ECM's miniPEMS and ~~microPEMs~~ QBFs Systems and Components

Dr. Ronald S. Patrick
ron.patrick@ecm-co.com
ECM, Engine Control and Monitoring Company
Santa Clara, CA, USA
www.ecm-co.com
© March 17, 2022

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

- AFR/Lambda/O_2
- EGR (O_2 in intake)
- NOx/O_2/CO_2
- CO/CO_2
- NH_3
- PM/PN
- Fast Temperature

ECM has control modules for <u>all</u> 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

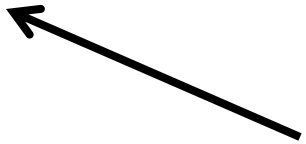
ex. NGK Spark Plug TC-6110 UEGO/Linear O_2 Module (ECM Product).

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

ECM

Exhaust Measurement Solutions

www.ecm-co.com

ECM

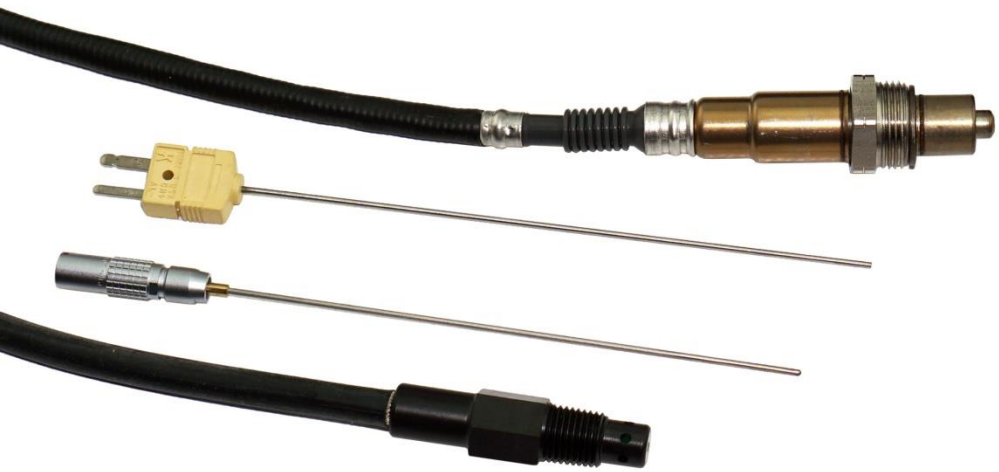
more Measurement Solutions

Particulate Matter

4x Temp

10x GPI

R_h, T, P



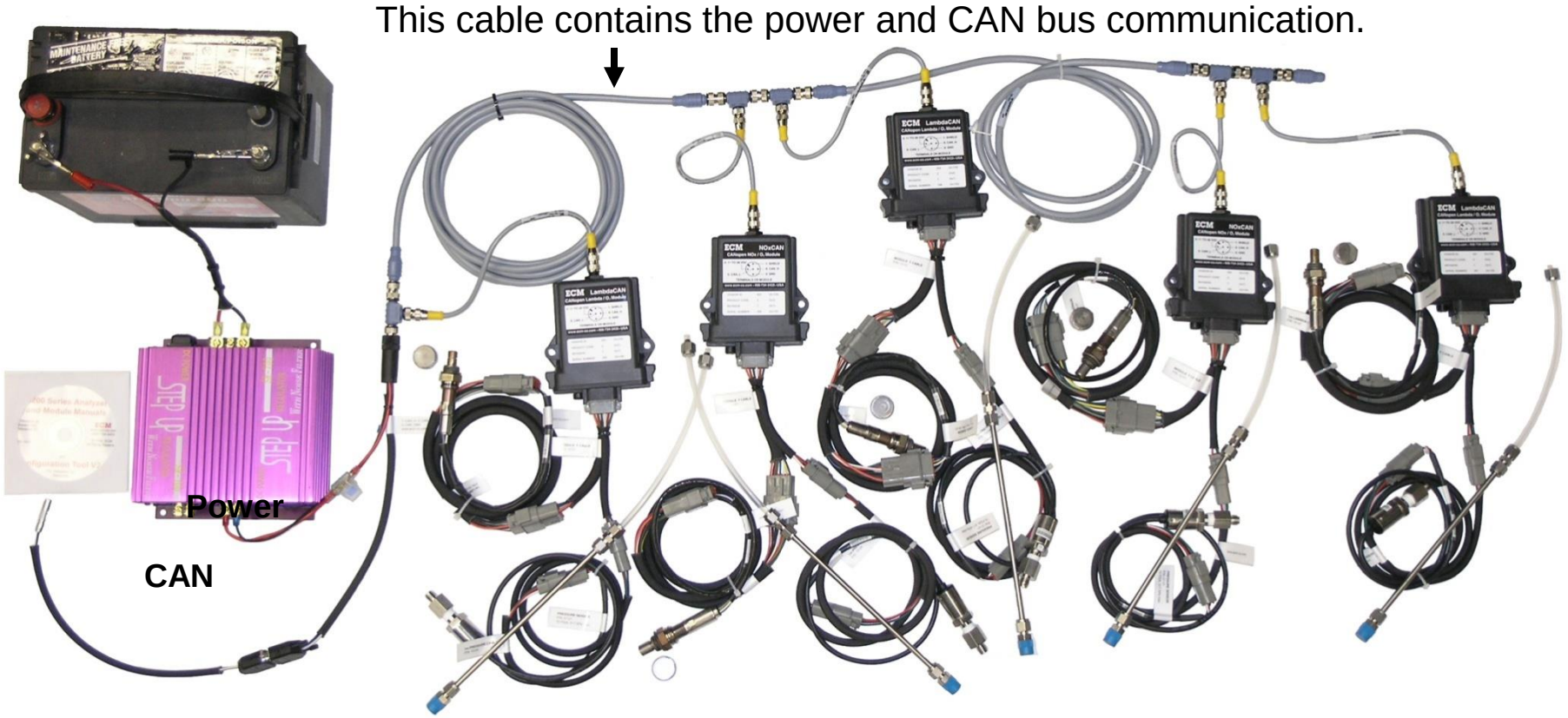
Fast Temperature Measurements

GPS and OBD (vehicle datastream)

