

## TermiNOx Emissions Upgrade Kit for LPG fueled LSI Engines

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Engine Control Systems

# Engine Control Systems (ECS)

- **Founded in 1980**
- **Owned by Lubrizol Corp. 1995 - 2005**
- **Owned by CapitalWorks LLC from 2006-2007**
- **Acquired by Catalytic Solutions Inc. Jan 2008**
- **Market leader in emission control solutions for non-automotive applications**



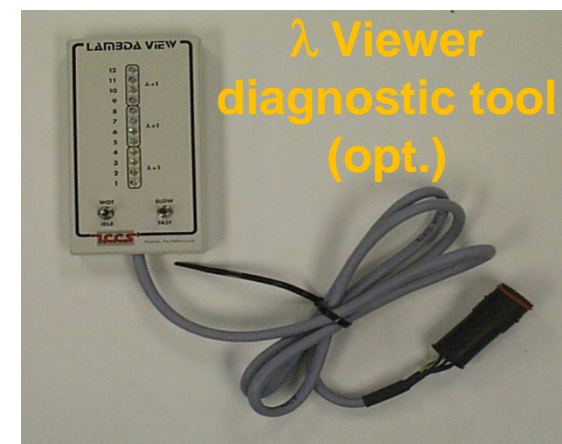
# TerminOx™ Engine Upgrade Kits for off-road LPG / CNG engines

- **TerminOx basics**

- Add-on system that converts carbureted fuel system to closed loop 3-way system (automotive style system)
- Not a fixed lean-out system
- can be installed on IMPCO, AISAN, NOLFF or Nikkei carburetion
- ECM is digitally programmable and allows for engine specific programming
- Up to 20% fuel savings over open loop fuel systems

