NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Overview: Octane number, efficient engines, ethanol, and infrastructure

Robert L. McCormick

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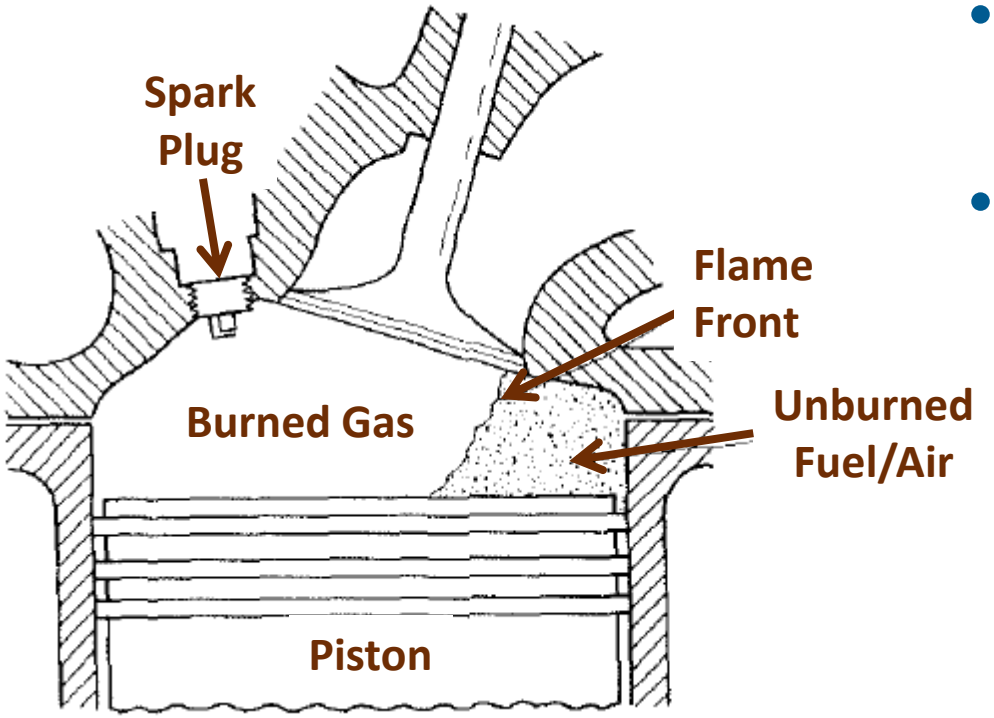
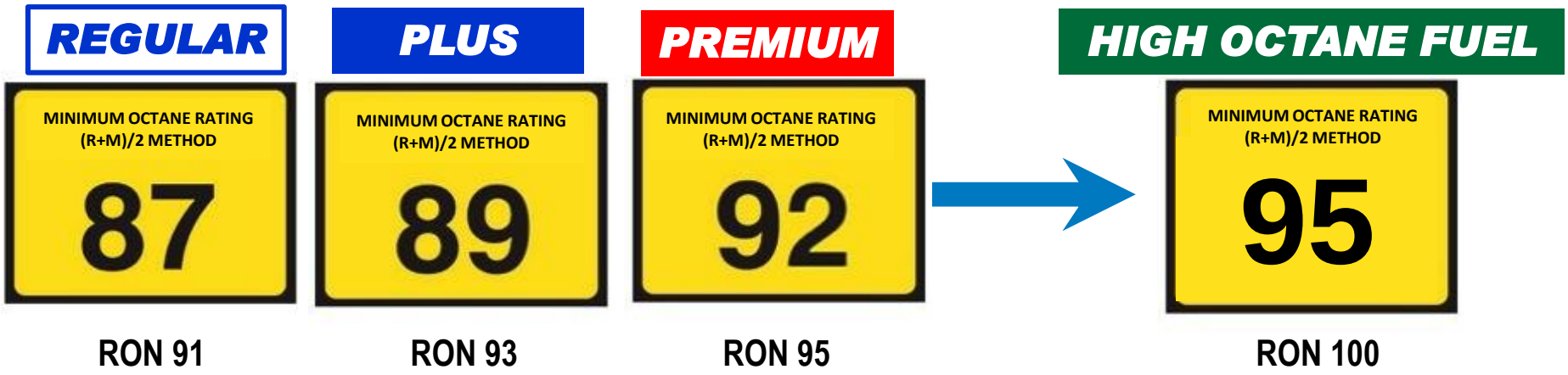
What is Engine Knock?

