APPENDIX E

TECHNICAL DETAILS ON THE FAILURE MODES OF EXHAUST GAS RECIRCULATION SYSTEMS AND TURBOCHARGERS

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APPENDIX E

Failure Modes of the EGR and Turbocharger Systems

Below is a discussion of the main failure modes of the EGR and turbocharger systems and how they can lead to emission increases. This section helps to understand how the components operate and what common issues can lead to failures.

The EGR system connects the exhaust manifold to the intake manifold (see Figure 1). It manages the pressures of both manifolds and uses the differential between them to force exhaust gas into the intake manifold. The system uses two major sub-components to control exhaust gas flow: the EGR valve, and the EGR cooler. The

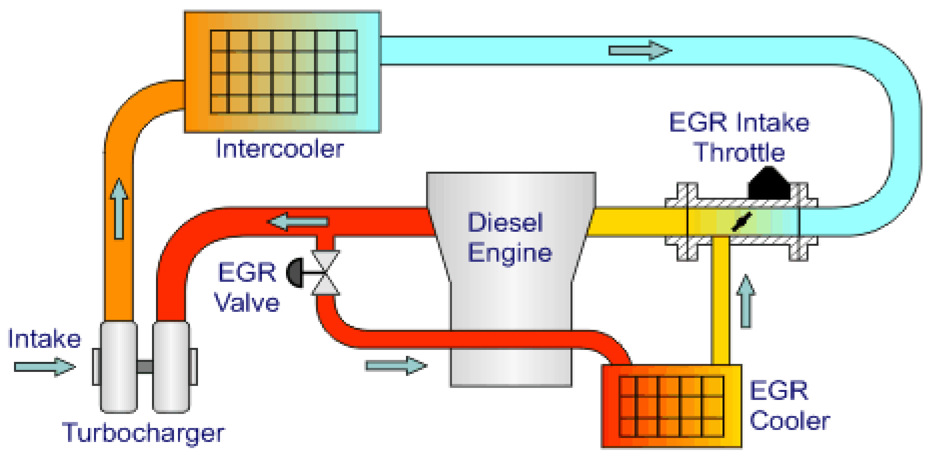

Figure 1. Simplified schematic of the EGR and turbocharger. The locations of the EGR valve and the EGR cooler are shown in relation to the turbocharger (Jääskeläinen & Khair, 2012).

EGR valve is used to regulate the amount of exhaust gas that is allowed back into the intake manifold. The EGR cooler is used to lower the temperature of the exhaust gas that is recirculated by the EGR system. Together they work to control the heat absorption capacity of the recirculated gases, and this in turn controls NOx emissions.

In order to reduce NOx emissions, the EGR system uses two methods. First, dilution of the intake air by the recirculated exhaust gas displaces the available oxygen and nitrogen with relatively non-reactive exhaust gases. Dilution of the fresh air provides less reactants to form NOx during the combustion process. Second, heat absorption by the recirculated gas during the combustion process lowers the combustion chamber temperature and inhibits the reaction mechanisms that lead to NOx formation.

An analysis by staff of reported warranty claims data reveals that the EGR exhibits some common failure modes, which are listed in Table I. The listed failure modes are not in any order of prevalence. Generally, these failures can contribute to the low-flow, high-flow, and slow-response conditions for the control of the exhaust gases.

Table 1. Most Common Failure Modes for the EGR System

EGR VALVE	EGR COOLER
• Soot deposits • Shoots deposits • Seal damage • Moisture intrusion • Valve sticking (stuck open or close) • Valve cracked	• Thermal fatigue (lean coolant) • Corrosion (leak coolant) • Excessive soot (plugged) • Cracked weld

The turbocharger is a turbine-driven device used in internal combustion engines to pressurize the intake system. The turbine is mounted on the same rotating shaft as an adjacent centrifugal pump and is used to increase the mass and density of the intake air as shown in Figure 1. A boost pressure sensor is typically located in the intake manifold to provide a feedback signal of the current turbocharger boost. As the turbocharger speed increases, the boost pressure in the intake manifold also increases. Proper boost control is essential to optimizing the emission levels, because short periods of over- or under-boost can result in undesired air-fuel ratios and corresponding emission increases. Additionally, the boost control system directly affects the exhaust and intake manifold pressures. This can interfere with the operation of the EGR system because it is very dependent on these two pressures.

The common failure modes for the turbocharger were determined as determined based on warranty claim data are listed in Table 2.

Table 2. Most Common Failure Modes for the Turbocharger System

TURBOCHARGER
• Seal ring/ turbine oil leak • Turbine nozzle foreign object damage • Turbine housing carbon build up • Shroud plate failure • Turbine wheel fatigue

These failure modes can lead to conditions of over-boost, under-boost, and slow response of the turbocharger. For example, the excessive buildup of carbon can cause the waste gate to stick in the closed position, which can lead to a malfunction that causes excessive exhaust pressures. The over-boost can then produce higher EGR flowrates at high-load conditions and have an adverse impact on emissions. In high-pressure EGR systems, higher exhaust pressures will generate more EGR flow and, conversely, lower pressures will reduce EGR flow.

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