PROCEEDINGS

American Academy of Forensic Sciences

66th Annual Scientific Meeting
Seattle, WA
February 17-22, 2014

C22 Fuel-Control Valve Failure Analysis

Michael Rosenfield, BS, 2420 E Hermosa Vista Drive, Mesa, AZ 85213; and Mark W. Arndt, BSME, Box 30717, Mesa, AZ 85275*

After attending this presentation, attendees will gain an understanding of readily-available tools and procedures used to answer the question of how a complex fuel-control valve can leak past some closed members but not others.

This presentation will impact the forensic science community by providing training on useful and inexpensive approaches to examine mechanical valve failures.

This presentation discusses the methods used to understand the failure conditions and mechanisms. These include bench tests, X-ray studies, and finally, the use of an inspection microscope.

Certain model trucks with dual fuel tanks use a fuel-pressure-controlled valve assembly to select from which tank to draw and return fuel. Under certain conditions, the fuel will be drawn from the rear tank, but returned to the front tank, leading to overfilling the front tank and eventually dumping fuel overboard.

There is a low-pressure (approximately 3 PSI) fuel pump in each tank and a high-pressure fuel pump on the frame rail, plumbed between the engine and the valve assembly.

The valve assembly, officially known as a "dual function reservoir," consists of a fuel inlet and return for each of two fuel tanks (front tank and rear tank), supply and return lines to the engine, a small fuel reservoir with fuel filter, and two over-pressure relief valves.

An O-ring-sealed, double-ended poppet valve is used to connect the engine fuel supply to either of the two fuel tanks. A second similar valve connects the engine fuel return to the appropriate tank return. These two valves are mechanically connected to force both to be actuated in the same direction at the same time, insuring fuel is drawn from, and returned to, the same tank.

During normal operation, the driver selects a tank from which to draw fuel with a switch on the vehicle's dash. This switch supplies power to the low-pressure fuel pump located in the desired tank (as well as connecting the correct fuel sender to the vehicle's fuel gauge). The in-tank fuel pump pressurizes the fuel line to the valve and causes a diaphragm attached to the valve linkage to move the valves to one end of travel, thus connecting one tank to the supply and return lines, and shutting off the connections to the other tank. When the driver selects the other fuel tank, the pressure on one side of the diaphragm is released, and the pressure on the other side increases, thus moving the valves to the opposite ends of their travel, and changing the tank connections.

In practice, sometimes the sealing of the return line to the front tank is incomplete, thus allowing fuel to return to the front tank when the rear tank is selected. If the front tank is nearly full, fuel can leak from the front tank and drip on the ground and vehicle frame.

There is a manufacturer-supplied bench test procedure to verify that the valve assembly is functioning correctly. A number of new and used valves were tested, and the failing valves were labeled for further study.

The valve assembly is able to be non-destructively disassembled, and when a failing valve is disassembled, sometimes there is no obvious defect — the O-rings appear undamaged and are in the correct location, and the other valve parts all appear to function properly. A method was needed to determine, in these cases, where the valve leak was occurring.

Using an industrial X-ray machine, it was determined that while the O-ring positions in the failing valves were different than normal valves, sealing should still occur.

Since valve sealing did not occur, examination under an inspection microscope was carried out, and it was determined that a combination of mechanical issues was preventing the O-rings from properly contacting the valve seat, thereby, allowing leakage.

Using these non-destructive testing methods, the failure mechanism of the failing valve assemblies was isolated, duplicated, and proven.

Valve, Failure, Analysis

C23 *In Situ* Hardening of a Steel Tank: Carbon Diffusion Over 35 Years at Ambient Temperatures

Anastasia Micheals, MS, Forensic Materials Consulting, 1784 Sanchez Street, San Francisco, CA 94131-2741*

After attending this presentation, attendees will understand the importance of diffusion in materials, particularly in surface hardening of steel.

This presentation will impact the forensic science community by presenting a case study where low temperature diffusion has a large impact on the properties of steel.

During recoating of the interior of a 35-year-old, 1.2MG municipal water tank, the interior coal tar pitch epoxy coating was being removed by sandblasting where the goal was a white metal finish. Initial sandblasting with silica resulted in unexpectedly low removal rates. Time was of the essence, so the abrasive was switched to steel abrasive, a more expensive material. The blasting still took much longer than scheduled and anticipated.

A disk taken from the roof of the tank was cut in half; Piece A, not cleaned in any way, and Piece B, sweep blasted with steel abrasive. Optical microscopy, Scanning Electron Microscopy (SEM), and Energy Dispersive X-ray Spectroscopy (EDS) were performed on both A and B.

Uncleaned A, under the optical microscope (Figure 1), showed a cracked coal tar pitch epoxy coating. In some areas, the coating had spalled away and red iron oxide scale formed. Under SEM, a region containing both coating and corrosion was examined (Figure 2). The corrosion had a typical iron oxide appearance (Figure 3). The coal tar coating (Figure 4) showed some surface deposits and surface cracks.

Elemental analysis of Piece A by EDS was unremarkable, with carbon, iron, and oxygen from the coal tar coating and steel tank material. Silicon, aluminum, potassium, magnesium, calcium, sulfur, and chlorine were also present, likely deposits from the well water held in the tank.

Optical microscopy of B showed that the sweep blasting, while incomplete, had removed most of the coal tar coating (Figure 4). Residual red iron oxide and black regions consistent with the coal tar coating seen on the uncleaned piece were found. Piece B was examined in the SEM. The surface was somewhat rough, indicating incomplete sweep blasting. EDS of the area again revealed no unexpected elements.

Spot elemental analysis was performed on an area of sweep-blasted B, where a cross-section from the pitch coating to the bare steel was visible (Figure 6) at three locations; pitch coating, mid coating, and bare steel (Table 1.). The additional elements detected, likely deposits from groundwater, were silicon, calcium, aluminum, magnesium, potassium, sulfur, and chlorine.