- **Fuel with adequate octane number is required to prevent engine knock**
- **Knock occurs when unburned fuel/air mixture auto-ignites – essentially a small explosion in the engine**
  - Higher octane fuel is more resistant to auto-ignition



- **Knock can cause engine damage**
- **Modern cars have knock sensors**
  - Reduce engine power and efficiency at knock onset
  - Drivers rarely experience knock

What is Octane Number?



- **Pump octane is the average of research octane (RON) and motor octane (MON) – also known as (R + M)/2**
  - Two tests to cover the full range of engine operating conditions 80 years ago when this was introduced
- **For modern technology engines, RON is the better measure of performance (knock prevention)**
- **There is no nationwide (ASTM) standard for minimum octane number in the United States**

Why do we care?

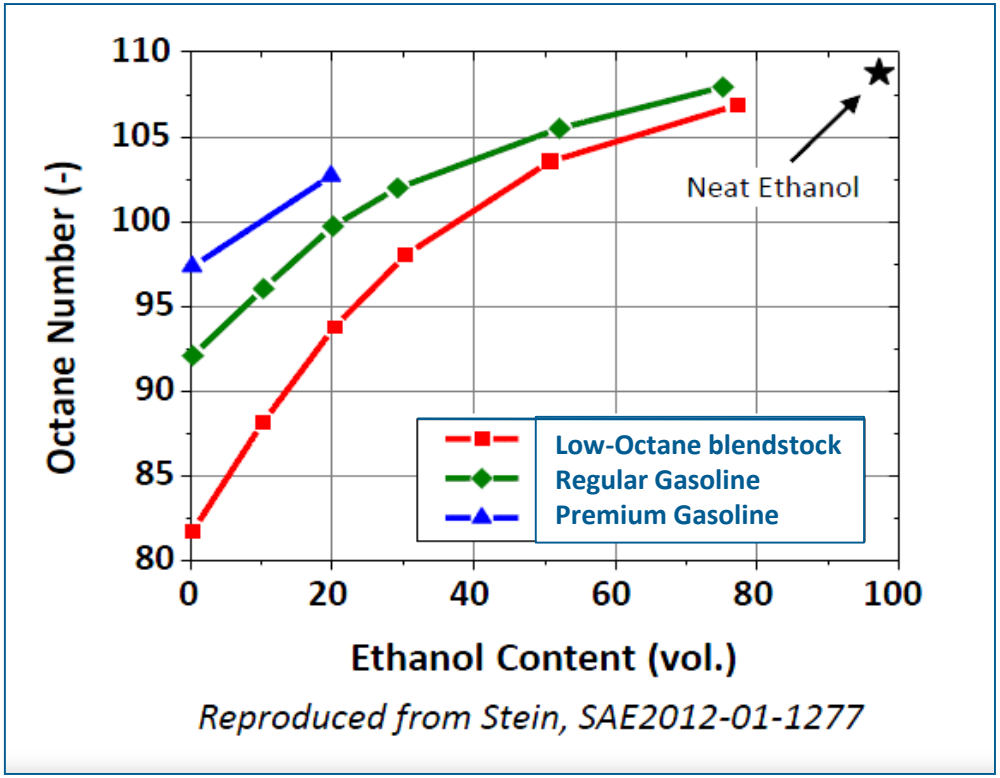
Strategies to Increase Engine Efficiency (and Lower GHG Emissions):

- **Increased compression ratio**
  - Greater thermodynamic efficiency
- **Engine downsizing/downspeeding**
  - Smaller engines operating at low-speed/higher load are more efficient
  - Optimized with 6 to 9 speed transmission
- **Turbocharging**
  - Recovering energy from the engine exhaust
  - Increase specific power allowing smaller engine
- **Direct injection**
  - Fuel evaporates in the combustion cylinder, cooling the air-fuel mixture

All of these strategies can take advantage of higher octane (more highly knock resistant) fuels

Ethanol and Octane Number

- **Ethanol has high RON**
  - RON = 109
  - Relatively low cost source of octane
- **What about charge cooling?**
  - Ethanol almost 3x higher than gasoline
  - MIT study suggests 1 RON unit increase for every 3˚C additional cooling
- **Optimum blend likely 20-40% ethanol**
  - Non-linear benefit of higher octane vs. linear decrease in energy density



