Catalyst Efficiency Monitor

The catalyst efficiency monitor uses an oxygen sensor before and after the catalyst to infer the hydrocarbon (HC) efficiency based on the oxygen storage capacity of the catalyst. During monitor operation the powertrain control module (PCM) calculates the length of the signal while the sensors are switching. Under normal closed-loop fuel conditions, high efficiency catalysts have significant oxygen storage. This makes the switching frequency of the rear heated oxygen sensor (HO2S) very slow and reduces the amplitude, which provides for a shorter signal length. The front HO2S switches more frequently with greater amplitude, which provides for a longer signal length. As the catalyst efficiency deteriorates due to thermal and chemical deterioration, its ability to store oxygen declines. The post-catalyst or downstream HO2S signal begins to switch more rapidly with increasing amplitude and signal length, approaching the switching frequency, amplitude, and signal length of the pre-catalyst or upstream HO2S. The predominant failure mode for high mileage catalysts is chemical deterioration (phosphorus deposits on the front brick of the catalyst), not thermal deterioration.

For the typical HO2S, the catalyst monitor counts the number of front HO2S switches during part-throttle, closed-loop fuel conditions after the engine is warmed-up and the inferred catalyst temperature is within limits. The number of front switches are accumulated, depending on the calibration, in up to three different air mass regions or cells. While catalyst monitoring entry conditions are being met, the front and rear HO2S signal lengths are continually being calculated. When the required number of front switches has accumulated in each cell, the total signal length of the rear HO2S is divided by the total signal length of the front HO2S to compute a catalyst index ratio. An index ratio near 0.0 indicates high oxygen storage capacity, hence high HC efficiency. An index ratio near 1.0 indicates low oxygen storage capacity, hence low HC efficiency. If the actual index ratio exceeds the threshold index ratio, the catalyst is considered failed.

For the universal HO2S, the catalyst monitor calculates the rear HO2S signal lengths for 10-20 seconds during part-throttle, closed-loop fuel conditions after the engine is warmed-up, the inferred catalyst temperature is within limits, and fuel tank vapor purge is disabled. The catalyst monitor is enabled for 10-20 seconds per drive cycle. When the catalyst monitor is active, the PCM commands a fixed fuel control routine. The fixed fuel control routine is the same for every vehicle with universal HO2Ss. During monitor operation the rear HO2S signal lengths are continually calculated. The calculated rear HO2S signal length is then divided by a calibrated signal length, which has compensation for mass air flow. The calibrated signal length is based on the signal length of an HO2S placed after a catalyst without a washcoat. An index ratio near 0.0 indicates high oxygen storage capacity, hence high HC efficiency. An index ratio near 1.0 indicates low oxygen storage capacity, hence low HC efficiency. If the actual index ratio exceeds the threshold index ratio, the catalyst is considered failed.

Inputs from engine coolant temperature (ECT) or cylinder head temperature (CHT), intake air temperature (IAT), mass air flow (MAF), crankshaft position (CKP), throttle position (TP), and vehicle speed sensors are required to enable the Catalyst Efficiency Monitor.

Typical Monitor Entry Conditions:

- Minimum 330 seconds since start-up at 21℃ (70℉)
- Engine coolant temperature is between 76.6℃ - 110° C (170℉ - 230℉)
- Intake air temperature is between -7℃ - 82℃ (20℉ - 180℉)
- Time since entering closed-loop is 30 seconds
- Inferred rear HO2S sensor temperature of 482℃ (900 ℉)
- EGR is between 1% and 12%
- Part throttle, maximum rate of change is 0.2 volts/0.050 sec
- Vehicle speed is between 8 and 112 km/h (5 and 70 mph)
- Fuel level is greater than 15%
- First Air Flow Cell
    - Engine RPM 1,000 to 1,300 RPM
    - Engine load 15 to 35%
    - Inferred catalyst temperature 454℃ - 649℃ (850℉ - 1,200℉)
    - Number of front HO2S switches is 50
- Second Air Flow Cell
    - Engine RPM 1,200 to 1,500 RPM
    - Engine load 20 to 35%

    - Inferred catalyst temperature 482℃ - 677℃ (900℉ - 1,250℉)
    - Number of front HO2S switches is 70
- Third Air Flow Cell
    - Engine RPM 1,300 to 1,600 RPM
    - Engine load 20 to 40%
    - Inferred catalyst temperature 510℃ - 704℃ (950℉ - 1,300℉)
    - Number of front HO2S switches is 30

The DTCs associated with this test are DTC P0420 (Bank 1 or Y-pipe system) and P0430 (Bank 2). Because an exponentially weighted moving average algorithm is used to determine a concern, up to six driving cycles may be required to illuminate the MIL during normal customer driving. If the KAM is reset or the battery is disconnected, a concern illuminates the MIL in two drive cycles.

General Catalyst Monitor Operation

Vehicles with Universal HO2S

The catalyst monitor duration is 12 seconds, once per drive cycle. If the catalyst monitor conditions are met, the catalyst monitor may run and complete after all of the upstream HO2S functional tests are complete and the EVAP system is functional, with no stored DTCs; however, the catalyst monitor may run and complete before the downstream HO2S decel fuel shut-off test is complete. In this case, the catalyst monitor I/M readiness flag may indicate complete before the O2S I/M readiness flag indicates complete. If the catalyst monitor does not complete during a particular driving cycle, the already accumulated switch/signal data is retained in the KAM and is used during the next driving cycle to allow the catalyst monitor a better opportunity to complete.

