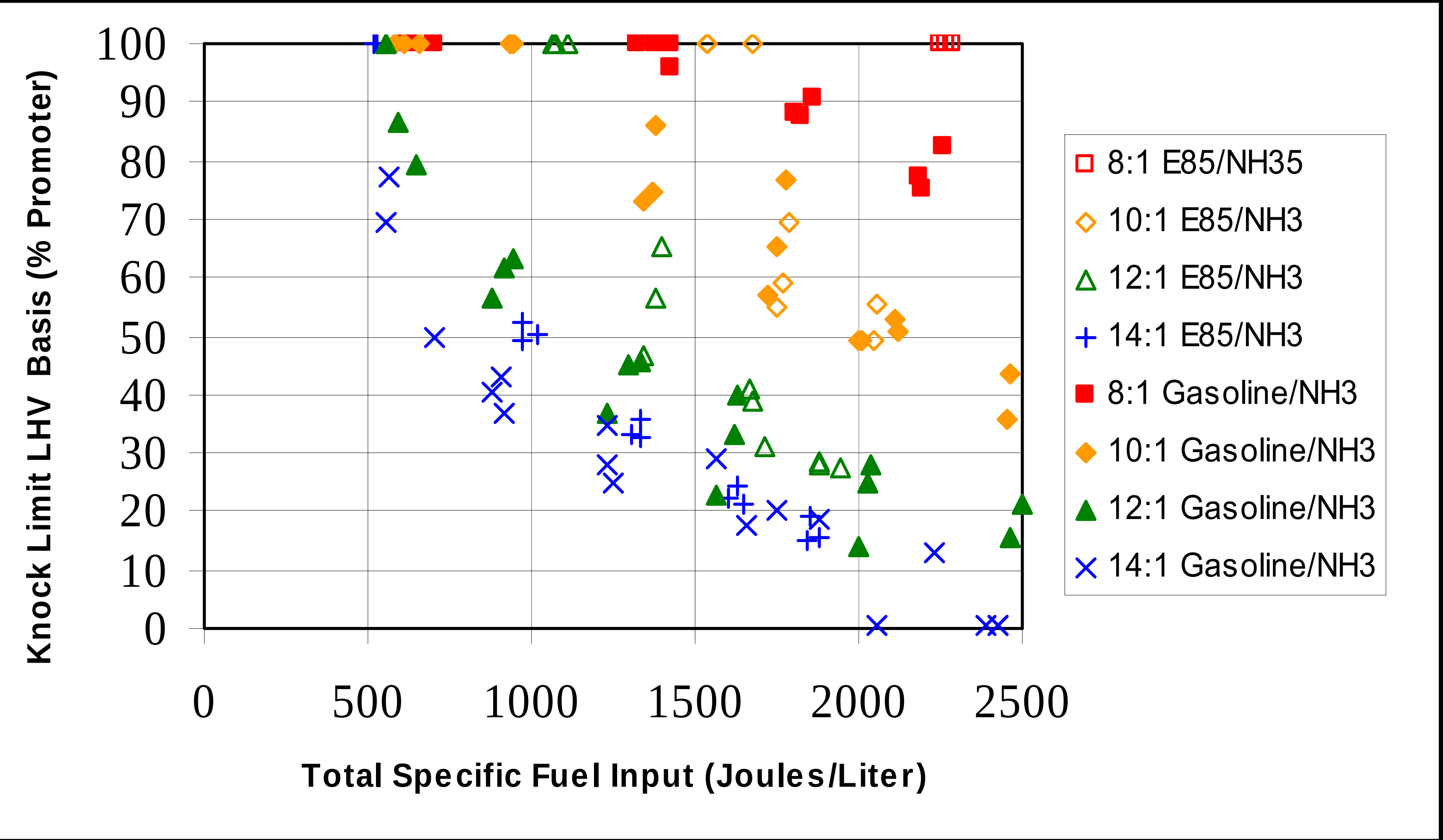
Promoter Input, 10:1, All Speeds



How Does Promoter Input Vary with Speed?