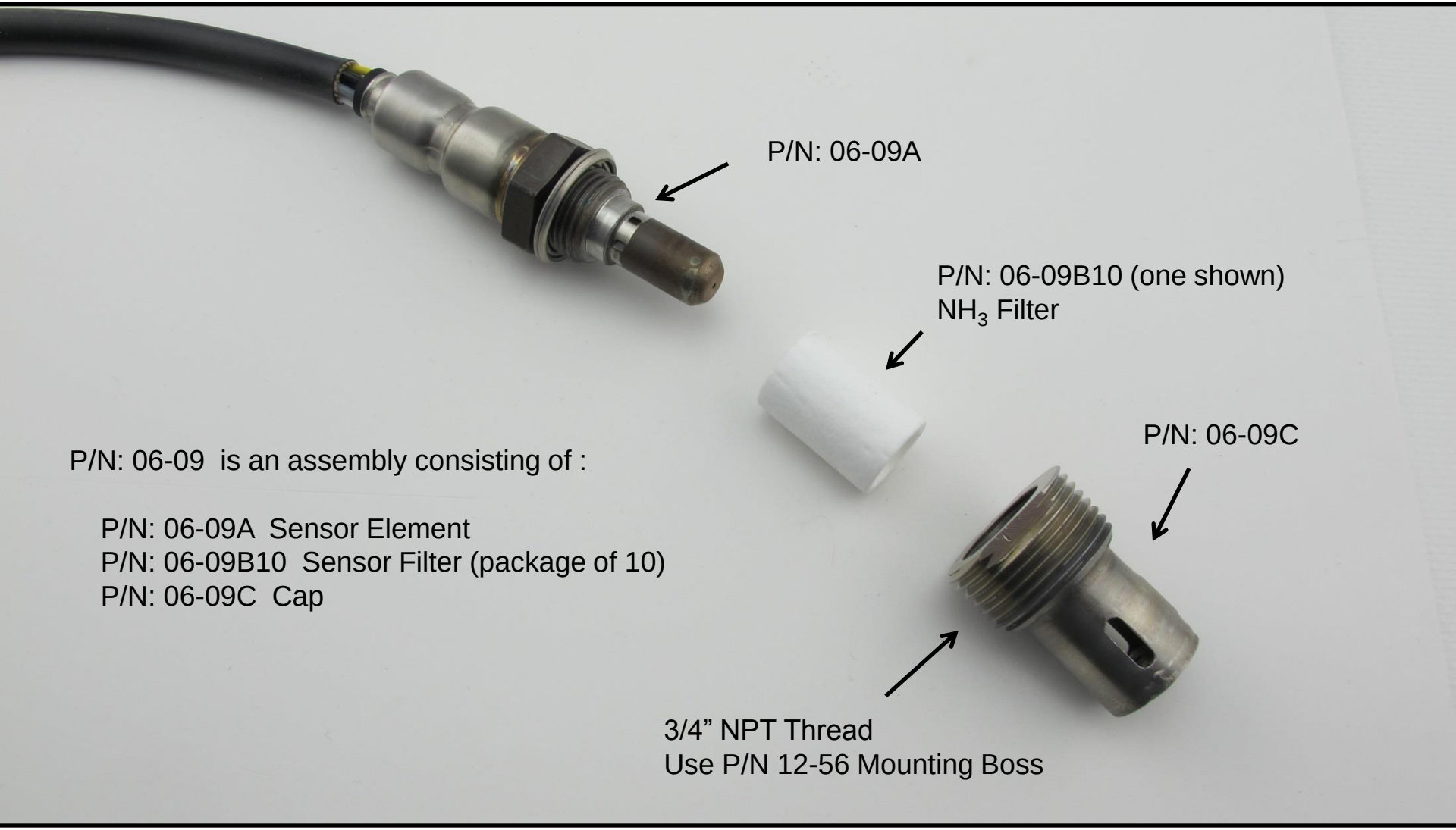
WAAS-Enabled GPS

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.)



ECM NOx, Type F Sensor
(NH_3 Insensitive, Use with NOxCANf Controller)

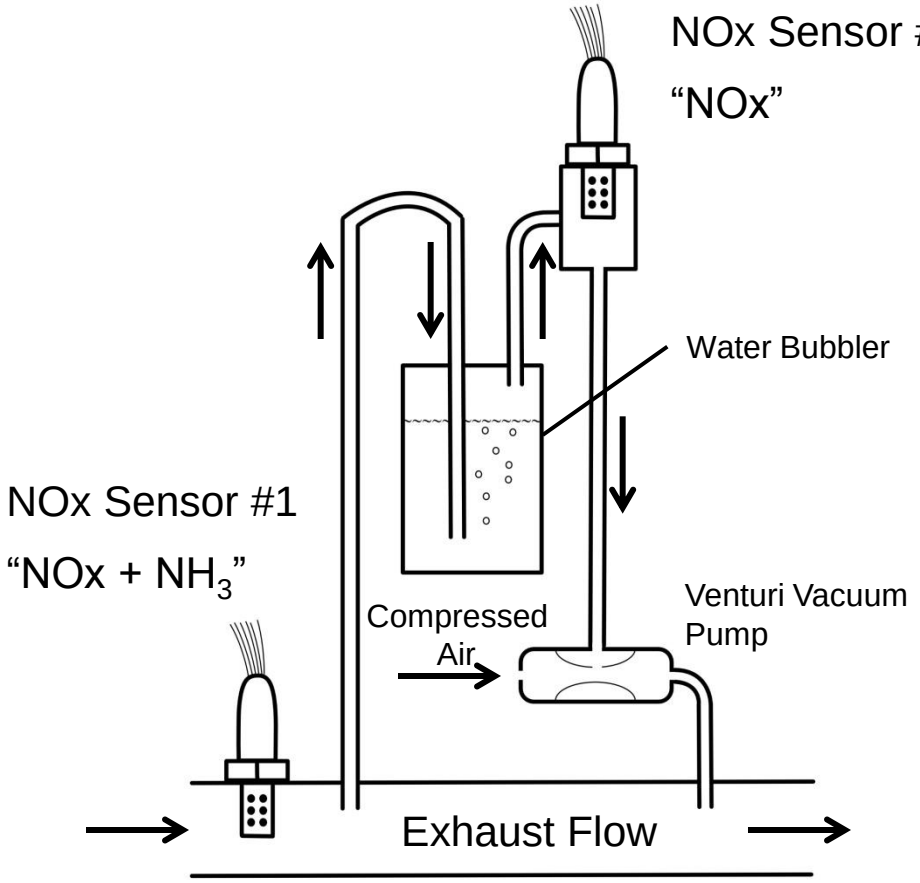


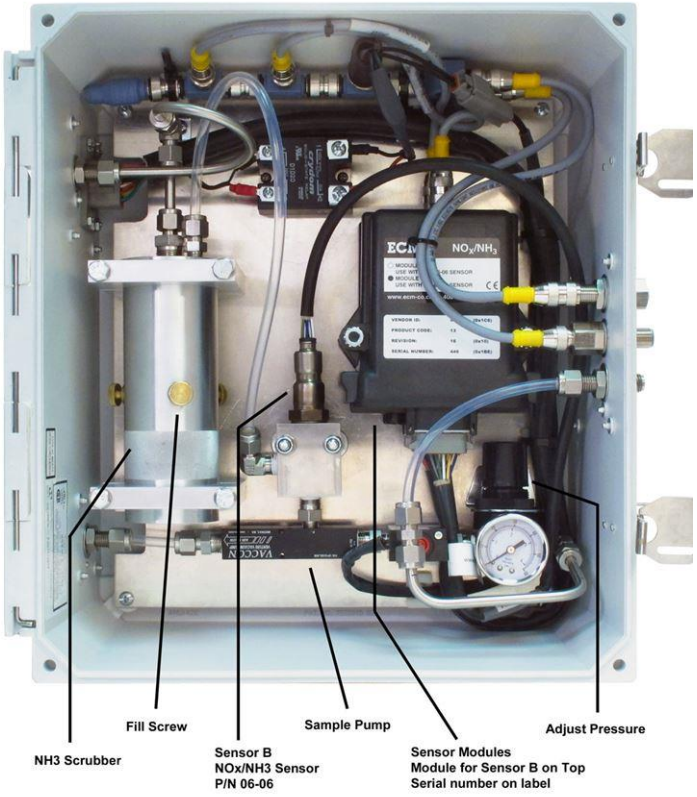
P/N: 06-09 is an assembly consisting of :

