

design news

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Thirty Year Quest for Lean Burn

References

1. Science and Technology, The spark plug that could save forests, *Economist*

2. Rebirth of lean-burn technology, DN, 11-3-97, <http://rbi.ims.ca/5709-536>

3. Lean Burn Lives, DN, 10.01.01, <http://rbi.ims.ca/5709-537>

Technical Referenes

1. SAE paper 890475, "A New Spark Ignition System for Lean ...",

2. SAE 2001-01-0548, *Advances in Combustion*, "High-Energy Spark-Flow Coupling in an IC Engine for Ultra-Lean and High EGR Mixtures"

3. GPC 2004 Proceedings, "High Efficiency Clean Combustion of Highly Dilute Mixtures in

Thirty Year Quest for Lean Burn

BIRTH, DEATH AND 'REBIRTH OF LEAN-BURN TECHNOLOGY'

LEAN-BURN TECHNOLOGY IS ALIVE

and well and can help the auto industry — if we let it. With lean burn used to its full extent, today's vehicles can improve fuel economy by 30 percent, identical to that of the direct-injection diesel. It could help us deal with government mandates on fuel economy — well before 2020.

It hasn't been that way for 25 years, since Chrysler and Honda first attempted lean burn in 1975. They achieved a lean air-fuel ratio (AFR) of 20:1 for better fuel economy, versus the normal 14.7:1 AFR. But, they were unable to burn lean enough to meet the EPA's standards for NOx.

Two other companies, Nissan and Ford, introduced the NAPS-Z and the PROCO around 1980, with two spark plugs per cylinder. They performed even better under dilute AFR conditions. They used exhaust gas recirculation (EGR) for very low NOx and obtained 60 percent of the gain in efficiency available with lean burn. Lean burn at light loads reduces pumping losses, heat transfer losses and increases Otto cycle efficiency. Despite their good results, both approaches were abandoned.

The three-way catalyst operates in a narrow range of 14.7:1 AFR, with oxidation of HC occurring above 15:1 and reduction of NOx occurring below 14.5:1. Under lean conditions, the catalyst cannot reduce NOx emissions. NOx peaks at 17:1 and falls off with leanness. An AFR of 25:1 is needed to satisfy EPA emission standards.

In 1977, CEI was formed to pursue lean burn. Initially, it pursued ignition aspects of lean burn and had its first success in 1986 on a Ford Escort at Lucas, England. Under conditions of 20, 35 and 50 percent load, it obtained 25, 17 and 10 percent gain in fuel efficiency at 24:1, 24:1 and 28:1 AFR, with negligible NOx — never seen before in a homogeneous charge engine, reported in the "Economist," July 5, 1986.

In 1987, CEI was invited to GM where it

ignited mixtures five AFRs leaner. In 1989, flow tunnel tests were conducted, but CEI was not shown the results. GM went no further despite the positive results.

Successful lean burn tests were also conducted at Mazda, but further ignition development was needed, especially in the one-coil-per-plug format.

Between 1990 and 1995, carmakers gave up on lean burn. California dictated the super-ultra-low emission standards to, in effect, kill lean burn and increase our dependence on imported oil.

Five years later, CEI finally received the flow-tunnel from GM. The results were astonishing. GM's HEI had a lean limit of 23:1 to 26:1 AFR. The CEI ignition gave, by comparison, 33:1 to 34:1 AFR, or a hard-to-believe eight AFRs gain. Flow-enhanced lean burn, contradicting Exxon's claim. Flow-coupling was seen to be the missing link in lean-burn technology.

Chrysler tested the CEI ignition on a four-cylinder engine and found it to be "an enabling technology for the lean-burn engines of the future," (<http://rbi.ims.ca/5709-536>). Three years later, CEI built a single-cylinder engine with two plugs and strong flow-coupling. The ignition was developed to deliver five times the energy with small coils. The engine results were, again, hard to believe. An air-fuel ratio was achieved above 30:1, never seen before, with an efficiency of the direct-injection diesel. Lean burn had been solved. See "Lean Burn Lives," (<http://rbi.ims.ca/5709-537>).

This year, a low-cost, high-efficiency, high-compression ratio lean-burn engine, similar to the May Fireball, was designed with a more than 40 percent gain in efficiency, with the promise of being the "Engine of the Future."

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