Piloting a Combined Heat and Power/Distributed Generation System Powered by Anhydrous Ammonia

Peter Sinsheimer, Ph.D., MPH
Executive Director, UCLA Sustainable Technology & Policy Program

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Diffusion Analysis: Barriers Categories and Barriers

Barrier Category	Barriers	Barrier Category	Barriers
Technical	Technically not viable/unreliable	*Market Failure/ Imperfection*	Highly controlled energy sector
	Lack of standard and codes and certification		Lack of information and awareness
	Lack of skilled personnel/training facilities		Restricted access to technology
	Lack of O&M facilities		Lack of competition
	Lack of entrepreneurs		High transaction costs
	System constraints		Missing market infrastructure
Economic and Financial	Economically not viable		High investment requirements
	High discount rates	*Institutional*	Lack of institutions/mechanisms to disseminate information
	High payback period		Lack of a legal/regulatory framework
	Market size small		Problems in realizing financial incentives
	High cost of capital		Unstable macro-economic environment
	Lack of access to capital		Lack of involvement of stakeholders in decision making
	Lack of access to credit to consumers		Clash of interests
	High upfront capital costs for investors		Lack of R&D culture
	Lack of financial institutions to support RETs, lack of instruments		Lack of private sector participation
Market Distortions	Favor (such as subsidies) to conventional energy		Lack of professional institutions
	Taxes on RETs	*Social, Cultural and Behavioral*	Lack of consumer acceptance of the product
	Nonconsideration of externalities		Lack of social acceptance for some RETs
	Trade barriers	*Other Barriers*	Uncertain governmental policies
			Environmental
			High risk perception for RETs

Painuly. J.P. (UNEP Collaborating Centre on Energy and Environment) *Barriers to renewable energy penetration; A framework for analysis*. 2001. Renewable Energy

California Policy Context:
2015 -- Senate Bill 350

- 50% RPS by 2030
- Increase RPS resources -- solar, wind, biomass, geothermal, and others.
- Double energy efficiency savings in electricity and natural gas end uses by 2030.
- Large utilities to develop Integrated Resource Plans (IRPs) showing how to meet customers resource needs, reduce greenhouse gas emissions, and ramp up the deployment of clean energy resources.

STPP Proposal Title:
"Piloting
Combined Heat and Power/
Distributed Generation System
Powered by Anhydrous Ammonia"

PROGRAM OPPORTUNITY NOTICE

Joint Renewable Energy and Advanced Generation, and Energy-Related Environmental Research, Development and Demonstration

PON-13-502

http://www.energy.ca.gov/contracts/index.html

State of California

California Energy Commission

October 2013

Research Areas:

A. Localized Efficient and Advanced Power and Heat Systems

B. Combined Heat and Power Applications for Associated Gas from Oil and Gas Production Fields

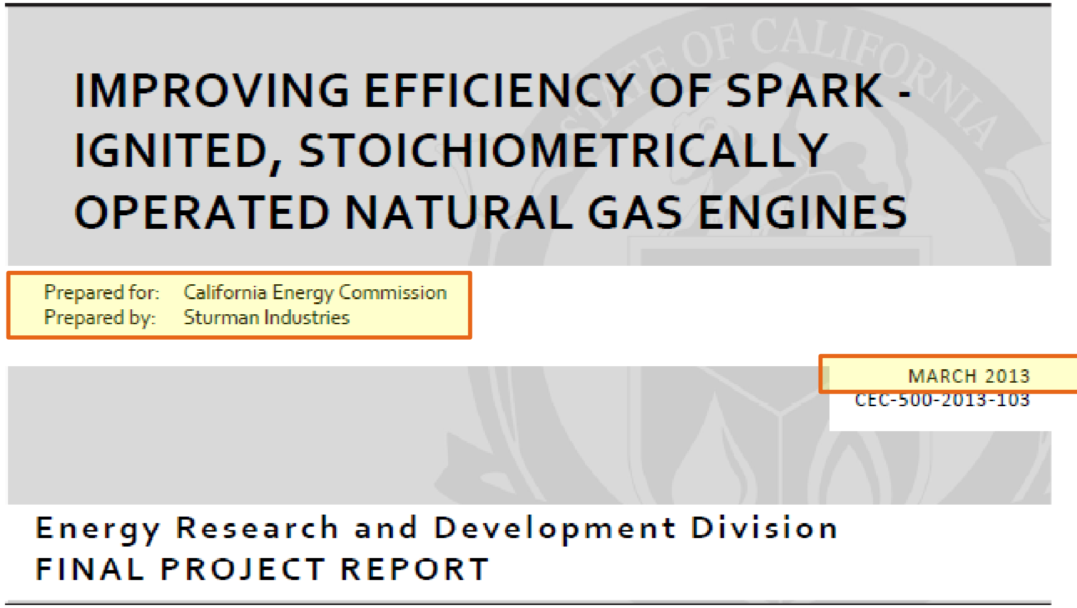
C. Reliable Power through Accelerated Demonstration and Deployment of Distributed Generation/Combined Heat and Power in Select Southern California Regions

