

PRACTICE EXAM 13: RED SEAL 421A

SIMULATION (135 QUESTIONS)

1. A technician is assigned to replace a final drive on an ultraclass mining truck. The final drive assembly weighs approximately 12,000 kg. The removal requires a 50tonne mobile crane positioned adjacent to the truck's rear axle. Before any lifting begins, what document must the crane operator and the technician jointly review and approve?

- A. The truck manufacturer's service manual procedure for final drive removal, which provides the crane requirements and rigging attachment points
- B. The mobile crane's annual inspection certificate, which confirms the crane is rated for the 12,000 kg lift at the required boom extension and angle
- C. The site's equipment maintenance schedule, which confirms both the truck and the crane are current on all preventive maintenance requirements
- D. A written lift plan that documents the load weight, rigging configuration, crane capacity at the working radius, ground conditions, overhead obstructions, and the stepbystep procedure for the lift — reviewed and signed by both the crane operator and the supervising technician before any rigging begins

2. A technician discovers a coworker using compressed air at 620 kPa (90 PSI) to blow dust from their clothing at the end of a shift. The shop's compressed air system operates at 860 kPa and is reduced to 620 kPa at the blowgun nozzle. What hazard does this practice create?

- A. Compressed air directed at the body can penetrate the skin and enter the bloodstream (air embolism), can rupture eardrums if directed near the head, and can drive particles into the eyes and skin at injurious velocities — using compressed air for personal cleaning is prohibited in most Canadian jurisdictions regardless of the regulated pressure at the nozzle
- B. The 620 kPa nozzle pressure is within the acceptable limit for personal use — Canadian OHS regulations permit compressed air for personal cleaning at pressures below 700 kPa

C. The only hazard is noise exposure — the highvelocity air produces noise above 85 dBA that requires hearing protection during the cleaning activity

D. The hazard is limited to eye injury from airborne dust particles — wearing safety glasses during the air cleaning eliminates the risk

3. A technician must enter a machine's hydraulic reservoir to perform an internal inspection. The reservoir is a large, enclosed tank with a single access hatch on top. After draining the oil, the technician opens the hatch and prepares to enter. What classification does this entry fall under?

A. The reservoir is a standard maintenance access point and does not require any special entry procedures beyond the standard lockout/tagout of the hydraulic system

B. The reservoir is a hotwork area that requires a fire watch during the inspection because hydraulic oil vapour may be present inside the drained tank

C. The reservoir meets the definition of a confined space — it is an enclosed area with limited entry and exit, not designed for continuous human occupancy, and may contain an oxygendeficient or toxic atmosphere from residual oil vapour. A confined space entry permit, atmospheric testing, ventilation, a rescue plan, and an attendant are required before the technician enters

D. The reservoir is a restricted work area that requires only a buddy system — one technician enters while a second stands at the hatch opening to maintain visual contact

4. A heavy equipment shop uses a parts washer that contains a petroleumbased solvent. The parts washer has a fusible link on the lid that automatically closes the lid if the solvent catches fire. During a routine inspection, the technician discovers the fusible link has been disabled — the link has been wired in the open position to prevent the lid from accidentally closing during use. What is the consequence of this modification?

A. No consequence — the fusible link is a convenience feature that prevents solvent splashing when the lid closes, and wiring it open does not affect the parts washer's fire safety

B. The disabled fusible link eliminates the parts washer's primary fire suppression mechanism — if the solvent ignites, the lid cannot close to smother the fire by cutting off the oxygen supply. The openlid fire can spread to adjacent combustible materials and escalate beyond the capacity of handheld fire extinguishers

C. The disabled link only affects the warranty coverage for the parts washer — the manufacturer requires the fusible link to be operational for the warranty to remain valid

D. The disabled link creates only an OSHA documentation deficiency — the modification must be recorded in the shop's equipment log but does not create an immediate safety hazard

5. A technician is troubleshooting a machine in the field during winter conditions. The ambient temperature is -25°C . The technician has been working outdoors for 2 hours. The technician's hands are numb and they are having difficulty gripping hand tools. What risk does continued work in this condition create beyond personal discomfort?