Vehicles with HO2S

The catalyst monitor will run up to 700 seconds, once per drive cycle. If the catalyst monitor conditions are met the catalyst monitor will run but the catalyst monitor inspection/maintenance (I/M) readiness flag will not indicate complete until the HO2S monitor is complete and the EVAP system is functional with no stored DTCs. If the catalyst monitor does not complete during a particular driving cycle, the already accumulated switch/signal data is retained in the KAM and is used during the next driving cycle to allow the catalyst monitor a better opportunity to complete.

Rear HO2S can be located in various configurations to monitor different kinds of exhaust systems. In-line engines and many V-engines are monitored by their individual bank. A rear HO2S is used along with the front, fuel control HO2S for each bank. Two sensors are used on an in-line engine and four sensors are used on a V-engine. Some V-engines have exhaust banks that combine into a single underbody catalyst. These systems are referred to as Y-pipe systems. They use only one rear HO2S along with the two front, fuel-control HO2S. The Y-pipe system uses three sensors in all. For Y-piped systems, the two front HO2S signals are combined by the PCM software to infer what the HO2S signal would have been in front of the monitored catalyst. The inferred front HO2S signal and the actual single, rear HO2S signal is then used to calculate the index ratio.

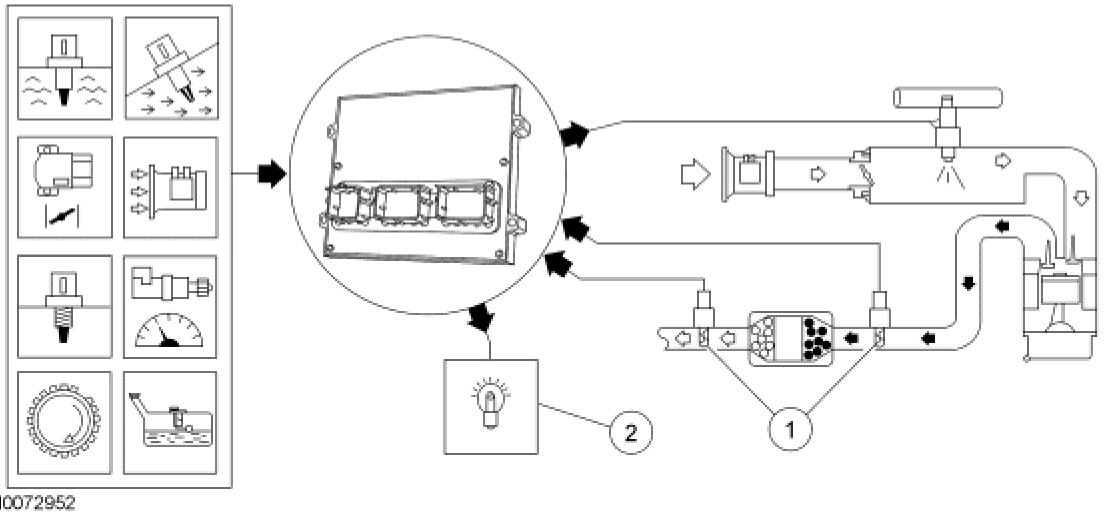
Exhaust systems that use an underbody catalyst without a downstream/rear HO2S are not monitored by the catalyst efficiency monitor.

Most vehicles that are part of the low emission vehicle (LEV) catalyst monitor phase-in, monitor less than 100% of the catalyst volume. Often this is the first catalyst brick of the catalyst system. Partial volume monitoring is done on LEV and ultra low emission vehicle (ULEV) vehicles in order to meet the 1.75 emission standard. The rationale for this strategy is that the catalyst nearest the engine deteriorates first, allowing the catalyst monitor to be more sensitive and illuminate the MIL correctly at lower emission standards.

Most applications use partial-volume monitoring, where the rear HO2S is located after the first light-off catalyst can or after the second catalyst can in a three can per bank system (a few applications placed the HO2S in the middle of the catalyst can, between the first and second bricks).

Some partial zero emission vehicles (PZEVs) use three HO2S. The front sensors or stream 1 (HO2S11) is the primary fuel control sensor. The next sensor downstream or stream 2 in the exhaust is used to monitor the light-off catalyst (HO2S12). The last sensor downstream or stream 3 in the exhaust (HO2S13) is used for very long term fuel trim in order to optimize catalyst efficiency (fore aft oxygen sensor control). For additional heated oxygen sensor information, refer to the Heated Oxygen Sensor (HO2S) Monitor in this section.

Index ratios for ethanol (flex fuel) vehicles vary based on the changing concentration of alcohol in the fuel. The threshold to determine a concern typically increases as the percent of alcohol increases. For example, a threshold of 0.5 may be used at E10 (10% ethanol) and 0.9 may be used at E85 (85% ethanol). The thresholds are adjusted based on the percentage of alcohol in the fuel. Standard fuel may contain up to 10% ethanol.



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