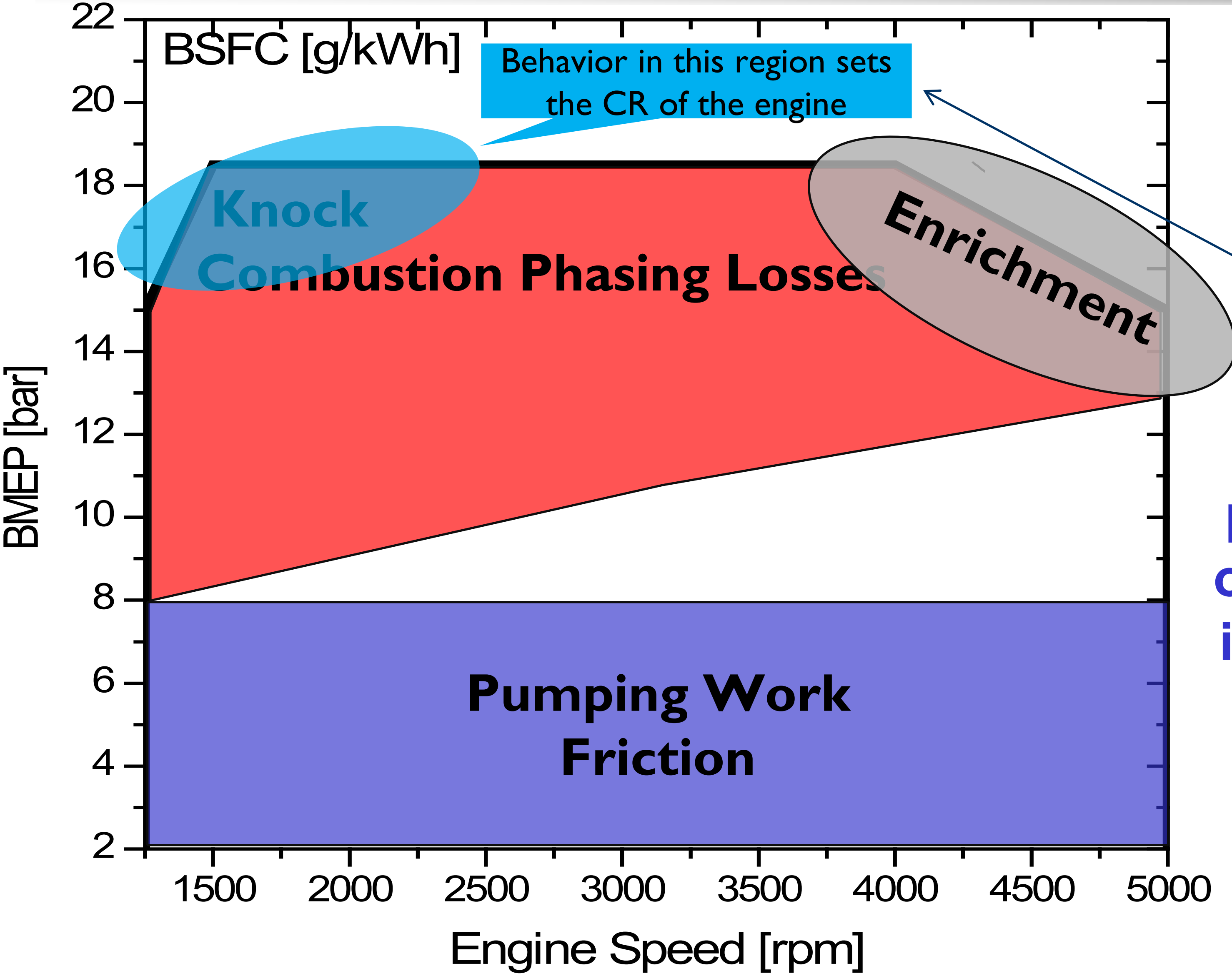
Low Reactivity SI Engine Lubricant Program

