Ethanol-Gasoline Blends: Fuel Economy and Emissions Benefits

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Overview

- EPA program in alcohol fuels
  - Background on EPA program
  - Neat ethanol fuel and ethanol-gasoline blends
    - Efficiency
    - Criteria, Greenhouse Gas (GHG) Emissions
- Summary & Future Outlook

EPA Program in Alcohol Fuels Research

NVFEL: A "Center of Excellence" for Alcohol Research

- **Fuels research and engine testing programs initiated at EPA in late 70's/early 80's**
  - Research in feasibility/safety of alcohols as automotive fuels
  - Successful engine and vehicle demonstrations with methanol

- **Lead role in engine fuel effects studies under PNGV program**
  - Led to development of advanced methanol-fueled engines for hybrid vehicles
  - More recent work with ethanol and ethanol blends

EPA Engine Test Program

Characteristics of EPA alcohol fuel test engine*

- 1.9L Port Fuel Injected, Spark Ignited, Turbocharged (VNT)
- Stoichiometric fueling
- Designed for use with neat alcohol fuels (e.g., E100, E85)
  - 19.5:1 compression ratio
  - 2.0 swirl ratio
- EGR, VNT used to modulate load from 6 to 20 bar BMEP.
  - Throttling at near-idle conditions to 6 bar BMEP
- Control of Intake Air Temperature (IAT)
  - Intercooler
  - EGR cooler
- Conventional FFV injectors, ignition system and three-way catalyst

(*-More Detail: SAE Paper 2002-01-2743)

