

ECM's miniPEMS and ~~microPEMS~~ Systems and Components

QBFs



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Santa Clara, CA, USA

www.ecm-co.com

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For 34 years, ECM has built Instruments that use Ceramic Sensors to Measure Exhaust Emissions

- AFR/Lambda/O₂
- EGR (O₂ in intake)
- NO_x/O₂/CO₂
- CO/CO₂
- NH₃
- PM/PN
- Fast Temperature



ECM has control modules for all ceramic exhaust sensors with better features, accuracy, speed-of-response, range, and diagnostics than OEM modules.

Most importantly, ECM modules allow for exhaust sensor calibration which ECM can perform on a plug-and-play, rotating sensor calibration basis.

Lambda Meter Product Line



In use for over 30 years in >90% of GM, Ford, and Chrysler dynamometers

Pre-OEM and OEM Sensor Control Modules



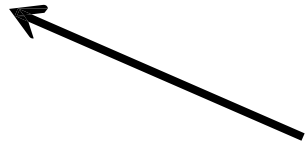
ex. NGK Spark Plug TC-6110 UEGO/Linear O₂ Module (ECM Product).

Tens of thousands of Pre-OEM and OEM modules distributed.

ECM has an incredible amount of in-use experience with ceramic sensors in on-road, off-road, stationary, and industrial applications.

ECM Measurement Modules*

(CAN-based components of miniPEMS systems)



The “ethernet” for cars and trucks. A communications bus and protocol that allows you to easily connect measurement modules in a daisy-chain manner to build a miniPEMS.

*you can buy these

AFR, Lambda, EGR, O₂



NO_x



CO₂, CO



NH₃



Dual-Channel
Dashboard Display

GPS and OBD (vehicle datastream)



WAAS-Enabled GPS



Data Bus Monitoring for
Cars, Light-Duty Trucks, and
Heavy-Duty Trucks

Easily build Sophisticated Measurement Systems (CAN-based. Just daisy-chain the modules together.)

This cable contains the power and CAN bus communication.



ECM NOx, Type F Sensor (NH₃ Insensitive, Use with NOxCANf Controller)



P/N: 06-09A



P/N: 06-09B10 (one shown)
NH₃ Filter



P/N: 06-09C



P/N: 06-09 is an assembly consisting of :

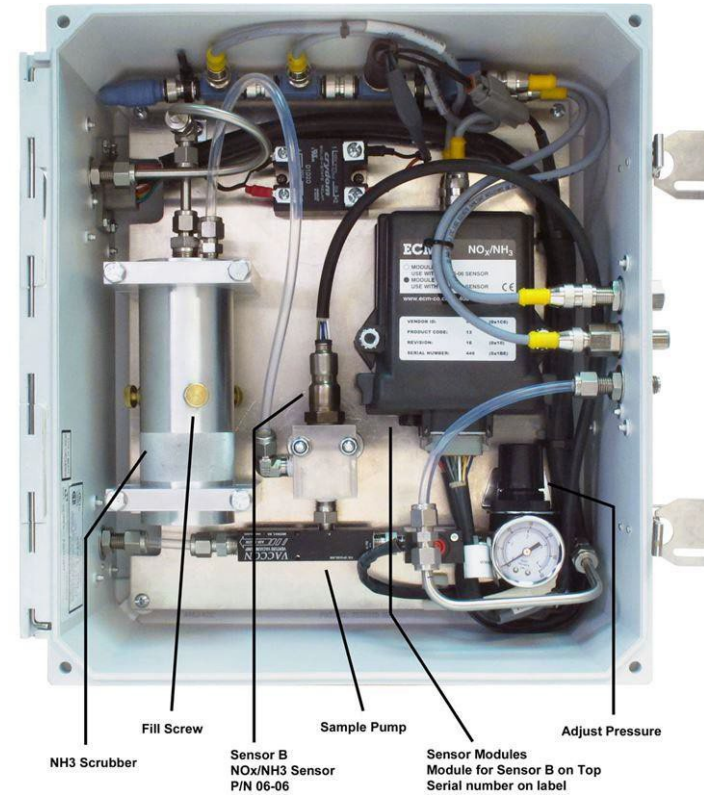
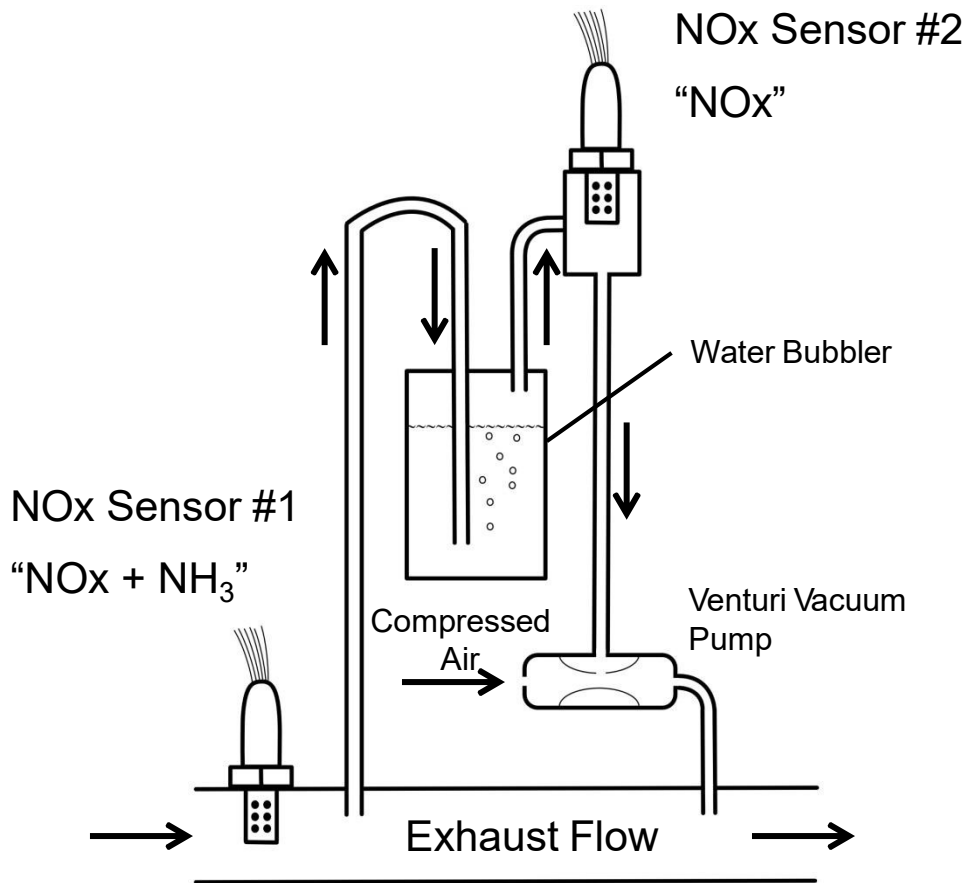
- P/N: 06-09A Sensor Element
- P/N: 06-09B10 Sensor Filter (package of 10)
- P/N: 06-09C Cap