A. The only risk is frostbite to the exposed fingers — the technician should apply hand warmers inside their gloves and continue the repair

B. The risk is limited to reduced productivity — cold hands work slower but the quality of the repair is not affected as long as the technician takes breaks to warm their hands

C. The risk is limited to dropped tools — the technician should tether all hand tools to prevent them from falling into the machine during the repair

D. Loss of fine motor control from cold-induced numbness increases the risk of injury from slipping tools, improper fastener torquing, incorrect component installation, and failure to detect tactile feedback (such as the feel of a crossthreaded fastener or a fitting that is not properly seated) — the technician should warm up in a heated enclosure until hand dexterity is restored before continuing precision work

6. A technician is performing a pressure test on a hydraulic cylinder using a hand pump. The test specification requires pressurizing the cylinder to 350 bar and holding for 5 minutes while monitoring for pressure decay. During the test, the technician notices the pressure gauge needle is vibrating rapidly. What does this vibration indicate?

A. The pressure gauge needle vibration indicates the test setup has an active leak — the hand pump's check valve is passing, or a fitting in the test circuit is leaking. Each leak pulse drops the pressure slightly and each pump stroke restores it, producing the rapid oscillation that the needle follows. The test must be paused and the leak located before a valid 5minute hold can be performed

B. The gauge needle vibration is a normal characteristic of handpump pressure testing — the pump's pulsating output produces pressure ripples that the gauge needle follows

C. The gauge has failed — the internal Bourdon tube has cracked and the escaping test fluid is causing the needle to vibrate as the fluid enters the gauge mechanism

D. The vibration indicates the cylinder's piston seal is oscillating between sealed and leaking states under the 350bar test pressure, producing the pressure fluctuation

7. A machine has been involved in a structural failure — the boom has cracked during operation and the bucket has dropped to the ground. No injuries occurred. The site supervisor instructs the technician to repair the crack and return the machine to service as quickly as possible. The technician examines the crack and determines it is a throughthickness fatigue crack at a weld toe in a highstress zone. What is the technician's professional obligation?

A. Perform the fastest acceptable repair — grind out the crack, reweld, and return the machine to service after a visual inspection confirms the weld is sound

B. Perform the repair using the higheststrength electrode available and apply a reinforcement plate over the weld to increase the joint strength above the original design

C. Inform the supervisor that a fatigue crack at a critical structural location requires engineering assessment before repair — the crack's root cause, the repair procedure, the NDE verification method, and the postrepair inspection requirements must be determined by a qualified structural engineer or the OEM before any welding begins. A field repair without engineering direction may not address the root cause and could fail catastrophically during operation

D. Refuse to perform the repair entirely — structural fatigue cracks cannot be repaired and the boom must be replaced with a new OEM component regardless of the crack's size or location

8. A technician is removing a track pin on a crawler dozer using a hydraulic track press. The press is applying force to push the pin from the link bore. The force gauge on the press reads 18 tonnes — near the press's 20tonne capacity. The pin has not moved. What should the technician do?

A. Increase the press force to the maximum 20tonne capacity — the additional 2 tonnes may be sufficient to overcome the pin's corrosion bond and push it from the bore

B. Stop increasing force and apply penetrating oil to both ends of the pin, then apply heat to the link lugs around the pin bore to expand the bores and break the corrosion bond — reduce the required extraction force before continuing. Operating the press at nearmaximum capacity with a seized pin risks sudden pin release that can eject the pin as a projectile

C. Rotate the press 90 degrees and apply the force from a different angle — the pin may have a wear pattern that resists removal from one direction but releases from the perpendicular direction

D. Cut the pin with an oxyacetylene torch rather than continuing to apply hydraulic force — the thermal cutting method eliminates the stored energy hazard of the hydraulic press

9. A technician is diagnosing an electrical fault on a machine. The diagnostic procedure requires measuring the resistance of a wire in the engine compartment harness. The technician's DMM probes have sharp tips that pierce the wire insulation to contact the conductor. After the measurement, the technician removes the probes and continues with the repair. What hazard has the probe piercing created?