D. Air Quality Implications of Using Biogas to Replace Natural Gas

Specific Technical and Cost Goals Based on Sturman Industry Camless Engine 2013 CEC Study Findings

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

Mode	RPM	TQ N-m	Weighted Power kW	BSNOx g/kW-hr	BSFC g/kW-hr	BSNMHC g/kW-hr	BSCO g/kW-hr	BTE %
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**
SCAQMD Threshold				**0.032**		**0.045**	**0.091**	



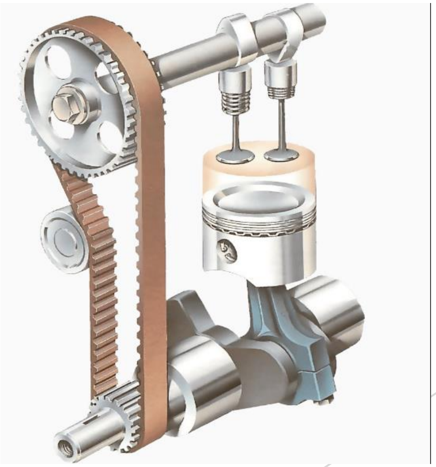
IMPROVING EFFICIENCY OF SPARK - IGNITED, STOICHIOMETRICALLY OPERATED NATURAL GAS ENGINES

Prepared for: California Energy Commission
Prepared by: Sturman Industries

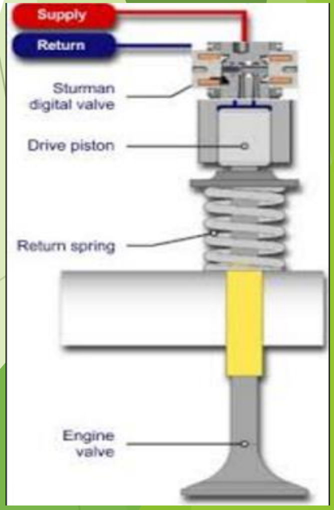
MARCH 2013
CEC-500-2013-103

Energy Research and Development Division
FINAL PROJECT REPORT

Camshaft Engine



Camless Engine



Specific Technical and Cost Goals

Component	*CHP-System Generation*	*Grid Power*
Electric engine capacity	1.00 MW	
Target electricity demand	4,568 MWh/yr	
Total efficiency of CHP system	75%	
Emissions (NOx)	<0.07 lbs/MWh	
CO_2 reduction	1,369 tons/yr	
Installed cost of CHP System	$2,500,000	
Self-Generation Incentive Program Credit	$490,000	
Capital cost recovery	$179,028/yr	
Maintenance (including inspections, overhaul)	$100,040/yr	
Natural gas fuel cost (at 92.5% of demand)	$115,359/yr	
Ammonia fuel cost (at 7.5% of demand)	$49,612/yr	
Total cost/yr	$444,039/yr	$822,220/yr
Cost of energy	$0.097/kWh	$0.180/kWh
Cost-effectiveness savings	$0.083/kWh	
Percent cost reduction	46%	