3/4" NPT Thread
Use P/N 12-56 Mounting Boss



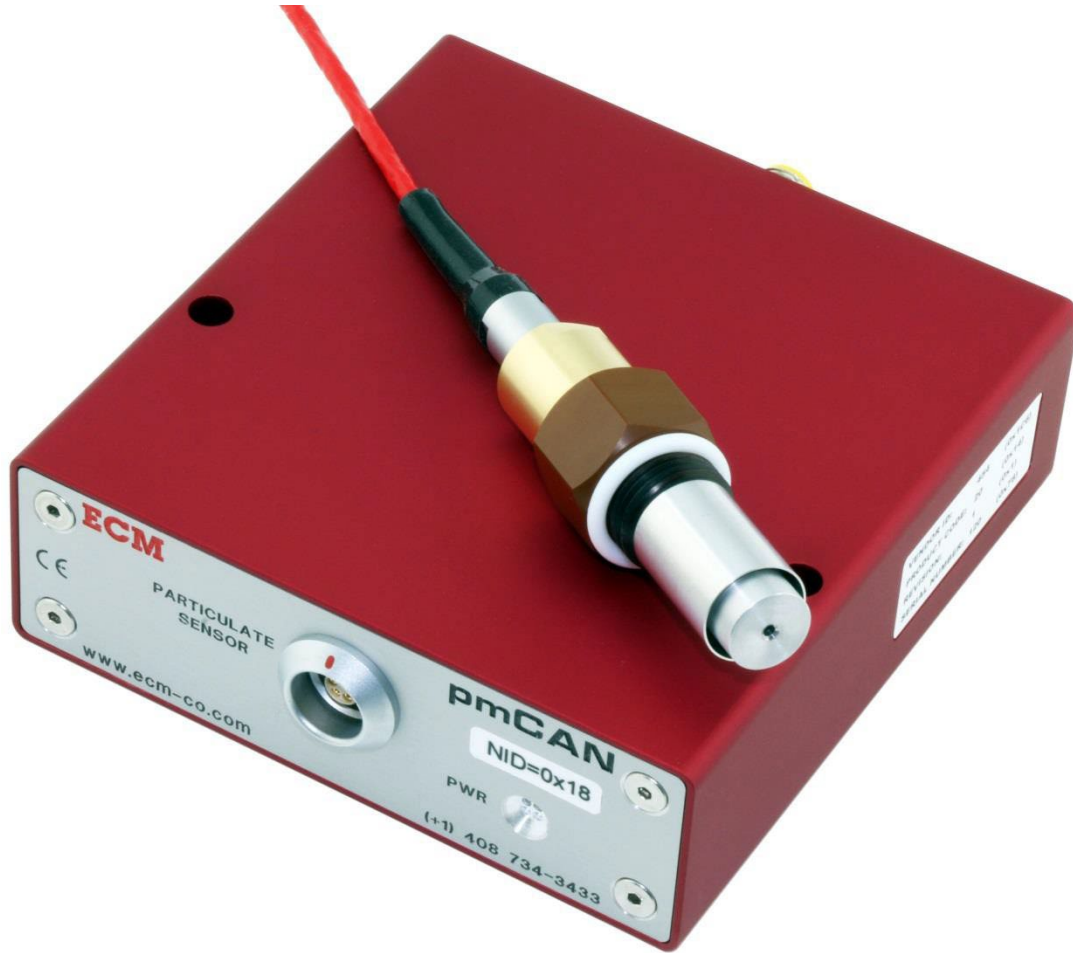
Using Two NOx Sensors to Measure NH₃ and NOx in Spark Ignition Engines

$$\text{NH}_3 = (\text{NOx} + \text{NH}_3)_{\text{sensor1}} - \text{NOx}_{\text{sensor2}}$$



