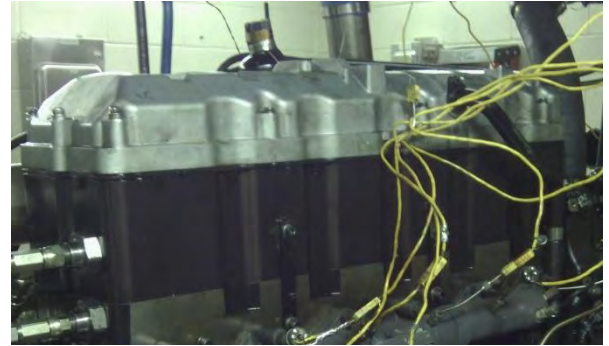


Features

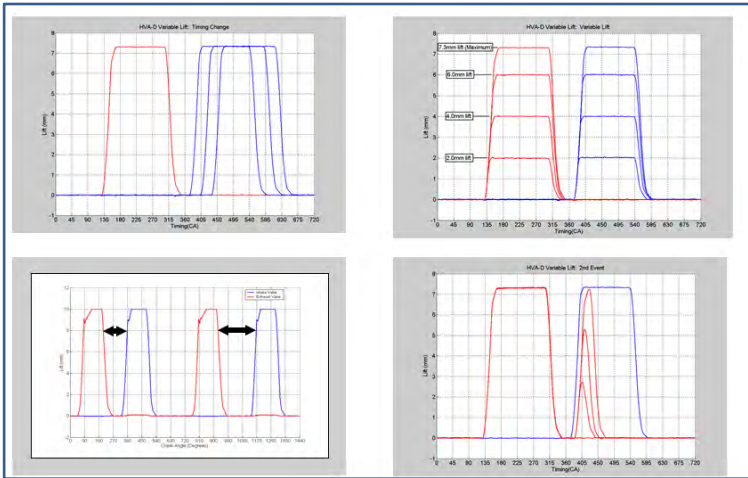
Digital Hydraulic Combustion Controls

- Advanced injectors- 10+ fuel injections/cycle
- Full camless head
- Total engine controller
- Flexible air control
- Multi-mode combustion
- High pressure fuel injection
- Low pressure fuel supply
- Accommodates all diesel type fuels - diesel, bio-diesel,...

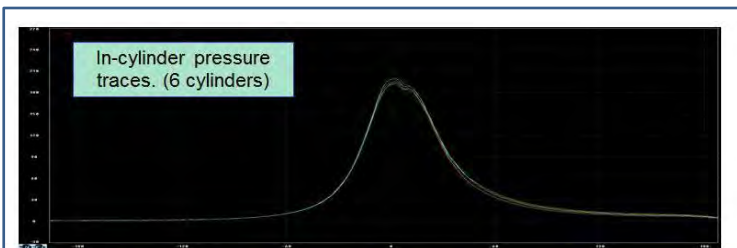


9.3 Liter Camless Engine

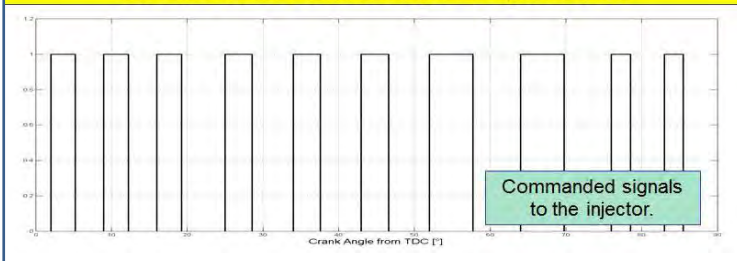
Flexibility



Injector performance



Consistent traces: 1 combustion cycle, 10 injection events



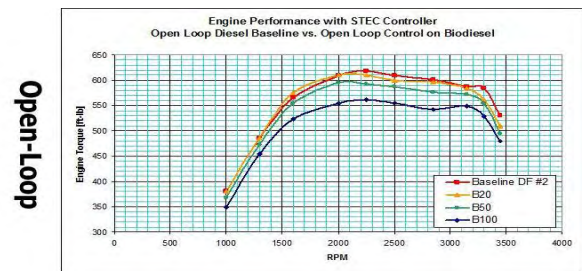
Commanded signals to the injector.

