New OBD-II Monitor Requirements

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New OBD requirements

- Old OBD-II
  - Catalyst Monitor
  - Misfire Monitor
  - Secondary Air Monitor
  - Fuel System Monitor
  - Oxygen Sensor Monitor
  - Comprehensive Component Monitor
  - Evap Monitor
  - EGR Monitor
  - PCV Monitor

- Current/New OBD-II
  - *Add NOx Catalyst Monitor*
  - Enhanced Misfire Monitor
  - *Enhanced Secondary Air Monitor*
  - Enhanced Fuel System Monitor
  - Enhanced Oxygen Sensor Monitor
  - Enhanced CCM Monitor
  - Add Cooling System Monitor
  - Add CSSR Monitor
  - Add VCT/VVT Monitor
  - Add In-use Performance Monitor
  - Add On-Board Service Information
  - Add Production Vehicle Validation
  - Add Diesel Catalyst and PM Monitor

NOx Catalyst Efficiency Monitor

NOx Catalyst Monitor

- **Requirement**: Monitor catalyst efficiency on LEV-II vehicles and detect when emissions exceed 3.5 x standard for 2005 and 2006 MY, 1.75 x standard for 2007 MY, except for SULEV applications which would be 2.5 x standard. HC threshold remains at 1.5 x standard.
- **Phase-in**: LEV-II, 30/60/100% starting in 2005 MY

NOx Catalyst Monitor

- **CARB Rationale:** CARB believes that HC – only monitoring would not provide sufficient protection from high NOx levels with LEV II applications as it did for LEV I applications. CARB further believes that catalyst oxygen storage capacity, which is used by most manufacturers as an estimate of HC conversion efficiency, can likewise be used as a measure of NOx conversion efficiency. CARB used manufacturers' data as shown on the next page to reach this conclusion.