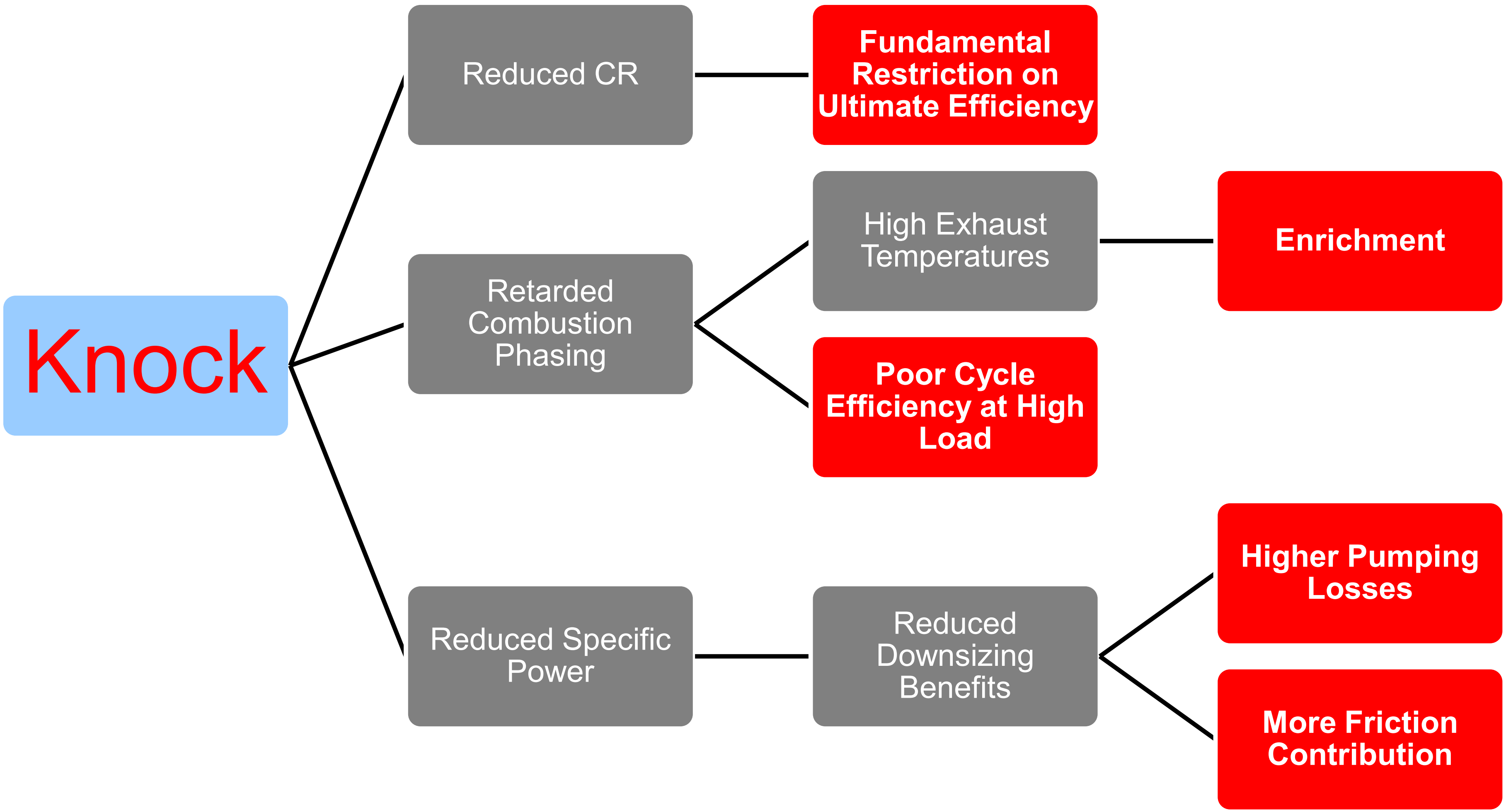
Southwest Research Institute

Barriers to High Efficiency Operation

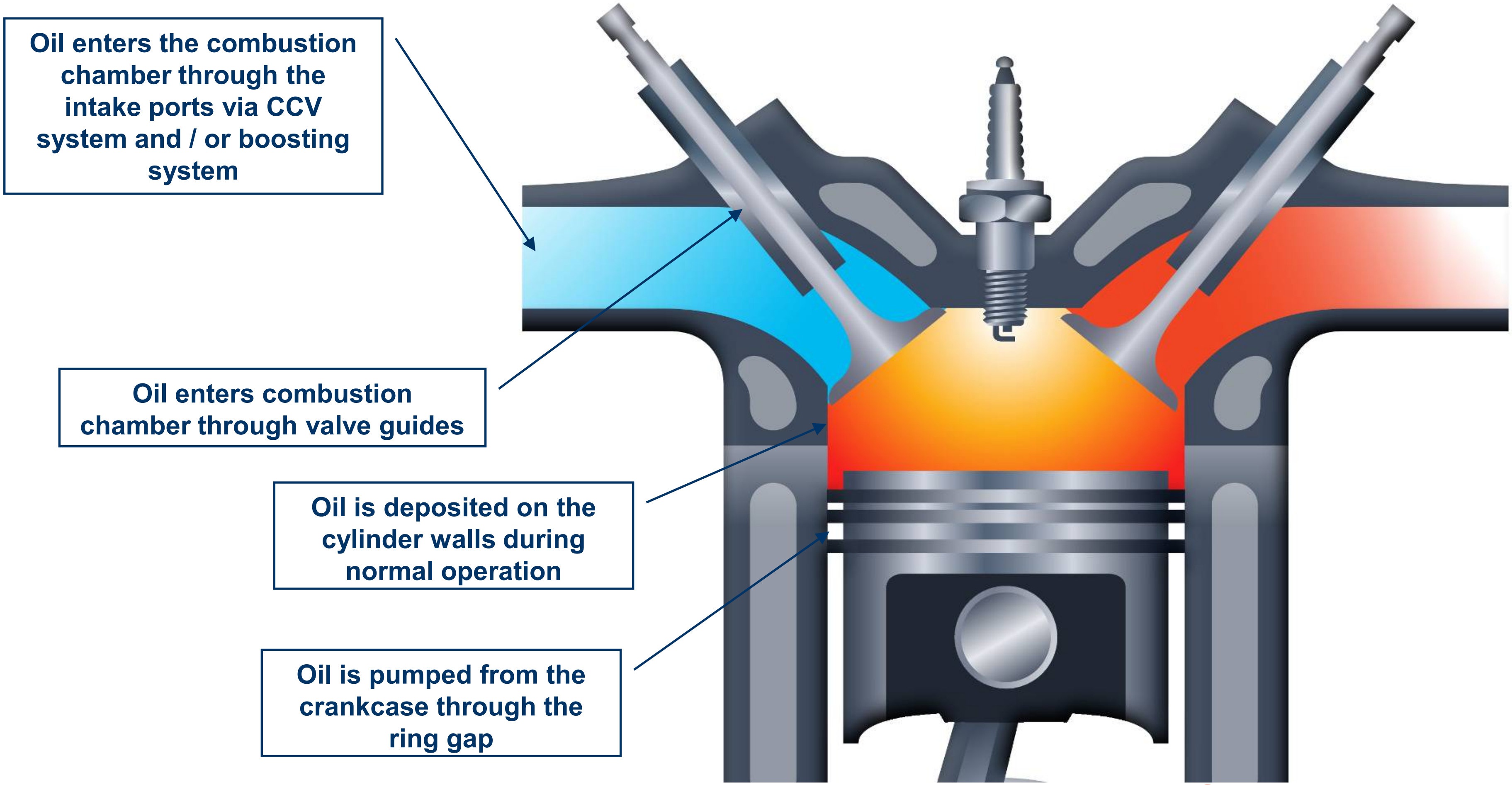


Knock is the prime source of inefficiency in SI engines!

Adverse Effects on Efficiency from Knock



The role of lubricant in engine knock



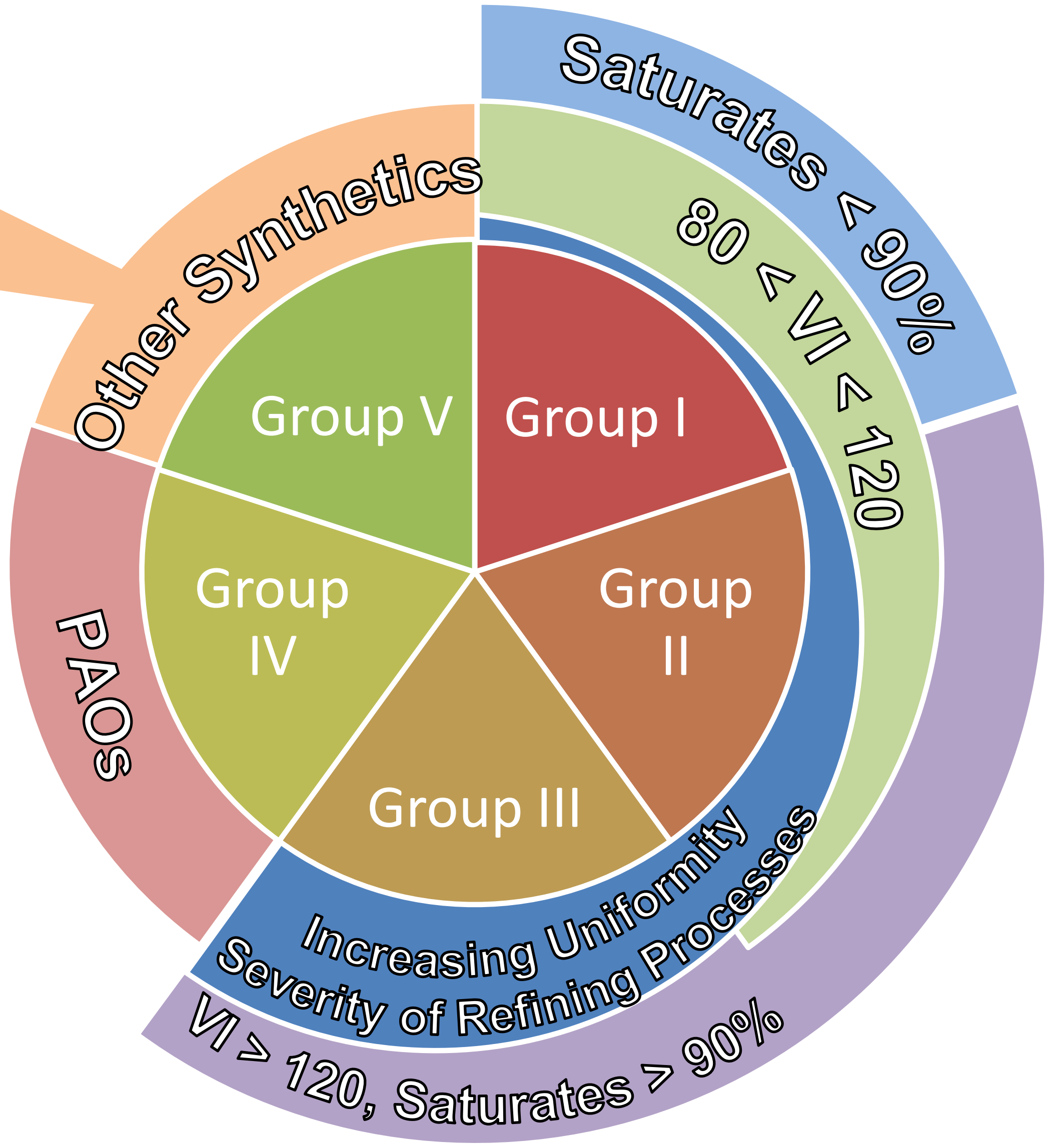
Lubricant is much more reactive than diesel fuel and will vaporize and auto-ignite at compression temperatures

What lubricant properties are important?

