ENGINE DESIGN AND LUBRICATION
A PARTNERSHIP FOR THE FUTURE

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AGENDA

HISTORICAL PARTNERSHIP

FUTURE TRENDS

ENGINES AND LUBRICATION

SUMMARY
HISTORICAL PARTNERSHIP
HISTORICAL PARTNERSHIP

The Automotive and Petroleum Industry have been partners in the most successful customer innovation in modern history, the automobile.

Ford Model T
Smithsonian Institution

Henry Ford, Billy Durant, Louis Chevrolet, Henry Leyland, Dodge Brothers, Fisher Brothers, Walter P. Chrysler, Ransom E. Olds…

John D Rockefeller
Edwin Drake, George Bissell, “Dad” Joiner, Anthony Lucas, Henry Flagler, Stephen Harkness, John Archbold

Karl Benz, 1886 (Germany)
Charles and Frank Duryea, 1893 (USA)

James Williams, Oil Springs, ON, 1858
Edwin Drake, Titusville, PA, 1859
HISTORICAL PARTNERSHIP

Keys to This Amazing Success

- Met an essential need – personal transportation
- Economic value – total cost of ownership
  - No hay, no barns, no clean up!
- QRD and Performance
  - OK, the first automobiles were not all that good ...
  - ... however, horses aren’t that easy, either! (flies!)
  - Customers made the choice

- *Every automobile had an engine ... every engine had oil!*
THE CUSTOMERS VOTED, THE HORSE DID NOT WIN!

- This Auto – Oil partnership began a transformation that changed the American economy forever
  - Roads
  - Infrastructure
  - Gas stations
  - Retail
  - Medical
  - Education
  - ... and on and on ...

Freedom of Mobility! ...
Now flash forward 110 years

- 254M registered light duty vehicles in USA
  (2009 US Bureau of Transportation Statistics)
FUTURE TRENDS
FUTURE TRENDS

1. Globalization

- The industry’s growth in new and emerging markets has impacted automotive engineering and development
  - Regional needs must be considered
    - Fuel, driving habits, roads, economics, etc.
  - ... however, engineering and development costs must be shared across regions to be economically viable

Source: OICA
FUTURE TRENDS

2. Regulation

- The need for greater fuel economy is driven by economics, environment, and government regulation
  - Regional laws and regulations converging around the world

- Emissions are also highly regulated
  - HC, CO, NOx, NMOG, Particulates
FUTURE TRENDS

3. Customer Changes

- The average age of the US Automotive fleet increased from 9.6 years in 2002 to 11.4 years in 2013 (IHS Polk)
  - Durability expectations
  - Lubrication/Maintenance

- Average age of drivers in USA is also changing (U of M, TRI)
  - Fewer young drivers
  - More older drivers
  - Short trips?

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<th>Licensed Drivers as a % of Age Group</th>
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Source: University of Michigan Transportation Research Institute, 2011
FUTURE TRENDS

Strategies to Address these Trends

Alternative Fuels
- Ethanol, Methanol, CNG, LPG, Hydrogen Fuel Cells

Electrification
- RVC, Start/Stop, Mild Hybrid, Full Hybrid, EREV, BEV

Diesel
- Light Duty market penetration

Traditional Automobile Efficiency Improvements
- Efficient Fundamentals
**FUTURE TRENDS**

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*Traditional Automobile Efficiency Improvements*
- Efficient Fundamentals
ENGINES AND LUBRICATION
What the Customer Paid for

What the Customer wanted.

35% - 40% Energy into Piston

60% - 65% Exhaust & Coolant heat

25% Crank Output

10% Engine Pumping & Friction

18% Wheel Torque

7% Trans & Final Drive Friction

Aero – 6%
Tires – 5%
Kinetic – 4%
Other – 3%
**ENGINES AND LUBRICATION**

*Automobile Efficiency Improvements – Focus Areas*

Mass improvements
- F150, Corvette, VW XL1

Aero improvements
- $C_d = 0.40, 0.30, 0.20, 0.18$

Friction/Rolling Resistance

Powertrain Improvements
- *Engines and Lubrication*

Everything comes at a price... Tradeoffs must be made.
Engine Focus Areas

35% - 40% Energy into Piston

25% Crank Output

18% Wheel Torque

Aero – 6%
Tires – 5%
Kinetic – 4%
Other – 3%

60% - 65% Exhaust & Coolant heat

10% Engine Pumping & Friction

7% Trans & Final Drive Friction

What the Customer Paid for

What the Customer wanted.

Percentages vary, these are typical numbers Used for example discussion only.
ENGINE AND LUBRICATION

Point Solutions are NOT Acceptable, Design must be robust to all driving conditions

Altitude
- 0 - 4300 m (14,000 ft.)

Temperature
- -40°C to 50°C (120°F)

Traffic conditions
- Long delays to “wide open”

Fuel
- 87 to 93 octane

Load
- Trailering?

Driver
- Aggressive? Short trips?

Oil
- End of life or new? Low?

The customer expects the car to perform under all of these various conditions!

Design Robustness - Bandwidth
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Some Engine Design changes targeting efficiency improvements that do not *directly* impact lubrication ...