NOx Catalyst Monitor

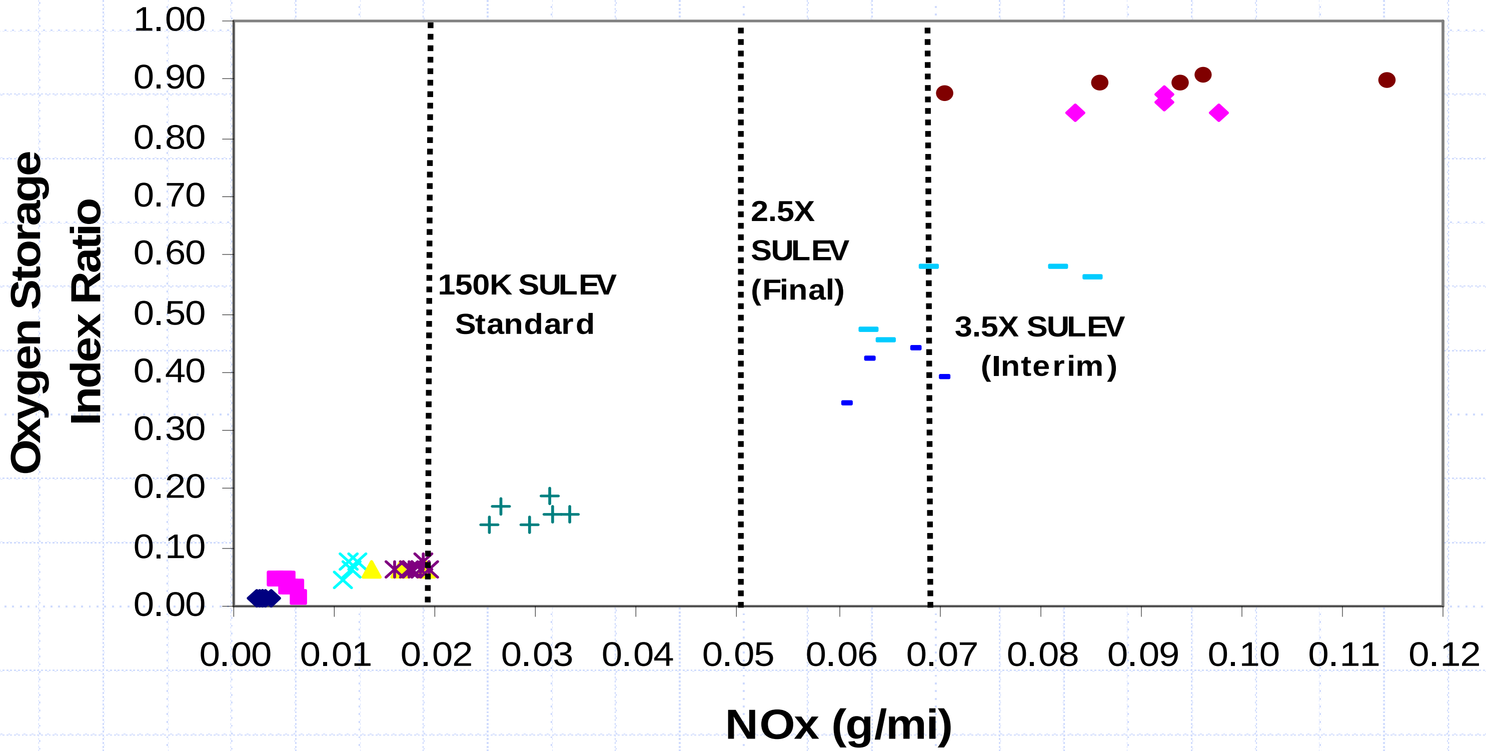


Figure 1

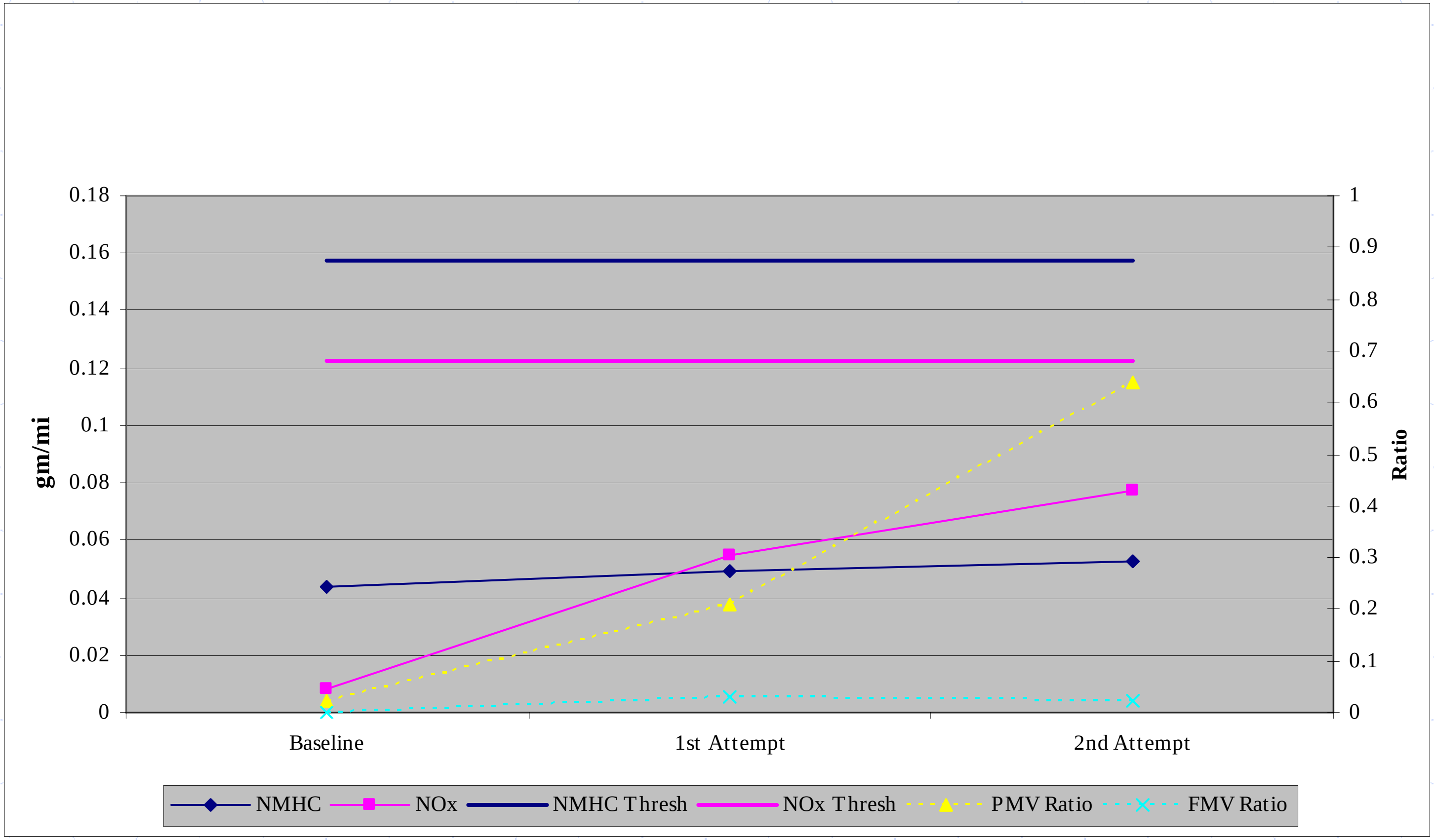
NOx Catalyst Monitor

- **Compliance Plan**: Refine current catalyst monitor using front and rear O2 sensors, correlate NOx conversion capability with catalyst oxygen storage capacity (OSC).

NOx Catalyst Monitor Implementation

- **Design Criterion:** Robust monitoring of NOx and HC efficiency requires low monitored volume O_2 storage capacity (OSC). Low OSC can be achieved through optimized catalyst loading and washcoats and/or reduced monitored catalyst volume. Fueling strategies also need to be optimized to minimize high OSC generation. The accompanying graph illustrates that NOx conversion is be damaged significantly easier than HC conversion and that partial volume monitoring is far better for NOx monitoring than is full volume.

NOx Catalyst Monitor Implementation



NOx Catalyst Monitor Issues

- Catalyst monitoring to HC and NOx thresholds is doable at the LEV II emissions level (but remains of concern at SULEV emissions level.
- The NOx requirement has driven costly system redesign on applications that were planned for obsolescence one model year after phase-in completion (with no tailpipe emissions benefit).
- Successful catalyst cost reductions implemented prior to the NOx requirement have been severely compromised.

Enhanced Secondary Air Monitor

Enhanced Secondary Air Monitor

- **Requirement**: Monitor secondary air system during normal operation and detect when emissions exceed 1.5 x standard.

- **Phase-in**: LEV-II, 2006 MY – but certain provisions, if exercised, could mean delay until 2008 MY.