Inside of ECM NOx/NH₃ Model 5240

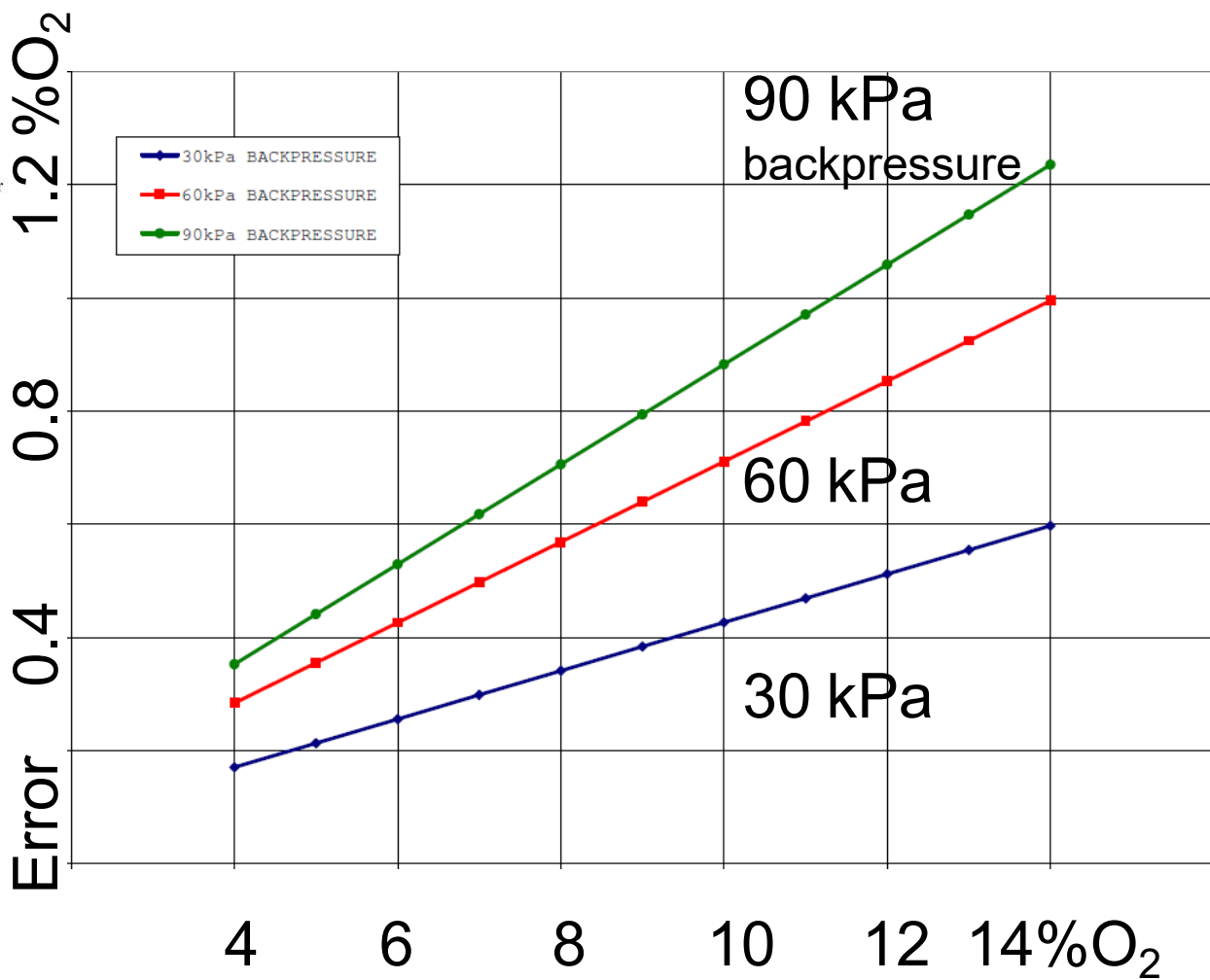
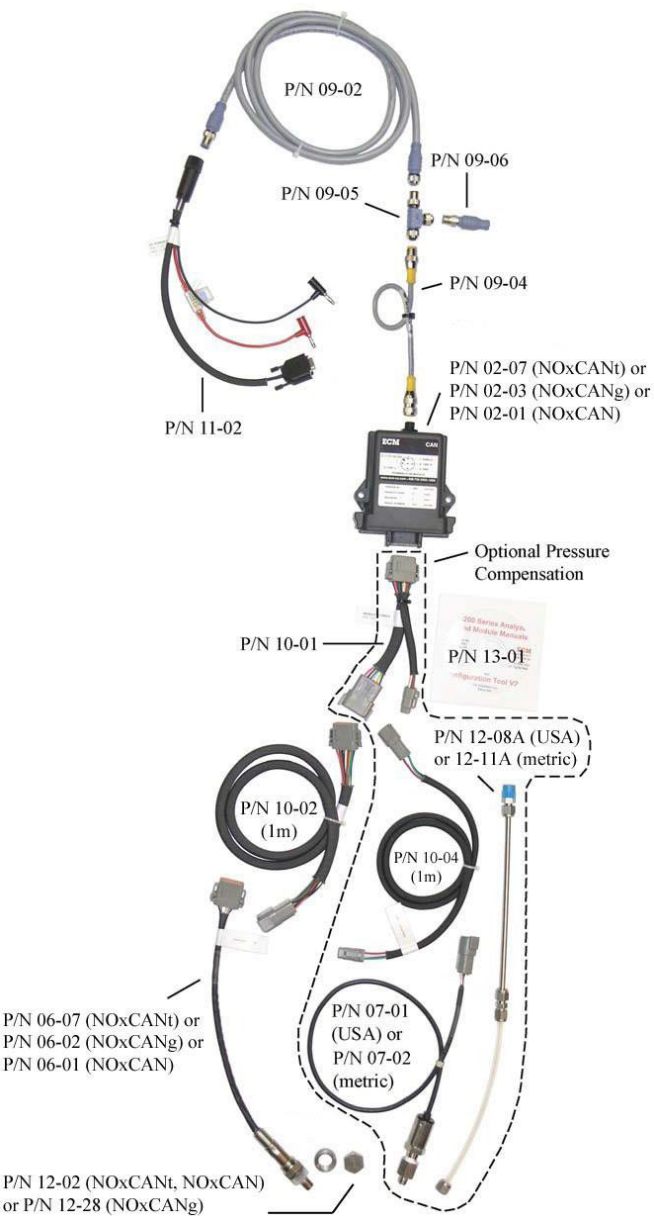
ECM Particulate Sensor (PM, PN)



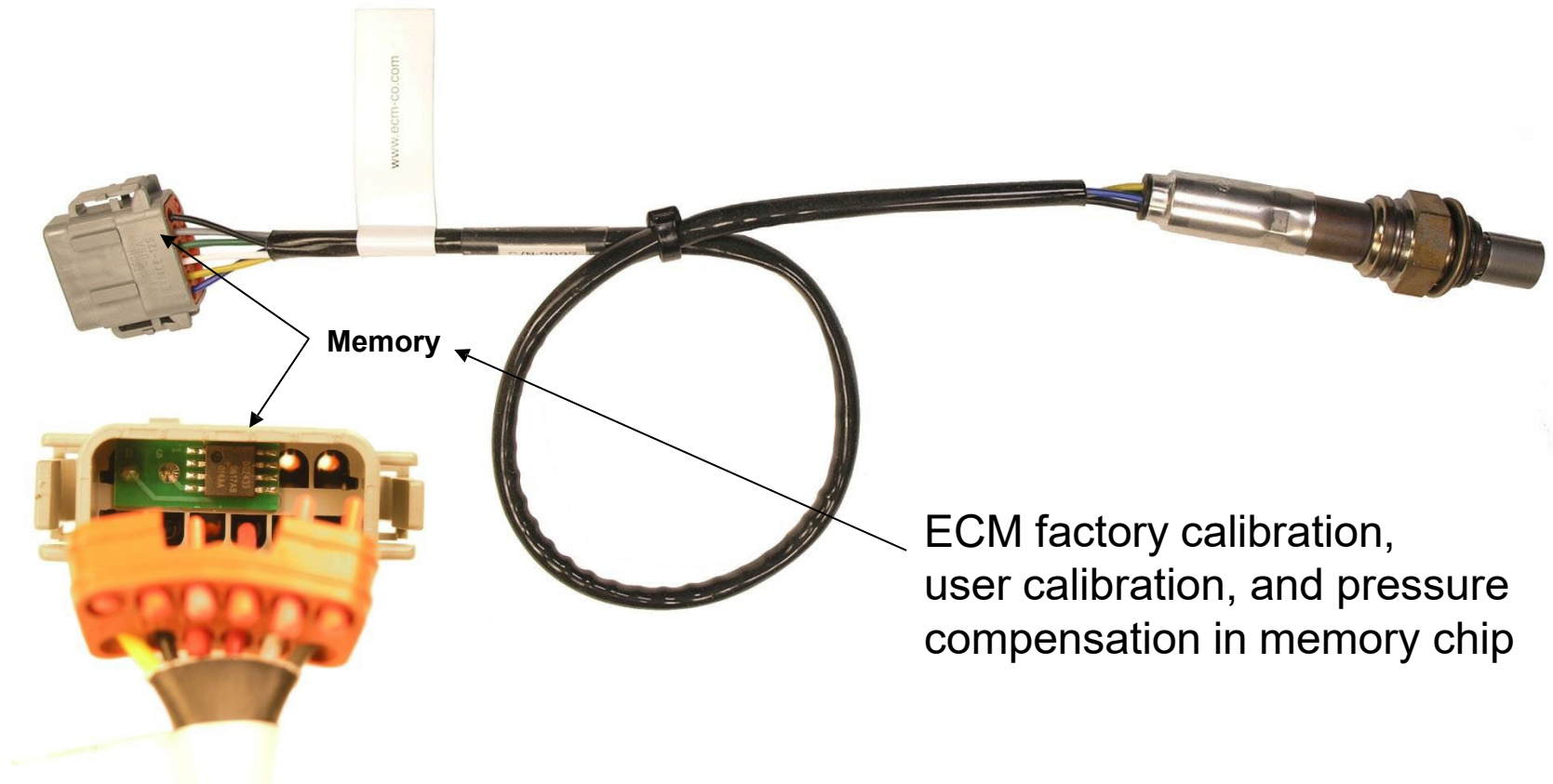
Can be disassembled for cleaning!
In fact, that's how you recalibrate it.