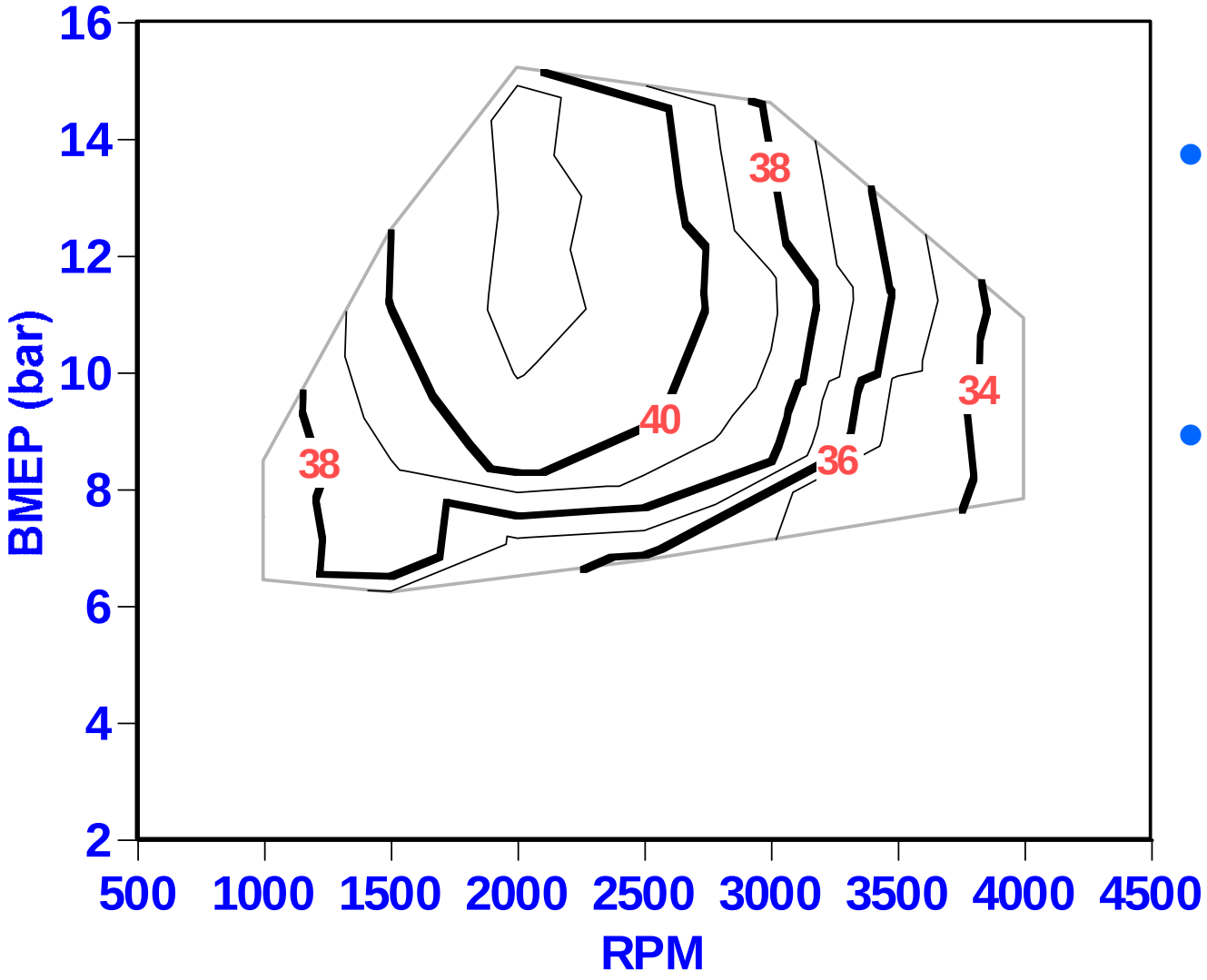
Results of Neat Alcohol Fuel Testing

- Fuels Tested: Ethanol (E100), Methanol (M100)
  - High Efficiency
    - 42% peak efficiency
    - >40% efficiency down to 6-8 bar BMEP
  - High Specific Power
    - >20 bar peak BMEP (turbocharged)
  - Low Criteria and Greenhouse Gas (GHG) Emissions
    - Criteria emissions on the level of Tier II
    - Use of low-GHG, renewable fuels

Extension to Ethanol-Gasoline Blends

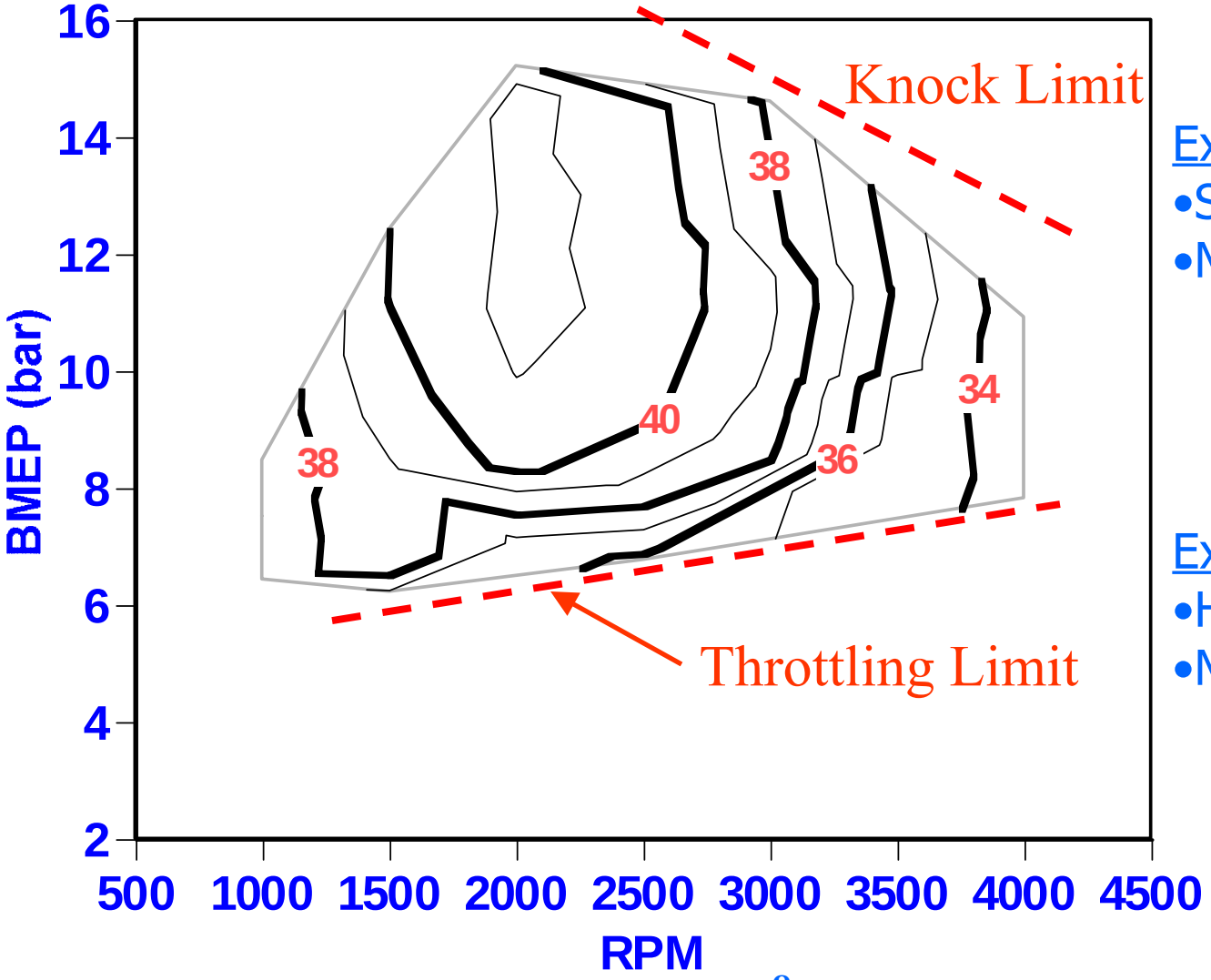
- EPA study to examine emissions/fuel economy benefits of ethanol blends
  - E85, E95: EPAct alternative fuels
  - E50, E30: best benefit/cost ratio?
  - E10: gasohol
- Other Implied Benefits:
  - Homeland security: reduced import dependence
  - Lower greenhouse gas (GHG) emissions
  - Lower air toxics emissions