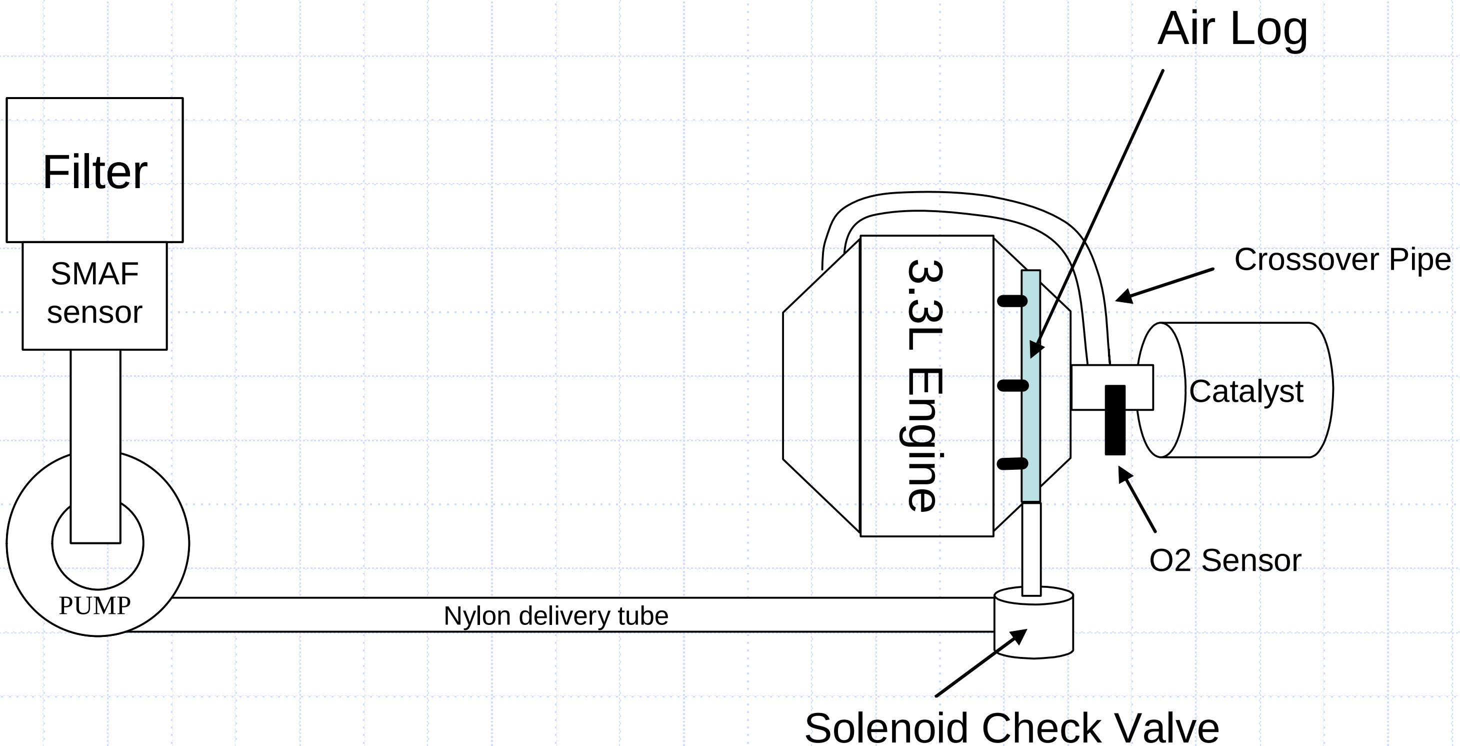
Enhanced Secondary Air Monitor

- **CARB Rationale:** Secondary air is intended to promote early catalyst light-off for emissions reduction. System failure can cause undetected emissions failures. This is of particular concern on high mileage vehicles where component deterioration or poor service re-assembly can result in the intended airflow being delivered to other than where intended. CARB believes that durability of such systems is difficult to determine, and that functional-only checks may only be effective long after failures have occurred; also concerned that some system failures may only occur during cold start operation, thus making intrusive diagnostics after the cold start of questionable value.

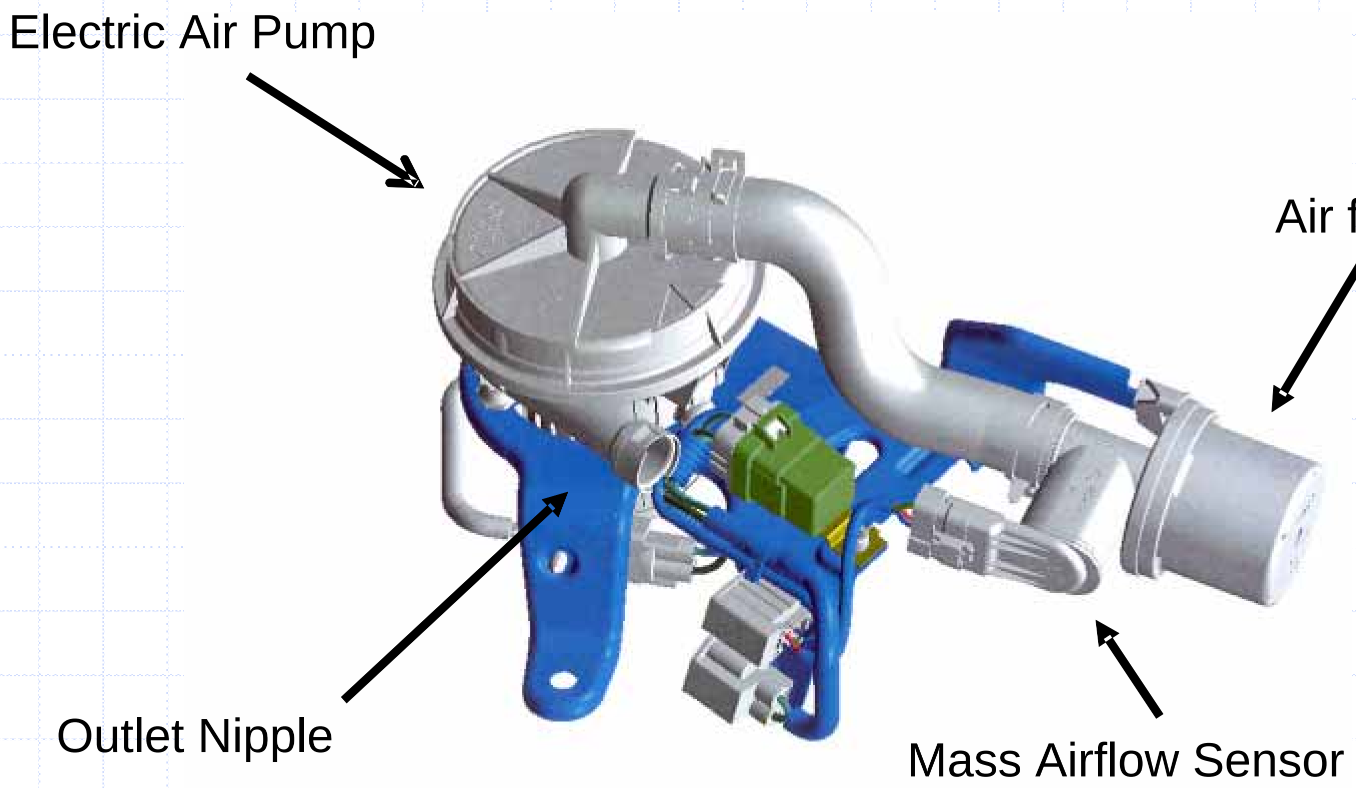
Enhanced Secondary Air Monitor

- **Compliance Plan**: Add monitoring hardware, i.e. pressure sensor/switch or MAF sensor to measure flow; use wide-range A/F sensor (UEGO); run secondary air in closed loop fuel and look for fuel trim change.