A. Each probe puncture has created a small hole in the wire insulation that allows moisture to reach the copper conductor — over time, moisture wicks along the conductor strands through the puncture,

corroding the wire and increasing its resistance until the circuit becomes intermittent or fails. The puncture sites should be sealed with liquid electrical tape or heatshrink to prevent moisture ingress

B. The probe punctures have weakened the wire's tensile strength at each puncture point, creating stress risers that will cause the wire to break under the vibration loading of the engine compartment

C. The probe punctures have no consequence — modern automotive wire insulation selfseals when the probe is removed, preventing any moisture ingress

D. The probe punctures are a concern only on highvoltage circuits above 48V — on the machine's 24V system, the low voltage cannot drive sufficient current through the moisture path to cause any measurable corrosion

10. A technician must perform a repair on a machine that requires the engine to be running during the diagnostic procedure. The repair location is inside the engine compartment near the rotating fan and belt-driven accessories. What specific precaution must be taken before the technician positions themselves near the running engine?

A. Wear a face shield to protect against fluid spray from the pressurized cooling and lubrication systems that are active during engine operation

B. Position a fire extinguisher within arm's reach in case a hydraulic hose fails and sprays oil onto the hot exhaust manifold during the diagnostic procedure

C. Ensure the engine's maximum governed RPM is reduced to idle through the diagnostic tool before positioning near the engine compartment

D. Identify all rotating components (fan, belts, pulleys, driveshafts) and ensure no loose clothing, jewelry, lanyards, or tools can contact any rotating part — all guards that can remain in place during the diagnostic must be installed, and the technician must maintain clearance from all unguarded rotating components at all times during the engine-running procedure

11. A technician receives two oil analysis reports taken 250 hours apart on the same engine. The first report shows iron at 25 ppm and silicon at 10 ppm. The second report shows iron at 55 ppm and silicon at 38 ppm. What is the most significant diagnostic conclusion from these two data points together?

A. The iron increase is from normal engine wear and the silicon increase is from a new silicone gasket sealant applied during a recent repair

B. The iron increase indicates a bearing failure that is independent of the silicon increase, which is from a degraded air filter element shedding silicon-containing fibres into the oil

C. The simultaneous rapid increase in both iron and silicon confirms dirt ingestion — silicon (from airborne dust) is entering the engine through a compromised intake system and the abrasive particles are dramatically accelerating the wear rate of iron components (liners, rings, gears), producing the correlated iron increase

D. The silicon increase is from coolant contamination (silicate corrosion inhibitors) and the iron increase is from the acidic coolant corroding the internal iron components

12. A diesel engine's fuel injector has a specified nozzle opening pressure (NOP) of 250 bar. The technician tests the injector on a pop tester and measures the NOP at 180 bar. What effect does the 70-bar low NOP have on the engine's combustion?

A. The low NOP produces a delayed injection because the fuel must build to a higher pressure before the nozzle opens — the delayed injection retards the timing and reduces power

B. The low NOP allows the nozzle to open earlier in the injection cycle at a lower pressure, producing a longer injection duration with larger fuel droplets. The larger droplets atomize poorly, burn inefficiently, produce excessive smoke, reduce power output from the affected cylinder, and may cause fuel to wash the cylinder wall oil film

C. The low NOP has no measurable effect on combustion — the ECM compensates for the reduced NOP by adjusting the injection timing and duration through the adaptive trim system

D. The low NOP causes the injector to remain closed longer because the lower spring pressure cannot hold the needle against the rail pressure, producing an overfuelling condition

13. A diesel engine equipped with a common rail system stores fuel at approximately 1,600 bar in the rail during loaded operation. The rail is made of forged steel with precisionmachined internal passages. What is the primary safety concern when working on or near the common rail and highpressure fuel lines while the engine is running?