Brake Thermal Efficiency: Ethanol (E100)



- Over 41% peak efficiency
  - MBT reached with 19.5:1 CR
- Broad regions of high efficiency
  - No throttling over range shown

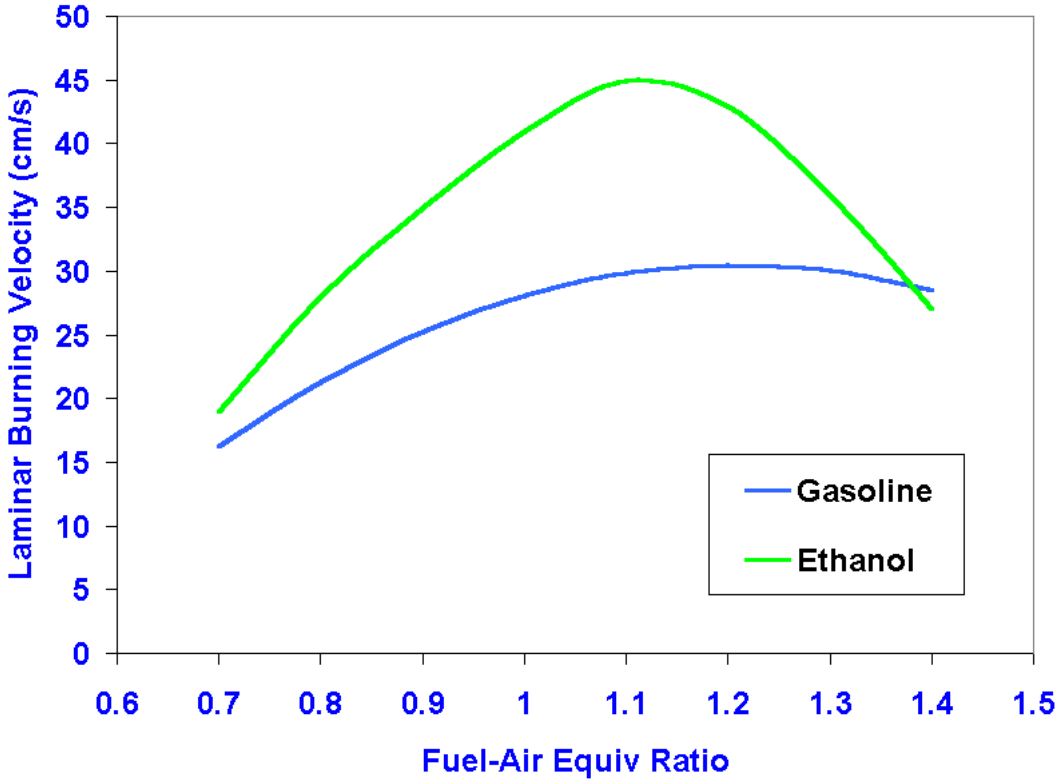
Upper Limits to Efficiency (E100)