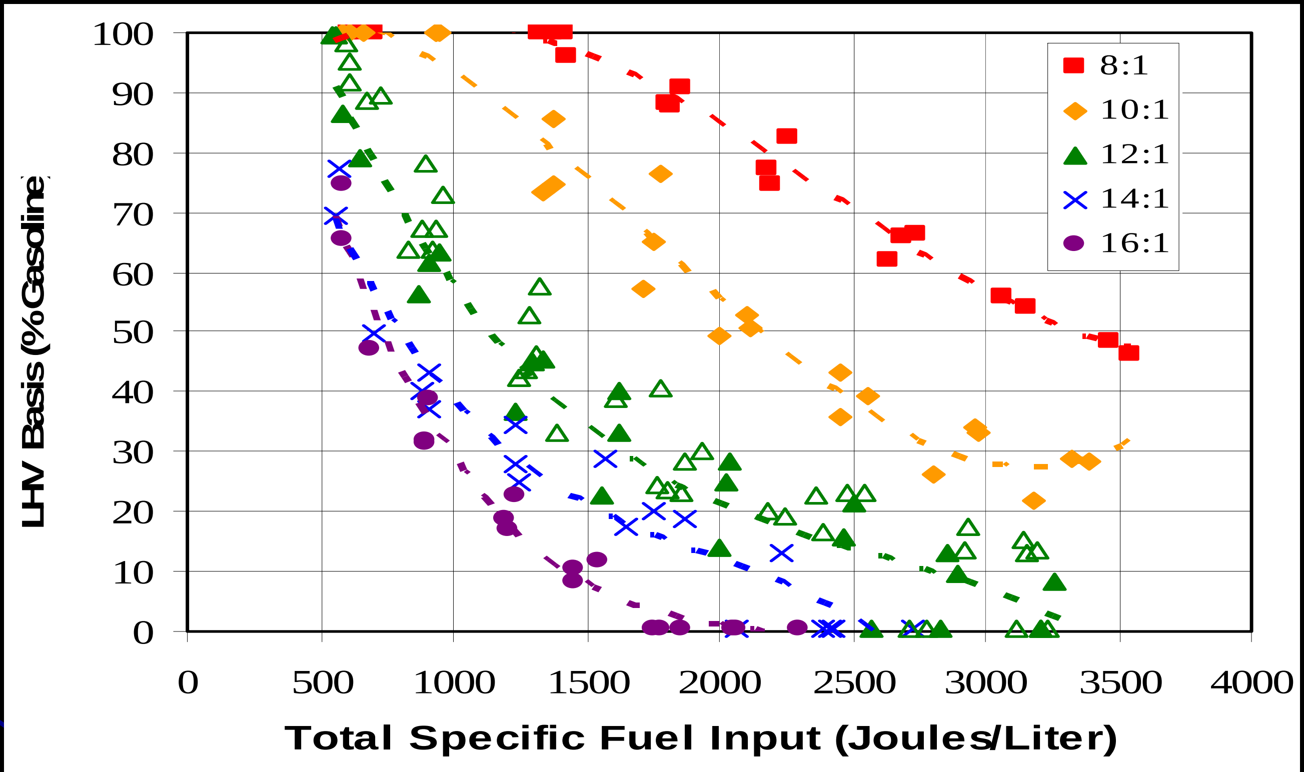


Knock Limit



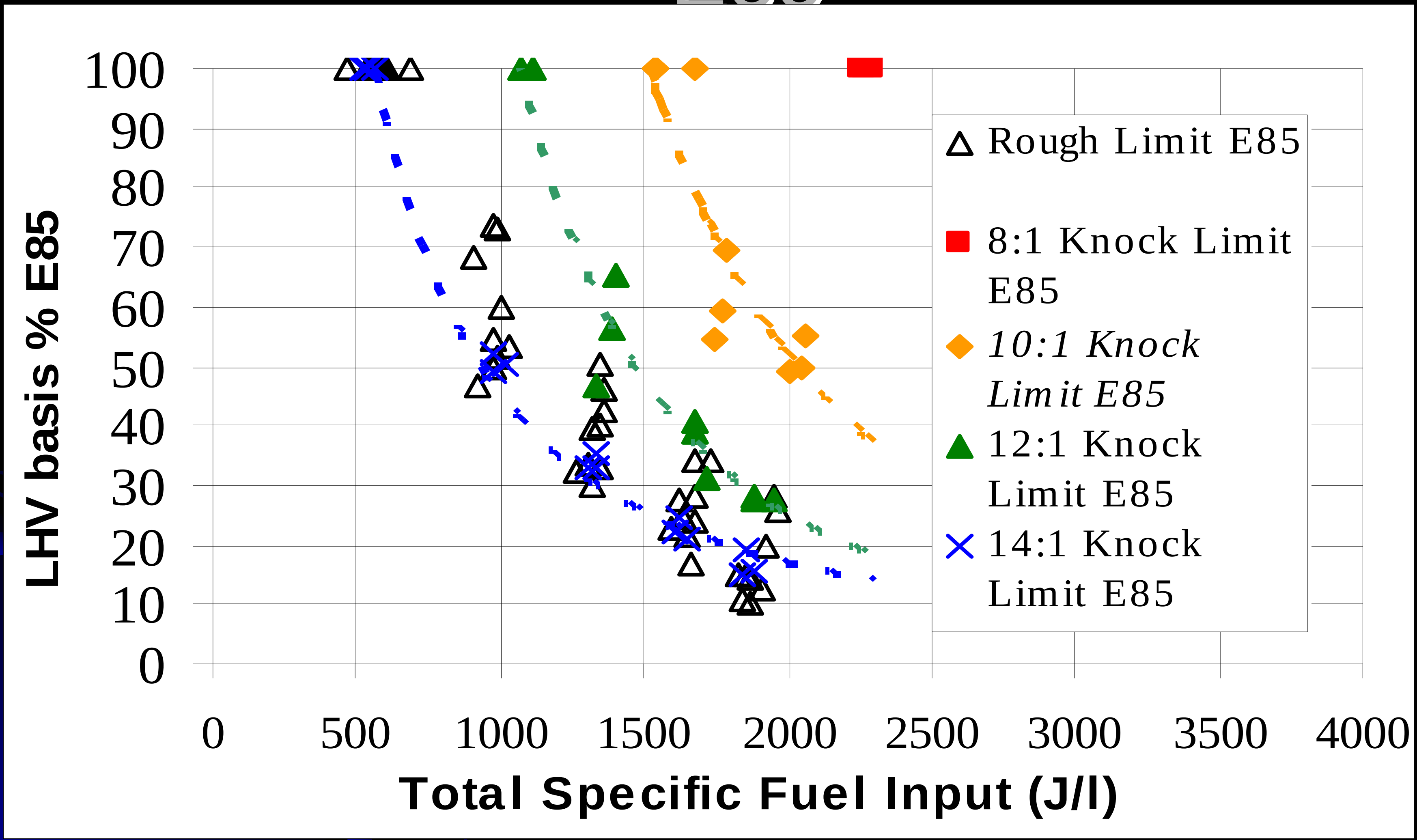
Knock Limit LHV Basis (% Promoter)
100
90
80
70
60
50
40
30
20
10
0
0
500
1000
1500
2000
2500
Total Specific Fuel Input (Joules/Liter)
8:1 E85/NH35
10:1 E85/NH3
12:1 E85/NH3
14:1 E85/NH3
8:1 Gasoline/NH3
10:1 Gasoline/NH3
12:1 Gasoline/NH3
14:1 Gasoline/NH3