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

Using Two NOx Sensors to Measure NH_3 and NOx in Spark Ignition Engines

$NH_3 = (NOx + NH_3)_{sensor1} – NOx_{sensor2}$

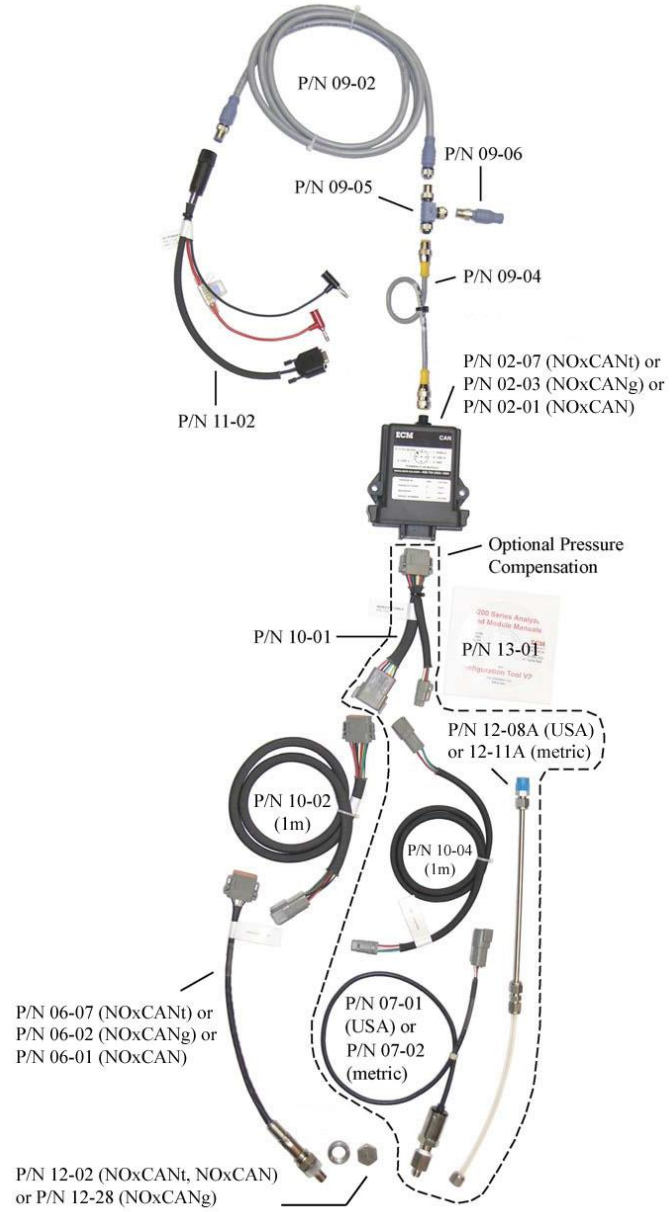




Inside of ECM NOx/NH_3
Model 5240

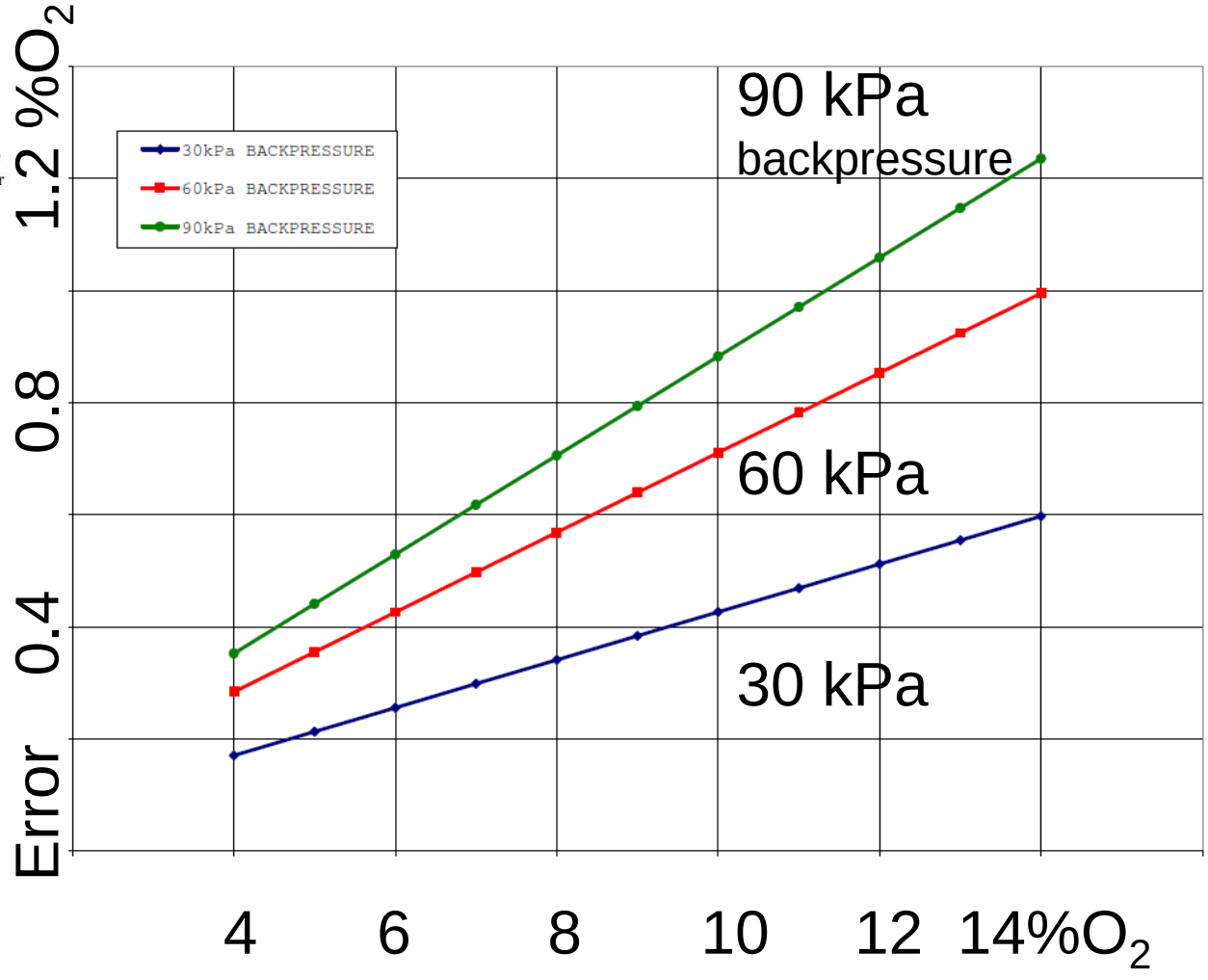
ECM Particulate Sensor (PM, PN)