Extended Knock Limit:
- Suppression with EGR
- Management of IAT

Extended Throttling Limit:
- Higher tolerance for EGR
- Management of IAT

Flammability Limits of Ethanol Blends

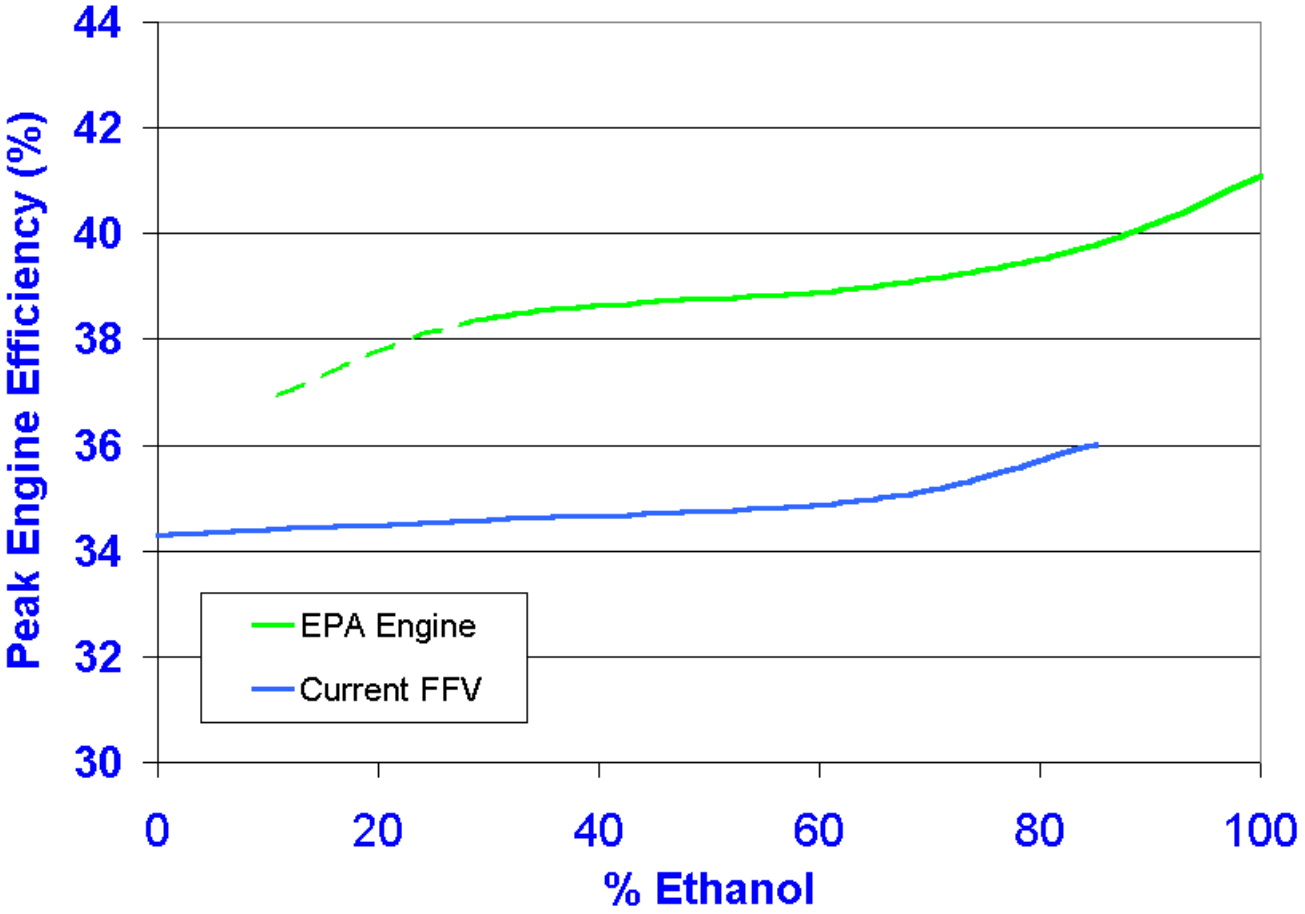


Higher Laminar Flame Speed:

- Extended dilute flammability limit for ethanol compared to gasoline
- Less throttling required at light loads