Knock and Rough Limit Crossover – Gasoline



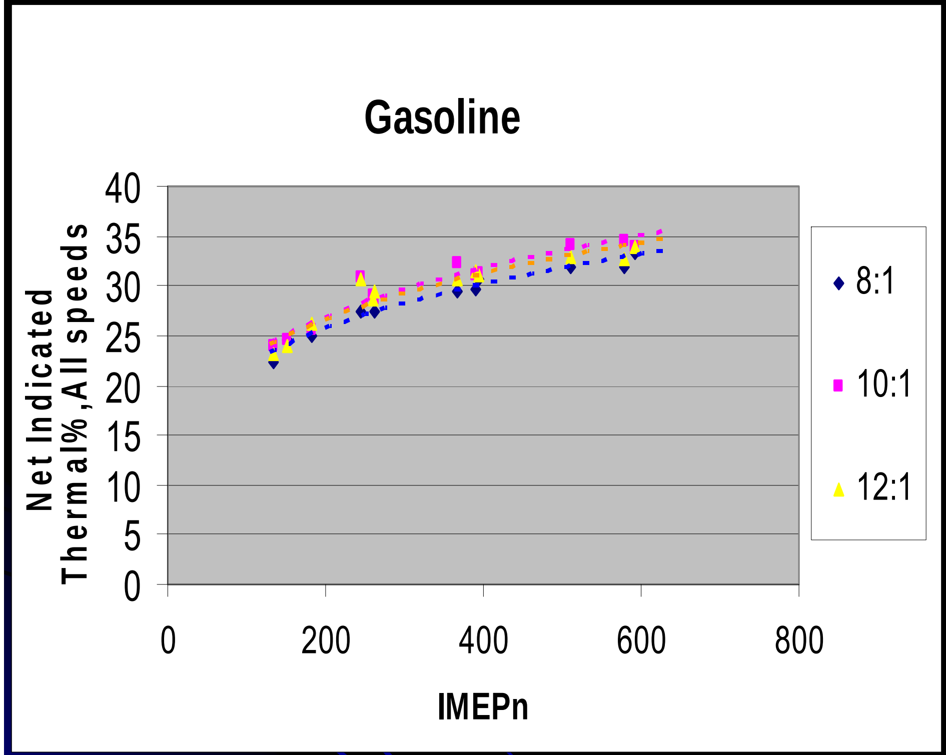
- %Gasoline decreases as total fuel input increases.
- At some point there is a crossover between roughness limited minimum gasoline fraction and knock limited maximum gasoline fraction. The crossover occurs at 12:1 Compression Ratio.