ECM Does Pressure Compensation (Ceramic Sensors have a Pressure Sensitivity)



All ECM Sensors have Calibration Chip in the Sensor



- Memory chip allows calibration to be offloaded from the operator and performed in a central location (ex. ECM). Swap in a new sensor and continue testing.
- Rotating sensor recalibration (send to ECM and get before and after calibration data)

ECM Calibration Solutions for Field Calibration



Other Sensors

TO ECM

Report No. FE-EC-99001
Nov. 29, 1999

↑
1999!!!

Fact:

For almost any exhaust gas component, there exists a low-cost ceramic exhaust sensor that can measure that component (ex. HC).

Unfortunately, many of them are hidden in laboratories waiting for an OEM order of 250,000 units.

 HC Sensor Technical Report

CONFIDENTIAL

Shoji
prepared by : Sh

Ryuji
checked by : Ry

Takafumi
approved by : Ta

PRODUCT DEVELOPMENT DEPT.
R & D CENTER



EPA's miniPEMS

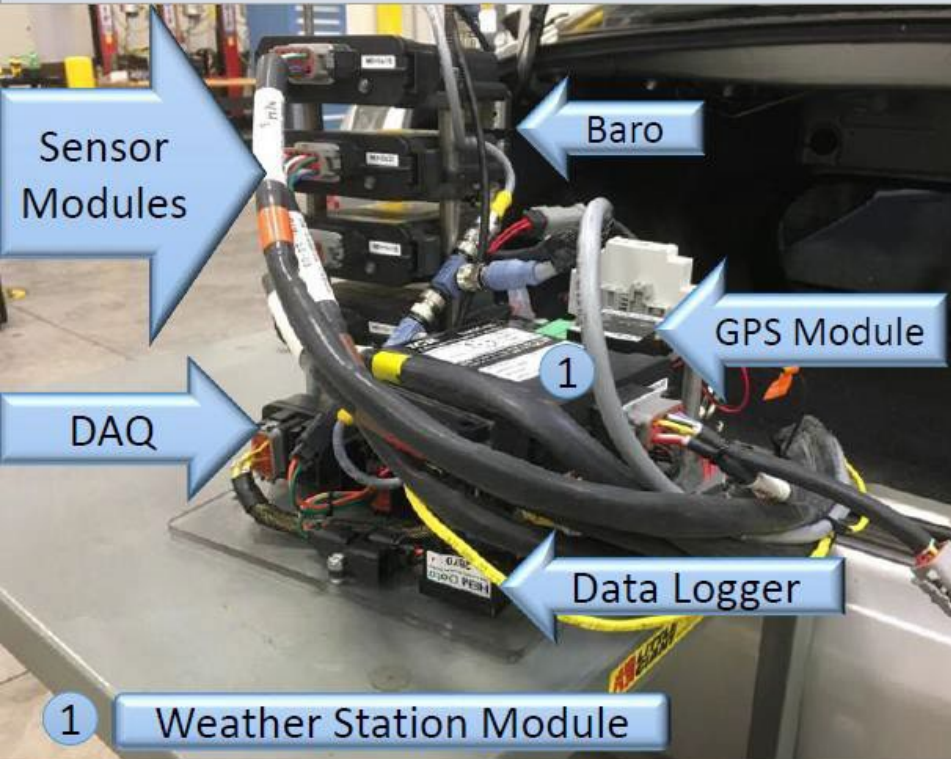
(built with ECM's measurement modules)



Challenges in Developing and Advancing Mini-PEMS

Measurement Setup – Sensors, Modules and DAQ*

Sensor Modules and DAQ



2.5" LDV Tailpipe Adapter



* Complete list of components provide in Appendix A

** Additional pictures of NOx sensor in Appendix B

Challenges in Developing and Advancing Mini-PEMS

Future Development – Robust Packaging

Development Design



Prototype Design



Next generation prototype expected to be smaller

Design Includes: Control Modules, DAQ, Data Logger, Battery (8 hours) and Barometric Pressure
Dimensions: W21"xH8.5"xD16"
Weight: approx. 25 lbs

ECM miniPEMS*

Assemblies of: Ceramic Sensor Emissions Modules

+ GPS

+ OBD (vehicle datastream)

+ Logging

* you can buy these too

ECM miniPEMS 1 (Motorcycles)

300mm x
250mm x
200mm

GPS

Data

OBD

ECM miniPEMS
Pollution Emissions Monitoring System
www.ecm-co.com • 408-734-3433 • USA

Up to 4
Modules

- Lambda, O₂
- NO_x
- NH₃
- CO, CO₂
- Exh T
- Baro
- V, I, DC, Freq
- Etc

Self-
Powered



ECM miniPEMS 2 (Cars, LD & HD trucks)

530mm x
460mm x
230mm



Data Storage/Communication Device
(logger/CAN adapter)

