BONUS SECTION 5: FUEL SYSTEM — PRESSURE, VOLUME & GDI

50 Questions — Targeted Review

1. A technician performs a static fuel pressure test on an MFI system. Key-on engine-off pressure builds to 58 psi and holds for 10 minutes with no decay. The technician then starts the engine — pressure drops to 43 psi at idle. This result indicates:

A. The fuel pressure regulator has failed closed — pressure should not drop when the engine starts

B. The fuel pump is weak — a strong pump maintains 58 psi at idle without dropping

C. Normal MFI fuel system operation — the pressure regulator reduces rail pressure from the pump's maximum output to the correct operating pressure once the engine starts and manifold vacuum is applied to the regulator, dropping rail pressure to the correct operating value

D. A leaking fuel pressure regulator diaphragm — a leaking diaphragm allows fuel into the intake and drops rail pressure

2. A vehicle has a P0087 — Fuel Rail Pressure Too Low. Static fuel pressure at key-on is 54 psi. Idle pressure is 49 psi. At 3,000 RPM fuel pressure drops to 28 psi. The MOST likely cause is:

A. Insufficient fuel volume delivery — fuel pressure that is acceptable at low demand but collapses under high-RPM high-demand conditions is the signature of a fuel delivery volume fault: a weak pump, severely restricted fuel filter, or partially collapsed fuel supply line that cannot deliver adequate flow rate under high demand

B. A failed fuel pressure regulator — a failed regulator would affect static and idle pressure equally

C. A clogged fuel injector — clogged injectors reduce consumption, which would raise pressure not lower it

D. A leaking fuel pressure regulator diaphragm — diaphragm failure affects pressure at all RPM ranges equally

3. A technician isolates the fuel rail by blocking the Schrader valve and monitors pressure decay over 20 minutes. Pressure holds with zero decay. The Schrader valve is then unblocked and the test is repeated — pressure decays from 52 psi to 28 psi in 8 minutes. The MOST likely cause is:

A. Leaking fuel injectors — the decay is in the fuel rail downstream of the Schrader valve, eliminating the injectors which are downstream of the rail isolation point

B. A weak fuel pump losing prime — pump prime loss would affect both tests equally

C. A failed check valve in the fuel pump module allowing fuel to drain back through the pump — the decay occurs when the Schrader valve is open (returning pressure path through the pump), confirming fuel is draining back through the pump check valve when the engine is off

D. A leaking fuel pressure regulator — with the Schrader valve blocked the decay still occurs

4. A vehicle has a hard start concern — the engine cranks normally but requires 4–5 seconds of cranking before firing on cold starts. Once running, all parameters are normal. Fuel pressure holds at 52 psi for 30 minutes after shutdown. The MOST likely cause is:

A. A clogged fuel filter reducing flow during initial cranking — pressure hold rules out a filter restriction affecting static pressure

B. A failed fuel pressure regulator causing pressure collapse during cranking — pressure hold rules out regulator leakdown

C. A leaking fuel injector bleeding down rail pressure during the cranking period

D. Fuel vapor lock in the supply line from heat soak — the pressure holds confirming the fuel system is sealed, but fuel in the supply line may vaporize from engine heat during a hot soak, requiring the pump to purge vapor before liquid fuel reaches the rail

5. A vehicle has a P0087. Fuel pressure at idle = 52 psi (within spec). At wide open throttle fuel pressure drops to 31 psi. The technician installs a fuel flow meter at the pump outlet — flow rate at WOT is 18 gph. Specification is 30 gph minimum. The MOST likely cause is:

A. A leaking fuel pressure regulator — a leaking regulator would show normal flow but low pressure

B. A partially collapsed fuel return line — a collapsed return line raises pressure, not lowers it

C. A weak fuel pump unable to maintain adequate flow rate at high demand — confirmed by the direct flow measurement showing 18 gph versus 30 gph minimum specification at WOT

D. Clogged fuel injectors reducing fuel consumption and causing pressure drop — clogged injectors reduce consumption, which raises not lowers pressure

6. A GDI fuel system has a high-pressure fuel pump (HPFP) and a low-pressure fuel pump (LPFP). The HPFP is driven by the camshaft. During diagnosis the technician confirms low-side pressure (LPFP output) is 55 psi — within specification. High-side pressure (HPFP output to rail) is 450 psi — well below the 2,000 psi minimum specification. The MOST likely cause is:

A. A failed LPFP — the LPFP is confirmed functioning at 55 psi, ruling out a low-side fault

B. A failed HPFP or a cam lobe worn flat on the lobe that drives the HPFP — with confirmed normal LPFP output, the inability to build high-side pressure points to the HPFP itself or its mechanical drive source on the camshaft

C. A failed high-pressure fuel rail pressure sensor — a failed sensor would show incorrect pressure readings, not actually prevent pressure buildup

D. A leaking high-pressure fuel injector — injector leakage causes fuel delivery to a cylinder, not low rail pressure

7. A vehicle with an MFI system has a P0172 — System Rich Bank 1. Fuel trims at idle: STFT = -22%, LTFT = -18%. The technician disables the EVAP purge solenoid — fuel trims shift to STFT = -4%, LTFT = -18%. The MOST likely conclusion from this test is:

A. Disabling the purge solenoid confirmed it was stuck open — the immediate shift toward zero confirms the purge solenoid was contributing significant excess fuel at idle, but the remaining negative LTFT confirms a second rich source is still present

B. The EVAP purge solenoid is the sole cause of the rich condition — disabling it fully resolves the fuel trim

C. The fuel pressure regulator is the primary cause — disabling the purge solenoid does not affect the regulator

D. The fuel trims confirm normal operation — negative trims indicate the system is correctly managing the air-fuel ratio

8. A vehicle has a P0171 — System Lean Bank 1. Fuel trims: STFT = +18%, LTFT = +22% at idle. At 2,500 RPM: STFT = +4%, LTFT = +22%. The MOST likely cause is:

A. A MAF sensor contamination fault — MAF contamination produces positive trims at idle that decrease at RPM (a non-linear pattern — positive idle, near-zero or negative at WOT)

B. A vacuum leak — positive trims at idle that normalize significantly at higher RPM is the classic vacuum leak pattern. At idle, unmetered air from a vacuum leak is a large percentage of total airflow. At 2,500 RPM the same leak is a smaller percentage of total airflow and the PCM can compensate with less correction

C. Weak fuel injectors — weak injectors produce positive trims at all RPM ranges equally, not just at idle

D. A leaking fuel pressure regulator diaphragm causing low fuel pressure at idle only

9. A GDI vehicle has a customer complaint of reduced power and rough idle at high mileage (142,000 miles). No DTCs are stored. A borescope inspection through the intake ports reveals heavy carbon deposits coating the intake valve faces and stems. The MOST likely cause of the carbon deposits is:

A. A clogged PCV valve causing excessive crankcase vapors to enter the intake manifold and deposit on the intake valves

B. A failed EVAP purge solenoid allowing raw fuel vapors to deposit on intake valves

C. The fundamental design of GDI systems — unlike port fuel injection where injector spray washes the intake valves with fuel on every intake stroke, GDI injects fuel directly into the cylinder, leaving the intake valves exposed to hot crankcase vapors and EGR gases with no fuel wash to dissolve and carry away deposits

D. Incorrect fuel octane causing incomplete combustion products to accumulate on the intake valve faces

10. A technician performs a fuel injector balance test on an MFI system. All seven injectors on a V8 (one was already replaced) produce 38–41 RPM drops when disabled. Cylinder 4 produces a 3 RPM drop. Cylinder 4 compression = 178 psi. Cylinder 4 COP waveform is normal. The MOST likely cause is:

A. A clogged cylinder 4 injector — confirmed by near-zero RPM drop with normal compression and normal ignition, indicating the cylinder has spark and compression but no fuel delivery

B. A cylinder 4 mechanical fault not detectable by static compression test

C. A cylinder 4 PCM injector driver fault — near-zero RPM drop indicates no fuel delivery which could result from a failed PCM driver

D. A cylinder 4 coil fault — the COP waveform rules out an ignition fault

11. A vehicle has a P0087 — Fuel Rail Pressure Too Low. Fuel pressure is 52 psi at idle and 48 psi at 3,000 RPM — both within specification. The DTC sets only during extended WOT acceleration runs on a track. The technician suspects a fuel delivery volume limitation. The MOST appropriate test is:

A. Replace the fuel filter — a dirty filter causes P0087 and should be replaced first regardless of test results

B. Replace the fuel pump — P0087 with confirmed normal pressure at idle confirms the pump has failed

C. A fuel flow volume test at maximum pump demand — a fuel pump may maintain adequate pressure at moderate demand but cannot deliver sufficient flow volume during sustained WOT. A fuel flow volume test with the pump at maximum electrical load simulates sustained WOT demand to confirm or rule out a flow volume limitation

D. A fuel pressure regulator bypass test — a restricted regulator causes high pressure, not low pressure

12. A GDI system has a high-pressure fuel rail pressure sensor. The PCM uses this sensor to control HPFP output through a fuel metering valve. The rail pressure sensor reads 2,800 psi at idle — significantly above the normal 2,000 psi idle specification. The MOST likely cause is:

A. A clogged high-pressure fuel injector causing pressure to build in the rail without fuel consumption

B. A faulty high-pressure fuel rail pressure sensor reading higher than actual pressure — the PCM uses the sensor signal to command the HPFP metering valve. If the sensor reads LOW (below actual), the PCM commands MORE pump output — raising actual pressure above normal

C. A stuck-open high-pressure fuel metering valve allowing the HPFP to run at maximum output regardless of demand — confirmed by rail pressure above specification

D. A failed LPFP causing the HPFP to overwork to compensate for low inlet pressure

13. A vehicle has both P0171 and P0174 — System Lean Bank 1 and Bank 2. Fuel trims at idle: both banks +24%. At 2,500 RPM: both banks +8%. No vacuum leaks are found. MAF sensor output at idle = 2.1 g/s — normal specification is 2.0–2.4 g/s at idle. The MOST likely cause is:

A. A MAF sensor fault — the MAF output is within specification ruling out a MAF fault

B. A fuel pressure problem — low fuel pressure causes equal lean conditions on both banks at all RPM ranges, not just idle

C. A vacuum leak — positive trims at idle normalizing at higher RPM on both banks simultaneously with no detectable vacuum leak suggests the leak is in a location not easily found by propane enrichment (under the intake manifold plenum, behind the throttle body, or at an EGR connection)

D. Weak fuel injectors causing lean conditions on all cylinders simultaneously — weak injectors produce positive trims at all RPM ranges proportionally, not idle-only positive trims that normalize at 2,500 RPM

14. A GDI vehicle has a P0087. Low-side fuel pressure (LPFP output) = 28 psi — specification is 50–65 psi. High-side fuel pressure (HPFP rail) = 380 psi. The MOST likely cause is:

A. A failed HPFP — the HPFP is producing 380 psi output confirming it is functioning; the fault is on the low side

B. A failed HPFP cam lobe — cam lobe failure prevents high-side pressure buildup; 380 psi confirms the cam lobe is driving the pump

C. A stuck-open high-pressure fuel metering valve allowing fuel to bypass the HPFP

D. A weak or failed LPFP — the low-side pressure of 28 psi is below the minimum 50 psi specification required to supply the HPFP inlet, and insufficient LPFP pressure causes the HPFP to be starved of inlet fuel, limiting high-side pressure despite the HPFP mechanically functioning

15. A vehicle has a P0172 — System Rich Bank 1. The technician disconnects the fuel pressure regulator vacuum line — fuel trims shift from -18% to +2%. The MOST likely conclusion is:

A. The EVAP purge solenoid is confirmed as the rich source — disconnecting the regulator vacuum line does not affect the purge solenoid

B. A vacuum line to the regulator was pulling in a vacuum from another source — confirming a misrouted vacuum line was applying excessive vacuum to the regulator and pulling extra fuel into the rail

C. A leaking fuel pressure regulator diaphragm is confirmed — disconnecting the vacuum line removes the vacuum that was pulling through the leaking diaphragm and adding fuel vapor to the intake manifold, and the fuel trim shift to near-zero confirms the leaking diaphragm was the rich source

D. The fuel pressure was too low — removing the vacuum line raises pressure and enriches the mixture

16. A vehicle has P0087 and the fuel pump runs continuously at full voltage. The technician checks fuel pressure — 21 psi at idle, specification 45–55 psi. Fuel pressure with a known-good external pump connected directly to the fuel rail = 52 psi. The MOST likely cause is:

A. A clogged fuel injector causing backpressure that reads as low fuel pressure

B. A failed fuel pump — confirmed by low pressure with the in-tank pump running and normal pressure with an external pump supplying the rail at specification

C. A leaking fuel pressure regulator — a leaking regulator would produce normal flow but low pressure on both internal and external pump tests

D. A collapsed fuel supply line restricting flow to the rail — a supply line collapse would affect both the internal pump and the external pump feeding through the same line

17. A GDI vehicle has an intake valve carbon deposit cleaning recommendation at 80,000 miles. The service procedure involves walnut shell media blasting through the intake ports. After the cleaning is performed the customer returns with P0300 — Random Misfire. A borescope through the intake ports shows clean valves. The MOST likely cause is:

A. A PCM calibration fault triggered by the cleaning procedure altering combustion characteristics

B. A vacuum leak created during the cleaning procedure at an intake port gasket or intake manifold connection — a new vacuum leak introduced during disassembly and reassembly for the cleaning procedure is the most common post-cleaning misfire cause

C. Walnut shell media remaining in a cylinder causing mechanical damage

D. The cleaning procedure removed protective carbon deposits from the cylinder head combustion chamber

18. A vehicle has a P0171 — System Lean Bank 1 only, with Bank 2 trims normal. STFT Bank 1 = +19%, LTFT Bank 1 = +21% at idle. STFT Bank 1 = +18%, LTFT Bank 1 = +20% at 2,500 RPM. The MOST likely cause is:

A. A Bank 1 vacuum leak — single-bank lean at all RPM ranges is not typical of a vacuum leak pattern (vacuum leaks normalize at RPM)

B. A MAF sensor fault — MAF faults affect both banks simultaneously

C. Weak fuel injectors on Bank 1 — single-bank lean at all RPM ranges, both idle and 2,500 RPM, is characteristic of injectors on that bank delivering less than commanded fuel volume (weak injectors, partial clog, low resistance), producing consistent lean conditions across all operating conditions

D. A Bank 1 O2 sensor fault — a failed O2 sensor producing false lean signal would affect STFT only, not drive both STFT and LTFT positive simultaneously

19. A vehicle has a P0171 and P0174. The technician suspects a MAF sensor fault. The MOST definitive test to confirm MAF contamination is:

A. Replace the MAF sensor and monitor fuel trims — replacement is the most definitive test

B. Clean the MAF sensor with MAF cleaner and monitor fuel trims for improvement

C. Check MAF sensor output in grams per second against a known-good vehicle of the same make, model, and engine at identical RPM and load conditions — MAF contamination causes the sensor to undercount actual airflow, producing positive fuel trims at idle that decrease at higher RPM as the PCM compensates based on other sensors. Comparing actual output to specification at multiple operating points reveals the non-linear undercounting pattern

D. Disconnect the MAF sensor and monitor fuel trim response — a significant fuel trim improvement after MAF disconnection confirms contamination

20. A GDI vehicle has a high-pressure fuel system. During a fuel pressure hold test with the engine off and the HPFP isolated, the high-side rail pressure decays from 2,400 psi to 800 psi in 45 seconds. Low-side pressure holds normally. The MOST likely cause is:

A. A failed high-pressure fuel pump check valve — the HPFP check valve is isolated in this test; the decay is in the rail itself

B. Leaking high-pressure fuel injectors — with the HPFP isolated, fuel in the high-pressure rail can only escape through the high-pressure injectors, a leaking high-pressure rail fitting, or a failed high-side check valve at the HPFP outlet — leaking HPFIs are the most common cause of high-side pressure decay with the pump isolated

C. A leaking low-pressure fuel pump check valve — the low-side is isolated and holding normally

D. A failed high-pressure fuel rail pressure sensor — a failed sensor shows incorrect readings without causing actual pressure decay

21. A vehicle has a P0087 at high engine load. A fuel pressure test shows pressure dropping to 22 psi at WOT. The technician suspects the fuel filter. The vehicle has a non-serviceable in-tank filter integrated with the pump module. The technician should:

A. Bypass the in-tank filter with an external in-line filter — bypassing an integrated filter is an accepted repair procedure

B. Perform a fuel flow volume test first — if the pump delivers adequate volume with low pressure, a filter restriction is confirmed

C. Replace the complete fuel pump module — on vehicles with integrated non-serviceable filters, a restricted filter that cannot be individually replaced requires complete pump module replacement to address the restriction

D. Clean the in-tank filter with fuel system cleaner additives — chemical cleaning is effective for integrated pump module filters

22. A vehicle has a P0172 — System Rich, Both Banks. Fuel trims: STFT -20%, LTFT -16% at idle. At 2,500 RPM STFT -6%, LTFT -16%. The technician disables the EVAP purge solenoid — fuel trims at idle shift to STFT -3%, LTFT -16%. The MOST appropriate next step is:

A. Replace the EVAP purge solenoid — disabling it resolved the rich condition confirming the solenoid is faulty

B. Clear the LTFT and monitor for trim rebuilding direction — the LTFT of -16% was built over time. With the purge solenoid confirmed as a contributing source but LTFT still negative after disabling the solenoid, a second rich source must be identified. Clearing LTFT and monitoring rebuilding direction with the solenoid disabled confirms whether the remaining negative LTFT is from a second active rich source or is legacy trim from before the solenoid was disabled

C. Verify that the EVAP system has no other stuck-open solenoids that may be contributing to the rich condition

D. Replace the fuel pressure regulator — LTFT remaining negative after purge solenoid disable confirms the regulator is leaking

23. A GDI vehicle has a P0087 — Fuel Rail Pressure Too Low. LPFP output = 58 psi (normal). HPFP rail pressure at idle = 1,600 psi (low — spec 2,000 psi minimum). The cam lobe driving the HPFP is inspected and shows normal lobe height. The technician measures HPFP fuel metering valve duty cycle = 92% (near maximum). Normal idle duty cycle specification is 40–55%. The MOST likely cause is:

A. A failed high-pressure fuel rail pressure sensor commanding excess duty cycle — a failed sensor producing false low readings would cause the PCM to command high duty cycle in an attempt to raise pressure

B. A failed PCM GDI fuel pressure control circuit

C. A leaking high-pressure injector causing the PCM to command maximum HPFP output in an attempt to maintain rail pressure — with normal LPFP, normal cam lobe, and near-maximum metering valve duty cycle, the HPFP is working at maximum capacity but cannot maintain pressure because one or more HPFIs are leaking fuel into the cylinder faster than the HPFP can supply it

D. A worn HPFP internal piston or check valve reducing HPFP pumping efficiency despite normal cam lobe height — with the HPFP running at near-maximum duty cycle but still achieving only 1,600 psi, the pump itself has reduced internal efficiency

24. A vehicle has a P0170 — Fuel Trim Malfunction Bank 1. The fuel trims are oscillating rapidly between +15% and -15% STFT at idle with no consistent direction. The LTFT is near zero. The MOST likely cause is:

A. A MAF sensor fault causing unstable airflow measurement and unstable fuel trim correction

B. A rapidly oscillating fuel pressure — unstable fuel pressure causes the PCM to constantly correct and over-correct, producing the observed rapid bidirectional STFT oscillation without a consistent lean or rich bias that would develop LTFT

C. A stuck-open EVAP purge solenoid causing intermittent rich pulses between normal cycles

D. An oxygen sensor with a degraded reference ground — a degraded O2 sensor ground can cause false oscillating voltage output driving the PCM to make rapid bidirectional corrections

25. A GDI vehicle has a confirmed HPFP failure. During the repair, the technician notes that the camshaft lobe driving the HPFP shows a flat spot worn into the lobe profile. The technician should:

A. Replace only the HPFP — the camshaft lobe damage is cosmetic and does not affect HPFP operation after pump replacement

B. Replace the HPFP and inspect the camshaft lobe wear depth against specification — a flat-spotted cam lobe reduces the stroke of the HPFP piston, directly reducing maximum high-side pressure output. If lobe wear exceeds specification, the camshaft requires replacement to restore HPFP mechanical drive efficiency

C. Replace the HPFP and perform a camshaft bearing clearance measurement to confirm engine wear is not the root cause

D. Replace the HPFP and flush the high-pressure fuel system with clean fuel to remove metallic debris from the failed pump

26. A vehicle has a P0171 — System Lean Bank 1. Fuel trims at idle: STFT +19%, LTFT +23%. At 2,500 RPM: STFT +20%, LTFT +23%. Fuel pressure at idle = 44 psi (spec 45–55 psi). Fuel pressure at 3,000 RPM = 31 psi. All injectors pass balance test at idle. The MOST likely cause is:

A. A vacuum leak — vacuum leak trims normalize at RPM; this pattern is lean at all RPM which is not consistent with a vacuum leak

B. A MAF sensor undercounting — MAF undercounting produces non-linear trim patterns (more positive idle, normalizing at RPM), not consistent lean trims at all RPM

C. A clogged fuel injector on Bank 1 — balance test at idle is normal; a clogged injector would show low RPM drop during contribution test

D. Low fuel pressure causing consistent lean condition at all RPM and load — borderline low pressure at idle plus significant pressure collapse at 3,000 RPM confirms the fuel system cannot sustain adequate pressure under demand, producing consistent lean trims across all operating conditions

27. A GDI vehicle with 95,000 miles has a complaint of hard cold starts and a carbon deposit history. No DTCs are stored. A borescope of the intake ports shows heavy carbon accumulation. The intake valve carbon is MOST likely causing hard cold starts by:

A. Absorbing the fuel charge during cold starts because GDI injectors spray directly past the intake valves

B. Partially obstructing the intake port, reducing intake airflow velocity during cold cranking when airflow is already minimal — reduced airflow velocity into the cylinder during cold cranking reduces mixture turbulence and homogeneity, causing incomplete vaporization of the injected fuel charge and resulting in poor cold combustion quality

C. Absorbing cold start enrichment fuel from port injectors installed on the GDI system

D. Creating hot spots on the intake valve face that cause preignition during cold start attempts

28. A vehicle has a fuel injector balance test result where cylinder 6 shows a 36 RPM drop and all others show 38–42 RPM drops. All cylinders have normal compression. The MOST likely cause and action is:

A. The cylinder 6 injector requires immediate replacement — a 36 RPM drop confirms significant flow restriction

B. The cylinder 6 injector is flowing slightly less than the other cylinders — a 36 RPM drop is within the acceptable range of cylinder contribution variation for most platforms. The technician should compare the result to manufacturer specification before condemning the injector, as this result may be within spec

C. The cylinder 6 injector is flowing more fuel than specified — a 36 RPM drop indicates excess fuel delivery

D. A cylinder 6 mechanical fault is causing the reduced RPM drop — a mechanical fault with normal compression is not possible

29. A GDI vehicle has a P0087 confirmed as a HPFP fault. The HPFP is replaced. After replacement the technician should perform which procedure BEFORE starting the engine?

A. Program the new HPFP with the PCM using a scan tool — GDI HPFPs require VIN programming before operation

B. Pressurize the high-side fuel system manually to 2,000 psi using a hand pump before starting

C. Prime the low-pressure fuel system using the scan tool or key-cycle procedure to ensure the HPFP has adequate inlet fuel pressure before the first start — starting a GDI engine with an unprimed low-pressure system can cause the HPFP to operate without adequate inlet fuel, potentially damaging the new pump on the first start

D. Bleed air from the high-pressure fuel rail through the Schrader valve before the first start

30. A vehicle has P0087. A fuel pressure test shows normal pressure at idle but pressure drops significantly under WOT. A fuel flow volume test confirms flow is below specification. The technician replaces the fuel pump. After replacement, fuel pressure at WOT is still low and fuel volume is still below specification. The MOST likely cause is:

A. The replacement fuel pump is also defective — back-to-back fuel pump failures indicate a supply chain issue

B. A partially collapsed fuel supply line between the tank and the fuel rail — a kinked or internally collapsed supply line restricts fuel flow regardless of pump capacity, producing low pressure and low volume at high demand even after pump replacement. The restriction, not the pump, is the limiting factor

C. A clogged fuel filter downstream of the pump — a post-pump filter restriction would have been resolved with pump replacement if the filter is integrated