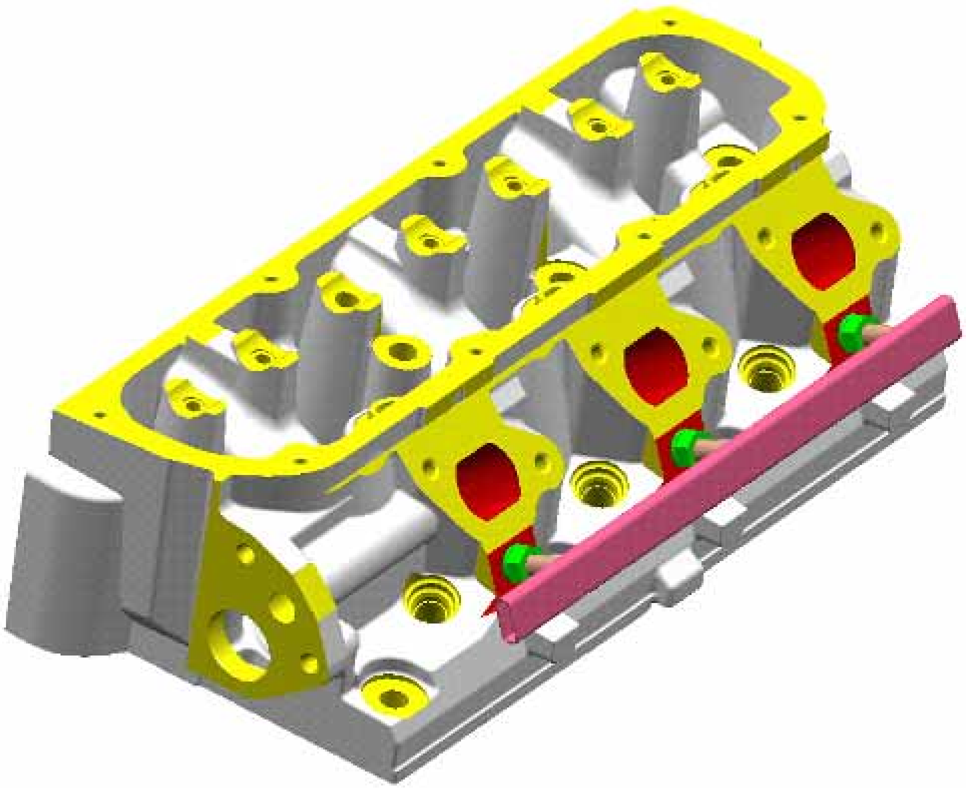
Secondary Air – Typical Hardware



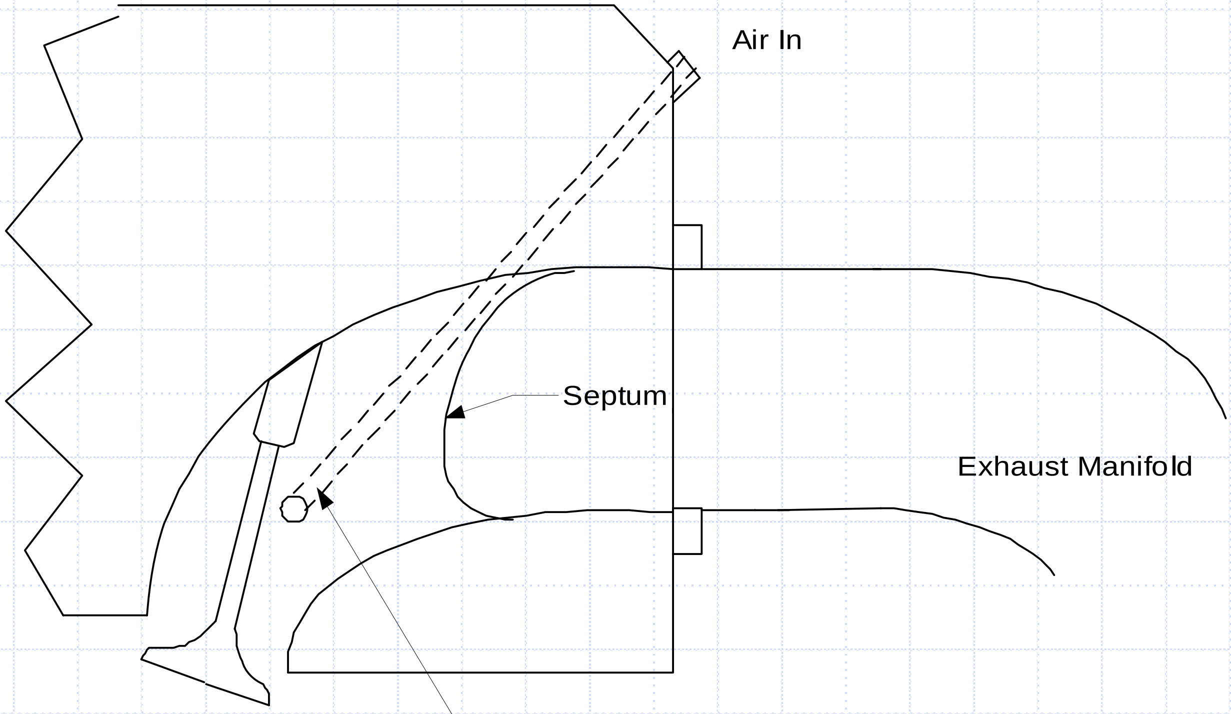
Secondary Air – Typical Hardware



Secondary Air – Typical Hardware



Secondary Air – Typical Hardware



Typical Secondary Air Systems

- DCA has chosen to use a secondary mass airflow (SMAF) sensor. This resistive device infers mass flow by the current required to maintain the elements control temperature. The SMAF sensor is used as input for the modeled fuel-air ratio at the catalyst face as well as input for the diagnostic airflow algorithm.

- Some manufacturers use pressure transducers, O2 sensor response, or primary air mass sensors (measuring incremental flow when pump is engaged) for the SAP diagnostics.

Typical Secondary Air Pump Systems

- Most Secondary Air Pump (SAP) systems today are equipped with an electric air pump, a control valve, and “plumbing”/ machined passages which deliver fresh air to the exhaust port area.
- The pump flow varies with battery voltage, ambient inlet air density, backpressure from the engine, etc. A typical bench flow rate for the pump alone is 45 kg/hr (12.5 g/sec).
- A control valve is required to allow air flow when the pump is energized and to block exhaust gas flow when pump is de-energized. The valve may be either mechanical, vacuum transducer actuated or electrical solenoid.

Typical Secondary Air Pump Systems

- Current delivery systems target the injection location to be within 20 – 25 mm of the exhaust valve seat. The exothermic reaction can not be initiated unless sufficient temperature is already present. Systems which deliver air further downstream of exhaust valve are not commonly in use today. The “further downstream” systems could not take advantage of the exhaust manifold thermal oxidation and only benefited from the catalytic oxidation of CO and HC emissions.

SAP Flow Diagnostics Metric

- (Measured SMAF – Modeled SMAF) / Modeled SMAF

- This normalizes the diagnostic metric for all engine operating conditions and ambient conditions.