High performance digital injector

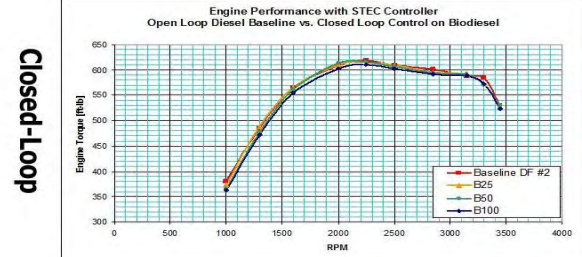


- High pressure injection- up to 3300 bar
- Low pressure fuel supply – 4.8 bar
- Hydraulic pressure to intensifier- 320 bar
- Capacity- up to 300 mm³
- Multiple events and rate shaping
- Adapts to changes in fuel qualities
- Superior performance and efficiency
- Fail-safe system

Bio-diesel performance



Open-Loop



Closed-Loop

Technology

Sturman Digital Hydraulic Valve Actuation (HVA) hardware & controller

- Full camless head
- High geometric compression ratio
- Un-throttled operation
- Cylinder deactivation
- 3-way catalyst & EGR for emissions control
- Sturman Total Engine Controller

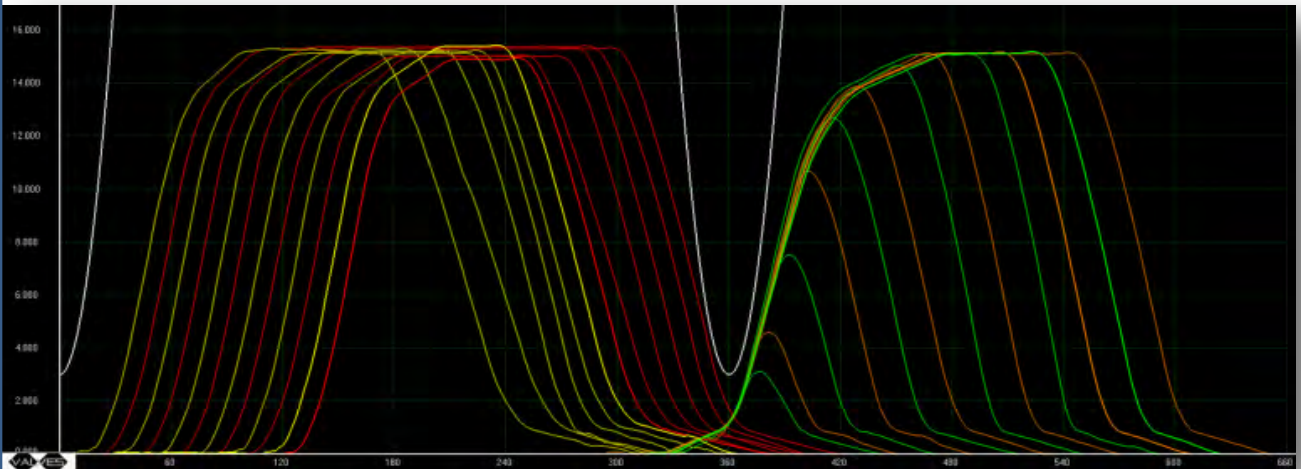
Performance Summary

- BTE > 40%
- Composite BTE > 38% on 13-mode cycle
- Composite NO_x < 0.01 g/kWhr



15 Liter NG Camless Engine

Test Results



Steady-state dynamometer test results

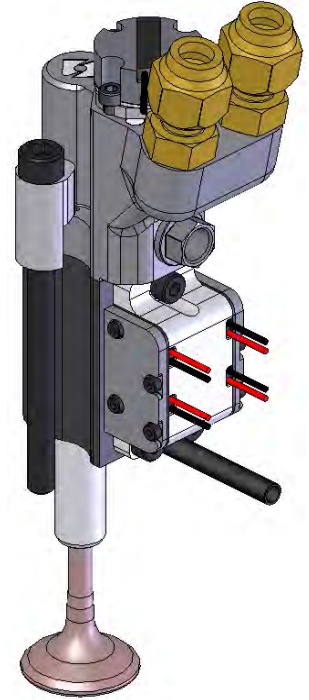
- Cylinder deactivation improved fuel efficiency by up to 18% at light load
- Camless system compensates for varying gas quality
- Cylinder tuning to increase knock margin via utilization of in-cylinder production pressure sensors

298 kW HP, Cummins ISX, Natural Gas System, Sturman HVA, Optimized (A25, B25, C25 3-Cyl), Mid-Loaded 3-Way Catalyst, EGR