Measurement Modules
(maximum of 7)

20A Fuse

Four 12V Batteries
(one in each corner)

Power Switch Box



gpsCAN (roof mount)

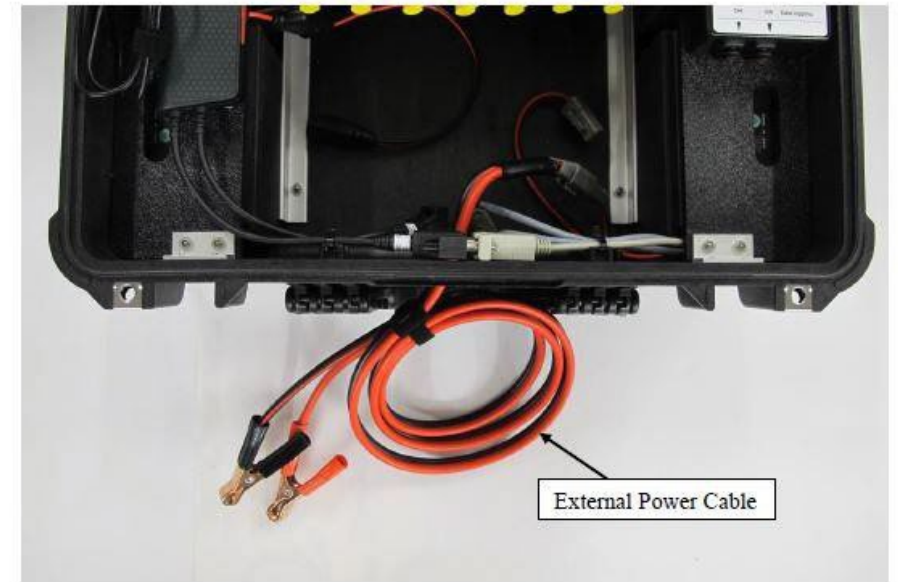
OBD Connector

Remote "Power to Logger" Switch

Remote "Power to Logger" Switch

Battery Charger

"100%" light



External Power Cable

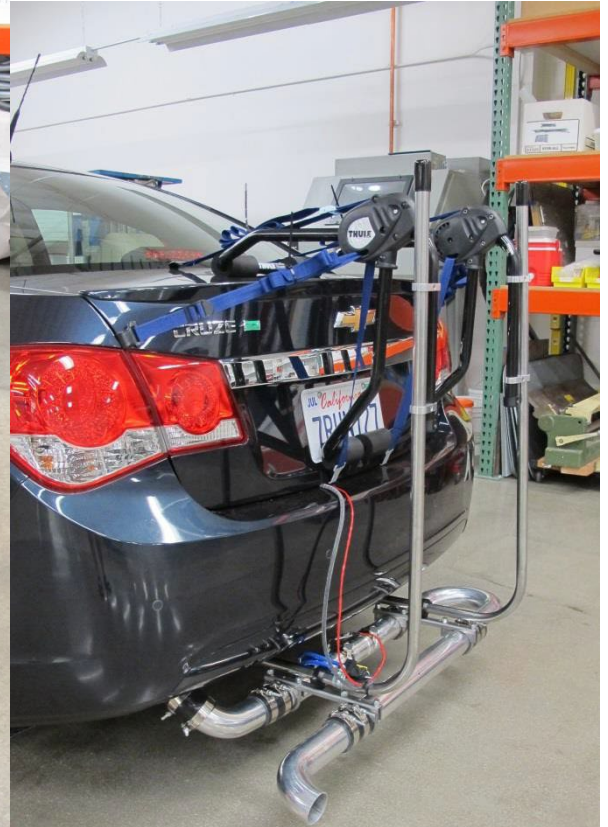
Sensor Mounting Options



Stubby Style



1m Extended



2m Extended

Produces Excel Files

minipems.xlsm - Microsoft Excel

File Home Insert Page Layout Formulas Data Review View Developer Load Test Team

Visual Basic Macros Record Macro Use Relative References Add-Ins COM Add-Ins Insert Design Mode Properties View Code Source Map Properties Import Expansion Packs Export Document Panel Refresh Data XML Modify