A. A fuel leak from a common rail fitting or highpressure line at 1,600 bar can produce a nearly invisible, highvelocity fuel jet that penetrates skin and underlying tissue (hydraulic injection injury). The technician must never use hands to search for leaks on a running common rail system — a piece of cardboard held near the suspected leak area detects the jet safely

B. The primary concern is fire — a fuel leak at 1,600 bar atomizes the fuel into a fine mist that ignites on contact with the hot exhaust manifold

C. The primary concern is environmental contamination — a common rail leak at 1,600 bar produces a largevolume fuel spill that requires immediate spill containment and cleanup

D. The primary concern is engine damage — a common rail leak reduces the rail pressure below the minimum for combustion and the engine stalls, potentially causing a safety hazard if the machine is in motion

14. A diesel engine's oil analysis report shows a sudden spike in lead — from a baseline of 3 ppm to 28 ppm in one sampling interval. All other wear metals are at trending levels. The engine has trimetal connecting rod bearings with a leadtin overlay. What does this lead spike indicate about the bearing condition?

A. The lead spike is from the engine oil's additive package — certain EP (extreme pressure) additives contain lead compounds that degrade over time and release lead into the oil

B. The lead spike is from the fuel — leaded diesel fuel contamination from a mixed fuel delivery has introduced lead into the oil through combustion blowby

C. The lead spike is insignificant — lead levels below 30 ppm are within the normal operating range for engines with trimetal bearings and do not indicate abnormal wear

D. The bearing overlay is wearing through at an accelerated rate — the leadtin overlay is the outermost sacrificial layer of the trimetal bearing, and a spike from 3 to 28 ppm (a ninefold increase) in one

interval confirms the overlay is being removed at a rate that will expose the copper intermediate layer within the next sampling interval if the cause is not identified and corrected

15. A diesel engine's electronic control module (ECM) uses a barometric pressure sensor to compensate for altitude. The sensor measures the atmospheric pressure and the ECM adjusts the fuel delivery and boost targets based on the available air density. If the barometric sensor fails and reads a permanently high altitude (low atmospheric pressure), how does this affect engine performance at the actual operating altitude (sea level)?

A. The engine overspeeds because the ECM increases the fuel delivery to compensate for the perceived thin air at altitude

B. The ECM reduces the fuel delivery and the boost pressure target because it believes the engine is operating at high altitude where less oxygen is available — the engine produces less than rated power at sea level because the ECM is limiting the fuel delivery based on the incorrect altitude signal

C. The ECM increases the fuel delivery beyond the rated amount because it believes the turbocharger must work harder to produce the required boost at altitude — the engine runs rich and produces excessive smoke

D. The barometric sensor failure has no effect because the intake manifold pressure sensor independently measures the actual air density and overrides the barometric sensor for fuel delivery calculations

16. A diesel engine's turbocharger has been in service for 15,000 hours. The technician measures the turbocharger shaft radial play (sidetoside movement) at 0.12 mm. The OEM specification maximum is 0.08 mm. The engine produces rated power and boost with no unusual noise. Should the turbocharger be replaced based on this measurement alone?

A. No — the turbocharger produces rated performance and the 0.12 mm play is within the extended service tolerance that applies to turbochargers with more than 10,000 hours of operation

B. No — radial play measurements on installed turbochargers are inherently inaccurate and the turbocharger should only be evaluated by its performance characteristics (boost pressure, exhaust temperature, oil consumption)

C. Yes — the radial play exceeds the OEM specification regardless of the current performance. The excess play allows the compressor and turbine wheels to contact their respective housings during transient conditions (rapid acceleration, deceleration, or sideloading). Continued operation risks a catastrophic wheel contact event that destroys the turbocharger and sends debris into the engine's intake and exhaust systems

D. Yes — but only if the oil consumption has also increased, confirming the worn bearings are allowing oil to leak past the shaft seals into the compressor and turbine housings

17. A diesel engine's cooling system uses a two-stage thermostat — the thermostat has two valves that open at different temperatures. The primary valve opens at 82°C to begin routing coolant through the radiator. The secondary valve opens at 90°C to increase the flow to the radiator for maximum cooling. What is the advantage of this two-stage design compared to a single-valve thermostat?