- Base stock
  - Molecular structure
  - Volatility
  - Surface tension
    - Droplet release and evaporation
- Additive package
  - Effects volatility and surface tension
  - Molecular structure may be important
- Initial investigations will focus on the molecular structure of the base stock
  - Largest component
  - Most likely to have large effect on CN

Base Stock Selection

Silicones
Polyisobutene
Esters
Polyalkylene glycol
Phosphate ester
Alkylated naphthalene

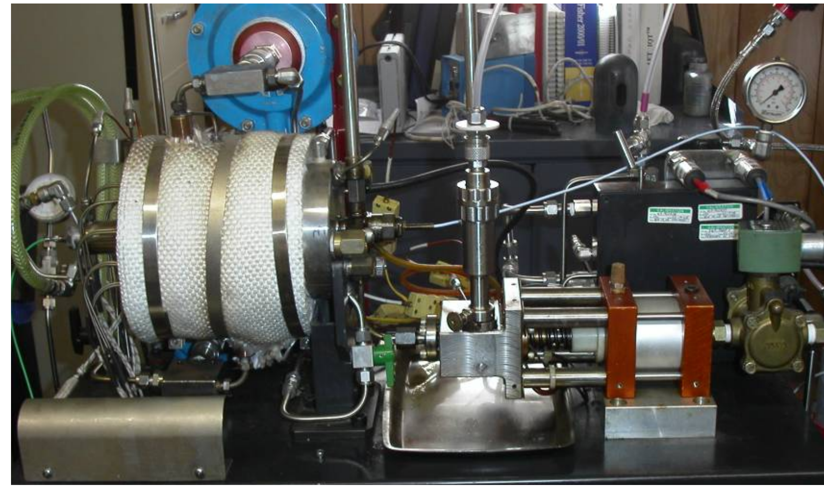


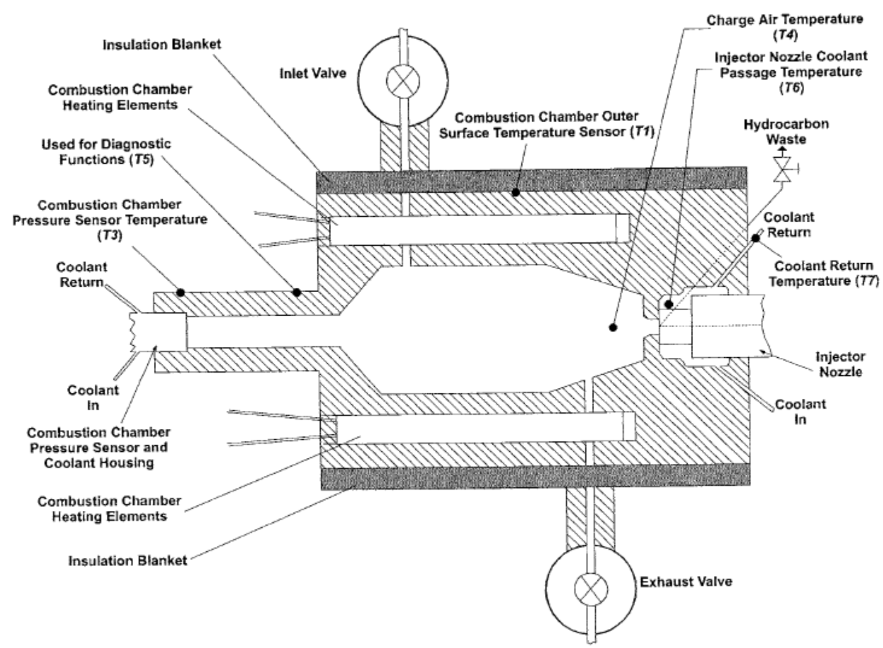
SwRI Initial Investigations

- An internal SwRI project was initiated to investigate oil reactivity and its affect on knock
- Work plan had two tasks
  - Benchtop Testing
  - Engine Testing
- Project objectives
  - Study oil base stock affect on reactivity
  - Investigate oil reactivity affects on knock

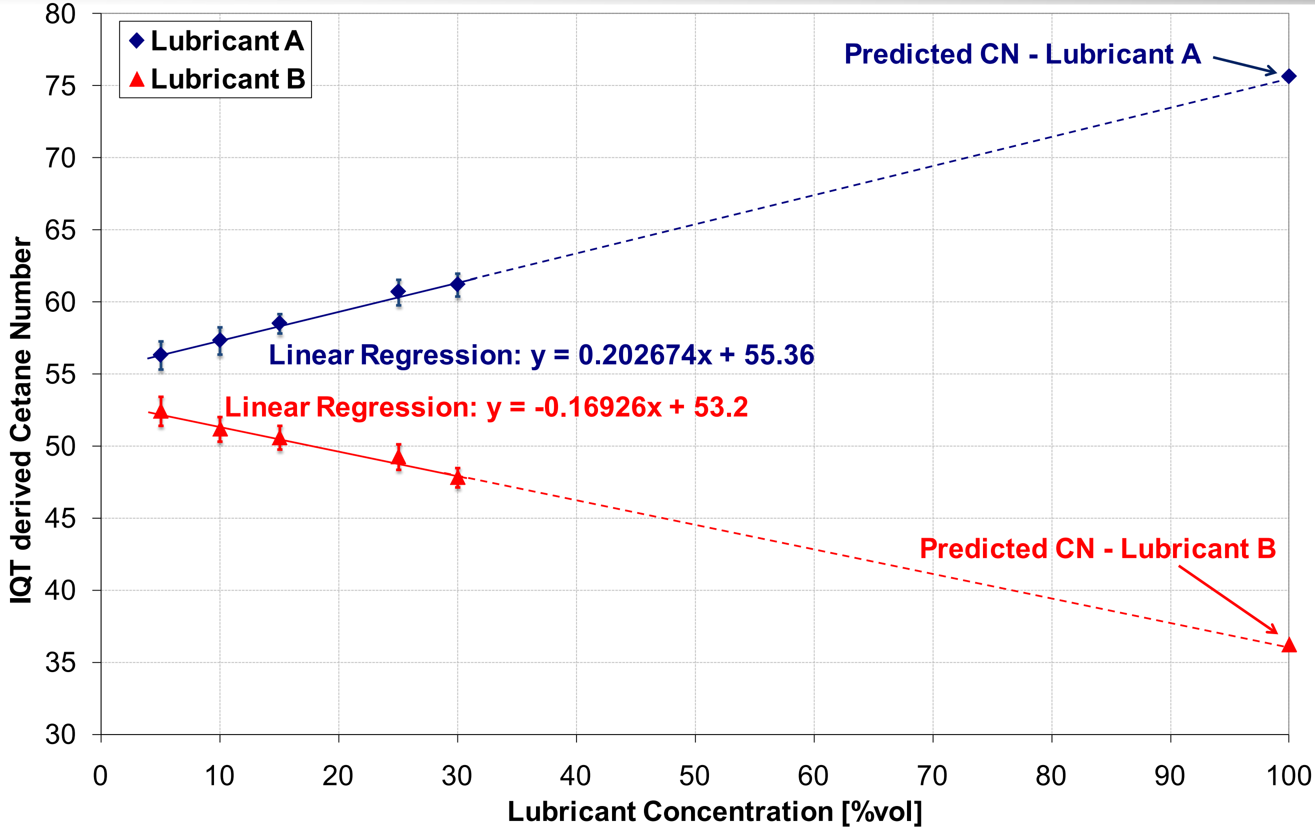
Benchtop Investigations

- Oil reactivity investigated using an Ignition Quality Tester (IQT)
  - ➢ Measures derived CN / ignition delay
  - ➢ Test conditions
    - Initial Pressure : 21.4 bar
    - Initial Temperature : 550°C
    - Peak Initial Temperature : 600°C