- Integrate the normalized error to allow diagnostic determination at variable times.

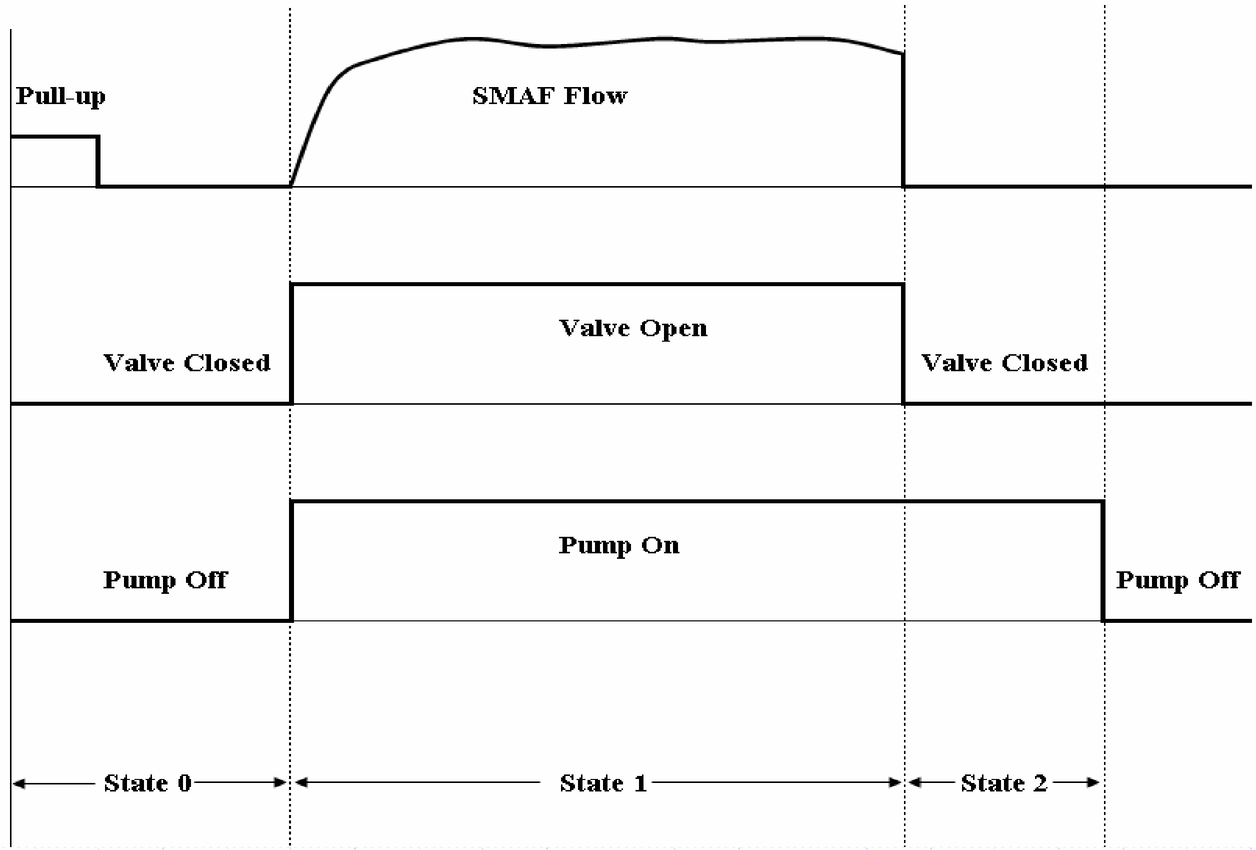
SAP Diagnostics Overview

- OBD I faults (one trip electrical checks)
  - Circuit check for SMAF shorted low (Pcode 2432)
  - Circuit check for SMAF shorted high (Pcode 2433)
  - Circuit check for Air pump relay (Pcode 0418)
  - Circuit check for Solenoid Shut-off Valve (Pcode 0412)
- State 0 (Pump off / Check valve closed)
  - Check SMAF sensor rationality.
  - During SMAF sensor power up, sensor voltage is pulled up. Then when sensor is ready, voltage drops back down if no air flow.
  - Pass rationality if power-up voltage cycle is detected and if SMAF sensor indicates no flow for the condition of pump off / check valve closed . Otherwise, set SMAF sensor circuit performance (Pcode 2431).