A. The two-stage design provides a more gradual transition from the bypass circuit to the radiator circuit — the primary valve begins partial radiator flow at 82°C, and the secondary valve increases to full flow at 90°C. This progressive flow increase reduces the thermal shock on the radiator core and produces a more stable engine operating temperature with less temperature cycling than a single valve that transitions abruptly from closed to fully open

B. The two-stage design provides a backup — if the primary valve fails, the secondary valve still provides cooling at 90°C, preventing a complete loss of radiator flow

C. The two-stage design is required only for engines with dual radiator cores — each valve controls the flow to one of the two cores independently

D. The two-stage design provides faster warmup — the primary valve is smaller and restricts flow more aggressively during warmup than a single large valve

18. A diesel engine has been operating for 2,000 hours since an overhaul. The oil analysis shows a gradual increase in aluminum over four consecutive samples: 5, 8, 12, 17 ppm. All other wear metals are stable at baseline levels. What is the most likely source of the increasing aluminum?

- A. The aluminum originates from the air filter housing — the filter housing's internal surface is corroding and releasing aluminum particles into the intake airstream that pass through the filter element
- B. The aluminum originates from the atmospheric dust that the air filter cannot completely remove — all air filters pass a small percentage of submicron aluminumoxide (alumina) particles from natural dust
- C. The aluminum is from the oil filter's antidrainback valve material — the valve deteriorates over the oil change interval and releases particles into the circulating oil
- D. The aluminum originates from a piston — the most common source of isolated aluminum in diesel engine oil is piston skirt wear. The gradual increase over four samples suggests one or more pistons are experiencing progressive scuffing, possibly from insufficient pistontobore clearance, inadequate oil cooling, or a cooling jet malfunction

19. A diesel engine equipped with EGR and SCR runs at rated power with no driveability complaints. The technician connects the diagnostic tool and reviews the emission system data. The postSCR NO_x reading is 45 ppm. The OEM specification maximum is 30 ppm. The DEF consumption rate is within the expected range. What should the technician investigate?

- A. The DEF quality — even though the consumption rate is correct, the DEF concentration may be below the 32.5% specification, delivering insufficient urea per volume to convert the NO_x at the required rate
- B. The SCR catalyst's efficiency — even with correct DEF quality and dosing rate, the catalyst's conversion efficiency may have degraded from thermal aging, sulfur poisoning, or hydrocarbon contamination to the point where it can no longer achieve the required NO_x reduction despite receiving the correct ammonia supply
- C. The EGR system — the NO_x entering the SCR may be higher than designed because the EGR system is not recirculating enough exhaust to reduce the engineout NO_x to the level the SCR was calibrated to handle

D. The exhaust temperature — the SCR catalyst requires a minimum temperature for the urea-to-ammonia conversion and the NOx-to-nitrogen reaction to occur efficiently

20. A diesel engine's coolant system uses an electronically controlled thermostat — the ECM commands the thermostat opening based on multiple inputs including coolant temperature, intake air temperature, engine load, and ambient temperature. What advantage does the electronically controlled thermostat provide over a traditional wax-element thermostat?