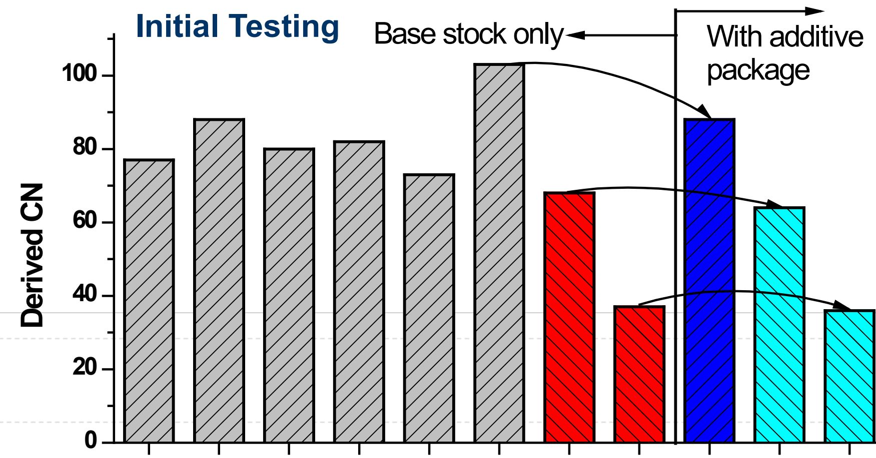
CN testing with solvent

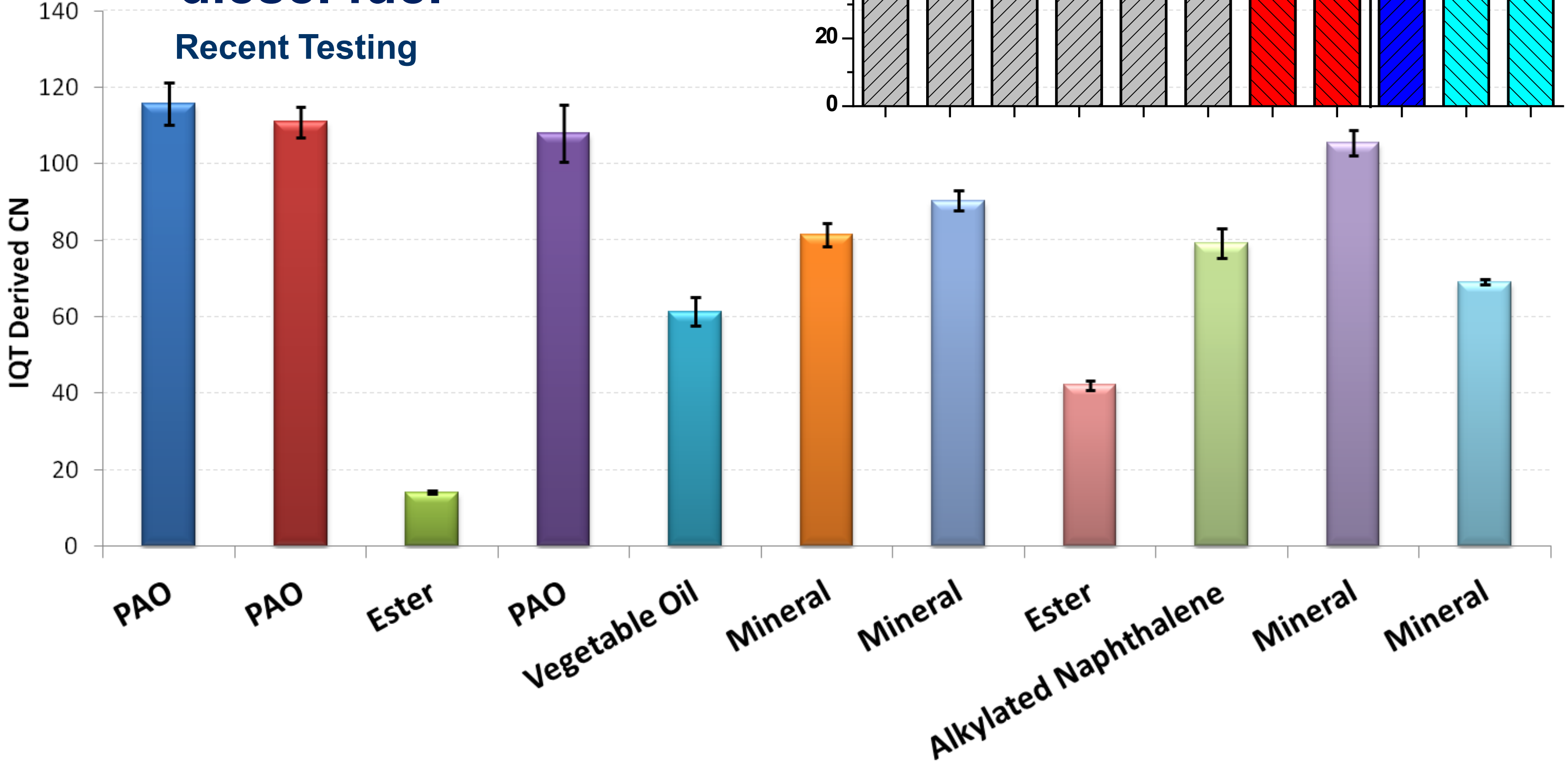


- To reduce the effect of oil viscosity and atomization, SwRI used a solvent
  - Extrapolate to 100% oil

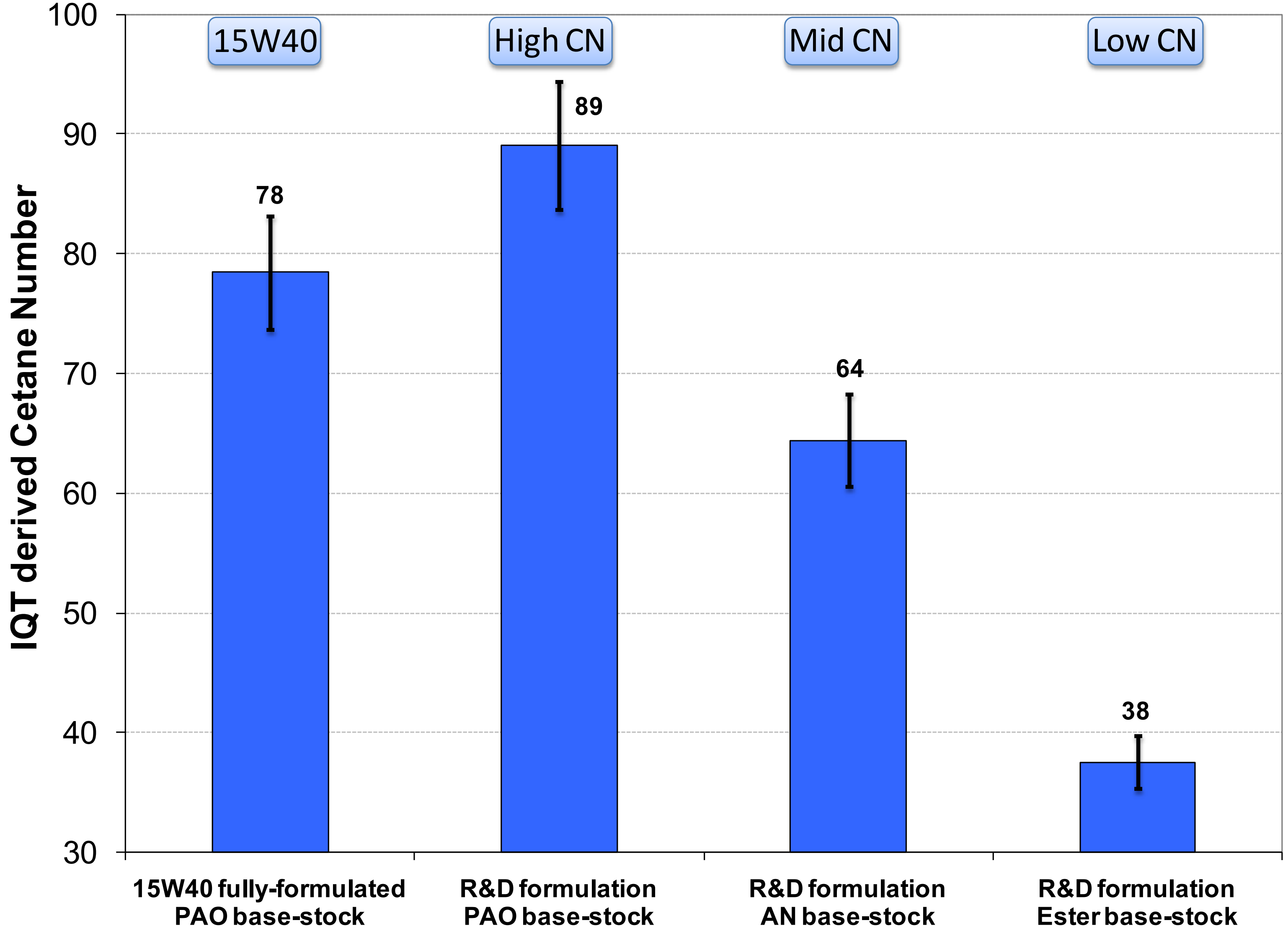
IQT Testing for Reactivity

- **Modern base stocks have very high CN numbers**
  - > 2x the reactivity of diesel fuel