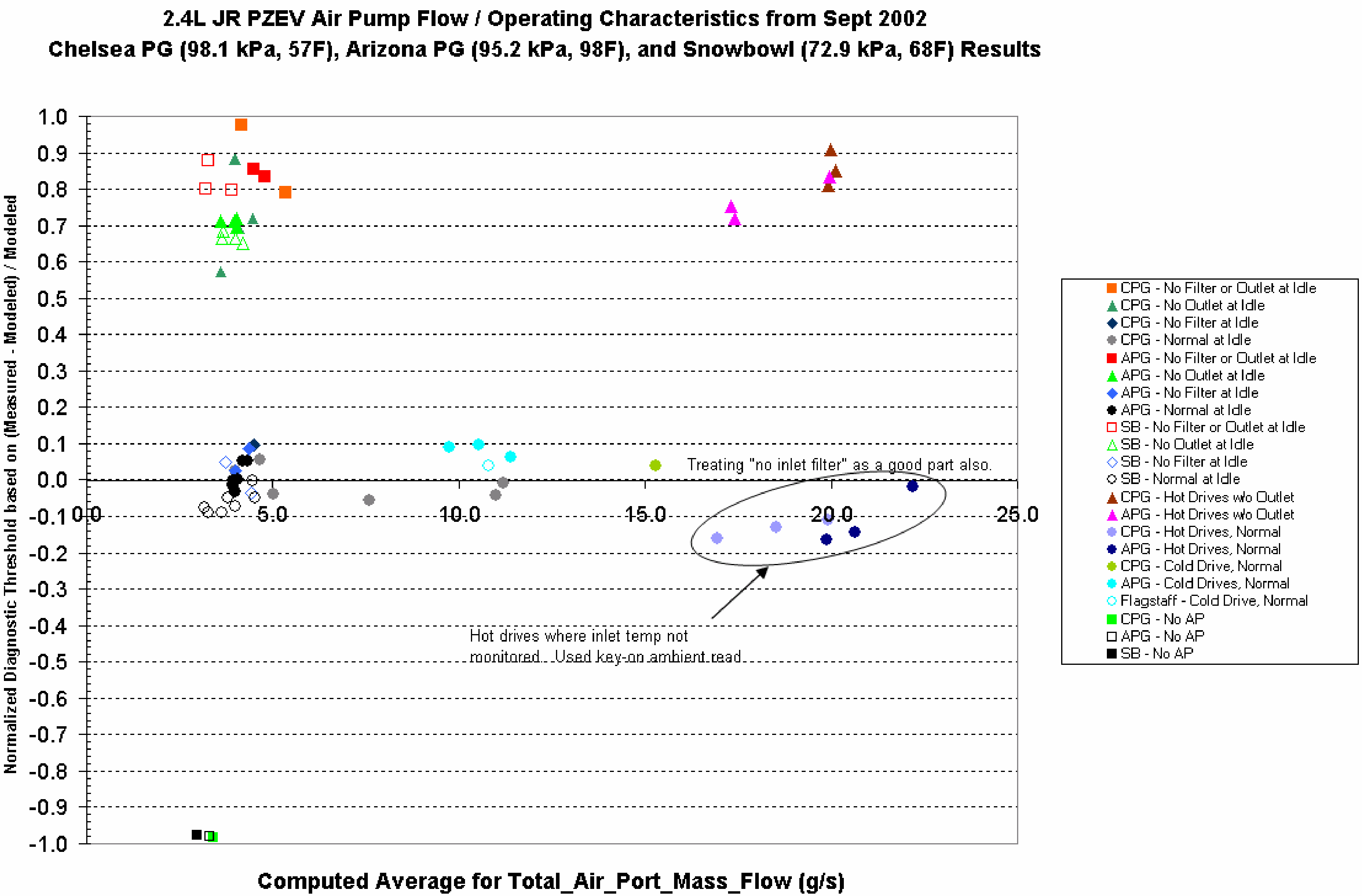
SAP Diagnostics Overview

- State 1 (Pump on / Check Valve open)
  - If integrated normalized error > High Threshold, then set "Secondary Air Injection System Incorrect Flow Detected" (Pcode 0411). Possible causes could be any leak in the air delivery system, either upstream or downstream of check valve).
  - If integrated normalized error < Low Threshold, then set "Secondary Air Injection System Insufficient Flow" (Pcode 0491). Possible causes could be air pump delivery blockage, air passage blockage in exhaust, check valve stuck closed, low output air pump, or low SMAF sensor.
- State 2 (Pump on / Check Valve closed)
  - Set Secondary Air Injection System Switching Valve Stuck Open (Pcode 2440), if SMAF reading is greater than maximum expected "no flow".