A. The electronic thermostat opens faster than a wax-element thermostat, providing quicker response to rapid temperature changes during load transients

B. The electronic thermostat eliminates the need for coolant temperature sensors because the thermostat itself contains a built-in temperature measurement that the ECM uses for all temperature-related control decisions

C. The ECM can optimize the engine operating temperature for different conditions — running the engine slightly cooler during heavy load (to prevent overheating) and slightly warmer during light load (to improve fuel efficiency and reduce emissions). A wax-element thermostat opens at a fixed temperature regardless of operating conditions

D. The electronic thermostat is more durable than a wax-element thermostat because it has no internal wax charge that degrades from repeated thermal cycling

21. A diesel engine's injector has an electrical connector that supplies the ECM's control signal. The connector has been exposed to moisture from a coolant leak above the injector's location. The technician cleans and dries the connector and the engine runs normally. Six months later, the injector develops an intermittent misfire. The technician finds green corrosion inside the connector despite it appearing dry externally. What mechanism caused the corrosion to develop after the initial cleaning?

- A. The cleaning solvent used to dry the connector left a chemical residue that accelerated the corrosion after the initial cleaning
- B. The initial moisture event introduced mineral salts from the coolant into the connector housing — even after drying, the salt residue remained on the terminal surfaces. The salt absorbs atmospheric moisture (hygroscopic effect) and reestablishes the corrosion process even without a new external moisture source. The connector should have been thoroughly flushed with electrical contact cleaner to remove all salt residue during the initial repair
- C. The green corrosion is from the coolant's dye — the green colour is the coolant's identification dye, not oxidation, and does not indicate a corrosion process
- D. The corrosion developed from the normal atmospheric humidity cycling in the engine compartment — all connectors corrode at this rate regardless of previous moisture exposure

22. A diesel engine's fuel system includes a fuelwater separator with a waterinfuel (WIF) sensor. The WIF sensor is a probe that detects the presence of water in the fuelwater separator bowl. The sensor illuminates a dashboard warning light when water is detected. If the WIF sensor fails in the "no water detected" state, what risk does this create?

- A. Water accumulates in the fuelwater separator without the operator's knowledge — the water eventually overflows the separator bowl and enters the secondary fuel filter and the highpressure injection system. Water in the HP system corrodes precision injector components, erodes nozzle seats, and causes injector seizure, producing expensive damage that the WIF warning was designed to prevent
- B. The failed WIF sensor drains the battery because the sensor circuit draws continuous current when in the nowater state
- C. The failed WIF sensor causes the ECM to reduce fuel delivery because the ECM interprets the nowater state as a fuel quality fault that requires protective action
- D. The failed sensor produces no operational risk because the fuelwater separator functions identically regardless of the sensor state — the separator continues to remove water from the fuel mechanically

23. A diesel engine's DPF has completed an active regeneration cycle. The technician checks the DPF differential pressure immediately after the regeneration and reads 3 kPa. The specification for a clean DPF is 1–2 kPa. What does the 3 kPa reading after regeneration indicate?

A. The regeneration was successful but the DPF has cooled and contracted, temporarily restricting the exhaust flow until the filter reaches operating temperature and expands to its normal geometry

B. The DPF differential pressure sensor has drifted from calibration and should be replaced to restore accurate soot loading measurement

C. The regeneration burned the soot but the DPF has accumulated ash (noncombustible metallic residue from engine oil additives) that cannot be removed by regeneration — the ash narrows the DPF's wallflow channels, producing a baseline restriction that increases over time and eventually requires offmachine professional cleaning

D. The 3 kPa reading is within the acceptable range for a postregeneration DPF — the 1–2 kPa specification applies only to brandnew DPF units and the specification relaxes as the DPF accumulates operating hours

24. A diesel engine equipped with a variable geometry turbocharger produces the following diagnostic data at rated RPM and full load: boost pressure = 180 kPa (specification 200 kPa), VGT position = 78% closed (specification 75% closed), exhaust backpressure = 45 kPa (specification maximum 40 kPa). What do these three data points together indicate?