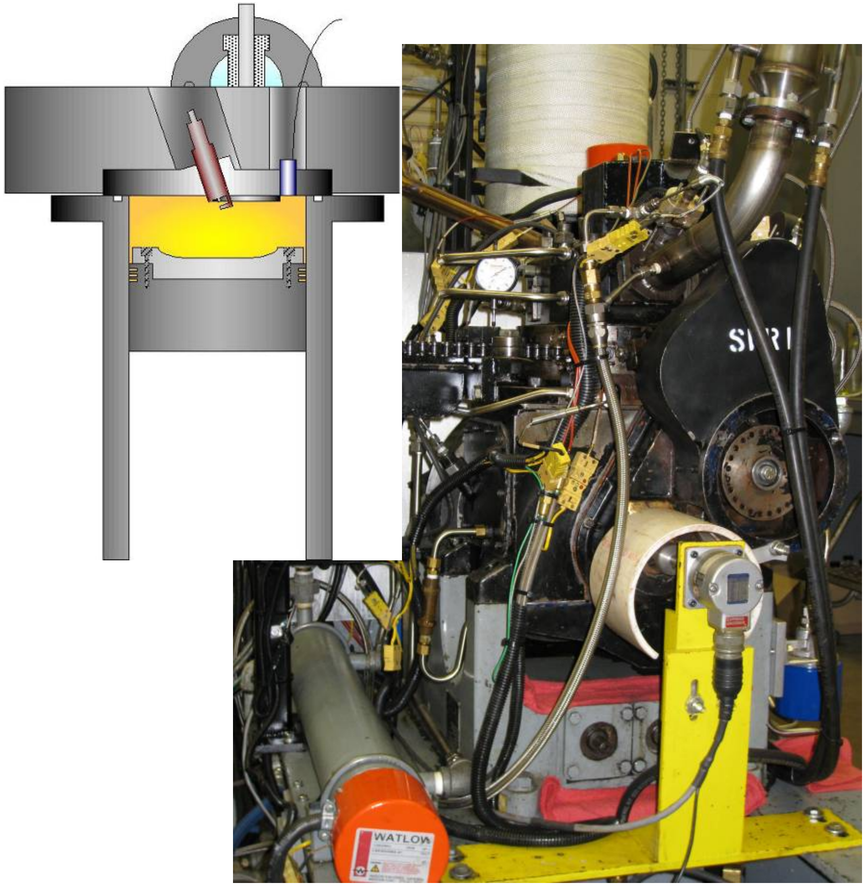


Lubricants Prepared for Engine Testing

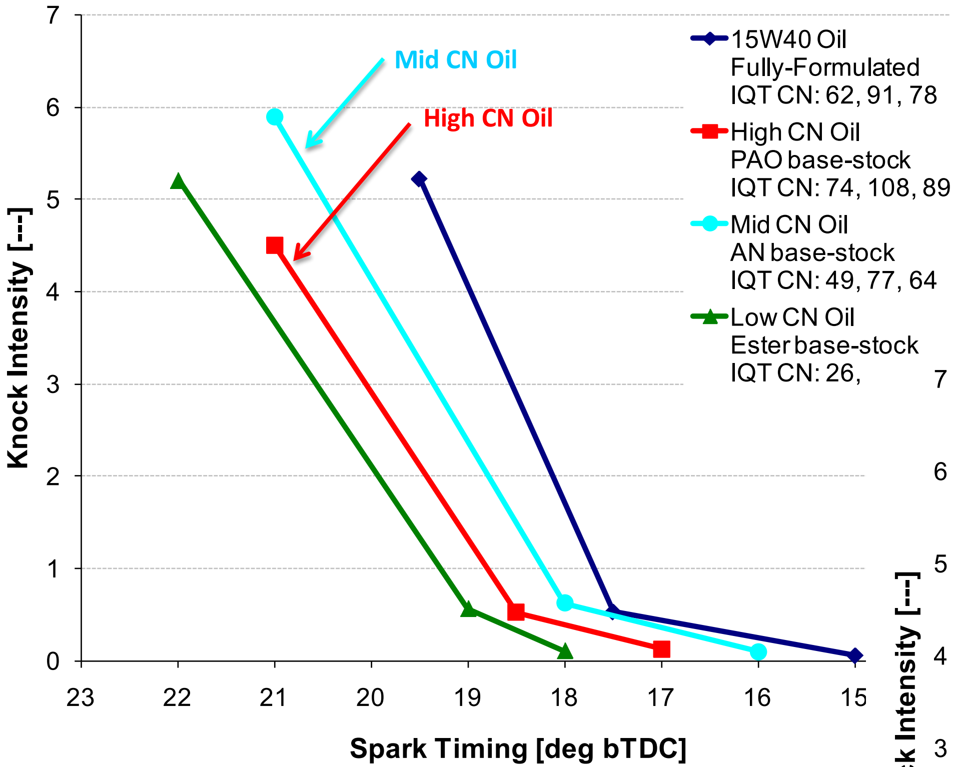


Engine Testing

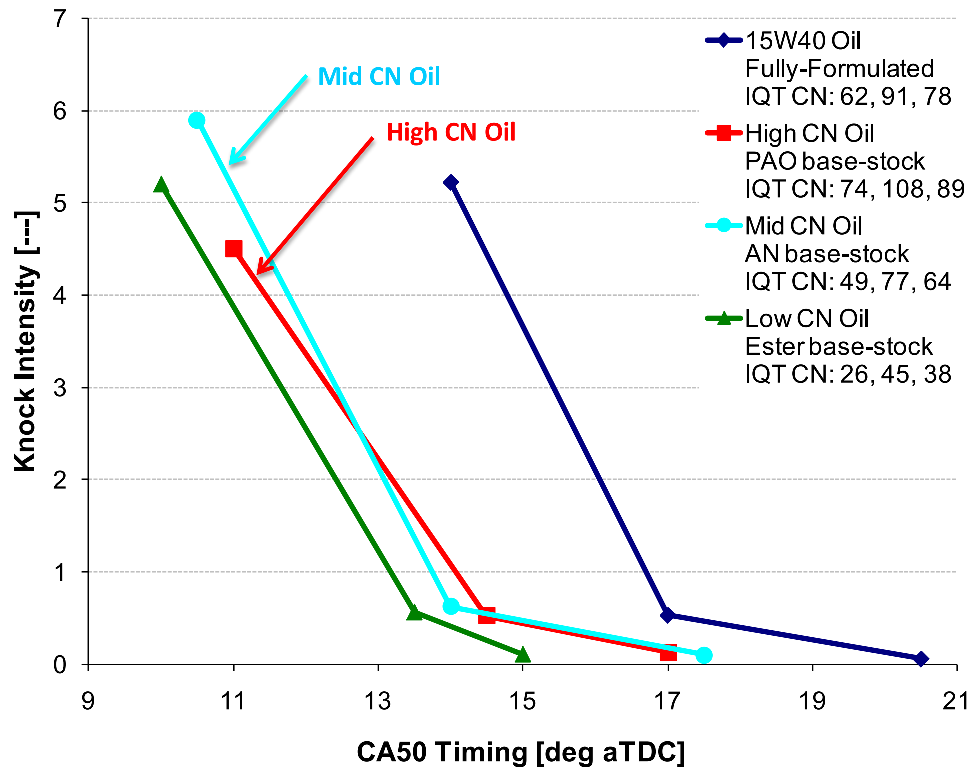
- **Initial testing performed on SwRI VCR engine**
  - ➢ **Combustion chamber based on diesel**
    - Slow-burn chamber
- **4 fully formulated fuels selected for testing**
- **Testing performed at three knock levels**
  - ➢ **Incipient (knock intensity < 0.2%)**
  - ➢ **Moderate (knock intensity of 5%)**
  - ➢ **Heavy (knock intensity of 10%)**