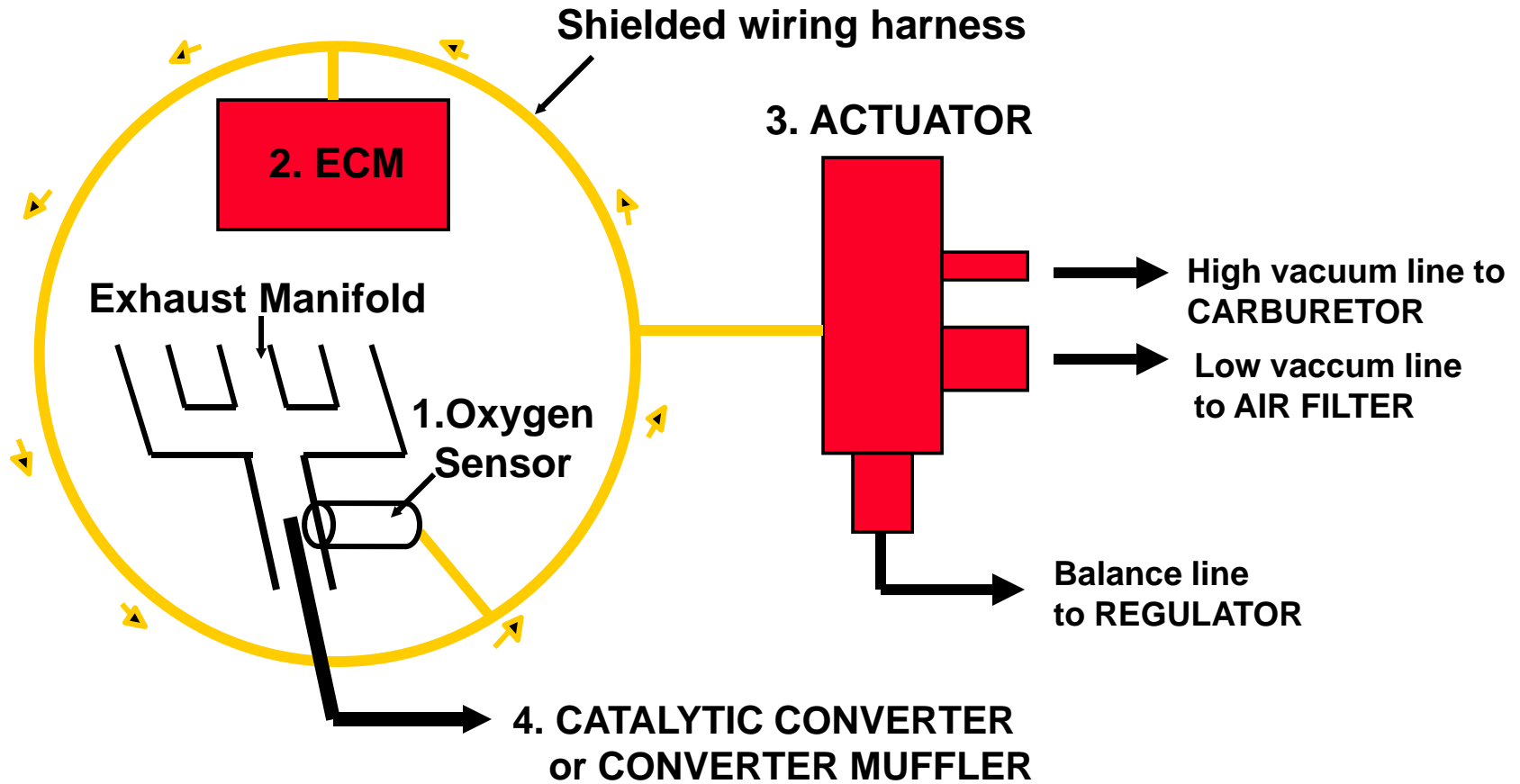


# TerminOx Engine Upgrade Kit Components



# Operation of TerminiNOx

## Closed Feedback Loop



# ARB Verification of TermiNOx



- First ARB LSI verified product
- For 1L to 3L in-line configuration engines, reduces HC + NOx emissions to <math><1.0\text{ g/hp-hr}</math> (>85%; Level 3a)
- For 3L to 8.2L in-line and V configuration engines from 3 to 8.2L reduces HC + NOx emissions to <math><3.0\text{ g/hp-hr}</math> (>75%; Level 2).

# TerminOx Testing Summary

Engine Description	Test Description	HC + NOx	CO	Test Facility
		(g/bhp-hr)	(g/bhp-hr)	
Nissan H20	C2- de-greened	0.37	0.90	SwRI
	Transient- de-greened	0.26	1.34	SwRI
1993 Mazda 4-121G, 2L, 34hp	C2- de-greened	0.58	1.59	SwRI
	C2 aged 4,034 hrs	0.51	3.25	SwRI
	Transient- aged 4,034 hrs	1.09	9.85	SwRI
1992 GM 181, 3L, 40hp	C2- de-greened	0.25	0.28	SwRI
	C2 aged 5,581 hrs	0.87	1.84	SwRI
	Transient- de-greened	0.43	1.85	SwRI
	Transient- aged 5,581 hrs	1.04	7.02	SwRI
Average transient cycle de-greened		0.35	1.60	
Average transient cycle aged >4000hrs		1.07	8.57	
Average overall		0.65	2.87	

\*Data supports that transient cycle data would <1.0 g/bhp-hr at end of 2500 hr emissions warranty

# TerminOx Testing Results

Engine	Test	THC	CH4	NMHC	CO	NOx	HC + NOx
Nissan H20	C2 degreened	90%			94%	99%	97%
	Transient degreened	93%			93%	99%	98%
Mazda 4-121	C2 degreened	87%	54%	89%	92%	97%	95%
	C2 aged	90%	69%	91%	84%	97%	95%
GM 181	C2 degreened	94%	79%	95%	98%	98%	98%
	C2 aged	94%	71%	96%	88%	91%	92%
Toyota 2L	C1	98%			99%	87%	90%
Average % Reductions		92%			93%	95%	95%
Minimum % Reductions		87%			84%	87%	90%

\*Data supports that transient cycle data would <1.0 g/hp-hr at end of 2500 hr emissions warranty.

# Testing at Carnot Emissions Services

- Two unregulated GM4.3L engines recovered lift trucks for test. As received from the field;
  - one ran fair as-received,
  - one ran too poorly to use as test engine, had burned valves on lean bank, required valve job
- Various stoichiometric and rich-bias programs tested to determine best one for in-use engines

# Test Summary

- Worst case engine is the GM4.3L due to imbalance in A/F ratio of the cylinder banks
- Current in-use engines prone to lean mis-fire due to A/F imbalance (valve damage)
- TerminiNOx retrofit strategy compromises NOx performance to address these 2 issues and effectively control CO (OSHA regulated)
- Despite this, emissions compare favorably to 2004 new engine certifications of various GM4.3L engines

## Aged TermiNOx Emissions Comparison to New 2004 4.3L Engine Certifications

Engine	HC + NOx (g/hp-hr)	CO (g/hp-hr)
4Z9XB04.3GPB	2.5	11.3
4KEM04.3LSI	2.0	13.9
4TIEB04.30G4	2.5	14.3
Aged TermiNOx on unregulated GM4.3L engine (Stoichiometric)	3	2.5

Note: 2001-2003 GM4.3L engines did not employ TWC's and were ARB certified as non-compliant

# Application Breadth

- Have Direct Fit Part Numbers for hundreds of Forklift Mufflers:
  - Hyster, Yale, Toyota, Komatsu, Mitsubishi, Caterpillar, Nissan, and many more
- Not just Forklifts:
  - Have designs for Concrete Polishers, Sweepers, Scrubbers, Aerial Platforms, Chippers, Carpet Cleaners, Ice Resurfacing Machines, etc.
- New Designs have quick turnaround time

# Summary

- TermiNOx is ARB Level 3a verified ( $<1.0$  g/hp-hr) for In-line engines from 1 to 3L
- TermiNOx is ARB Level 2 verified ( $<3.0$  g/hp-hr) for V-Configuration and In-line engines from 3L to 8.2L in displacement
- In-use unregulated GM4.3L engine with an aged TermiNOx System yielded similar emissions to 2004 model year ARB certified versions of the GM4.3L engine

# Contact

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