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

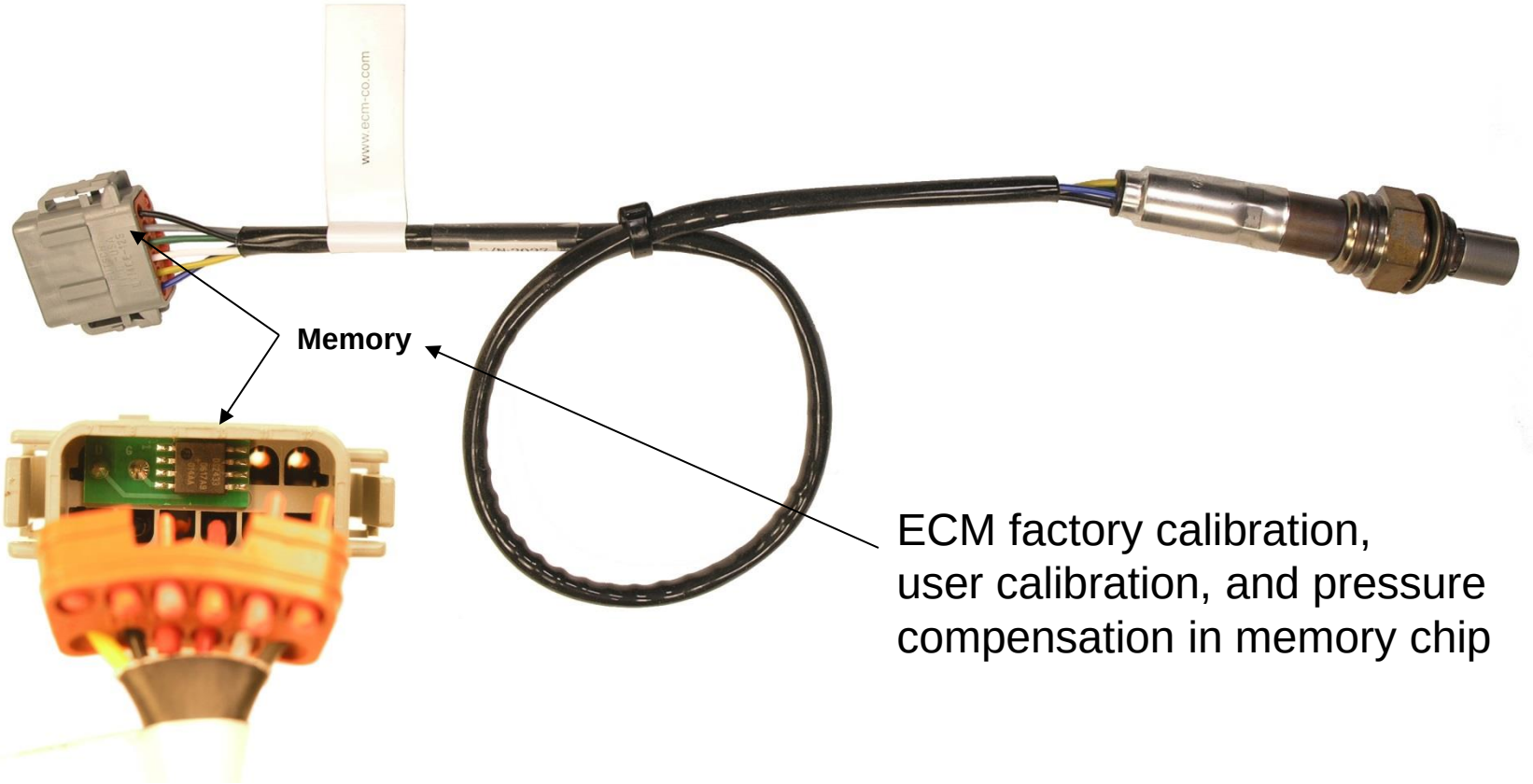


ECM Does Pressure Compensation

(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)

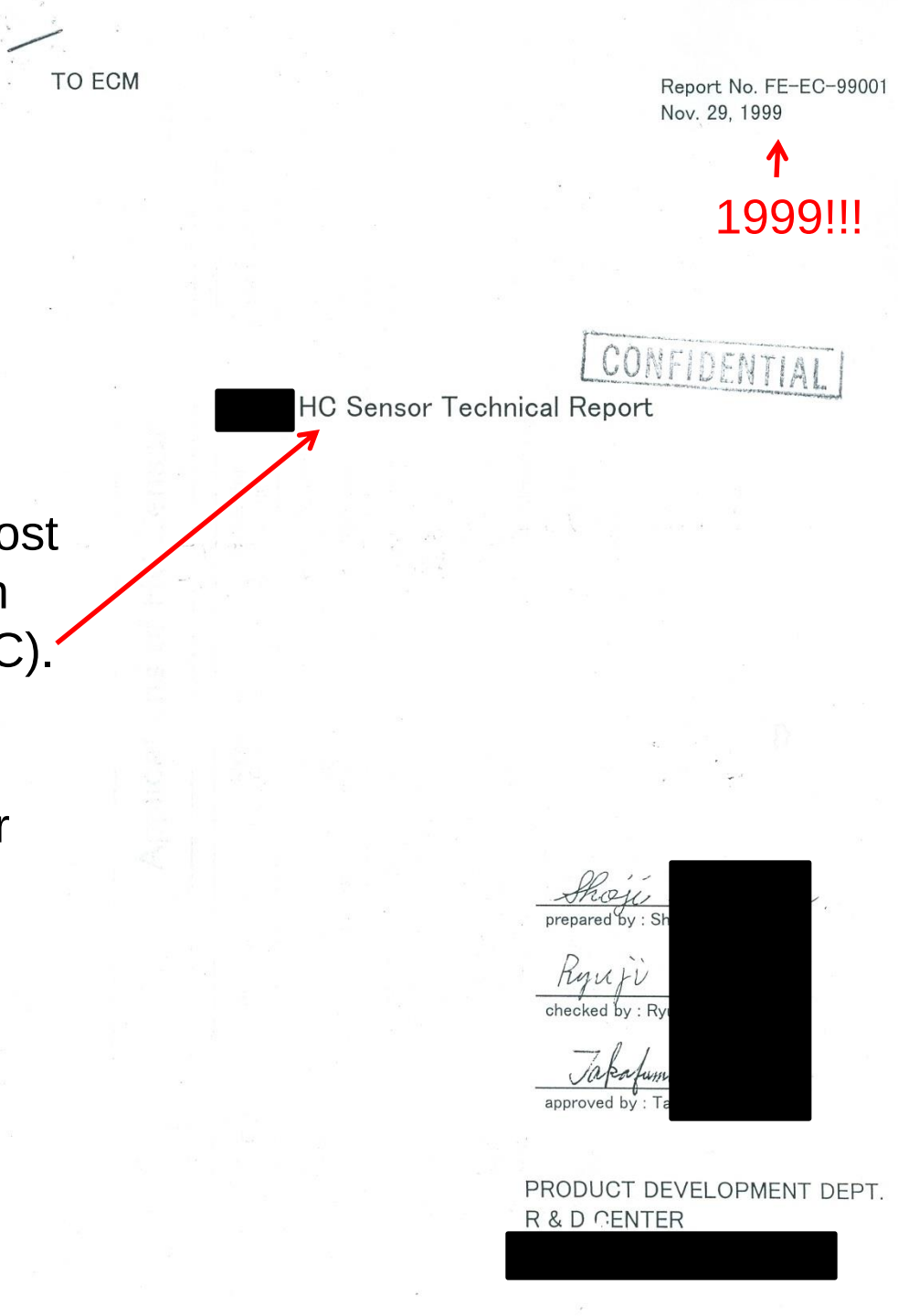
ECM Calibration Solutions for Field Calibration