D. A fuel pressure regulator stuck partially closed — a stuck regulator raises pressure, not lowers it

31. A vehicle has P0172 — System Rich, Both Banks. The technician suspects a leaking fuel pressure regulator. The MOST definitive test for a leaking FPR diaphragm is:

A. Remove the vacuum line from the FPR and check for fuel smell — a faint fuel smell is normal due to proximity to the fuel rail

B. Check fuel pressure with and without vacuum applied to the regulator — fuel pressure should rise when vacuum is removed and drop when vacuum is applied. Excessive pressure drop with vacuum applied (more than specification) confirms the diaphragm is pulling too much fuel

C. Remove the vacuum line from the FPR and inspect for liquid fuel or strong fuel odor — a leaking FPR diaphragm allows liquid fuel to pass through the damaged diaphragm into the vacuum line. Liquid fuel in the vacuum line is the definitive confirmation of a failed diaphragm

D. Measure the fuel pressure drop when the engine is turned off — excessive pressure drop after shutdown confirms FPR diaphragm failure

32. A vehicle has a P0171 — System Lean Bank 1. The technician suspects a fuel injector supply voltage fault. Battery voltage = 12.6V at idle. Injector supply voltage at the Bank 1 injector harness connector = 11.1V. Specification is battery voltage minus 0.5V maximum drop. The MOST likely cause and effect is:

A. The 11.1V injector supply voltage is within normal range for MFI injectors — no fault is present

B. A 1.5V voltage drop in the injector supply circuit — excessive supply voltage drop reduces the injector's pintle opening force and rate, causing the injector to deliver less fuel per pulse width than commanded — effectively making the injector appear weak and causing the lean condition

C. A ground circuit fault on Bank 1 — the 11.1V supply voltage indicates the ground side is the fault location

D. A PCM injector driver fault reducing supply voltage to Bank 1 injectors only

33. A GDI vehicle has a P0087 that occurs intermittently and cannot be duplicated on demand. The customer reports it occurs after the vehicle sits in the sun for 4–6 hours on hot days. Cold and warm normal-ambient starts are fine. The MOST likely cause is:

A. A HPFP fault that only occurs when the pump is hot from extended engine operation

B. A PCM calibration issue with the fuel pressure control strategy during hot ambient restarts

C. Fuel vapor in the low-pressure supply line from heat soak — during extended hot ambient soaking, fuel in the low-pressure supply line can vaporize. On the restart, the LPFP must purge the vapor before delivering liquid fuel to the HPFP — if vapor purging takes too long, the HPFP starves and high-side pressure drops below threshold, setting P0087 before the system normalizes

D. A heat-sensitive LPFP check valve losing prime during hot ambient soaking — a failed check valve allows the low-side system to drain back during hot soaks, requiring extended cranking to reprime

34. A vehicle has been diagnosed with injector deposits causing flow restrictions. The technician recommends an on-car ultrasonic injector cleaning service. After cleaning, a post-cleaning injector balance test shows all cylinders now within 2 RPM of each other. Before cleaning, the spread was 14 RPM between the best and worst cylinder. The MOST appropriate conclusion is:

A. The cleaning confirmed the injectors needed replacement — the pre-cleaning spread of 14 RPM confirms severe injector failure

B. The on-car cleaning successfully restored injector flow balance — a post-cleaning balance test showing all cylinders within 2 RPM confirms the deposits were cleaned and flow was equalized. The customer complaint should be re-evaluated to confirm the symptom is resolved before releasing the vehicle

C. The injectors will re-deposit within 1,000 miles and require replacement

D. One injector with significantly different flow should still be replaced despite the post-cleaning balance result

35. A vehicle has a P0087 and the fuel pump draws 8.2 amperes at key-on engine-off. The specification for this pump is 4.5–6.0 amperes. The MOST likely cause is:

A. A weak fuel pump motor — a weak motor draws less current, not more

B. A high-resistance ground in the fuel pump circuit — a high-resistance ground reduces current flow, not increases it

C. A seized or mechanically restricted fuel pump — a pump whose impeller is seized or mechanically binding draws significantly higher than normal current as the motor works against the restriction while producing inadequate fuel flow and low pressure

D. A partially shorted fuel pump motor winding — a shorted motor winding reduces impedance and can increase current draw while reducing mechanical output efficiency

36. A GDI vehicle has P0087. The technician confirms HPFP failure and replaces the pump. After replacement the high-side rail pressure at idle = 2,050 psi (normal). At 3,500 RPM rail pressure drops to 1,200 psi. LPFP output remains at 58 psi throughout. The MOST likely cause is:

A. The replacement HPFP is also defective — rail pressure is normal at idle confirming the pump is functional at low demand

B. A worn camshaft lobe that was not inspected at the time of HPFP replacement — a cam lobe with reduced height produces adequate pump stroke at idle but cannot sustain adequate pumping rate at higher RPM when demand increases — causing high-side pressure to fall at elevated speeds. Cam lobe inspection during HPFP replacement is mandatory

C. A leaking high-pressure fuel injector causing pressure drop at high RPM — a single leaking HPFI would not typically cause a 40% pressure drop at 3,500 RPM

D. A failed high-pressure fuel rail pressure sensor producing false low readings at higher RPM

37. A vehicle has P0171 and P0174 — System Lean Both Banks. Fuel trims: Both banks STFT +22%, LTFT +19% at idle. At 2,500 RPM: STFT +22%, LTFT +19% (no change). Fuel pressure = 46 psi at idle (slightly low, spec 48–58 psi) and 42 psi at 2,500 RPM (within lower spec). All injectors pass balance test at idle. No vacuum leaks found. A MAF sensor comparison to a known good vehicle shows the suspect vehicle MAF reads 14% lower at identical conditions. The MOST likely cause is:

A. The fuel pressure is the primary cause — borderline low pressure is the most common cause of equal lean conditions at all RPM

B. A vacuum leak — vacuum leaks normalize at higher RPM; the trims remain constant from idle to 2,500 RPM ruling out a vacuum leak

C. MAF sensor undercounting — a MAF reading 14% lower than a known-good vehicle at identical conditions causes the PCM to command 14% less fuel than needed for the actual airflow, producing lean conditions at all RPM proportionally. The fact that trims do not decrease at 2,500 RPM rules out a vacuum leak and is consistent with MAF undercounting which affects all RPM ranges proportionally

D. Weak injectors — weak injectors produce consistent lean at all RPM but the balance test shows all cylinders contributing equally

38. A vehicle has a P0172 — System Rich, Bank 1. The technician performs a five-gas exhaust analysis: HC = 620 ppm (high), CO = 3.8% (high), CO2 = 11.2% (low), O2 = 0.3% (low). These results MOST indicate:

A. A misfire condition causing unburned mixture to exit as high HC and O2 with low CO

B. A lean combustion condition — low O2 and high CO confirm a lean mixture

C. A rich combustion condition — high HC and CO with low O2 and reduced CO2 confirm rich combustion: excess fuel is consuming available oxygen (low O2), producing excess CO from incomplete combustion of excess fuel, and elevated HC from fuel that did not fully combust. Low CO2 indicates combustion efficiency is reduced

D. A catalytic converter fault — high HC at the tailpipe always indicates catalyst failure

39. A GDI vehicle has a P0087. LPFP output = 60 psi. HPFP output = 1,850 psi at idle (slightly low, spec 2,000 psi). Under load HPFP output drops to 900 psi. Cam lobe height is within specification. A fuel metering valve current test shows the valve responds correctly to PCM commands. The technician measures HPFP inlet pressure during engine operation and finds it drops to 18 psi at 3,500 RPM despite LPFP static output of 60 psi. The MOST likely cause is:

A. A failed HPFP with worn internal sealing rings — a failing HPFP would not show correct response to metering valve commands

B. A failed fuel pressure regulator on the low-pressure side — a failed regulator would affect static LPFP pressure, not dynamic pressure drop under load

C. A restricted or undersized low-pressure fuel supply line that cannot maintain adequate flow volume to the HPFP under high engine speed demand — LPFP output is 60 psi static but pressure collapses at the HPFP inlet at 3,500 RPM, indicating the supply line cannot flow adequate volume at high demand to keep up with HPFP consumption. This is confirmed by the 18 psi inlet reading at 3,500 RPM