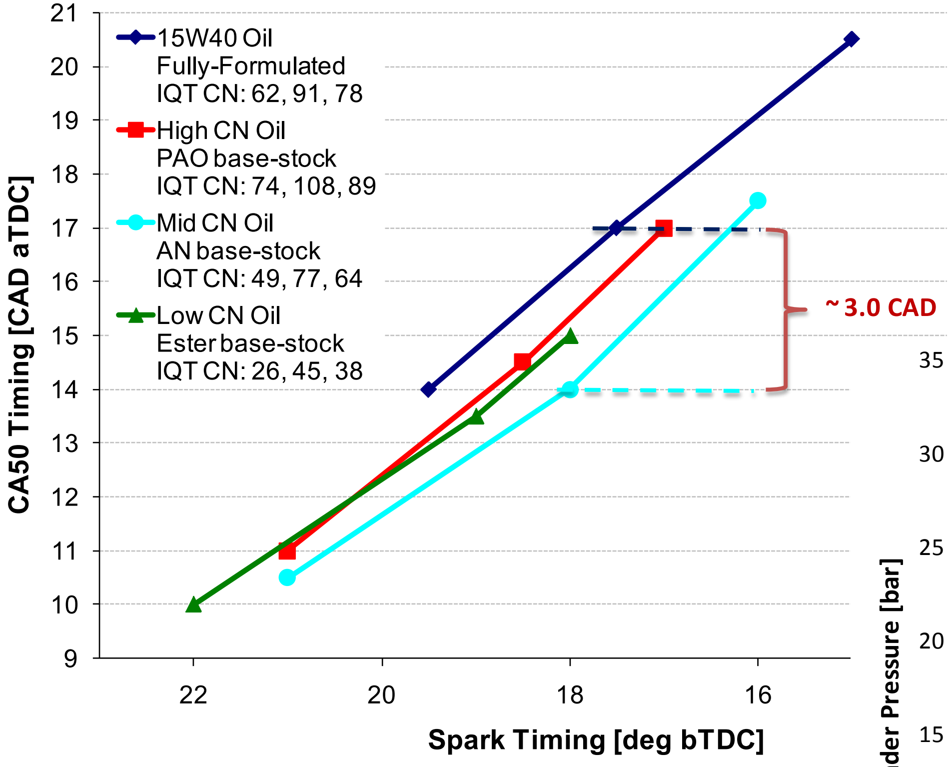
Lubricant Effect on KLSA and CA50



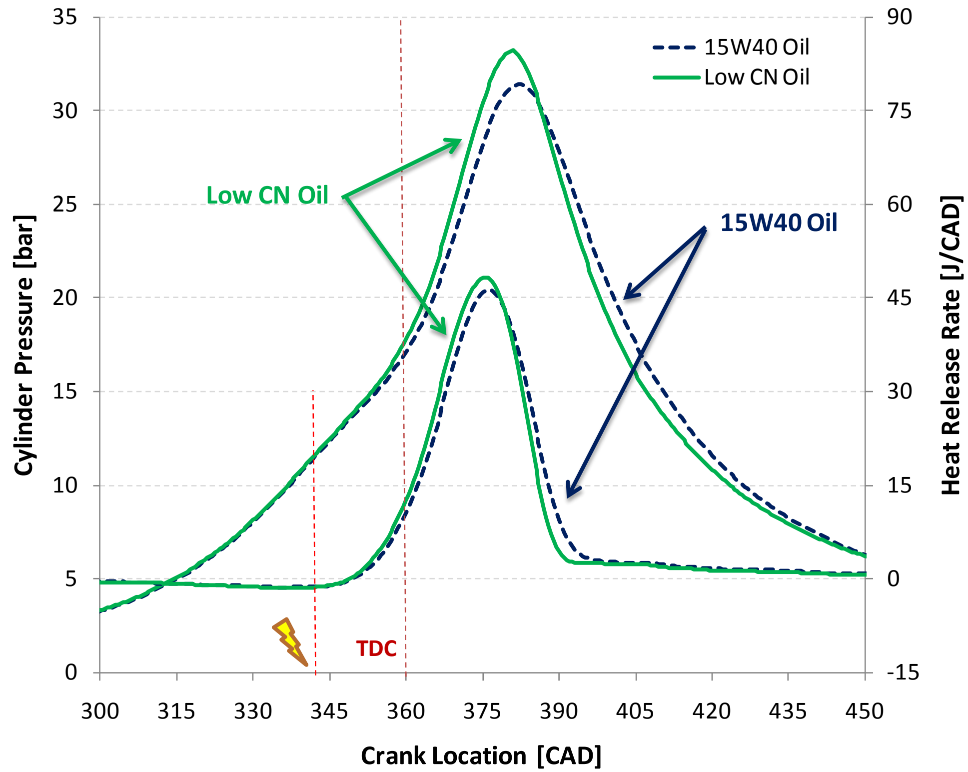
Lubricant not only has an effect on knock limited spark timing but also on combustion phasing (CA50 timing)



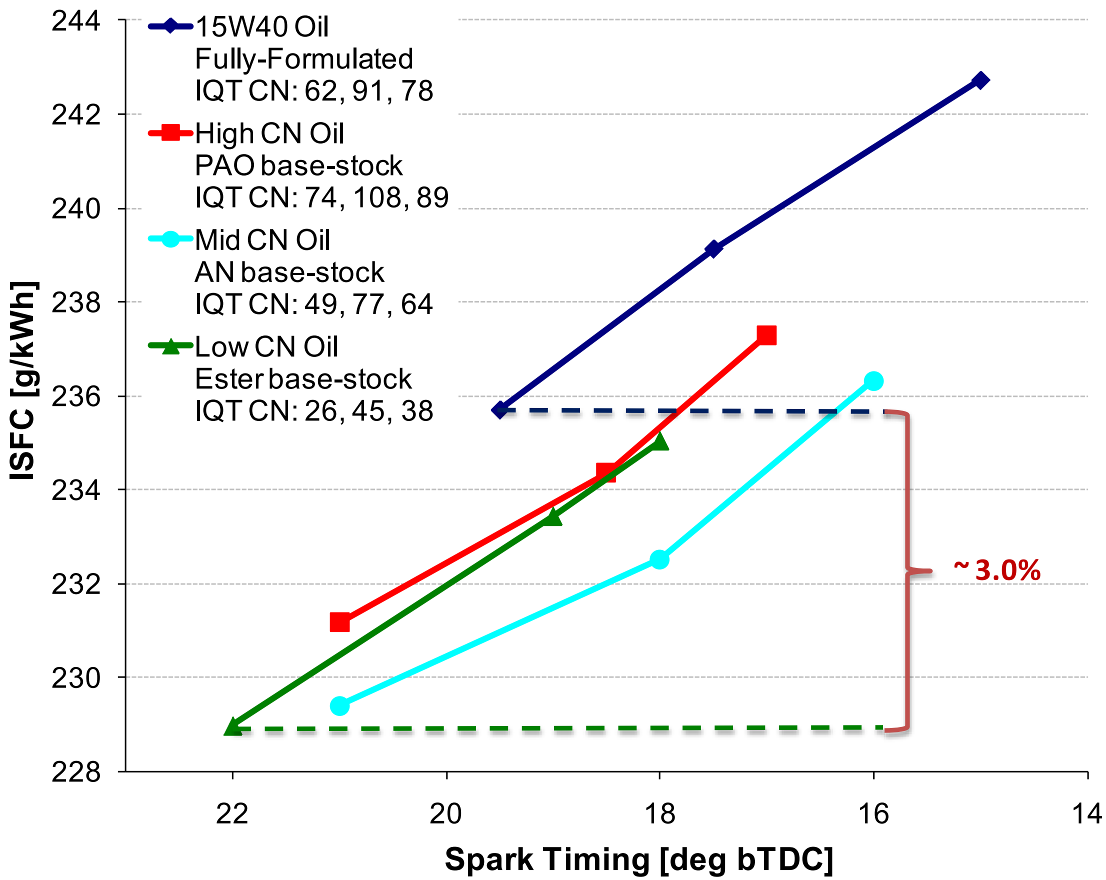
Lubricant Based Combustion Effects



Lubricant effect on all parts of combustion not only end-gas region.