A. The VGT actuator is overcommanding the vanes to a more closed position than specified, creating excessive backpressure

B. The VGT is operating near its commanded position (78% vs 75% specification — a minor deviation), but the boost is 20 kPa below specification while the backpressure is 5 kPa above specification. This combination indicates the turbocharger's efficiency has decreased — the turbine is creating the expected restriction (high backpressure) but cannot convert that exhaust energy into proportional compressor output (low boost). The turbocharger's internal losses (worn bearings, eroded wheels, or increased clearances) are consuming the energy

C. The data confirms a restricted DPF — the elevated backpressure from the DPF restriction limits the turbocharger's ability to produce rated boost despite the VGT commanding the correct vane position

D. The data confirms an intake restriction — the low boost is caused by a restricted air filter or charge air cooler that limits the compressor's output regardless of the turbine's energy input

25. A diesel engine is equipped with a crankcase ventilation system that routes blowby gases to the intake manifold for recombustion. The engine has been operating for 8,000 hours. The technician measures the blowby at 95 L/min. The OEM specification maximum for this engine is 100 L/min. The previous measurement (at 6,000 hours) was 70 L/min. What is the diagnostic significance of comparing these two data points?

A. Both readings are within specification and the engine is in acceptable condition — the 25 L/min increase over 2,000 hours is normal wear progression for a diesel engine at this point in its service life

B. The current 95 L/min reading is within specification, but the rate of increase (25 L/min in 2,000 hours compared to the previous trend) may indicate accelerating ring or liner wear — if the trend continues at this rate, the engine will exceed the 100 L/min limit within the next 400 hours. The technician should schedule an oil analysis and compression test to verify the wear rate before the limit is exceeded

C. Both readings are within specification and no further action is needed until the blowby exceeds the 100 L/min maximum

D. The 25 L/min increase is excessive and the engine should be removed from service immediately for an inframe overhaul before the blowby exceeds the specification

26. A diesel engine's oil cooler thermostat normally routes oil through the cooler when the oil temperature exceeds 80°C. A technician discovers the thermostat has been removed and a blank plate installed in its place — all oil now bypasses the cooler at all times. The machine has been operating in this configuration for approximately 500 hours. What damage may have occurred?

A. The engine oil has been operating at elevated temperatures for 500 hours without cooling — the sustained high temperature has accelerated the oil's oxidation rate exponentially, depleted the additive

package prematurely, reduced the oil's viscosity below the bearing film strength threshold, and may have caused bearing surface damage from inadequate lubrication at the reduced viscosity

B. No damage has occurred — the engine's coolant-to-oil heat transfer through the block casting provides adequate oil cooling without the dedicated oil cooler circuit

C. The elevated oil temperature has caused the oil filter bypass valve to remain permanently open, allowing unfiltered oil to circulate and contaminate the system with wear debris

D. The only damage is to the oil itself — the engine internals are protected by the oil film regardless of temperature, and changing the oil now restores full protection

27. A diesel engine's intake manifold has a crankcase ventilation (CCV) inlet that connects to the crankcase ventilation system. The CCV system routes blowby gases and oil mist from the crankcase to the intake for recombustion. If the CCV inlet hose disconnects from the intake manifold, what two symptoms develop simultaneously?

A. The engine overspeeds from the unmetered air entering through the disconnected CCV hose, and oil sprays from the disconnected hose onto the hot exhaust manifold

B. The engine runs rich because the ECM does not account for the air entering through the CCV port, and the fuel trim system cannot compensate for the unmetered air volume

C. The engine develops positive crankcase pressure (because blowby gases cannot exit through the disconnected path to the intake vacuum) and the crankcase pushes oil past external seals — simultaneously, unmetered air enters the intake through the open CCV port, which may cause a lean condition that the ECM's adaptive trim attempts to compensate for, and the discharged oil mist from the open hose contaminates the engine compartment

D. The engine stalls immediately because the large air leak through the disconnected CCV hose overwhelms the ECM's ability to maintain the correct air/fuel ratio

28. A diesel engine has developed a condition where the oil level on the dipstick rises above the full mark between oil changes. The oil has a distinct fuel odour. There are no external leaks. The engine runs normally with no performance complaints. What is occurring?

