

Use of Leaded Gasoline in Cars and Aircrafts: History, Facts, and Future Challenges

Fokion N. Egolfopoulos

Professor

Department of Aerospace & Mechanical Engineering

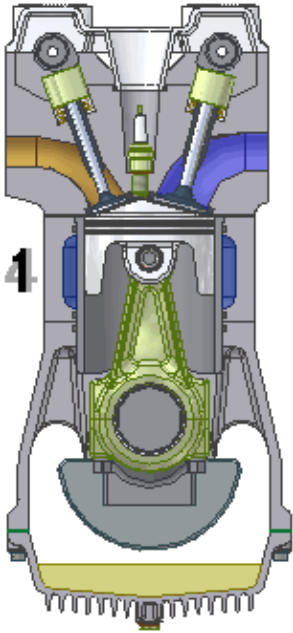
University of Southern California

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The Two Types of Internal Combustion Engine



Gasoline engine

Introduced by Nikolaus Otto in 1876

Low compression ratio ~10:1

Maximum pre-combustion pressure 8-14 bar

Light engines

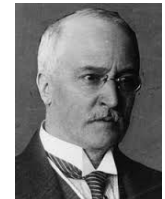
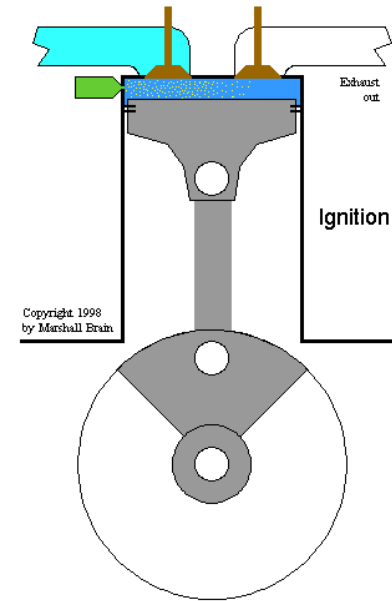
Light fuels, C₅-C₈

Clean burning

Efficiency 25-20%

Spark ignition (no cold start problem)

Engine knock is a major problem



Diesel engine

Introduced by Rudolph Diesel in 1893

High compression ratio ~20:1

Maximum pre-combustion pressure 40-50 bar

Heavy engines

Heavy fuels, C₁₂-C₁₆

Burning is not as clean

Efficiency 40% (up to 50% for large marine engines)

Compression ignition (cold start problem)

Engine knock is not a problem

- **Both engines are practically the same since their introduction in 120-130 years ago!**
- **There is no science and/or computers available to design an engine from first principle.**
- **Current engine designs are based on empiricism and experience.**
Not good enough!
- **Fuel plays a critical role in engine operation and performance.**
- **Again, current fuel design is based on empiricism and experience.**
Again, not good enough!

Brief History of Leaded Gasoline

- **Engine knock is a major problem for gasoline engines and its presence can be detrimental to the engine.**
- **Suppressing knock means that the fuel reactivity needs to be suppressed.**
- **In the 1920's, tetraethyl lead (TEL) with chemical formula $(\text{CH}_3\text{CH}_2)_4\text{Pb}$ was introduced as an “octane” booster.**
- **In the mid 1970's TEL was phased out in the US because of its neurotoxicity and its damaging effect on catalytic converters.**
- **Today, leaded fuel is a thing of the past, unless**
- **You fly a private plane!**

Leaded Fuel in Small Aircrafts

- **Gasoline, spark-ignition type of engines are used by ~75% of small aircrafts, based on small cost and weight, as well as using fuel that can survive altitudes.**
- **Leaded avgas emits a very small portion of lead once emitted by cars, but it affects people living close to 20,000 or so airports that is used – about 16 million people live with one kilometer and 3 million children attend schools in the same radius.**
- **Leaded avgas has been under the radar for a while as it is a niche market.**
- **Note: Lead is not needed in jet fuels as jet engines do not knock!**

Leaded Fuel in Small Aircrafts

- **Unleaded fuel can be used in piston aircraft engines but only for low performance operations.**
- **Unleaded fuel will knock at higher performance levels that are typically needed in aircrafts.**
- **Increasing performance means that the pressure in the engine can increase, which in turn favors knock directly.**
- **While increasing performance is not that critical for passenger cars, it is important for aircrafts that can fall out of the sky under severe or unpredictable conditions.**

Summary of Avgas Grades

- **Avgas 100: Standard high octane fuel with high lead content and it is dyed green.**
- **Avgas 100LL: Low lead version of Avgas 100, but there is still up to 0.56gm of lead per liter of fuel and it is dyed blue.**
- **Avgas 82 UL: Relatively new grade, unleaded, appropriate for low compression ratio engines and it is dyed purple.**

- **On June 10, 2013, FAA issued a request for candidate fuel producers to submit viable unleaded fuel formulations.**
- **Achieving that goal will not happen overnight and will not be easy.**
- **It will require extensive research in academia and industry, as the mechanisms that result in knock are still poorly understood**
- **Using additives such ethanol is not viable.**
- **Modifying the fuel composition and invent new additives may be part of the solution.**
- **The small size of the market does not create a great incentive either.**