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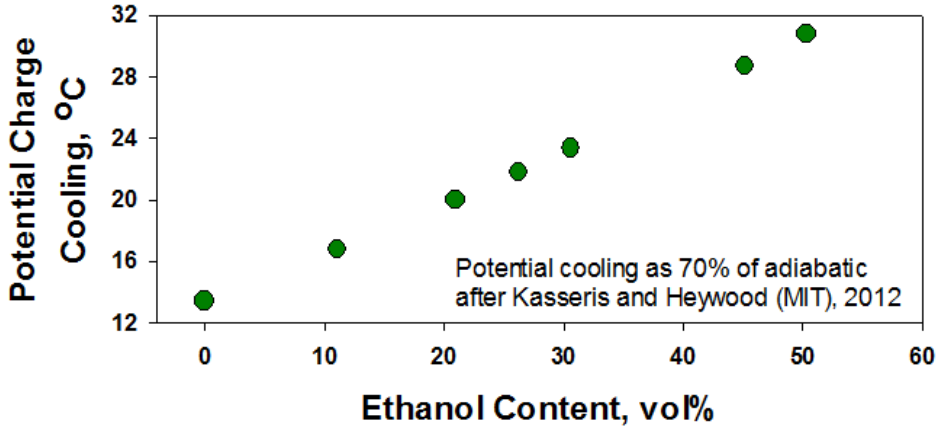


Large Challenges to New Fuel Introduction

- **EPA Requirements – Clean Air Act**
  - Emission Control Equipment Compatibility
  - Toxic Emissions and Health Effects
  - Registration
  - Misfueling Mitigation
- **Safety and Infrastructure Compatibility**
  - Prevention of Leaks
  - Fire Safety
  - Ground Water Protection
- **Engine Compatibility – Quality Standards**
  - New Vehicle Development/Deployment
  - Consumer Protection and State Fuel Quality Regulation
- **Coordinated investments in vehicles, biorefineries, and refueling infrastructure**

Joint National Lab Study

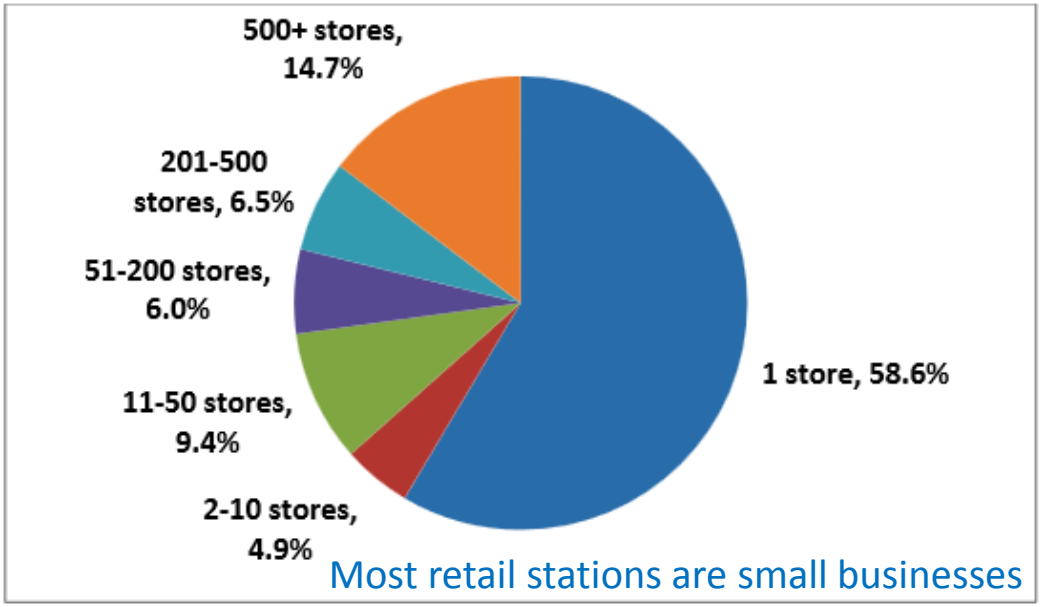
- **The potential benefits of high octane fuels (HOF) and optimized vehicles appear to be large – pump-to-wheels**
- **HOF may also create additional demand for ethanol with significant well-to-pump GHG benefits**

Three national laboratories have jointly been conducting a scoping study directed at:

- *Understanding hurdles*
- *Proposing resolutions*
- *Quantifying potential benefits*
- *Determining if additional R&D is warranted*

E20 to E40 Blends in Refueling Infrastructure

- **Most underground tanks are compatible with any ethanol blend**
- **Potential issue: refueling stations are not required to keep equipment records - a challenge to determine compatibility**
  - But can be determined by an experienced inspector
- **Fuel dispensers would have to be upgraded:**
  - Current E10 dispensers can be retrofitted to E25
  - For higher blends an E85 dispenser is required (more expensive)



Most retail stations are small businesses

Estimate that ~ 20% of stations have to carry new fuel for it to be considered convenient