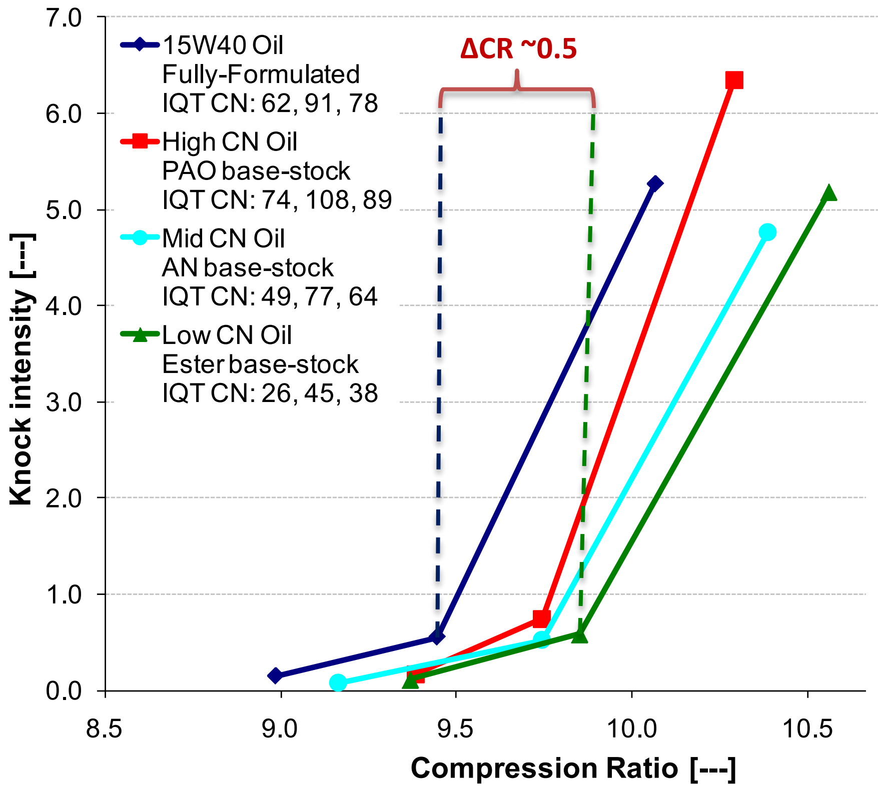


Fuel Economy

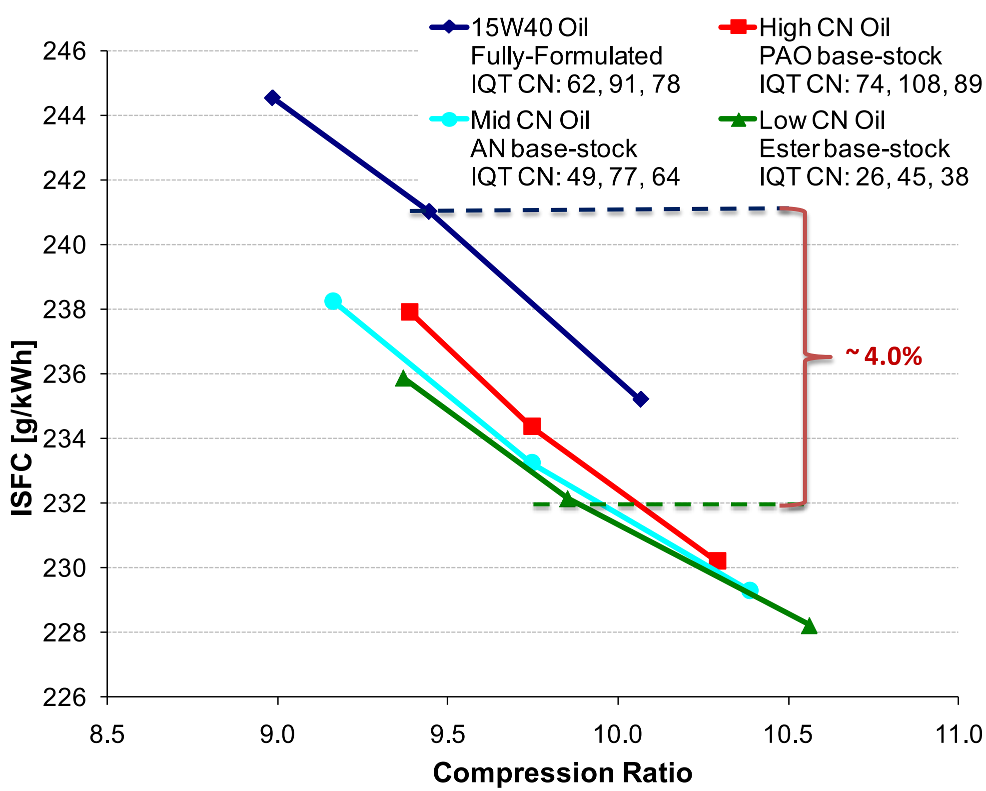


- Using single-cylinder VCR engine, at 1200rpm – 7.0bar nIMEP, a fuel economy improvement of ~3.0% could be realized
- Spark timing advanced from no knock to KLSA

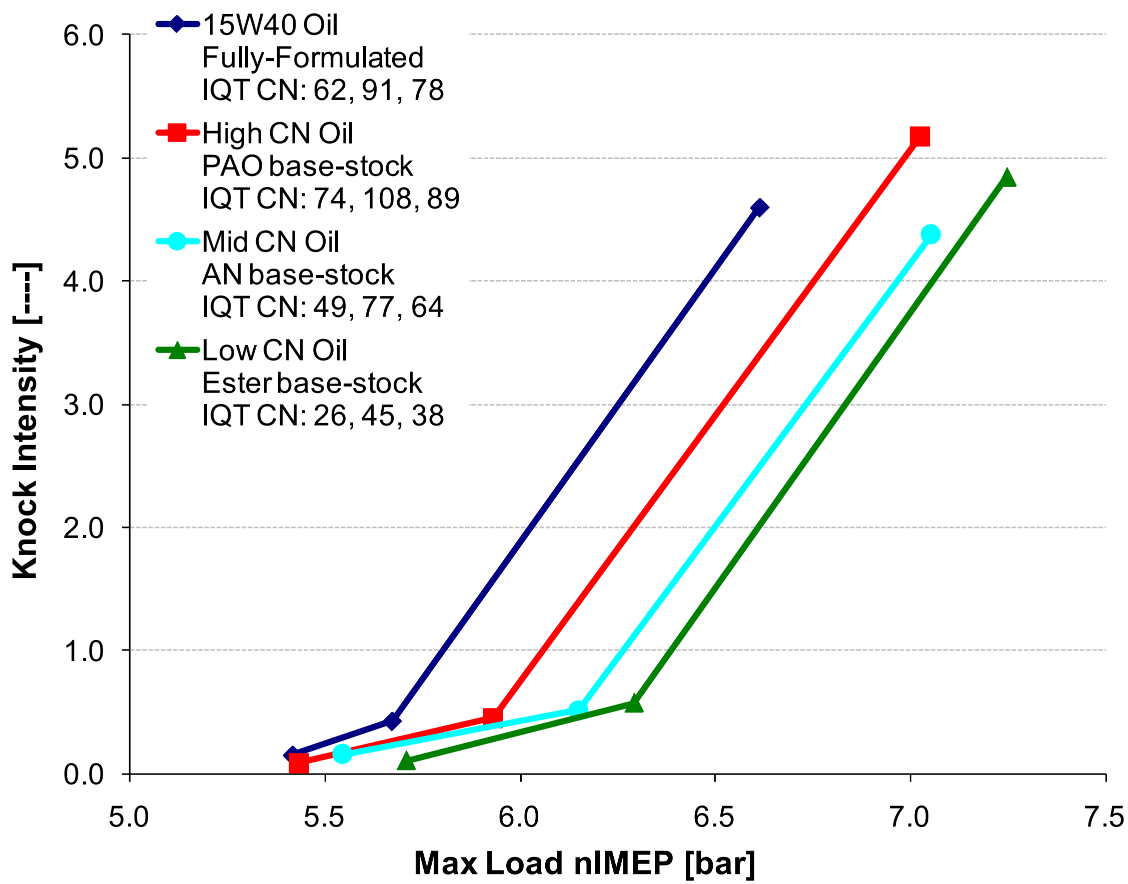
Knock Limited CR at Fixed Combustion Phasing