Overview of Diagnostic States

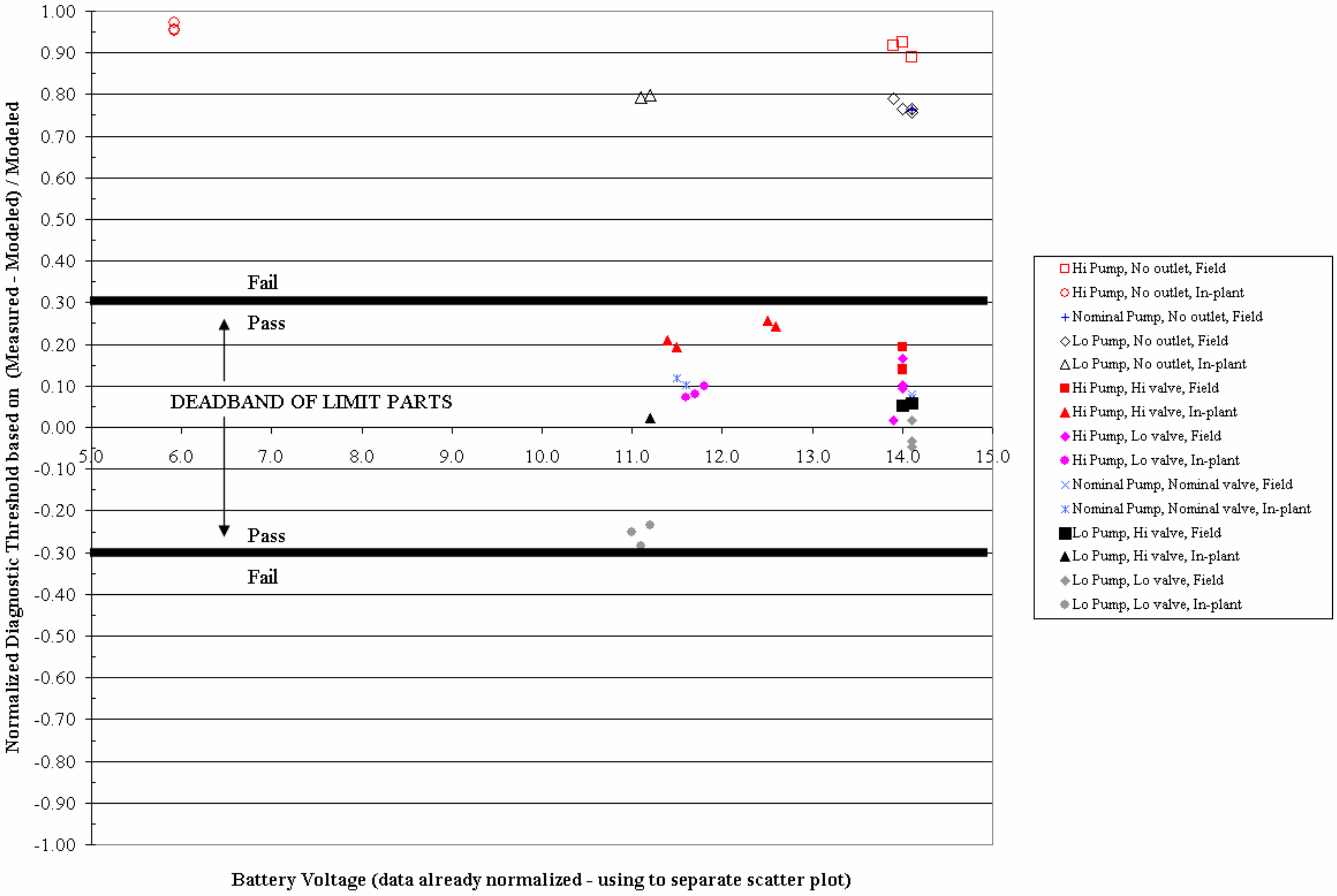


Algorithm based on normalized air flow

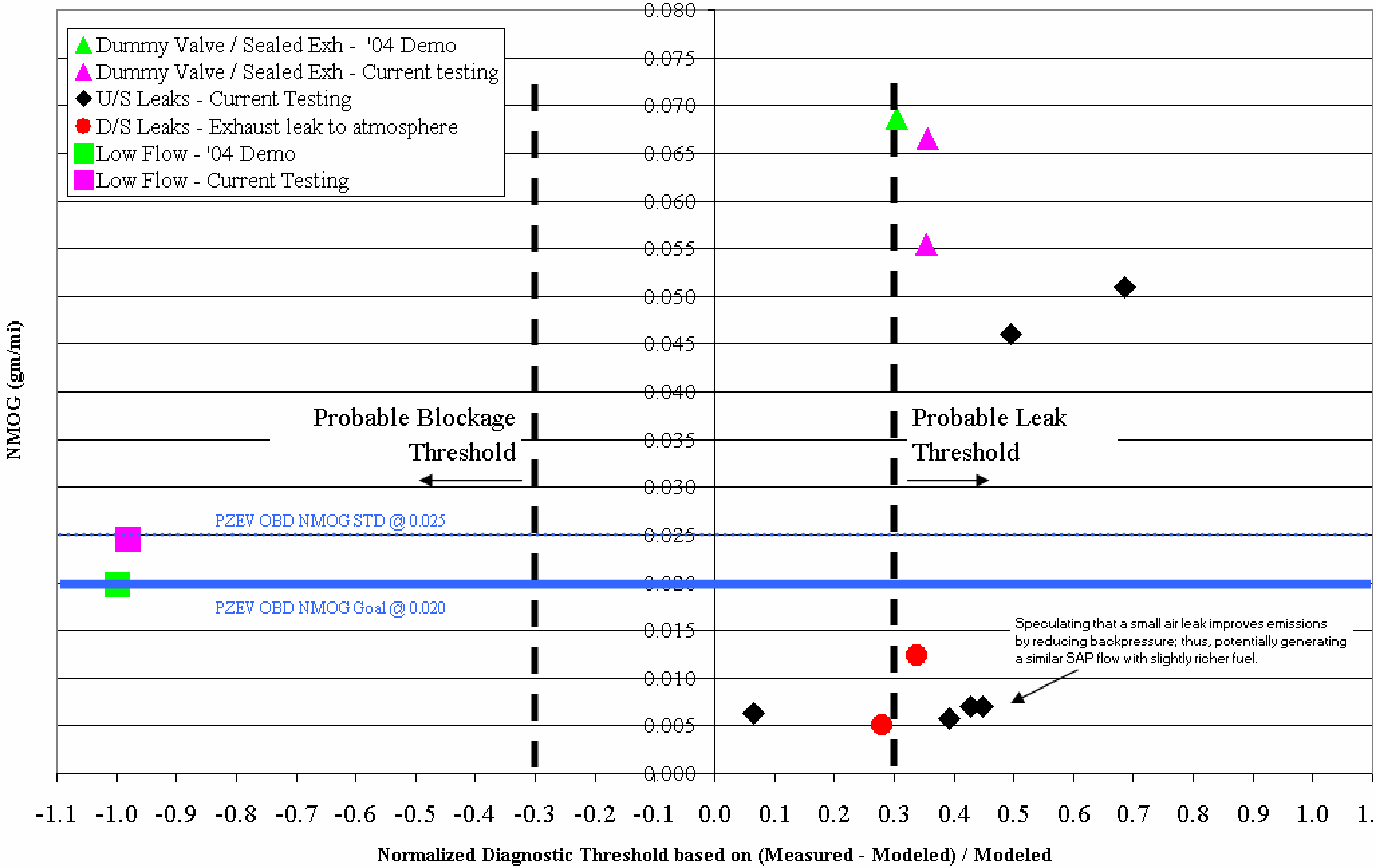


Secondary Air Limit Part Testing

Hi & Lo Pumps, Hi & Lo Check Valves, Mechanical Valves



Emission Trends for 2.4L JR PZEV with Mechanical Check Valve

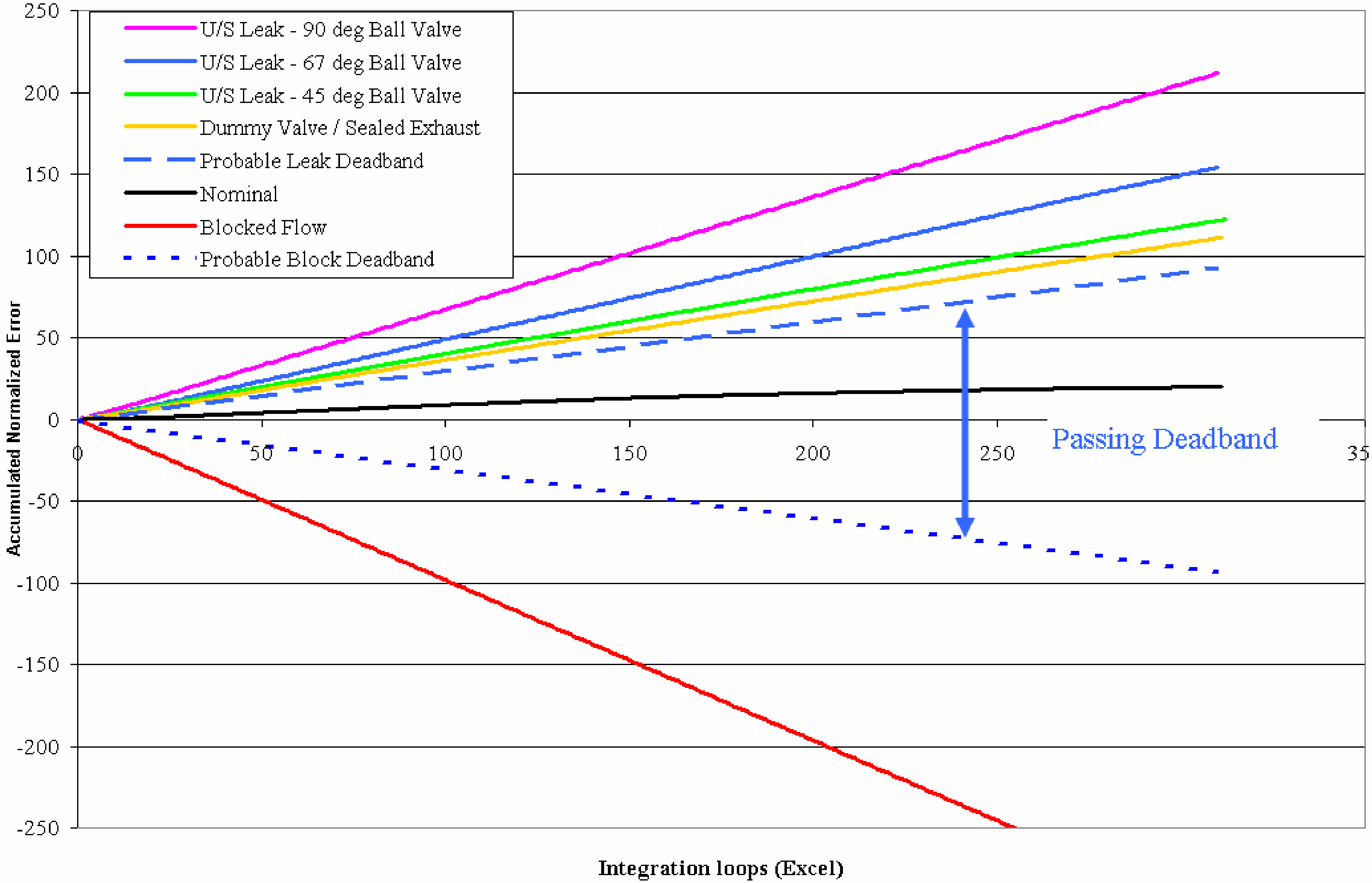


Integrated Error and Rate-Based

- Rate based performance is optimized by integrating the normalized SMAF error.
- SMAF flow diagnostics can made for variable air pump run times.
- Longer run times provide greater confidence, but shorter run times can be used for rate based performance.
- Simple comparison between integrated error and a threshold table for both “Insufficient flow” and “Improper flow”.