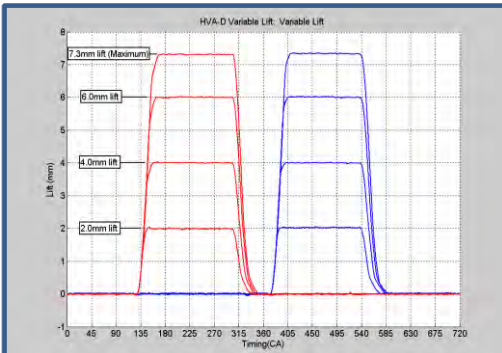
		TQ	Weighted Power	BSNO _x	BSFC	BSNMHC	BSCO	BTE
Mode	RPM	N-m	kW	g/kW-hr	g/kW-hr	g/kW-hr	g/kW-hr	%
Idle	713	0	0.00	0.000	0.0	0.000	0.000	0.0
A25	1130	406	2.40	0.000	262.4	0.004	0.089	32.8
A50	1118	823	4.82	0.011	234.9	0.000	0.043	36.6
A75	1129	1251	7.40	0.015	219.2	0.003	0.052	39.2
A100	1130	1682	15.92	0.005	207.9	0.035	0.043	41.4
B25	1482	434	6.74	0.000	260.5	0.004	0.207	33.0
B50	1478	945	14.62	0.000	232.4	0.000	0.253	37.0
B75	1479	1450	22.47	0.005	218.1	0.024	0.074	39.4
B100	1482	1928	26.93	0.005	213.6	0.000	0.084	40.3
C25	1828	292	2.79	0.015	314.3	0.000	-0.009	27.4
C50	1830	675	6.46	0.006	256.2	0.013	0.437	33.6
C75	1829	1065	10.20	0.011	227.2	0.008	0.020	37.8
C100	1828	1420	21.75	0.005	228.7	0.003	0.068	37.6
13-Mode Composite				0.006	226.8	0.010	0.105	38.13

2010 California Stationary Emissions Targets ≤ 0.0794 ≤ 243 ≤ 0.0227 ≤ 0.1134

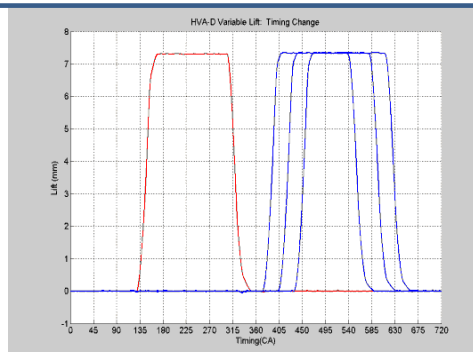
- Flexible Mounting
- Variable Control Of:
 - Valve Lift
 - Opening & Closing Timing
 - Open & Close Durations
 - Multiple Valve Events
 - Valve Deactivation
 - Cycle to Cycle Control



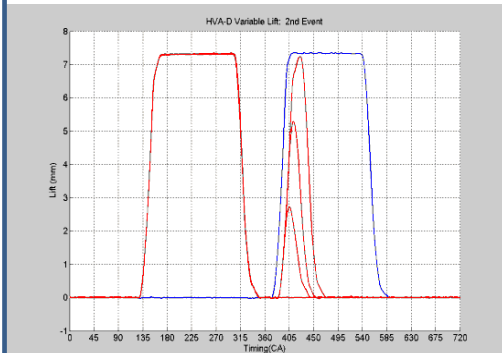
Parameter	Small Module	Large Module
Type of Engine	Gasoline, Diesel, Natural Gas and others	
Engine Speed Range	1000 RPM to 7000 RPM	1000 RMP to 3500 RPM
Typical Cylinder Displacement	0.25 to 2.0 liters per cylinder	
Working Fluid	Engine oil or Hydraulic oil	
Variable Lift Range	1 to 10 mm	1 to 12 mm
Lift Accuracy	+/- 0.15 mm	
Lift Repeatability	+/- 0.10 mm	
Opening or Closing Time	From 1 mm of max. lift in < 3.0 msec.	
Multiple Valve Events per piston cycle	Yes	
Valve Seating Velocity	0.2 m/sec – 0.4 m/sec	
Operating Temperature	15 to 120 deg. C	
System Supply Voltage	12 V dc	
Communication Protocol	Can link with engine ECU	
Valve Stem Diameter Range	5.5 mm to 10 mm	
Hydraulic Supply	Engine Mounted or Stand Alone	



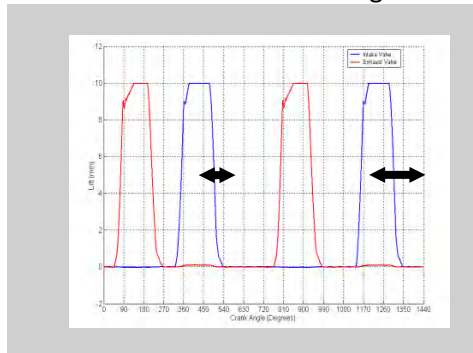
Variable Valve Lift



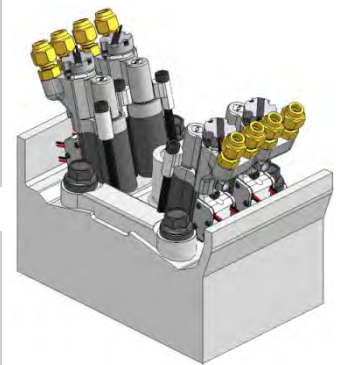
Variable Valve Timing



Multiple Valve Events



Cycle to Cycle Flexibility



4 Valve Cylinder Example