D. A failed LPFP that cannot sustain pressure under dynamic load despite adequate static pressure — a failing LPFP pump motor would show reduced static pressure as well as dynamic pressure

40. A vehicle has a P0171 — System Lean Bank 1. The technician confirms a Bank 1 vacuum leak using smoke machine testing — a small leak is found at a cracked Bank 1 intake manifold runner gasket. The vacuum leak is repaired. After repair, fuel trims at idle are: STFT = +3%, LTFT = +18%. The MOST appropriate next step is:

A. Clear the LTFT and perform a drive cycle to allow the PCM to relearn fuel trim — the LTFT of +18% is legacy trim that was learned during the period the vacuum leak was present. After repairing the leak, the PCM requires a drive cycle to relearn correct trim values. The STFT near zero confirms the active lean source is resolved

B. Investigate a second lean source — STFT near zero confirms the vacuum leak was the only active lean source; the high LTFT is legacy and will not self-correct without a drive cycle

C. Replace the Bank 1 O2 sensor — high LTFT after vacuum leak repair confirms O2 sensor bias

D. Inspect the fuel injectors — LTFT remaining high after vacuum leak repair confirms injectors are weak

41. A vehicle has P0087 with a confirmed weak fuel pump. The fuel pump is in the fuel tank. When the technician drops the tank to replace the pump, they find the fuel level at only 1/8 of a tank. The customer reports the vehicle frequently runs on low fuel. The MOST likely contributing factor to the premature pump failure is:

A. Ethanol in the fuel supply damaging the pump motor over time

B. A voltage regulation fault causing overvoltage damage to the pump motor

C. Frequent operation on low fuel — the fuel pump is cooled and lubricated by the surrounding fuel. Operating consistently on low fuel exposes the pump to higher operating temperatures and reduced lubrication, accelerating pump wear and premature failure

D. A ground fault causing intermittent over-current damage to the pump motor armature

42. A GDI vehicle has a complaint of slight hesitation on cold starts followed by normal operation. No DTCs. Fuel trims are normal. LPFP pressure = 58 psi. HPFP pressure at cold start = 380 psi, rising to 2,050 psi after 8 seconds. The MOST likely cause is:

A. A cold-start LPFP fault causing temporary low inlet pressure to the HPFP on cold starts

B. A GDI HPFP that requires several pump strokes to build full high-side pressure after a cold start or extended shutdown — normal HPFP operation requires multiple pump strokes following startup to pressurize the high-pressure rail from residual low pressure. A brief hesitation during the 8 seconds of pressure build-up is normal on some GDI platforms and may not indicate a fault if pressures are within specification after normalization

C. A cold-start cam timing fault retarding the cam that drives the HPFP during cold starts

D. A failing high-pressure fuel rail pressure sensor drifting low on cold starts and causing the PCM to over-command the HPFP

43. A vehicle has a P0172 — System Rich, Both Banks. The technician suspects excessive fuel pressure. Key-on engine-off fuel pressure = 58 psi (spec 45–55 psi). The technician pinches the fuel return line — pressure rises immediately to 85 psi. The MOST likely cause is:

A. A partially clogged fuel return line — a clogged return line raises pressure above specification, which is consistent with the initial 58 psi reading

B. A weak fuel pump — a weak pump cannot maintain pressure and would show low pressure, not high pressure

C. A stuck-closed fuel pressure regulator — a regulator that is stuck fully closed would show very high pressure even without pinching the return line, above 85 psi at key-on

D. A partially stuck-closed fuel pressure regulator — the initial pressure of 58 psi above the 55 psi maximum specification combined with the pressure rising to 85 psi when the return is pinched suggests the regulator is not fully opening to regulate pressure down to specification — a regulator with a sticky or partially stuck valve seat

44. A GDI vehicle has high-pressure fuel injectors that are leaking internally — confirmed by a high-side pressure hold test. The customer asks why GDI injector leakage is more significant than port injector leakage. The MOST accurate explanation is:

A. GDI injectors operate at lower pressure than port injectors, so leakage represents a larger percentage of total fuel delivery

B. GDI injectors spray directly into the cylinder — a leaking GDI injector allows raw fuel to drip directly onto the piston crown and into the oil film on the cylinder wall during engine-off periods, causing fuel dilution of the engine oil and potentially washing the cylinder wall lubrication on the first start

C. GDI injector leakage causes intake valve deposits to accelerate because leaked fuel deposits on the intake valves

D. GDI injectors have no return circuit so leaked fuel has nowhere to go and accumulates in the intake manifold

45. A vehicle has a P0087. Fuel pressure at idle = 52 psi (normal). At 3,000 RPM = 49 psi (normal). At WOT sustained for 30 seconds = drops progressively to 24 psi. A fuel pump current test shows 5.8 amperes at idle (within spec 4.5–6.5 A) but the pump supply voltage drops from 14.2V to 10.8V during sustained WOT operation. The MOST likely cause is:

A. A weak fuel pump motor drawing low current under load

B. A clogged fuel filter causing pump motor overload during sustained WOT

C. A high-resistance fuel pump power supply circuit — the supply voltage drop from 14.2V to 10.8V during sustained WOT pump operation confirms excessive resistance in the pump supply wiring, relay contacts, or fuse holder. The voltage starved pump cannot maintain adequate flow at high demand, producing P0087 only during sustained WOT operation

D. A failing alternator unable to maintain charging voltage during high electrical load at WOT

46. A GDI vehicle has a concern of engine oil dilution confirmed by oil analysis showing 12% fuel content. No external fuel leaks are found. No performance complaints. Fuel trims are normal. The MOST likely cause is:

A. EVAP purge solenoid stuck open allowing fuel vapors to enter the intake and contaminate the oil through blowby

B. A leaking GDI fuel injector allowing high-pressure fuel to drip onto the piston crown when the engine is off — high-pressure fuel (2,000+ psi) leaking past the injector tip drips directly onto the piston and runs down the cylinder wall past the rings into the crankcase, progressively diluting the engine oil without producing rich fuel trims because the leaked fuel evaporates during normal engine operation rather than pooling in the intake

C. A HPFP internal seal failure allowing high-pressure fuel to enter the engine oil through the camshaft housing

D. A leaking fuel pressure regulator in the GDI return circuit dumping fuel into the crankcase

47. A vehicle has P0171 and P0174. The technician performs a propane enrichment test — adding propane to the air intake causes fuel trims to shift toward zero. The technician concludes this is a vacuum leak. The technician then performs a smoke test — no smoke leaks are found. The MOST likely explanation is:

A. The propane enrichment test was performed incorrectly — a positive result without a smoke leak rules out a vacuum leak

B. A smoke machine limitation — some vacuum leaks are too small for smoke detection but large enough to affect fuel trims

C. The vacuum leak is in a location the smoke test cannot reach or seal effectively — common locations include under-manifold gaskets that cannot be smoke-tested without manifold removal, throttle body gaskets in recessed locations, or EGR passages with internal cracks that do not communicate externally where smoke can be detected

D. The propane test result was a false positive — propane enrichment always shifts trims toward zero regardless of whether a vacuum leak is present

48. A GDI vehicle has a P0087 confirmed as a HPFP fault. During diagnosis the technician connects a scan tool and monitors the high-pressure fuel rail pressure PID. At idle the pressure oscillates between 1,600 psi and 2,100 psi in a regular pattern. The MOST likely cause is:

A. Normal HPFP operation — GDI rail pressure oscillates between minimum and maximum values as the PCM duty-cycles the metering valve

B. A failing high-pressure fuel rail pressure sensor producing oscillating false readings

C. A HPFP with a worn or sticking metering valve that alternates between underperforming and normal pumping strokes — the regular oscillation pattern corresponds to alternating pump strokes where the sticking valve delivers insufficient pressure on some strokes and normal pressure on others

D. A PCM fuel pressure control strategy fault commanding oscillating metering valve duty cycles

49. A vehicle has a P0172 — System Rich, Both Banks after a fuel pump replacement. Before the pump replacement fuel trims were normal. After replacement, STFT = -19%, LTFT = -4% at idle. The MOST likely cause is:

A. The replacement fuel pump has a failed pressure regulator producing normal pressure — fuel trim change immediately after pump replacement with no other changes confirms a pump-related issue