CFD and Combustion Optimization
Cylinder De-Activation, Active Fuel Management
Packaging
Component Mass Reduction
Aftertreatment
Transmission speeds
... etc.

I want to focus on the engine changes that WILL impact lubrication!

Active Fuel Management, V8 – V4
Turbocharging and/or supercharging is a growing trend in engine design

- Downsize Boosting
- Mass Reduction
- Results in higher temperature profile duty cycles & soaks
- Can lead to Stochastic Pre-Ignition (SPI)
- Significant influence on oil specifications
Direct Injection

High Pressure Direct Injection of Gasoline into the combustion chamber

- Power and efficiency improvements
- Fast Response with optimal fueling
- Wall wetting and fuel dilution impact on lubrication
- Crankcase ventilation and intake cleanliness

1950 Chevrolet carburetor

2014 Central Direct Injection

2014 Side Direct Injection
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Valvetrain

Cam phasing and valve lift
- Every engine manufacturer pursuing
- Significant part of combustion improvement and pumping losses
- Lubrication demands of high speed, high load sliding components
- Use of engine oil as a “working hydraulic fluid”, ie reduced oil aeration
- Reduced pumping losses makes crankcase ventilation and fuel purge more difficult
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Friction Reduction

Major area of engine design
- Parasitic losses, “silent killer”
- Particularly significant on small engines
  - Measured as Friction Mean Effective Pressure, FMEP
- Bearings, liners, rings, crank offsets, all are included in this design space
- Decreased viscosity of oil
- Low Temperature viscosity reduction
ENGINES AND LUBRICATION
Temperatures & Thermal Mgmt

Major area of engine design
- Underhood Packaging and Air Flow
- Thermal Management and heat rejection
- Downsize Boosting and Turbocharging
- Some tendency for localized higher temperatures, above 150°C
- Smaller sump volumes
- Significant increase in duty cycle and “time at temperature”
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Start/Stop

New development for US Market, very common in Europe
- From ~50k to ~350k starting events
  - Can go even higher with coasting events
- Reduced fuel usage at stop/idle events
- More time in boundary lubrication
- Reduced pumping and friction are key
- Requires oil “pump ability”, reduced aeration, and sliding friction enhancements
ENGINES AND LUBRICATION

Engine Oil – the KEY ingredient to Engine Efficiency

One of the earliest design decisions made in engine architecture development

- What oil are we using?

Highly engineered component, very long lead times

Service implications to customer over the life of the vehicle

- Impacts total cost of ownership, unique among engine design solutions
- Recommended oil drain intervals would not change ~20 Oil Changes over vehicle life!

Key role in engine efficiency improvements

- Aeration
- Ventilation
- Liner/Ring interface
- Pumping
- Friction
- Temperature
- SPI
- Start/Stop
- Fuel/Water dilution
ENGINES AND LUBRICATION

Desired future state of Oil and Automotive Partnership

It is all about “Systems Engineering”
- A turbo by itself just adds mass and cost...however, when combined with downsize boosting and direct injection it can dramatically reduce total mass and improve efficiency.

The company that puts the best system combination together, as perceived by the customer, will win in the marketplace.

Engine oil is a key enabler for many of these new technologies
- Turbos – temperature and duty cycle
- Direct Injection – fuel dilution, ventilation, ring/liner/oil interface
- Start/Stop – friction, pumping
- Valvetrain – aeration, friction
- Bearings – friction ... etc.

Tomorrow’s engine oil will help meet these challenges!
OEM’s Develop 1st Oil Tests

Model Year Warranty Approved

API SA

API SB

API SC

API SD

API SE

API SF

API SG

1st True S-Category

OEM’s Dissatisfied: ILSAC Created

Additional Tests Added

First Global GM Engine Oil Specification

ILSAC GF-1 (API SH)

ILSAC GF-2 (API SJ)

ILSAC GF-3 (API SL)

ILSAC GF-4 (API SM)

ILSAC GF-5 (API SN)

ILSAC GF-(6A&B) (API SP)

1950 Chevrolet L6
105 Hp

Straight Mineral Oil

Inhibited Only

1964 - 1968 - 1972


1997 - 2001 - 2005

2012 - 2015 - 2017

2011 - 2014

Next Generation

2014 Chevrolet V8
(430 Hp)

1968

1972

1980

1989

1992

1997

2001

2005

2012

2015

2017

THE JOURNEY CONTINUES ...
SUMMARY

Historical Partnership continues

A journey that began over 110 years ago continues today

Regulation, environment, economics, and customer preferences continue to put pressure on the oil and auto industries to meet the new challenges

Engine oil will continue to play a key role in meeting these challenges

This is an exciting time to be in the industry!

Tomorrow’s Engines will use Tomorrow’s Oil!
THANK YOU!
QUESTIONS?
ACKNOWLEDGEMENTS
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Kevin Wong and Scott Miller – Efficient Fundamentals
Angela Willis
Eric Johnson
Dale Gerard
Coleman Jones
Mark Maher
Jim Tuttle
Dave Thompson
Matt Hamilton
Adam Kwiatkowski
Rick Balsley
GM Heritage Center Archives