B1

	B	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	
1				Node ID: 0x11 Prod Code: 0x0D (NOxCAN) Rev #: 16 Serial #: 444										Node ID: 0x30 Prod Code: 0x10114 (4tcCAN) Rev #: 66306 Serial #: 32513061										Node ID: 0x00 Prod Code: 0x00 (gpsCAN) Rev #: 0 Serial #: 21454									
2	Preview Chart																																
3																																	
4																																	
5																																	
6	Date & Time (Excel forr	Elapse Time (Exc	NOX(ppm O2R(%	IP2(uA)	IP1(mA)	VSW(V)	TEMP(dej	CANopen	CANopen	CANopen	ECM_ErrC	ECM_Aux	ECM_ErrCode2	TC1(degC	TC2(degC	TC3(degC	TC4(degC	CANopen	CANopen	CANopen	ECM_ErrC	ECM_Aux	ECM_ErrCode2	Speed(m	Course(d	Latitude(d	Longitude	Altitude					
3830	3/15/2016 20:49:01.112	0:02:03.112	8.9364	20.942	0.02553	5.99758	12.933	33.49	5	65280	129	0	0	0	28.55	11.45	0	0	0	5	61441	1	4	0	0	11.8782	331.135	37.4167	-121.973	-29.29			
3831	3/15/2016 20:49:01.212	0:02:03.212	8.9364	20.942	0.02553	5.99758	12.933	33.49	5	65280	129	0	0	0	28.55	11.45	0	0	0	5	61441	1	4	0	0	11.5202	329.428	37.4167	-121.973	-29.29			
3832	3/15/2016 20:49:01.218	0:02:03.218	8.9364	20.942	0.02553	5.99758	12.933	33.49	5	65280	129	0	0	0	28.45	11.55	0	0	0	5	61441	1	4	0	0	11.14	325.618	37.4167	-121.973	-29.29			
3833	3/15/2016 20:49:01.251	0:02:03.251	8.9364	20.942	0.02553	5.99758	12.933	33.49	5	65280	129	0	0	0	28.45	11.55	0	0	0	5	61441	1	4	0	0	11.14	325.618	37.4167	-121.973	-29.29			
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3841	3/15/2016 20:49:01.487	0:02:03.487	8.9364	20.942	0.02553	5.99758	12.933	33.49	5	65280	129	0	0	0	28.45	11.65	0	0	0	5	61441	1	4	0	0	10.6031	321.011	37.4167	-121.973	-29.29			
3842	3/15/2016 20:49:01.493	0:02:03.493	8.9364	20.942	0.02553	5.99758	12.933	33.49	5	65280	129	0	0	0	28.45	11.65	0	0	0	5	61441	1	4	0	0	10.6031	321.011	37.4167	-121.973	-29.02			
3843	3/15/2016 20:49:01.499	0:02:03.499	8.9364	20.942	0.02553	5.99758	12.933	33.49	5	65280	129	0	0	0	28.45	11.65	0	0	0	5	61441	1	4	0	0	10.6031	321.011	37.4167	-121.973	-29.02			
3844	3/15/2016 20:49:01.505	0:02:03.505	8.9364	20.942	0.02553	5.99758	12.933	33.49	5	65280	129	0	0	0	28.45	11.65	0	0	0	5	61441	1	4	0	0	10.6031	321.011	37.4167	-121.973	-29.02			
3845	3/15/2016 20:49:01.511	0:02:03.511	8.9364	20.942	0.02553	5.99758	12.933	33.49	5	65280	129	0	0	0	28.45	11.65	0	0	0	5	61441	1	4	0	0	10.6031	321.011	37.4167	-121.973	-29.02			
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3847	3/15/2016 20:49:01.523	0:02:03.523	9.3426	20.942	0.02669	5.99758	12.933	33.49	5	65280	129	0	0	0	28.45	11.65	0	0	0	5	61441	1	4	0	0	10.4018	320.415	37.4167	-121.973	-29.02			
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3849	3/15/2016 20:49:01.535	0:02:03.535	9.3426	20.942	0.02669	5.99758	12.933	33.49	5	65280	129	0	0	0	28.45	11.65	0	0	0	5	61441	1	4	0	0	10.4018	320.415	37.4167	-121.973	-29.02			
3850	3/15/2016 20:49:01.618	0:02:03.618	9.3426	20.942	0.02669	5.99758	12.933	33.49	5	65280	129	0	0	0	28.45	11.65	0	0	0	5	61441	1	4	0	0	10.4018	320.415	37.4167	-121.973	-29.02			
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3852	3/15/2016 20:49:01.751	0:02:03.751	9.3426	20.942	0.02669	5.99758	12.933	33.49	5	65280	129	0	0	0	28.25	11.55	0	0	0	5	61441	1	4	0	0	10.2004	317.602	37.4167	-121.973	-29.02			
3853	3/15/2016 20:49:01.818	0:02:03.818	9.3426	20.942	0.02669	5.99758	12.933	33.49	5	65280	129	0	0	0	28.25	11.55	0	0	0	5	61441	1	4	0	0	10.2004	317.602	37.4167	-121.973	-29.02			
3854	3/15/2016 20:49:01.858	0:02:03.858	9.3426	20.942	0.02669	5.99758	12.933	33.49	5	65280	129	0	0	0	28.25	11.55	0	0	0	5	61441	1	4	0	0	10.1557	314.76	37.4167	-121.973	-29.02			
3855	3/15/2016 20:49:01.918	0:02:03.918	9.3426	20.942	0.02669	5.99758	12.933	33.49	5	65280	129	0	0	0	28.25	11.55	0	0	0	5	61441	1	4	0	0	10.1557	314.76	37.4167	-121.973	-29.02			
3856	3/15/2016 20:49:01.991	0:02:03.991	9.3426	20.942	0.02669	5.99758	12.933	33.49	5	65280	129	0	0	0	28.25	11.55	0	0	0	5	61441	1	4	0	0	9.97675	311.832	37.4167	-121.973	-29.02			
3857	3/15/2016 20:49:02.002	0:02:04.002	9.3426	20.942	0.02669	5.99758	12.933	33.49	5	65280	129	0	0	0	28.25	11.55	0	0	0	5	61441	1	4	0	0	9.97675	311.832	37.4167	-121.973	-29.02			
3858	3/15/2016 20:49:02.018	0:02:04.018	9.3426	20.942	0.02669	5.99758	12.933	33.49	5	65280	129	0	0	0	28.25	11.55	0	0	0	5	61441	1	4	0	0	9.97675	311.832	37.4167	-121.973	-29.02			
3859	3/15/2016 20:49:02.118	0:02:04.118	9.0718	20.942	0.02592	5.99758	12.933	33.49	5	65280	129	0	0	0	28.25	11.55	0	0	0	5	61441	1	4	0	0	9.95438	309.088	37.4167	-121.973	-29.02			
3860	3/15/2016 20:49:02.218	0:02:04.218	9.0718	20.942	0.02592	5.99758	12.933	33.49	5	65280	129	0	0	0	28.25	11.55	0	0	0	5	61441	1	4	0	0	9.75906	306.951	37.4167	-121.973	-29.02			
3861	3/15/2016 20:49:02.252	0:02:04.252	9.0718	20.942	0.02592	5.99758	12.933	33.49	5	65280	129	0	0	0	28.25	11.55	0	0	0	5	61441	1	4	0	0	10.0439	304.682	37.4167	-121.973	-29.02			
3862	3/15/2016 20:49:02.318	0:02:04.318	9.0718	20.942	0.02592	5.99758	12.933	33.49	5	65280	129	0	0	0	28.25	11.55	0	0	0	5	61441	1	4	0	0	10.0439	304.682	37.4167	-121.973	-29.02			
3863	3/15/2016 20:49:02.359	0:02:04.359	9.0718	20.942	0.02592	5.99758	12.933	33.49	5	65280	129	0	0	0	28.25	11.55	0	0	0	5	61441	1	4	0	0	9.97675	301.089	37.4167	-121.973	-29.02			
3864	3/15/2016 20:49:02.418	0:02:04.418	9.0718	20.942	0.02592	5.99758	12.933	33.49	5	65280	129	0	0	0	28.25	11.55	0	0	0	5	61441	1	4	0	0	9.97675	301.089	37.4167	-121.973	-29.02			
3865	3/15/2016 20:49:02.475	0:02:04.475	9.0718	20.942	0.02592	5.99758	12.933	33.49	5	65280	129	0	0	0	28.25	11.55	0	0	0	5	61441	1	4	0	0	9.95438	296.723	37.4167					

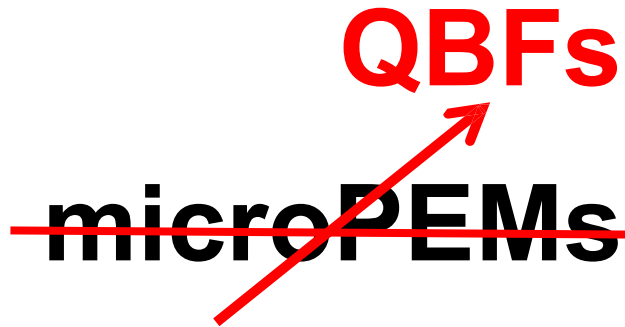
In my opinion...