Other Sensors

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.


TO ECM

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

1999!!!

CONFIDENTIAL

[redacted] HC Sensor Technical Report

prepared by : Sh[redacted]

checked by : Ry[redacted]

approved by : Ta[redacted]

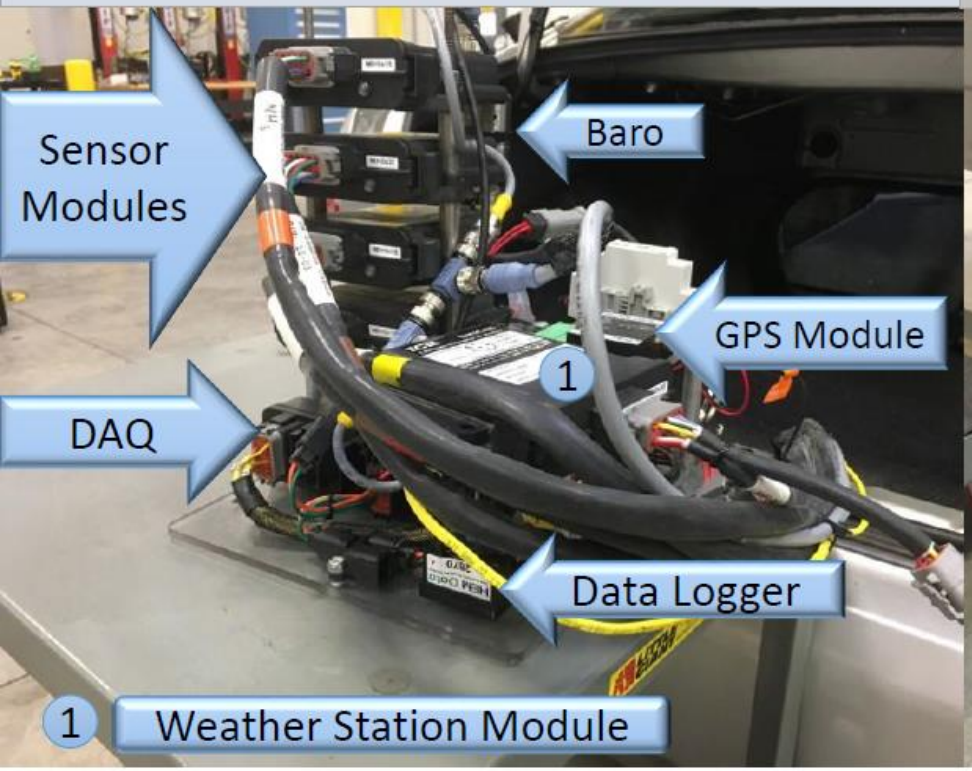
PRODUCT DEVELOPMENT DEPT.
R & D CENTER
[redacted]

EPA's miniPEMS

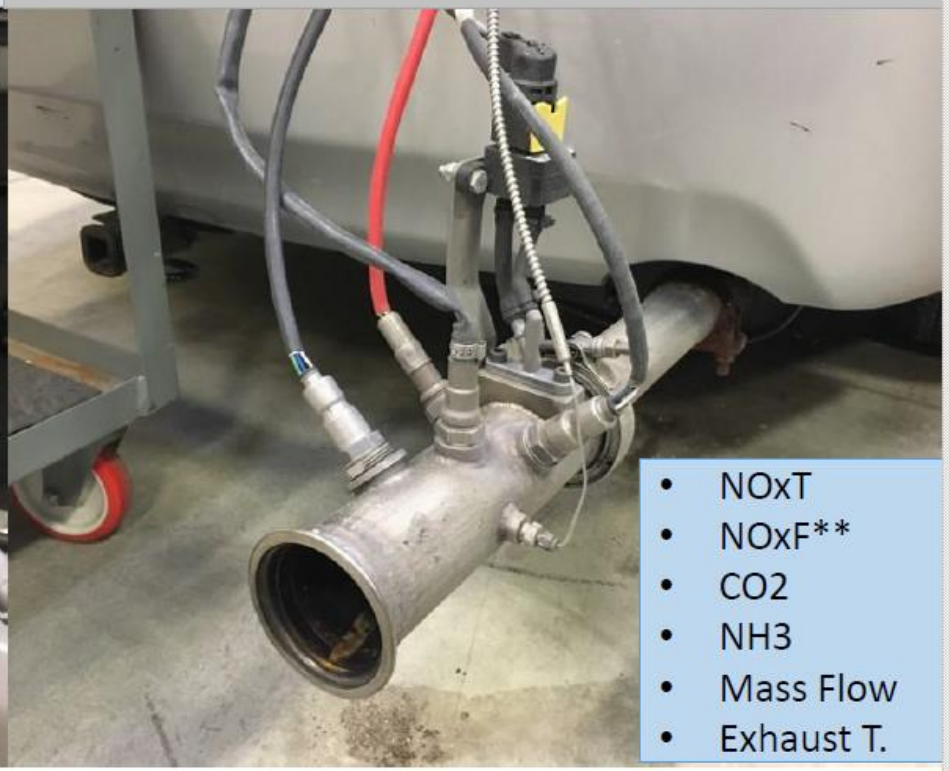
(built with ECM's measurement modules)

