What’s Next?
An introduction to the
Sturman Digital Engine

Presented By:
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Woodland Park, CO
IN THIS PRESENTATION...

Digital Technology Platform

Digital Engine & Sturman Cycle

Digital Technology Platform

Camless Digital Engine
Digital Controls
Digital Hydraulic Valves
Digital Pneumatic Valves
Digital Pump
Digital Fuel Injection Systems
Digital Valves
Digital Actuators
Digital HVA Systems
Digital Regulator

Development Status
The Core Technology: STURMAN DIGITAL VALVE

45 Years of Experience

Space Foundation Hall of Fame
PERFORMANCE ENABLING
Extremely fast, small & intelligent

DIGITAL TECHNOLOGY PLATFORM

Camless Digital Engine

Digital Controls
Digital Pump
Digital Fuel Injection Systems
Digital HVA Systems

Digital Hydraulic Valves
Digital Pneumatic Valves
Digital Valves
Digital Actuators
Digital Regulator
Fuel Injector

HVA
The new Digital Engine
Builds on past experience
From Delivery of 17 HVA systems
To customers around the world
The Digital Engine applies the experience of over 15 years of diesel fuel injector development including a production launch for an OEM in 2002.
NEW DIGITAL INJECTOR

- 3000 bar demonstrate
- 3500 bar target
- Multi-Fuel Capable
- Rate Shaping – multiple events
- High Safety
- Small Quantity Control
Digital Injector Simulation

Rail pressure 100 MPa
Pilots & start of main and post with IR = 2.0, end of main with IR = 3.3

Quantities:
1.17 / 1.12 / 85.23 / 1.10 mm³

Dwells:
280 / 290 / 250 usec

Peak Sac Pressures:
18 / 19 / 326 / 20 MPa

Needle Open Velocities:
0.2 / 0.3 / 1.1 / 0.3 m/s

Needle Close Velocities:
0.6 / 0.8 / 3.6 / 0.8 m/s
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AIR & HYDRAULIC HYBRID ENGINE

(12) United States Patent
Sturman et al.

(10) Patent No.: US 6,415,749 B1
(45) Date of Patent: Jul. 9, 2002

(54) POWER MODULE AND METHODS OF OPERATION

(76) Inventors: Oded E. Sturman, One Innovation Way, Woodland Park, CO (US) 80863;
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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: 09/301,004
(22) Filed: Apr. 27, 1999

FOREIGN PATENT DOCUMENTS
DE 37 27 335 A1 2/1988 .......... F02B/71/00
GB 941453 11/1963

* cited by examiner

Primary Examiner—Willis R. Wolfe
Assistant Examiner—Hai Huynh
The Digital Engine enables complete control of fuel and air throughout ANY combustion cycle
COMPLETE CONTROL OF THE COMBUSTION PROCESS

➤ Economical
➤ Powerful
➤ Efficient
➤ Clean

Photos from http://www.avl.com
1. Exhaust Valve Open (E.V.O)
2. E.V.C.
3. Fuel Injection Starts
4. Fuel Injection ends
5. Air Injection Opens
6. Air Injection Closes
7. Ignition
8. Air Injection Opens
9. Air Injection Closes
Because the Sturman Cycle atomizes fuel thermally rather than mechanically, it is compatible with almost any fuel type.
By implementing a more reversible combustion cycle, the Digital Engine can potentially gain back some of the efficiency losses inherent to a flame-front combustion process.

Inherent benefits of the Digital Engine:

Stroke = 2, 4, 6, 8 ...
Potential benefits of the Digital Engine running the Sturman Cycle include:

- Power
- Efficiency
- NOx, PM, CO₂
- Cost
- Engine Size

After-Treatment
Development

Progress
Single cylinder

External air source
This is a video of cylinder pressure traces in real-time during dyno testing of the Digital Engine.
Increase in Torque & Power
Single cylinder testing has been successful!

The next step is a dual cylinder design.
The dual cylinder design adds a compressor cylinder to the system to replace the external air source.
The goal of the dual cylinder testing is to collect data showing improved emissions, efficiency, and performance.
Next Steps:
US 2010 Emissions Capable Camless Heavy-Duty On-Highway Natural Gas Engine

“The NOx emissions on the 13-mode test are 0.005 g/kW-hr., which are well below the target of 0.27 g/kW-hr.”

“The Sturman HVA system enables full use of high compression ratio pistons, where full compression ratio can be used at light loads and a reduced effective compression ratio can be used at high loads to avoid knock.”

“The Sturman system enables throttleless operation, using early intake valve closing to control load.”
Production Scheduled
Summer 2013