B. A vacuum leak introduced during the fuel pump replacement procedure — a vacuum leak causes lean trims, not rich trims

C. The replacement fuel pump has an incorrect pressure specification — if the replacement pump produces higher fuel pressure than the original specification (such as an aftermarket pump with a higher-pressure integrated regulator), the excess pressure causes all injectors to deliver more fuel than commanded, producing system-rich fuel trims on both banks immediately after installation

D. A stuck-open EVAP purge solenoid coincidentally failing at the same time as the pump replacement

50. A GDI vehicle has a P0087 that sets consistently at highway speeds but not at city speeds. LPFP output = 58 psi. HPFP output at city speed = 2,100 psi (normal). At highway speed HPFP output drops to 1,400 psi. The technician monitors HPFP metering valve duty cycle — it rises to 98% at highway speed. Engine cam timing is confirmed within specification. HPFP inlet pressure at highway speed = 52 psi. The MOST likely cause is:

A. A failed HPFP metering valve stuck partially closed causing inadequate pumping at highway speed

B. A failing HPFP with worn internal check valves or piston sealing — with confirmed normal LPFP pressure, confirmed cam timing, confirmed adequate inlet pressure at highway speed, and a metering valve at near-maximum duty cycle attempting to compensate for insufficient output, the HPFP itself has reduced internal pumping efficiency from worn check valves or a worn piston seal — producing normal pressure at low demand but insufficient pressure at high highway speed demand

C. A highway-speed fuel demand that exceeds this vehicle's maximum HPFP design capacity — normal operation for this platform

D. A leaking high-pressure fuel rail fitting creating pressure loss at high fuel flow rates

BONUS SECTION 5: ANSWER KEY AND EXPLANATIONS

1. C — Normal MFI Fuel System Operation — MFI fuel pressure regulators use manifold vacuum to reference atmospheric pressure differential. At key-on engine-off, no vacuum is present and the regulator holds maximum pressure. When the engine starts and manifold vacuum develops, the regulator references vacuum and reduces rail pressure to the correct operating specification. A drop from key-on pressure to a lower operating pressure when the engine starts is normal regulator function, not a fault.

2. A — Insufficient Fuel Volume Delivery — Fuel pressure that is acceptable at idle and moderate RPM but collapses under high RPM high-demand conditions is the classic fuel delivery volume failure pattern. Adequate pressure at low demand confirms the pump can produce pressure against low flow resistance. The collapse at 3,000 RPM confirms the pump cannot deliver adequate flow volume when demand is high. A fuel flow volume test at maximum demand confirms this diagnosis.

3. C — Pump Check Valve Failure — Blocking the Schrader valve isolates the fuel rail from the pump. With the rail isolated, pressure holds — confirming no injector leakage or rail fitting leakage. When the Schrader valve is reopened, fuel now has a return path through the pump module. The pressure decay with the path open confirms fuel is draining backward through a failed check valve in the pump module, which should hold fuel in the supply line and rail after shutdown.

4. D — Fuel Vapor Lock from Heat Soak — The pressure hold test rules out injector leakdown and regulator leakdown as causes of the long crank — the fuel system is sealed and holds pressure. Vapor lock is a heat soak phenomenon where residual engine heat vaporizes fuel in the supply line during the off period. On restart, the pump must purge vapor before liquid fuel reaches the injectors. This creates a long crank before fuel delivery begins, with normal operation once liquid fuel purges the vapor.

5. C — Weak Fuel Pump — Fuel pressure below specification under high demand combined with a direct fuel flow measurement of 18 gph versus 30 gph minimum specification confirms the fuel pump cannot deliver adequate flow volume at maximum demand. The direct flow measurement is the most definitive confirmation of a pump volume fault because it measures actual fuel delivery capability rather than pressure alone, which can be influenced by other system variables.

6. B — Failed HPFP or Worn Cam Lobe — LPFP output at 55 psi confirms the low-pressure circuit is functioning correctly and the HPFP has adequate inlet fuel supply. With confirmed adequate low-side inlet pressure, the HPFP's inability to build high-side rail pressure (450 psi vs. 2,000 psi minimum) points to either a mechanically failed HPFP pump assembly or a worn cam lobe that no longer provides sufficient mechanical stroke to the HPFP piston. Cam lobe inspection is required alongside HPFP diagnosis.

7. A — Purge Solenoid Stuck Open — A Confirmed Contributing Source, Second Source Present — Disabling the purge solenoid and observing STFT shift from -22% toward -4% confirms the stuck-open purge solenoid was delivering significant excess fuel at idle. However, STFT returning to only -4% (not zero) and LTFT remaining at -18% confirms a second rich source is still active. The LTFT was built over time from a rich source that persisted before the purge fault developed or simultaneously with it.

8. B — Vacuum Leak — Positive fuel trims at idle that normalize significantly at 2,500 RPM is the textbook vacuum leak fuel trim pattern. At idle, unmetered air entering through a vacuum leak represents a significant percentage of the total airflow into the engine. The MAF does not measure this extra air, causing the PCM to deliver too little fuel for the actual air present — creating a lean condition. At 2,500 RPM, the same fixed amount of unmetered leak air is a much smaller percentage of total airflow and the lean effect is substantially reduced.

9. C — GDI Design Without Intake Valve Fuel Washing — In MFI systems, the injector sprays fuel directly onto the back of the intake valve on every intake stroke — the fuel spray physically washes combustion deposits and oil film from the valve face. GDI injectors spray directly into the cylinder, bypassing the intake valve entirely. The intake valve is exposed to hot crankcase vapors from PCV flow and EGR gases with no periodic fuel washing — deposits accumulate over time and cannot be removed by normal engine operation.

10. A — Clogged Cylinder 4 Injector — A near-zero RPM drop (3 RPM vs. 38–41 RPM for all others) during a contribution test with confirmed normal compression and confirmed normal COP ignition waveform indicates the cylinder has mechanical integrity and ignition capability but is not receiving fuel. A clogged injector delivers little to no fuel, producing near-zero combustion contribution. Normal compression rules out mechanical fault and normal COP waveform rules out ignition fault.

11. C — Fuel Flow Volume Test at Maximum Demand — Normal pressure at idle and 3,000 RPM rules out a static pressure fault. A P0087 that only sets during extended WOT track conditions is a sustained maximum demand scenario. A fuel pump may maintain adequate pressure at moderate demand but cannot sustain adequate flow volume under prolonged maximum demand. A fuel flow volume test at maximum pump electrical and mechanical demand simulates the track conditions to confirm or rule out a flow volume limitation.

12. C — Stuck-Open High-Pressure Fuel Metering Valve — The GDI PCM uses the high-pressure rail sensor feedback to duty-cycle the HPFP metering valve. A stuck-open metering valve allows the HPFP to pump at maximum output regardless of what the PCM commands, driving rail pressure above specification. A stuck-closed valve would cause low pressure. A failed sensor reading low would cause the PCM to command more output — also raising pressure — but a stuck-open metering valve directly causes uncontrolled maximum output.

13. C — Vacuum Leak in Inaccessible Location — Both banks positive at idle with normalization at RPM is the vacuum leak pattern. MAF output within specification eliminates MAF contamination. The absence of a detectable smoke leak does not rule out a vacuum leak — common inaccessible locations include under-manifold plenum gaskets, vacuum passages within the intake manifold casting, EGR system internal passages, and throttle body gaskets in deep recesses that cannot be smoke-tested without significant disassembly.

14. D — Weak or Failed LPFP — The HPFP requires consistent adequate inlet pressure from the LPFP to function correctly. An LPFP producing only 28 psi when the minimum required is 50 psi is unable to adequately supply the HPFP inlet. The HPFP, starved of adequate inlet pressure, cannot build full high-side pressure regardless of its own condition — producing below-specification high-side pressure (380 psi vs. 2,000 psi minimum) that resolves when the low-side fault is corrected.

15. C — Leaking Fuel Pressure Regulator Diaphragm — The FPR diaphragm separates the fuel side from the vacuum side. A leaking diaphragm allows liquid fuel to pass through the damage into the vacuum port and be drawn directly into the intake manifold by manifold vacuum — causing a rich condition. Disconnecting the vacuum line removes the vacuum-driven suction pulling fuel through the leaking diaphragm, eliminating the fuel introduction path and shifting fuel trims to near-zero — confirming the leaking diaphragm as the rich source.