- Although ceramic exhaust sensors can be used to build impressive, low-cost, and robust pseudo-PEMS systems, there will never be a miniPEMS system that sells for \$10,000 that can mimic a \$450,000 AVL or Horiba PEMS.
- Even if we could make a \$10,000 PEMS, the time to install, the system calibration, and the necessity of a skilled operator keeps the number of tests that we can perform in a year below what is required for a rigorous survey of the world's vehicles.
- We're looking for needles in a haystack. We need a better way.

- I see a need for a new class of approved* test devices and procedures to find the needles in the haystack: **QBFs**
QBFs (Quick Bad-vehicle Finders) are devices that can be installed, used, and removed in under 20 minutes by a non-expert. **QBFs** focus on specific failures (ex. gNOx/kWh > limit).
- For this purpose, ceramic exhaust sensors with a centralized calibration service are well-suited.
- These are potentially \$1,000/ea devices.
- Companies are required to have independent audits of their finances to be permitted to sell securities (i.e. stocks). Can there be legislated a similar requirement for independent audits of emissions that can be performed by accountants?

* Approved means blessed, promoted, legislated, and funded by our government agencies. Otherwise there is little incentive for shareholders to develop devices and techniques.

QBFs
~~microPEMs~~



- Quick Bad-vehicle Finders (QBFs)
 - specialized field testers
 - red light/green light devices,
 - “signature analysis” devices

EZ-PEMS: The Euro 6 NOx Tester

A gNOx/kWh Threshold Indicator

(you'll get to see it at UCR later today)



- Install one pre-calibrated sensor, drive for 10-20 minutes
- Lights indicating PASS, FAIL, and System Condition
- Self-powered via internal battery
- Optional display, OBD, and Real-time to Cloud Data Storage



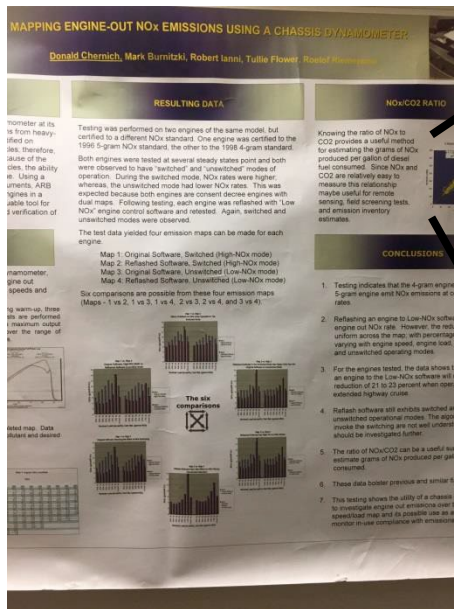
ECM NOx Tester

- 0.000-0.000-0.000-0.000
- 0.000-0.000-0.000-0.000
- 0.000-0.000-0.000-0.000
- 0.000-0.000-0.000-0.000

FWZ 381

www.upplandsmotor.se

Method of Operation Based on CARB Report (that's the California Air Resources Board)



Knowing the ratio of NO_x to CO₂ provides a useful method for estimating the grams of NO_x produced per gallon of diesel fuel consumed. Since NO_x and CO₂ are relatively easy to measure this relationship maybe useful for remote sensing, field screening tests, and emission inventory estimates.

So (NO_x ppm/CO₂ ppm) proportional to gNO_x/gFuel

Method of Operation (continued...)

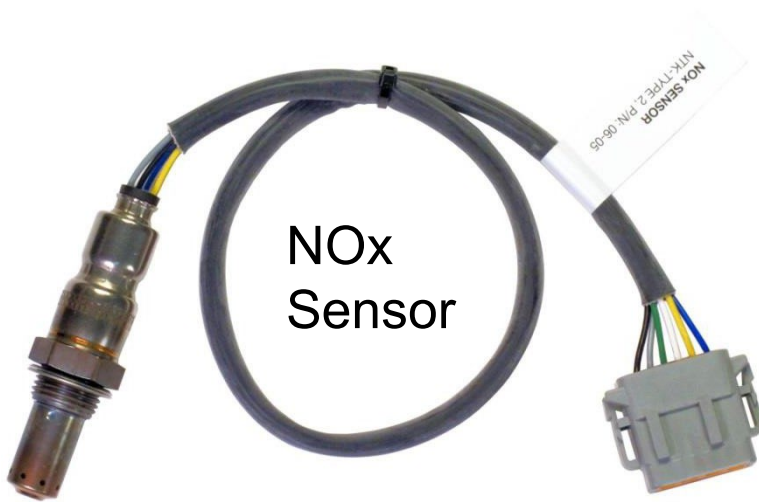
- And since HD engines typically have a BSFC of between 160-165 g/kWh during test cycles, you can modify the relationship to say:

(NOx ppm/CO₂ ppm) proportional to gNOx/kWh

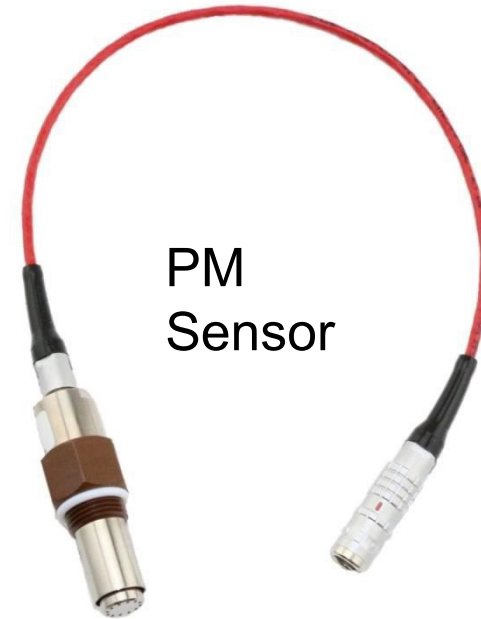
- Depending on the Euro (ex. Euro 6) standard and conformity factor, there is a gNOx/kWh limit.
- Our device operates by calculating an average of gNOx/kWh over a short (~4km) arbitrary test route. The instantaneous values of gNOx/kWh come from the NOx ppm and CO₂ ppm measurements of the NOx sensor.
- After a certain period of time, either the PASS or FAIL light activates.