Project Tasks and Goals

Tasks	Goals
Design of Multi-Fuel/CHP/DG System	• Develop and conduct advanced prototype testing of the Sturman engine using NH_3 and natural gas for performance and emissions • Develop design options for the multi-fuel/CHP/DG System at pilot site
System Metering Equipment	• Identify metering equipment • Install meters during System installation
Field-Based System Optimization	• Optimize the Multi-Fuel/CHP/DG System
Data Collection for System Evaluation	• Collect 6+ months on data on all System inputs and outputs • Calculate total system efficiency and specific system efficiency • Collect economic data • Calculate total cost of power • Calculate the cost-effectiveness of the System compared to electricity from the grid or other self-generation options
Evaluation of Project Benefits	• Report the benefits resulting from this project
Technology/Knowledge Transfer Activities	• Develop a plan to make the knowledge gained, experimental results, and lessons learned available to the public and key decision makers
Production Readiness Plan	• Determine the steps that will lead to the manufacturing of technologies

Key Partnerships

Industry Partner		
Sturman Industries		
UCLA Research Team		
Name	*Affiliation*	*Expertise*
T.C. Tsao	School of Engineering	Camless Engine Systems
Abdon Sepulveda	School of Engineering	System Design
Adrienne Lavine	School of Engineering	Heat Exchange
Yifang Zhu	School of Public Health	Engine Emissions
Technical Advisory Committee		
Name	*Organization*	*Title*
Paul Delaney	Southern California Edison	Emerging Technologies Program Manager
Steve Simons	Southern California Gas Company	Senior Project Manager, Power Generation RD&D Program
Kjell Ostensen	LADWP	Engineering Specialist II
Rizaldo Aldas	California Energy Commission	Program Lead, Renewable and Advanced Generation R&D
Mohsen Nazemi	SCAQMD	Engineering and Compliance Deputy Executive Officer & Permit Streamline Ombudsman
Joe Lyou	Coalition for Clean Air	CEO; SCAQMD Board member
Michael Bowman	Sustainable Biodiesel Alliance	Founding Board Member
John Holbrook	NH_3 Fuel Association	Executive Director of the NH_3 Fuel Association


California
Electric Utility Service Areas
PacifiCorp
Area served by both
Surprise Valley Electric Co-Op
& PacifiCorp
Surprise Valley Electric Co-Op
Trinity
Shasta Lake
Redding
Shelter Cove
Lassen
Area served by both
Lassen & Plumas-Sierra
Plumas-Sierra
Biggs
Gridley
PG& E
Truckee-Donner
Liberty Utilities
Kirkwood Meadows
Ukiah
Pittsburg
Healdsburg
Roseville
SMUD
Lodi
Port of
Stockton
Area served by both
MID & PG& E
Alameda
Port of Oakland
City and
County of S.F.
MID
TID
Merced
Palo Alto
Silicon Valley
Power
Valley Electric
LADWP
PG& E
SAN JOAQUIN
VALLEY
MOJAVE DESERT
SOUTH CENTRAL COAST
SOUTH COAST
SALTON
SEA
SAN DIEGO
Lompoc
LADWP
Vernon
Industry
Cerritos
Anaheim
Corona
Riverside
Moreno Valley
San Onofre
California Energy Commission
STEP Division
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To inquire about ordering this map or information on
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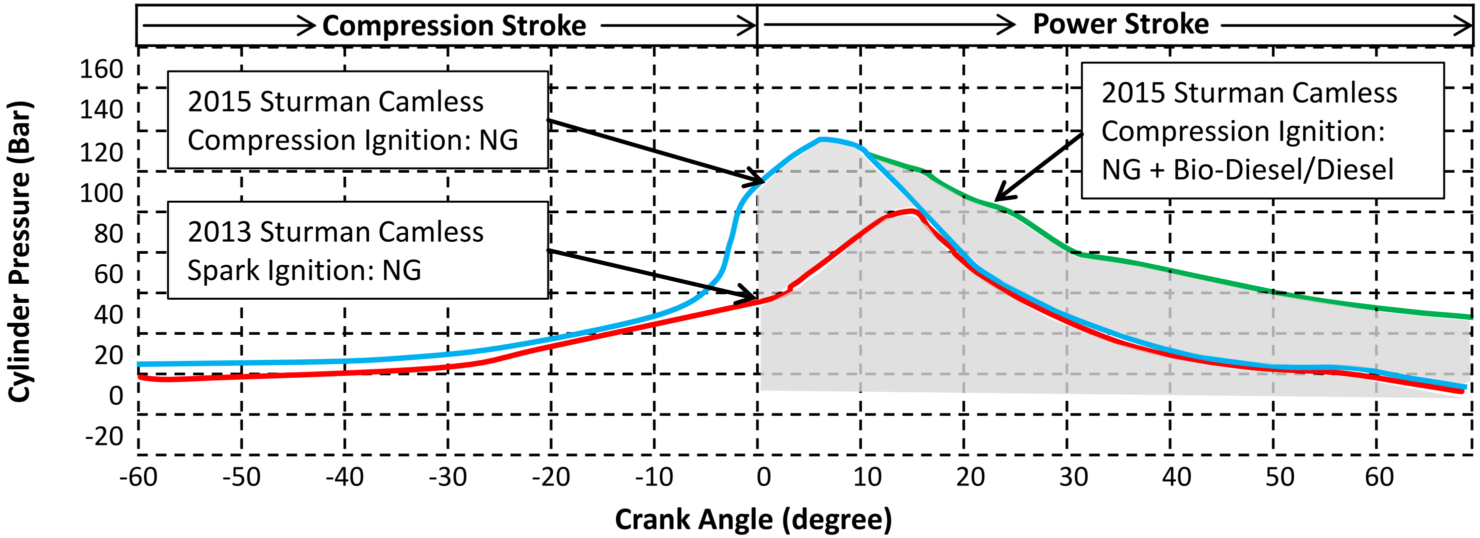
Comparison: Sturman Camless Spark Ignition vs Sturman Camless Compression Ignition