16. B — Failed Fuel Pump — Low fuel pressure (21 psi) with the in-tank pump running at full voltage combined with normal pressure (52 psi) when an external pump supplies the same rail through the same system confirms the in-tank pump has failed. The external pump test rules out a supply line restriction and a rail-side fault — the only variable between the two tests is the pump itself. The failed internal pump is the confirmed cause.

17. B — Vacuum Leak from Cleaning Procedure — Walnut shell blast cleaning requires removal of intake components including intake manifold, vacuum lines, and associated connections. A gasket that does not seal correctly after reassembly, a vacuum hose not fully reseated, or a manifold bolt not torqued correctly introduces a new vacuum leak that was not present before the cleaning. P0300 random misfire from a new vacuum leak after intake service is a common post-cleaning complication that must be investigated at all intake manifold connections and gaskets.

18. C — Weak Bank 1 Injectors — Single-bank lean at ALL RPM ranges (both idle and 2,500 RPM equally positive) is the fuel delivery volume fault pattern for that bank's injectors — not a vacuum leak (which normalizes at RPM), not a MAF fault (which affects both banks), and not a sensor fault. Weak injectors, partially clogged injectors, or injectors with increased internal resistance on Bank 1 deliver less fuel per commanded pulse width at all operating conditions, producing consistent lean conditions across all RPM ranges equally.

19. C — Compare MAF Output to Known-Good Vehicle — MAF contamination produces a non-linear undercounting pattern that is most apparent at idle and decreases at higher RPM because the PCM has more corroborating sensor data at higher loads. The most definitive confirmation is comparing actual MAF output in grams per second against a known-good identical vehicle at the same RPM and load conditions — if the suspect MAF reads significantly lower, contamination is confirmed. This test avoids the variables introduced by cleaning or replacement.

20. B — Leaking High-Pressure Fuel Injectors — With the HPFP isolated and the low-side holding normally, the only path for high-side pressure decay is through the high-pressure injectors themselves, through a leaking high-pressure rail fitting, or through a failed HPFP outlet check valve. On GDI systems, high-pressure fuel injector tip leakage is the most common cause of high-side pressure decay after HPFP isolation — the high-side pressure gradient forces fuel past the HPFI needle seat directly into the cylinder when the engine is off.

21. C — Replace Complete Fuel Pump Module — An integrated non-serviceable in-tank filter cannot be individually replaced. When the filter becomes restricted to the point of causing P0087 under demand, the only repair option that addresses the restriction is complete fuel pump module replacement, which includes both the pump and the integrated filter assembly. Chemical cleaning additives are ineffective at dissolving physical filter element restriction, and bypassing the integrated filter eliminates a critical fuel system component.

22. B — Clear LTFT and Monitor — The purge solenoid disable test confirmed it was a contributing source — STFT shifted from -20% to -3% at idle. However, LTFT remains at -16%. LTFT represents learned correction built over many drive cycles. After disabling the purge solenoid, clearing LTFT and monitoring which direction it rebuilds during a drive cycle confirms whether the LTFT represents a second active rich source or is simply legacy trim from the period the purge was stuck open. If LTFT rebuilds toward zero, no second source is present.

23. D — Worn HPFP with Reduced Internal Efficiency — With normal LPFP output, normal cam lobe height, and the fuel metering valve at 92% duty cycle (near maximum) but only achieving 1,600 psi (below spec), the HPFP is working at maximum commanded capacity but cannot achieve specification pressure. This combination — maximum PCM command, normal mechanical drive, normal inlet supply, but inadequate output — confirms the HPFP itself has reduced internal pumping efficiency from worn check valves, a worn piston, or degraded sealing within the pump body.

24. B — Rapidly Oscillating Fuel Pressure — Unstable fuel pressure causes the PCM's closed-loop fuel control to continuously correct in one direction, overshoot, correct in the other direction, and overshoot again — producing rapid bidirectional STFT swings without a net lean or rich bias. Because the pressure oscillates rather than consistently deviating in one direction, no LTFT develops. A pressure transducer on the fuel rail while monitoring fuel trims simultaneously would confirm pressure oscillation as the cause.

25. B — Replace HPFP and Evaluate Cam Lobe Wear — A flat-spotted cam lobe is the mechanical cause of HPFP failure in many cases — the reduced lobe height delivers reduced pump piston stroke, increasing pump wear from over-extension and reducing maximum pressure output. Replacing the HPFP without addressing the cam lobe wear guarantees premature failure of the new pump. Cam lobe height must be measured against manufacturer specification to determine whether the camshaft also requires replacement to prevent repeat HPFP failure.

26. D — Low Fuel Pressure at All RPM Ranges — Borderline low pressure at idle (44 psi with 45 psi minimum specification) and significant pressure collapse at 3,000 RPM (31 psi) confirms an inadequate fuel pressure condition that worsens under demand. Consistent lean fuel trims at both idle and 2,500 RPM without any vacuum leak and with normal injector balance are consistent with consistently insufficient fuel pressure delivering less fuel than commanded across all operating conditions.

27. B — Intake Port Obstruction Reducing Cold Cranking Airflow Velocity — During cold cranking, intake airflow velocity is minimal and the fuel charge is difficult to vaporize. Carbon deposits partially obstructing the intake ports reduce what little airflow velocity exists during cold cranking — further reducing mixture turbulence and the homogeneity of the injected fuel charge in the cylinder. Poor mixture homogeneity at low cranking speed and cold temperature results in incomplete early combustion events, extending the number of cranking cycles required before sustained firing.

28. B — Within Acceptable Variation — A 36 RPM drop versus 38–42 RPM on all other cylinders represents a small variation (approximately 5–10% below average). Acceptable RPM drop variation between cylinders varies by manufacturer specification but typically allows 10–15 RPM variation. Condemning an injector based on a 2–6 RPM drop below the other cylinders without verifying the manufacturer's specified acceptable variation range risks unnecessary injector replacement. The result must be compared to specification before any repair recommendation.

29. C — Prime Low-Pressure System Before First Start — GDI HPFP operation requires adequate inlet pressure from the LPFP to prime the pump's internal passages and fill the HPFP inlet before the first engine start. Starting the engine with an unprimed low-pressure system allows the HPFP to operate momentarily without adequate lubrication and cooling from inlet fuel — potentially damaging the new pump within the first seconds of operation. Key-cycling or a scan tool prime function pressurizes the low-side circuit before the first start.

30. B — Partially Collapsed Fuel Supply Line — When P0087 returns with confirmed low pressure and low volume after a new fuel pump installation, the restriction causing the fault is not in the pump. A partially collapsed supply line between the fuel tank and the fuel rail restricts fuel flow regardless of pump output capacity — the pump may be able to move adequate fuel through an unobstructed system but cannot overcome the supply line restriction. The supply line must be inspected for internal collapse, kinking, or external crushing.

31. C — Liquid Fuel in the Vacuum Line — A healthy FPR diaphragm separates fuel and vacuum sides completely. A failed diaphragm develops a hole or tear that allows liquid fuel under rail pressure to be pushed through the damaged diaphragm into the vacuum line. Removing the vacuum line from the FPR and finding liquid fuel or a strong saturated fuel odor (indicating fuel-soaked vacuum line walls) is the definitive confirmation of diaphragm failure. A faint odor alone is insufficient — liquid fuel presence is the definitive finding.

32. B — Injector Supply Voltage Drop Reducing Fuel Delivery — A 1.5V drop (12.6V - 11.1V) in the injector supply circuit exceeds the 0.5V maximum specification. This voltage drop is caused by resistance in the supply wiring, connector, relay contacts, or fuse holder. The reduced voltage at the injector solenoid produces reduced magnetic force on the injector pintle — causing slower opening, reduced pintle lift, or incomplete opening on some pulses — effectively reducing fuel delivery below commanded amount and creating the observed lean condition on Bank 1.

33. C — Fuel Vapor in Low-Pressure Supply Line from Heat Soak — The hot ambient soak scenario combined with normal cold and warm operation points to a heat-soak vapor lock phenomenon. During extended parking in direct sun, the low-pressure fuel line absorbs heat from the engine compartment and vaporizes fuel in the line. On restart, the LPFP must purge vapor and re-establish liquid fuel flow to the HPFP. If vapor purging is prolonged, the HPFP inlet starves, high-side pressure collapses, and P0087 sets before the system normalizes.