- Ethanol content determines EGR tolerance, hence breadth of efficiency islands

Peak Efficiency: Ethanol-Gasoline Blends

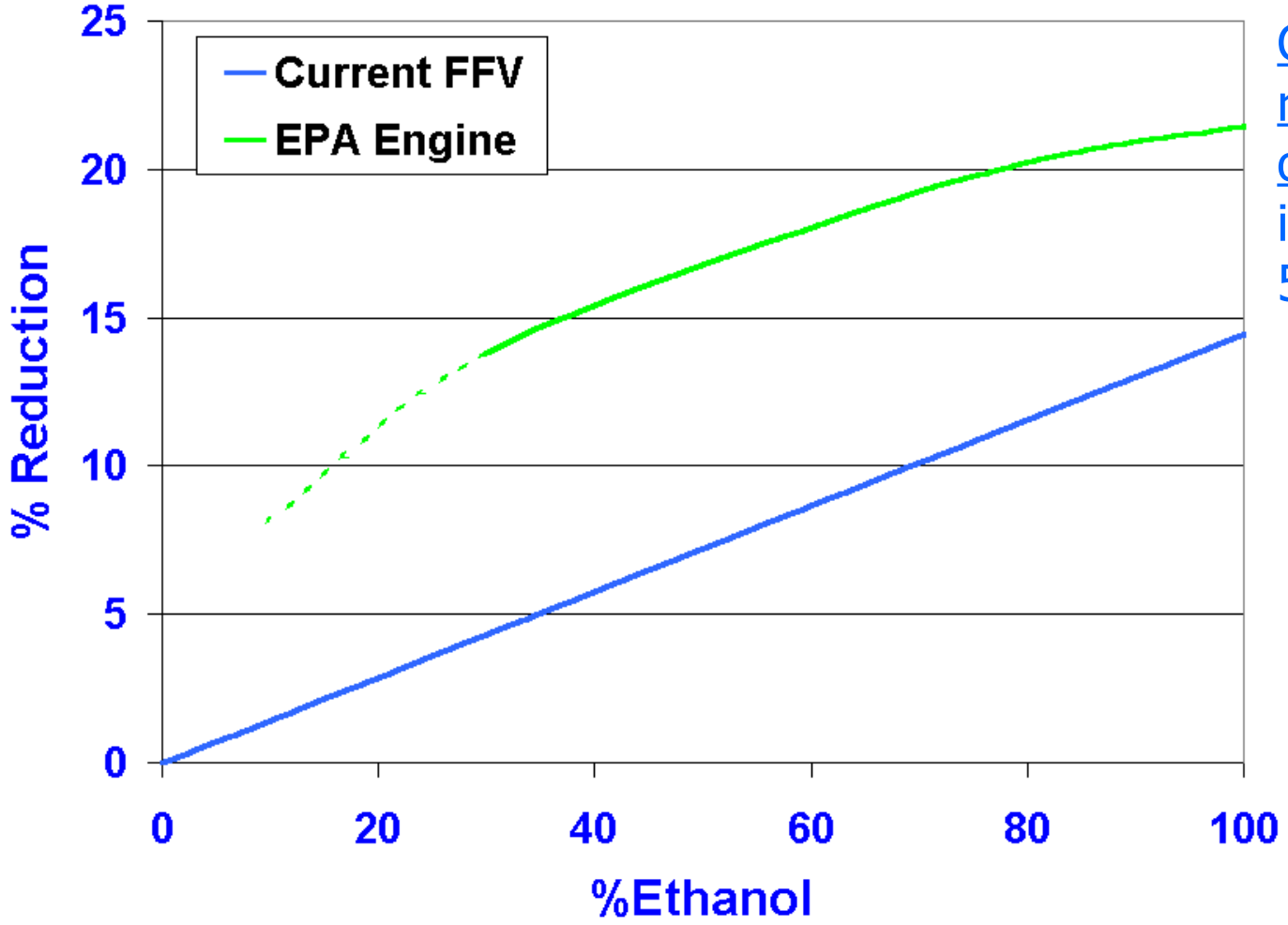


EPA Engine: peak efficiency highlights the benefit of higher compression ratio

Criteria Emissions Results

- Engine Out Emissions
  - NOx: lower with increasing alcohol %
  - CO, Soot: ultra-low due to oxygen in fuel
  - HC, aldehydes: High
- Conventional aftertreatment options
  - Stoichiometric operation permits Three-Way Catalyst (TWC)
  - Past work at EPA has demonstrated effective TWC performance on M100 vehicles operating over the FTP

GHG Emissions



Greatest GHG reduction per gallon of ethanol: may lie in the range of 10-50%

Summary & Future Outlook

Benefits of Ethanol-Gasoline Blends

- High efficiency: comparable to state-of-the-art diesel
- Low criteria, GHG and air toxics emissions

Next Steps in Alcohol Engine Research

- Develop a basis for evaluating market tradeoffs of ethanol-gasoline blends
  - Determine best ethanol blend fraction(s)
  - Determine "optimal" engine hardware, calibration
- Demonstrate the technology on a vehicle platform
  - Hydraulic hybrid vehicle
  - Conventional powertrain

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