Category	Measure	Sturman Spark Ignition Engine (APT -- Complete)
Performance	Thermal efficiency (max)	38-41%
	Power generation (max)	Standard
	Scalability (small industry to large utility)	Yes
Emissions	Existing after-treatment (SCR or 3-way cat)	< SCAQMD thresholds
Cost	Capital cost relative to existing NG gensets	≈ or ↓
	Operating cost	↓ Existing
	Use existing service infrastructure	Yes
Fuel Options	Gas	Yes
	Liquid	No
	Gas and Liquid Dual Fuel Cycle	No
Fuel Markets	Potential to transition from fossil fuels to carbon-neutral/ carbon-negative fuels	Limited
	Potential to drive markets for wide range of renewable fuels	Limited

Cylinder Pressure Change During Compression and Power Stroke: Comparison of Spark Ignition to Compression Ignition to Dual-Fuel Combustion



Key Project Challenges and Responses to Date

Challenges	Responses
Preference by Sturman to use compression ignition system in pilot	• Willingness to wait for APT on emissions and performance
SCAQMD request NH_3 not be used at first commercial pilot	• Sturman agrees to conduct all NH_3 testing at their facility
Initial pilot site selected no longer interested in proceeding	• CEC willingness to change demonstration site • Willingness of utility TAC members to help identify alternative sites

Project Tear Sheet:

Translating Potential Performance and Emissions Benefits of New Compression Ignition System to Technical Specifications

- Tear Sheet: way for seller to communicate with buyer about essential product specifications – kW, efficiency, emissions

STURMAN INDUSTRIES

Proposed Specifications: Multi-Fuel DICE Generator Block

Target Date: 4th quarter, 2016

STURMAN INDUSTRIES

UCLA-CEC Pilot Program (250 kilowatts)

Specification Sheet: Multi-fuel DICE Generator Block

Description

The Sturman Industries DICE (Digital Internal Combustion Engine) generator block system is a fully integrated, flexible, and scalable, electrical power generation solution. Utilizing proprietary digital injection and hydraulic valve actuation technology, the power generation system is able to cleanly, efficiently, and cost-effectively convert a wide range of liquid and/or gas fuels into cheap, renewable, sustainable electrical energy.

Highlights

- **Clean**
  State-of-the-art digital injector and camless valve technology enable precise

Generator block specs

Governor regulation class	ISO 8528 Part 1, Class G1
Voltage regulation	±1%
Random voltage variation	±1%
Frequency regulation	Isochronous
Random frequency variation	±0.5%
Radio frequency emissions compliance	IEC 801.2 – 801.5; MIL STD 461C, Part 9
Single step load pickup	Industry competitive
Intermodal container class	ISO 668:2013

Engine Specs

Design	Twin International biturbo N10's