Extensive testing in Sweden, Denmark, and Germany

...add another sensor and we can also do PN/kWh or gPM/kWh



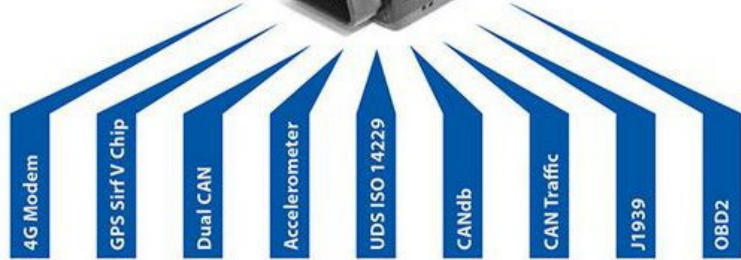
Gives Pass/Fail for **gNOx/kWh**
-calibrate by sending it to us



Gives Pass/Fail for **PN/kWh** or **gPM/kWh**
-calibrate by cleaning

*** Note that exhaust flowmeter is not required ***

...add an OBD Dongle and we can do Real-Time to Cloud
 *** It's up and working ***



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Select Vehicle

Vehicles

Vehicle	VIN	Trips	Number Plate	Name	Logger	Vehicle Type
<input type="text" value="Search..."/>	<input type="text" value="Search..."/>	<input type="text" value="Search..."/>	<input type="text" value="Search..."/>	<input type="text" value="Search..."/>	<input type="text" value="Search..."/>	<input type="text" value="Search..."/>
354678055518984	WDD2132041A314444	21			354678055518984	Car

[+ Create Vehicle](#)

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Select Trip

ID	Start Time	Stop Time	Duration	Journey Length	Start Address	Stop Address	VIN	Exports	Configuration	Custom GPS Source	DTCs	Markers
<input checked="" type="checkbox"/>	4/20/2019 6:01:32 AM	4/20/2019 9:16:49 AM	15 min	1 km	Västra Brändstgen 2, 271 60 Västas, Sweden	Suarta vägen 18, 271 60 Västas, Sweden	WDD2132041A314444	Export as v	GPS			
<input type="checkbox"/>	4/19/2019 9:44:48 AM	4/19/2019 11:57:58 AM	133 min	195 km	BROCKAD 104, 305 93 Halmstad, Sweden	Suarta vägen 14, 271 60 Västas, Sweden	WDD2132041A314444	Export as v	GPS			
<input type="checkbox"/>	4/19/2019 5:12:02 AM	4/19/2019 4:58:47 AM	158 min	144 km	Skanstaden 431 53 Mönsterl, Sweden	Enslöv 122, 313 97 Åsö, Sweden	WDD2132041A314444	Export as v	GPS			
<input type="checkbox"/>	4/19/2019 11:53:16 AM	4/19/2019 12:10:12 AM	17 min	13 km	Kungälvskölen 428 36 Källered, Sweden	Kontrollvägen 10, 431 50 Västas, Sweden	WDD2132041A314444	Export as v	GPS			
<input type="checkbox"/>	4/19/2019 6:40:23 AM	4/19/2019 8:07:19 AM	97 min	31 km	von Uffallgatan 11, 415 05 Götterö, Sweden	Brickvägen 38, 437 42 Lindome, Sweden	WDD2132041A314444	Export as v	GPS			
<input type="checkbox"/>	4/17/2019 10:45:24 AM	4/17/2019 11:06:04 AM	21 min	17 km	Garnia rikvägen 104, 415 05 Götterö, Sweden	von Uffallgatan 20, 415 05 Götterö, Sweden	WDD2132041A314444	Export as v	GPS			
<input type="checkbox"/>	4/17/2019 12:32:20 AM	4/17/2019 12:41:05 AM	9 min	1 km	Garnia rikvägen 104, 415 05 Götterö, Sweden	Brickvägen 38, 437 42 Lindome, Sweden	WDD2132041A314444	Export as v	GPS			

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View Data

DATA 4/20/2019, 9:01:32 AM - 4/20/2019, 9:16:49 AM (15 min) (1 km) < Prev Next >

MAP | Drive Behavior: On

GRAPHS

NOX (Candts)

Vehicle Speed (auto) (GPS)

SIGNALS

ERCO	NOX	RPVS	VHCM	GPS_DIR	GPS_SAT
0 bits	39.16 ppm	1560 ohms	9.25 v	113.85 deg	6

GPS_SPEED	LAT	LONG
32.02 km/h	55.43103	13.85301

EPA QBF Research

2020-01-0372 Published 14 Apr 2020



Motor Vehicle Emission Control Quality Monitoring for On-Road Driving: Dynamic Signature Recognition of NO_x & NH₃ Emissions

Xiaoguo Tang, John Kargul, and Dan McBryde US Environmental Protection Agency

2018-01-0650 Published 03 Apr 2018



Vehicle Exhaust Emission Control-Dynamic Signature Measurement and Analysis - A Method to Detect Emission Testing Irregularities

Xiaoguo Tang, Walter Caldwell, and Dan McBryde US EPA

A Simple Test Method to Monitor Emission Control Operating State Space (Emission Control Failure & Defeat Device Recognition)

2016-01-2324

Published 10/17/2016

Xiaoguo Tang and Dan McBryde

USEPA National Vehicle Fuel/Emission Lab

CITATION: Tang, X. and McBryde, D., "A Simple Test Method to Monitor Emission Control Operating State Space (Emission Control Failure & Defeat Device Recognition)," SAE Technical Paper 2016-01-2324, 2016, doi:10.4271/2016-01-2324.

Summary

1. ECM has extensive experience with ceramic exhaust sensors.
 - 34 years in the business
 - Tens of thousands of units
 - Can control all of the sensors
 - Extensive usage experience
 - Offer rotating sensor calibration service
2. Don't hold your breath for the \$10,000 AVL/Horiba-mimicking miniPEMS.
3. We have all the parts to develop low-cost **QBFs** (Quick Bad-vehicle Finders) that can be deployed in the thousands and used by non-conventional “technicians” (ex. accountants from Accenture).

Once we've identified the bad vehicles, further investigation with a real PEMS can be justified.

4. Without the USEPA and CARB actively working on and supporting **QBFs**, with the goal to certifying their use for legitimate and legislated applications, nothing is going to happen.
5. I see too many underfunded and understaffed projects being worked on to clean the same air. It's time we worked together and got something deployed. Otherwise, we have a "Gilligan's Island" situation where we are pretending to get off the island but in reality, we're just playing around.