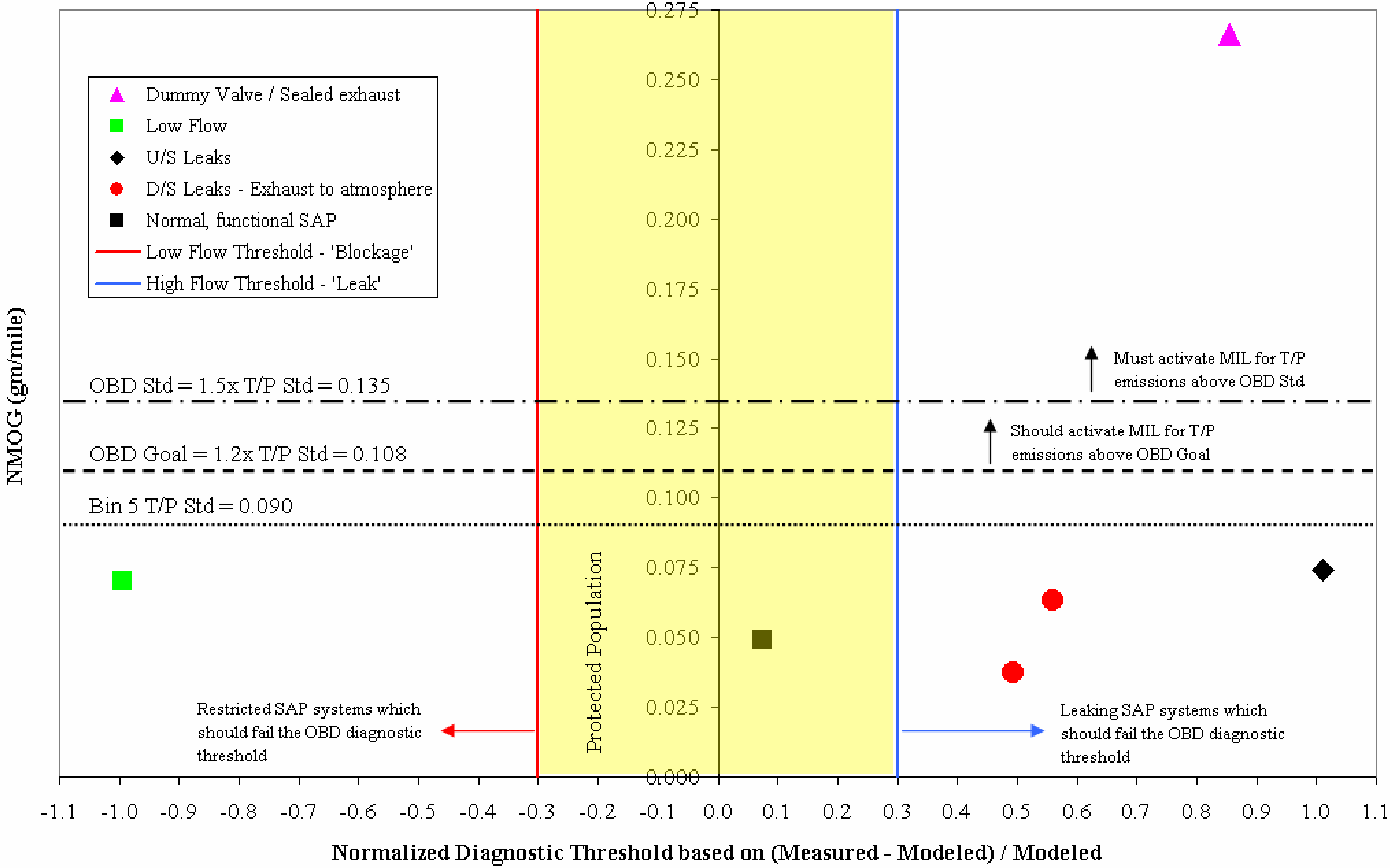
Integrated Error

Allows Rate Based Compliance for Variable Operating Pump Times



Normalized Air Flow Metric for V-6 Rear Bank Secondary Air

Bin 5 NMOG 75F Emission Threshold (tested with E85 fuel) versus Normalized Model Air Flow



DCA Secondary Air Pump - Final Points

- Intention would be to demonstrate with two cold EPA 74 prep cycles where faults would be matured. Air pump enrichment will be disabled with the MIL. Cold EPA 75 will be run for emission levels with the enrichment disabled.
- Enrichment strategy where the lesser of modeled or measured SMAF is used for fueling is needed to prevent the over fueling condition for leaking systems.
- Exhaust leak versus sealed exhaust demonstrations….direction TBD.