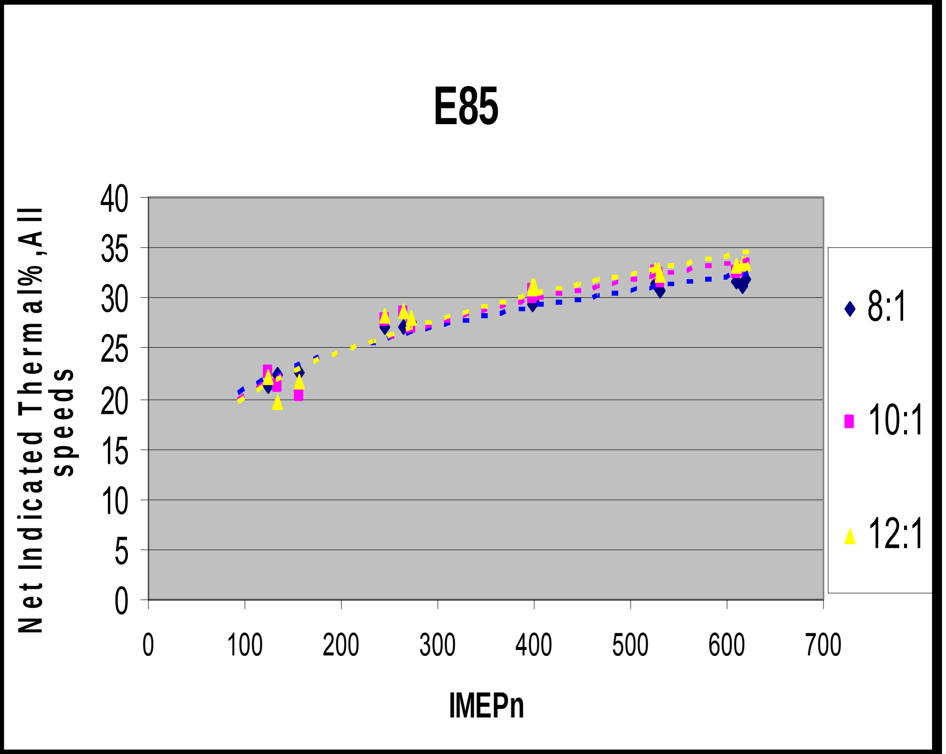
Knock and Rough Limit Crossover – E85



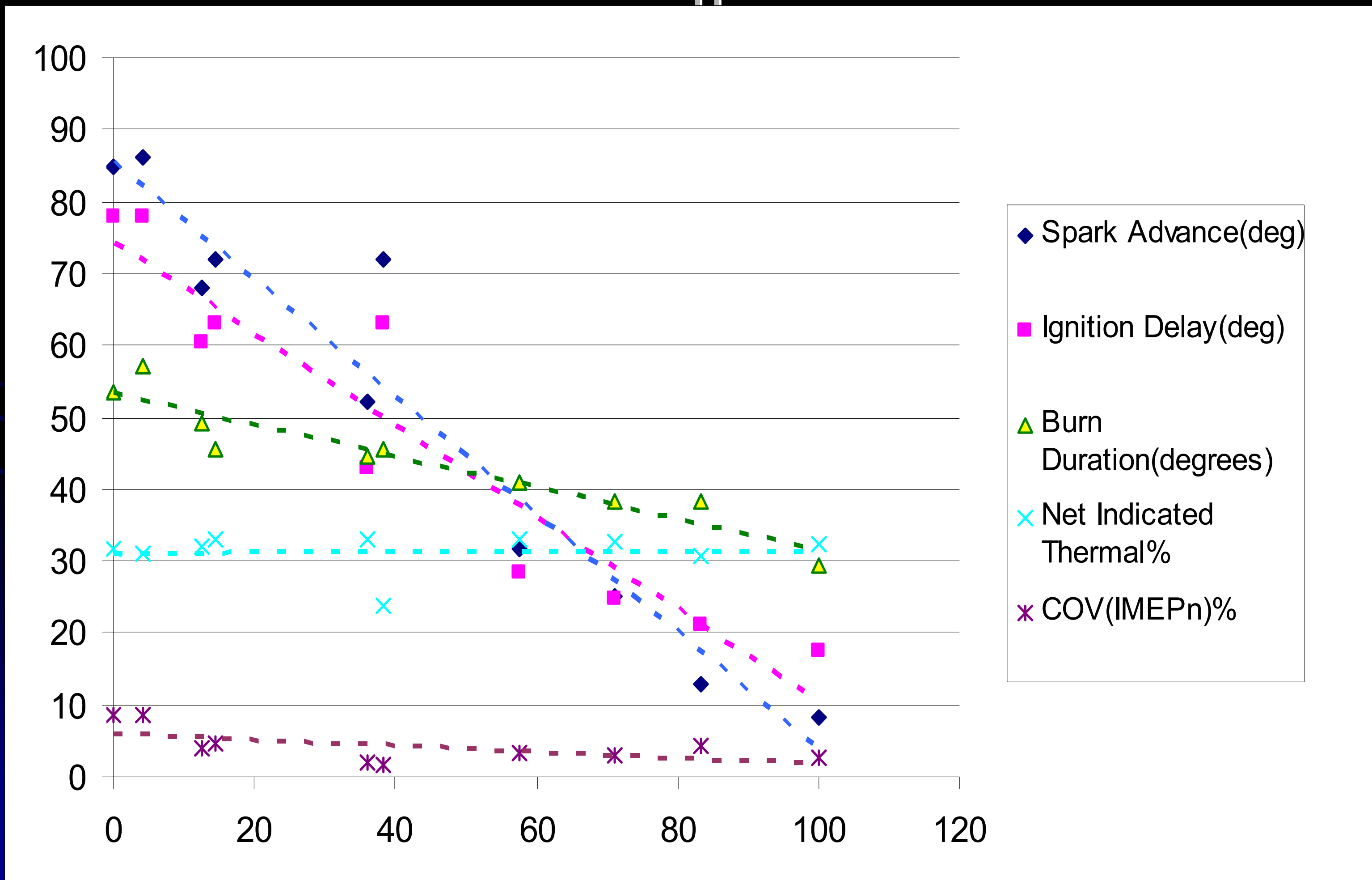
The Crossover occurs at 13.5:1 Compression Ratio.

Thermal Efficiency At Rough Limit





Summary of Ethanol/NH3 Combustion put into figure…Fuel Mix Sweep at 1600 RPM, 10:1 and IMEP$_n$ ~ 550 kPa.



Conclusions

- The knock and rough limit crossover occurs at ~13.5:1 for E85 and ~12:1 for gasoline.
- E85/NH_3 has higher knock limit and allows for a higher maximum compression ratio and thermal efficiency.
- Gasoline/NH_3 has a lower roughness limit and allows for a slightly more fuel mixture flexibility.
- The roughness limited promoter fraction is found to be almost the same for both (Ethanol &Gasoline) when used with Ammonia as the primary fuel.
- The fuel blend does not change much with speed.
- E85 is an attractive combustion promoter, like gasoline, when used with ammonia as the primary fuel.

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