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 NOxF sensor in Appendix B

Future Development – Robust Packaging

Development Design

Prototype Design

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

Next generation prototype expected to be smaller

10.00 x 7.50 in

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

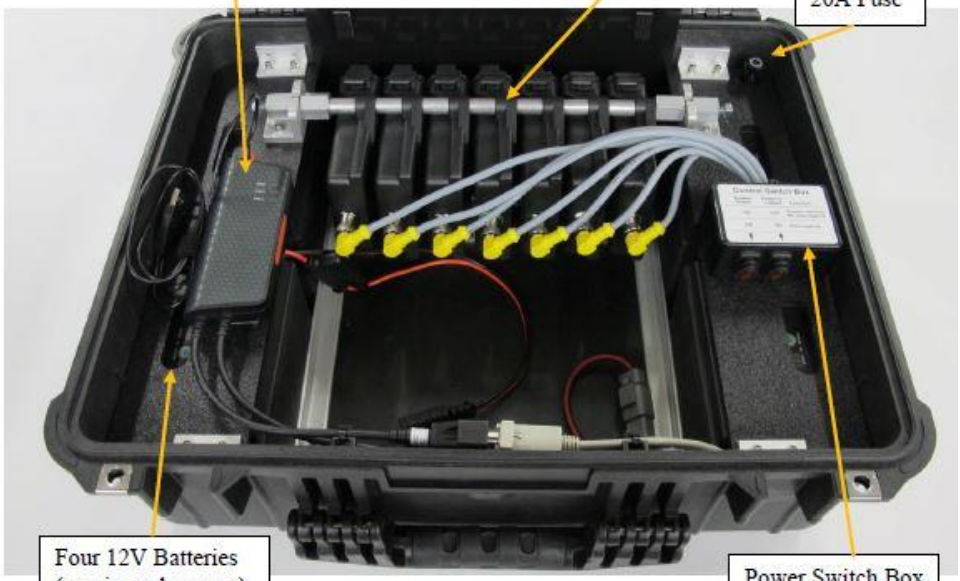
Up to 4 Modules

- Lambda, O_2
- NOx
- NH_3
- CO, CO_2
- Exh T
- Baro
- V, I, DC, Freq
- Etc

Self-Powered

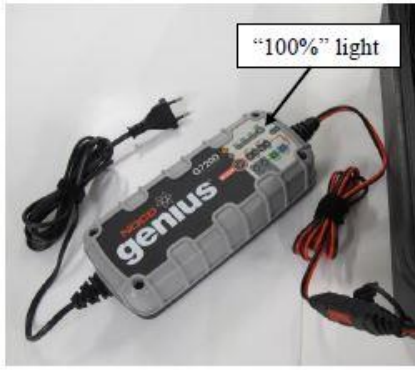
ECM miniPEMS 2 (Cars, LD & HD trucks)