- Low reactivity lubricant allowed increase in compression ratio
- Fuel economy improvement of ~4% could be observed



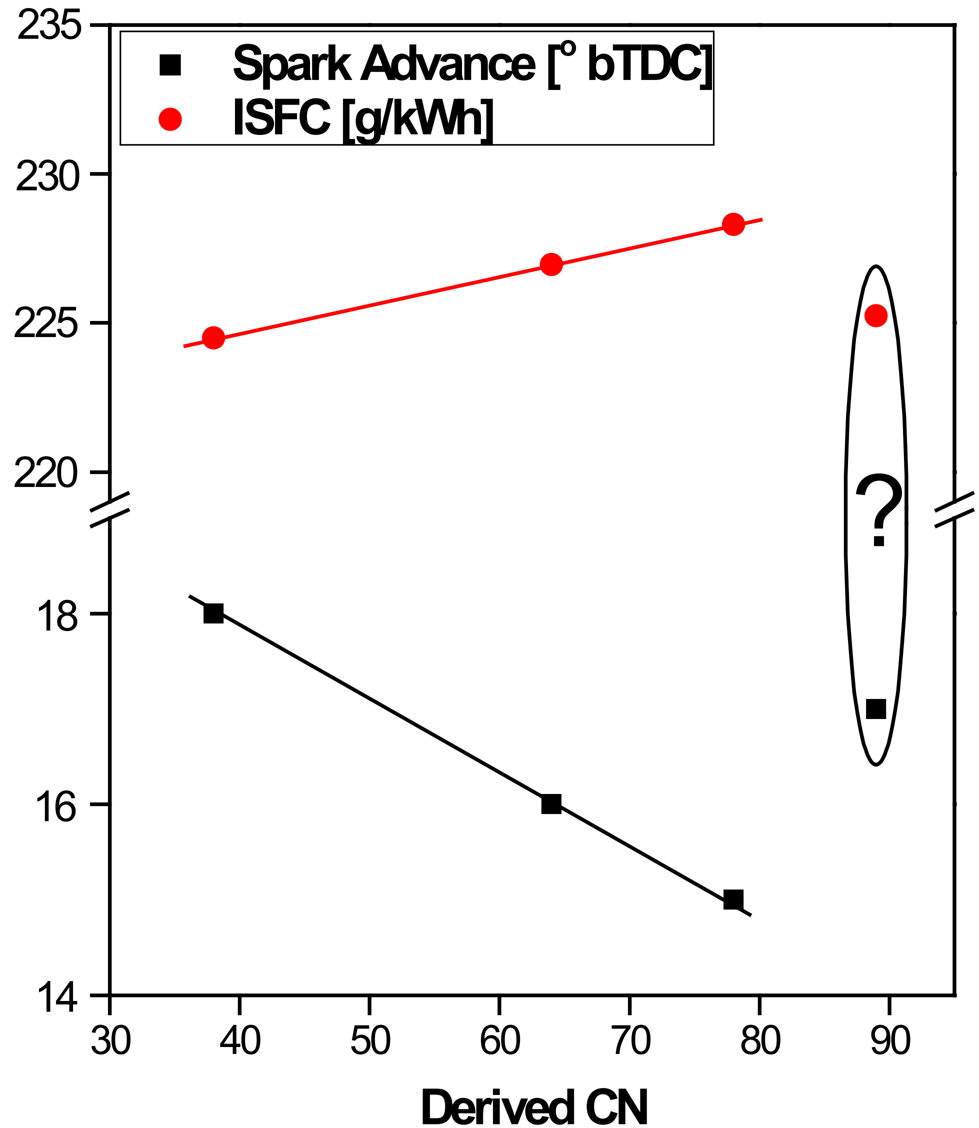
Max Load at MBT Timing



- Using low-reactivity lubricant, higher engine loads at MBT combustion phasing could be achieved
- Advanced formula lubricant may increase downsizing potential

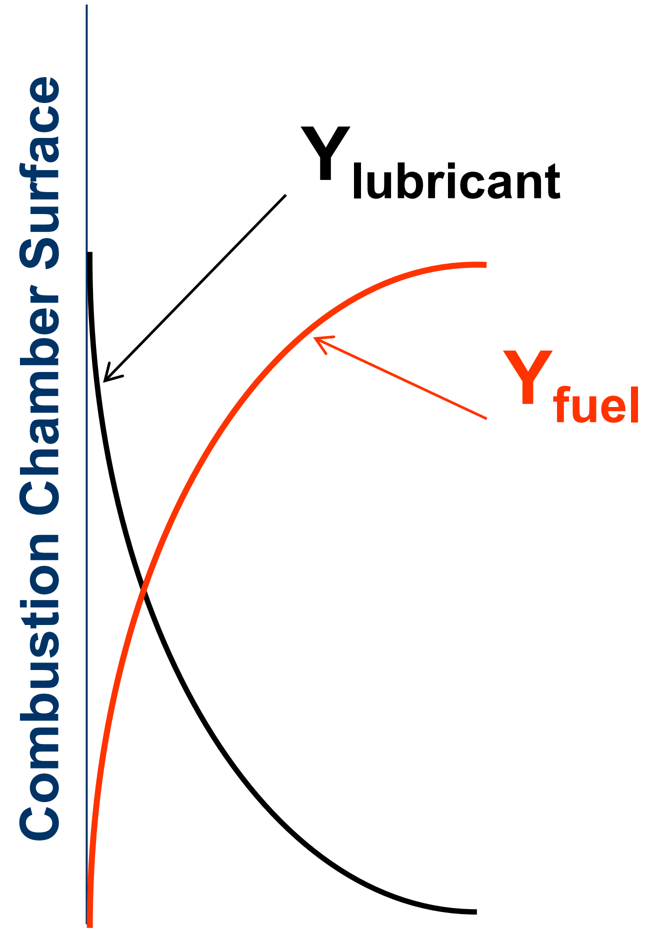
Relationship between CN, Spark Advance and ISFC

- **Very high CN oil is an outlier**
  - ➢ **Other properties may dominate its performance**
    - Volatility
    - Surface tension
  - ➢ **Indicates a need for further refinement of the method**
- **Mechanism for improvement**
  - ➢ **Less knock = more advance permitted = lower fuel consumption**



Effect of Oil Consumption

- Modern engines have low oil consumption
- Tests of oil introduced into the intake or mixed with the fuel indicate a large amount of oil is required to effect combustion
- However, distribution of oil and fuel is NOT homogeneous
  - Very high oil levels near wall
  - Outside the boundary layer, oil levels are significantly lower



Conclusions

- **Initial results indicate that typical commercial lubricants have high reactivity**
- **SwRI identified alternate base stocks that appear to have reduced the reactivity of the lubricant**
  - **Lower reactivity lubricants appear to have a beneficial effect on spark knock**
- **Additives appear to effect the oil reactivity**
  - **Individual component contribution currently unknown**
  - **Potential exists to identify low reactivity components**
- **Utilization of low reactivity lubricants appears to have a potentially significant fuel consumption benefit**
  - **Other properties may play a role**
    - Volatility
    - Viscosity
    - Surface Tension
    - etc.…

SwRI's New Internal Research Program

- **The objective of this project is to investigate lubricant effects on knock in a high performance engine**
  - **Engine lubricant properties will be tested**
    - Physical and chemical properties
  - **Selected base stocks will be examined in the Ignition Quality tester (IQT)**
    - Further refinements to this specialized test procedure will be conducted
  - **Some testing will be conducted in a constant volume combustion chamber**
    - Test method will be developed to test engine oil film / combustion interaction
- **Final versions of the lubricants will be tested in a modern, boosted GDI engine application**