34. B — Cleaning Successfully Restored Flow Balance — An on-car injector cleaning reducing the balance spread from 14 RPM to 2 RPM confirms the cleaning was effective in removing deposit-induced flow restrictions and restoring injector flow balance. The post-cleaning balance test is the objective confirmation that the service was successful. The symptom that prompted the cleaning should be verified as resolved during a drive cycle before releasing the vehicle — confirming that restored injector balance addresses the original customer concern.

35. D — Partially Shorted Fuel Pump Motor Winding — A partially shorted pump motor winding reduces the winding's electrical impedance — allowing higher current flow without a proportional increase in mechanical output. The motor draws excess current (8.2A vs. 4.5–6.0A specification) while potentially delivering reduced flow due to the partial short causing inefficient electromagnetic conversion of electrical energy to mechanical work. A seized pump would draw very high current (well above 8.2A) and produce zero flow.

36. B — Worn Camshaft Lobe Not Inspected at HPFP Replacement — Normal idle pressure on the new HPFP confirms the pump is capable of adequate output at low stroke demand. Rail pressure dropping 43% at 3,500 RPM where the HPFP must sustain rapid high-volume pumping confirms the mechanical drive is insufficient at high demand. A cam lobe worn below height specification provides adequate stroke at low RPM (when each pump stroke delivers enough pressure for low demand) but cannot sustain adequate pumping rate at high RPM — exactly the symptom presented.

37. C — MAF Sensor Undercounting — The definitive finding is the MAF comparison: 14% lower than a known-good vehicle at identical conditions. MAF undercounting causes the PCM to command proportionally less fuel than the actual airflow requires at all RPM ranges — producing lean conditions that are equal at idle and 2,500 RPM. This is the key differentiator from vacuum leak (which normalizes at RPM). The consistent trim pattern from idle to 2,500 RPM with a confirmed low MAF comparison is the MAF undercounting signature.

38. C — Rich Combustion Condition — The five-gas pattern (high HC, high CO, low O_2, low CO_2) is the rich combustion signature. Excess fuel consumes all available oxygen (O_2 near zero) and produces carbon monoxide from incomplete combustion of excess hydrocarbons (CO elevated). HC is elevated from unburned fuel molecules that did not fully combust. CO_2 is reduced because combustion efficiency is lower — less of the carbon in the fuel completes the full oxidation to CO_2. This is the opposite of a lean or misfire five-gas pattern.

39. C — Restricted Low-Pressure Supply Line — LPFP static output at 60 psi is normal. However, HPFP inlet pressure collapsing to 18 psi at 3,500 RPM while LPFP output remains at 60 psi proves the fault is in the delivery path between the LPFP outlet and the HPFP inlet — not in either pump itself. A restricted supply line with adequate static pressure but inadequate dynamic flow capacity cannot deliver sufficient fuel volume to the HPFP at high speed, causing inlet starvation despite adequate LPFP pump output.

40. A — Clear LTFT and Perform Drive Cycle — The STFT at +3% confirms the active lean source (the vacuum leak) has been repaired. The LTFT of +18% is legacy trim — the PCM learned this correction value over the period the vacuum leak was present and stored it in long-term memory. The PCM will not automatically subtract the legacy LTFT until it observes that the fuel trim is consistently accurate without the high LTFT. Clearing the LTFT and performing a drive cycle allows the PCM to relearn the correct trim value.

41. C — Fuel Pump Cooling and Lubrication by Surrounding Fuel — The in-tank fuel pump is designed to be constantly surrounded by fuel that provides both cooling for the motor and lubrication for the pump bearings and impeller. When the fuel level is consistently low (1/8 tank), the pump operates in minimal fuel — reducing cooling airflow around the motor and reducing lubrication. Over time, the elevated operating temperatures and increased friction from reduced lubrication accelerate motor wear and lead to premature pump failure.

42. B — Normal GDI HPFP Cold Start Pressure Build-Up — After an extended cold shutdown, the high-pressure rail bleeds down toward low-side pressure. On cold start, the HPFP requires several pump strokes — typically 5–10 seconds on many platforms — to fully pressurize the high-pressure rail from its cold-start low pressure condition. A reading of 380 psi building to 2,050 psi over 8 seconds with normal LPFP supply and no DTCs may be within normal platform specification. The technician should compare the build-up time to the manufacturer's cold start pressure specification.

43. D — Partially Stuck-Closed Fuel Pressure Regulator — A key-on pressure of 58 psi with a 55 psi maximum specification confirms the regulator is not fully opening to regulate pressure down to specification. The pressure of 85 psi when the return is pinched confirms the pump is capable of higher pressure and the regulator is the limiting factor — but the pressure of 58 psi (just above spec) indicates the regulator is not fully stuck, only partially restricted. A stuck-closed regulator would show much higher pressure (potentially 80+ psi) without pinching the return line.

44. B — GDI Injector Leakage Causes Oil Dilution — GDI injectors spray directly into the combustion chamber at 2,000+ psi. When a GDI injector leaks with the engine off, high-pressure fuel drips directly onto the piston crown at the top of the bore — running down the cylinder wall past the ring pack into the crankcase oil. Unlike a port injector leak that drips into the intake manifold, a GDI injector leak bypasses the intake entirely and goes directly into the combustion chamber and past the rings, causing progressive engine oil fuel dilution with each cold soak.

45. C — High-Resistance Pump Power Supply Circuit — Normal pump amperage and normal pressure at idle confirm the pump is mechanically functional at low demand. The supply voltage drop from 14.2V to 10.8V during sustained WOT (3.4V drop) confirms excessive resistance in the pump supply circuit — the supply wiring, relay contacts, or fuse holder cannot carry the increased current at sustained WOT without a significant voltage drop. The voltage-starved pump cannot maintain flow rate, producing P0087 only under sustained high-demand conditions.

46. B — Leaking GDI Injector Causing Crankcase Oil Dilution — GDI injectors are located in the combustion chamber and operate at 2,000+ psi. A leaking HPFI with the engine off allows high-pressure fuel to drip directly onto the piston crown. The fuel runs down the cylinder wall past the piston rings into the crankcase during the shutdown period. Because the fuel evaporates during normal engine operation (hot combustion temperatures vaporize the leaked fuel before it can be detected in exhaust), fuel trims remain normal — masking the ongoing oil dilution from routine monitoring.

47. C — Vacuum Leak in Inaccessible Location — A positive propane enrichment result confirms unmetered air is entering the intake — the propane compensates for it and trims shift toward zero. A negative smoke test does not rule out the leak; it confirms the leak is in a location the smoke test cannot access. Under-manifold gaskets between the lower intake manifold and the cylinder heads, internal EGR passages with casting cracks, or throttle body gaskets in recessed mounting positions are common locations that require manifold removal to smoke-test effectively.

48. B — Failing High-Pressure Fuel Rail Pressure Sensor — A failing rail pressure sensor can produce oscillating false readings that cause the PCM to alternately command more and less pump output in response to the false sensor signal — resulting in actual pressure oscillation following the false sensor oscillation pattern. A scope test of the sensor signal voltage while monitoring rail pressure with a mechanical high-pressure gauge would differentiate a sensor fault (mechanical gauge steady, sensor signal oscillating) from an actual metering valve fault (both readings oscillating together).

49. C — Replacement Pump with Incorrect Higher Pressure Specification — A system-rich condition (both banks, equally negative trims) appearing immediately after a fuel pump replacement with no other changes indicates the replacement pump is introducing excess fuel. An aftermarket pump with an integrated regulator calibrated to a higher pressure than the vehicle specification delivers fuel at higher than commanded pressure — causing all injectors to flow more fuel per pulse width than the PCM commanded, producing equal rich conditions on both banks with no other fault present.

50. B — HPFP with Worn Internal Check Valves or Piston Sealing — All external factors are confirmed normal: LPFP pressure, HPFP inlet pressure at highway speed, cam timing, and metering valve response. The HPFP at 98% duty cycle is being commanded to maximum output but cannot achieve specification pressure at highway speed demand. With all mechanical drive and supply factors confirmed normal, reduced internal HPFP pumping efficiency from worn check valves, a worn piston, or degraded internal sealing is the only remaining cause consistent with normal low-demand performance but inadequate high-demand performance.