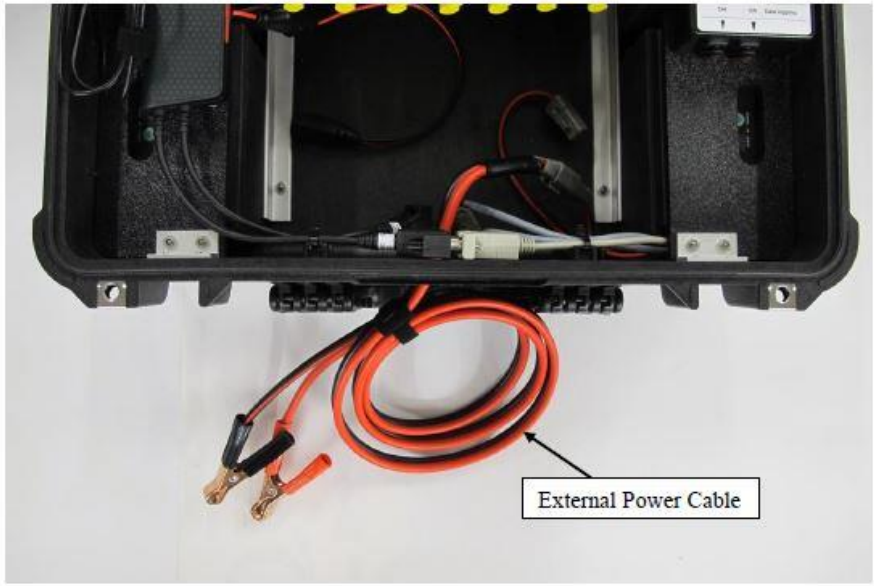
530mm x
460mm x
230mm



Remote "Power to Logger" Switch

Battery Charger



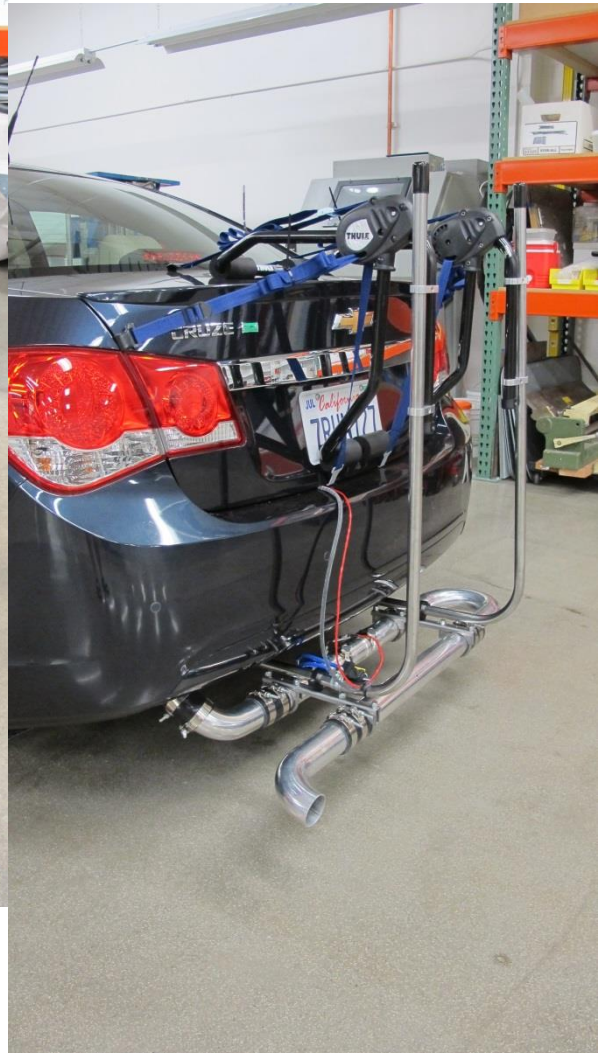


Sensor Mounting Options

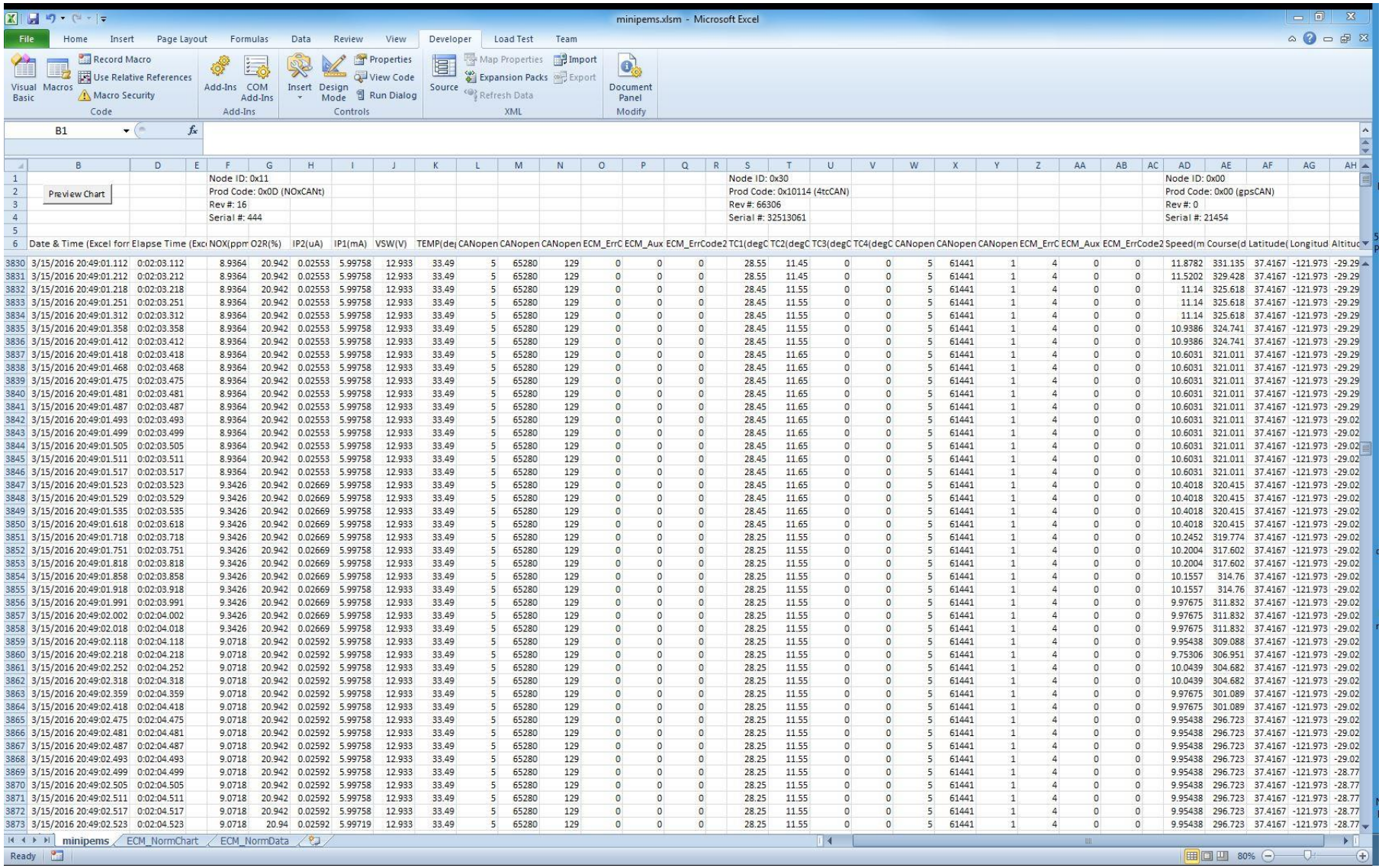
Stubby Style

1m Extended

2m Extended



Produces Excel Files



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.

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

EZ-PEMS: The Euro 6 NOx Tester

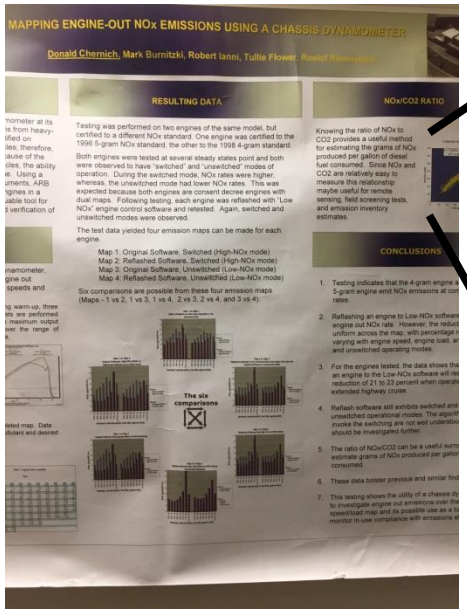
A gNOx/kWh Threshold Indicator

(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
FWZ 381
www.upplandsmotor.se

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



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

So (NOx ppm/CO_2 ppm) proportional to gNOx/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/CO_2 ppm) proportional to gNOx/kWh

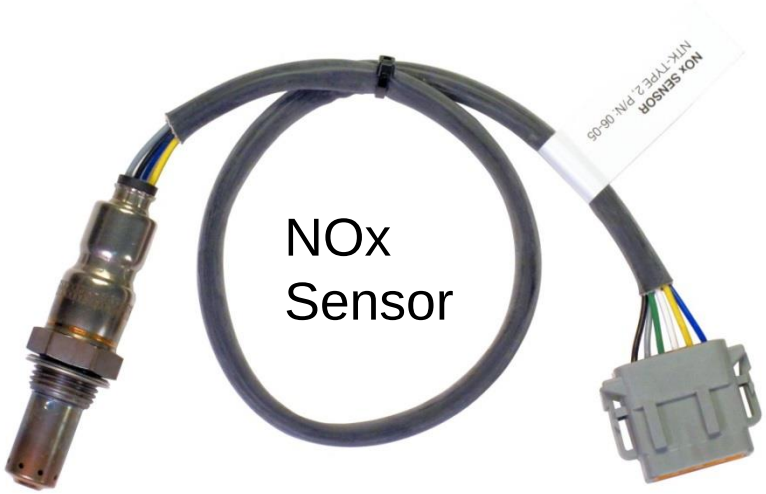
- Depending on the Euro (ex. Euro 6) standard and conformity factor, there is a gNOx/kWh limit.

- 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 CO_2 ppm measurements of the NOx sensor.

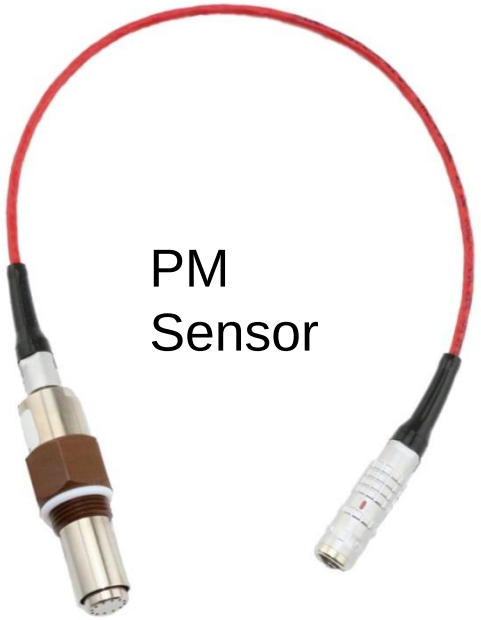
- After a certain period of time, either the PASS or FAIL light activates.

Extensive testing in Sweden, Denmark, and Germany

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



NOx
Sensor



PM
Sensor

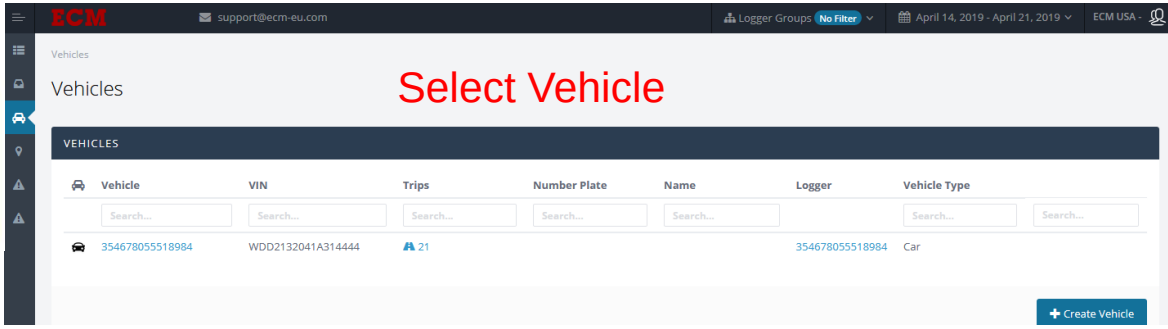
Gives Pass/Fail for gNOx/kWh
-calibrate by sending it to us

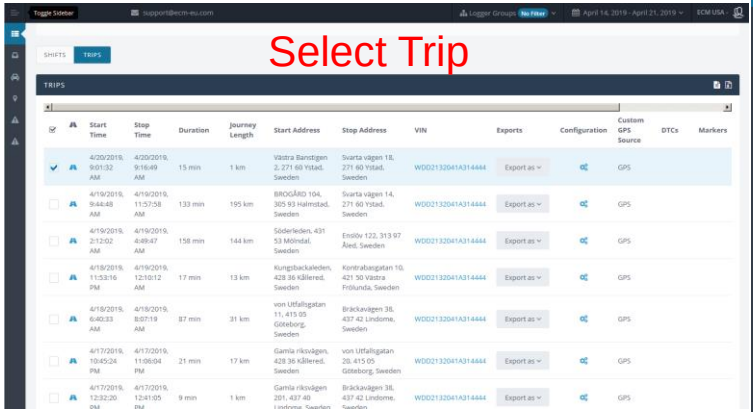
Gives Pass/Fail for PN/kWh or gPM/kWh
-calibrate by cleaning

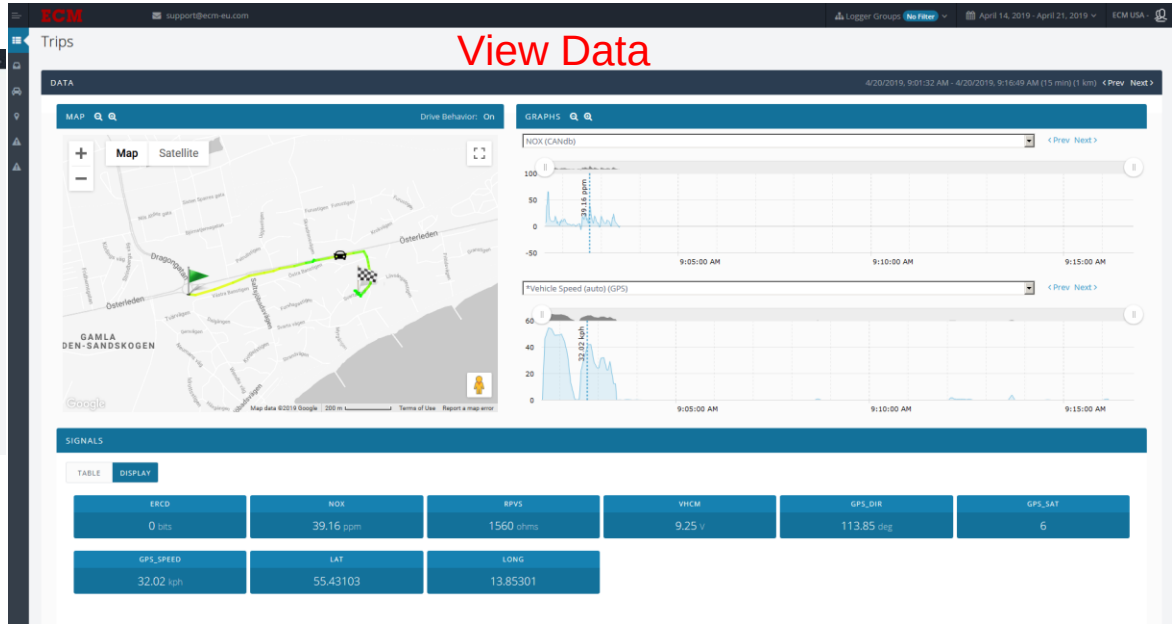
*** Note that exhaust flowmeter is not required ***

…add an OBD Dongle and we can do Real-Time to Cloud

*** It's up and working ***







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 & NH_3 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.

Copyright © 2016 SAE International

Summary

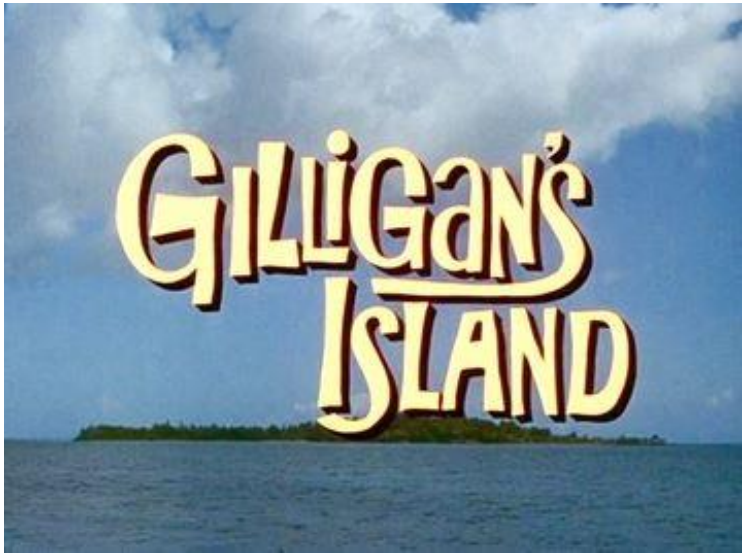
1. ECM has extensive experience with ceramic exhaust sensors.

   - 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.