A. The engine's crankcase ventilation system is drawing fuel vapour from the fuel tank vent into the crankcase through a misrouted hose connection

B. The oil level is rising from water condensation that accumulates in the crankcase from the engine operating below its designed temperature range — the water has dissolved the fuel odour from normal combustion blowby

C. The oil additive package is breaking down and the released chemical compounds produce a fuel-like odour that mimics diesel fuel contamination

D. Diesel fuel is entering the crankcase — the most common cause is a leaking injector that allows fuel to wash past the piston rings during injection or postinjection events, or a fuel supply component that leaks fuel into an oil-wetted area inside the engine. The diluted oil has reduced viscosity and load-carrying capacity that will progressively damage bearing surfaces if not corrected

29. A diesel engine has been diagnosed with a cracked cylinder head. The crack runs between the injector bore and the valve seat on Cylinder 3. Before removing the head for replacement, the technician must determine if the crack has caused secondary damage. What specific secondary damage should be investigated?

A. Coolant contamination of the engine oil — the crack may have created a path for coolant to leak from the water jacket through the crack into the combustion chamber or oil gallery, contaminating the oil. The technician should check the oil for coolant contamination (milky appearance, rising level, coolant odour) and perform a coolant analysis for combustion gas contamination before removing the head, because the secondary damage determines the scope of the repair beyond the head replacement alone

B. Exhaust manifold warping — the thermal stress from the cracked head has transferred through the manifold bolts and warped the exhaust manifold gasket surface

C. Turbocharger damage — the coolant that entered the combustion chamber through the crack passed through the turbocharger turbine and damaged the turbine wheel coatings

D. Flywheel housing misalignment — the cracked head has allowed the block to shift under the head bolt clamping load, changing the flywheel housing bore alignment

30. A diesel engine's electronic governor controls the engine speed by adjusting the fuel delivery based on the operator's throttle input and the feedback from the engine speed sensor. The governor's response characteristics include two key parameters: gain (how aggressively the governor responds to a speed error) and stability (how quickly the governor settles to the target speed without oscillation). If the governor gain is set too high, what symptom does the operator experience?

A. The engine responds sluggishly to throttle changes because the high gain limits the maximum fuel delivery change per governor cycle

B. The engine surges (oscillates above and below the target speed) because the governor overreacts to each speed deviation — the correction overshoots the target, which triggers a correction in the opposite direction, and the cycle repeats as a rhythmic speed oscillation

C. The engine cannot reach full rated speed because the high gain causes the governor to reduce fuel delivery before the engine reaches the target RPM

D. The engine stalls during rapid load changes because the high gain cannot track the speed demand fast enough to prevent a momentary fuel cut during the transient

31. A large mining truck's steering system uses two independent steering circuits — each with its own pump, valve, and set of cylinders. Both circuits operate simultaneously during normal steering. If one circuit fails completely, the remaining circuit provides emergency steering at reduced response rate. During a routine test, the technician isolates Circuit A and tests the steering on Circuit B alone. The steering functions but requires noticeably more turns of the steering wheel to achieve the same turn angle. Why does singlecircuit operation require more steering wheel input?

- A. The single circuit's pump produces half the flow of the combined twocircuit system, and the reduced flow fills the steering cylinders more slowly, requiring more wheel turns at the same steering wheel rotation rate to displace the same cylinder volume
- B. Singlecircuit operation reduces the steering pressure by half, and the reduced pressure cannot move the cylinders as quickly against the tireto ground resistance
- C. The single circuit activates a flowlimiting valve that restricts the maximum steering speed as a safety measure during emergency singlecircuit operation
- D. Singlecircuit operation uses only one set of steering cylinders (the other set is inactive), and the singlecylinder set has half the displacement of the combined twocylinder system

32. A machine's wet disc brake has been rebuilt with new friction discs and separator plates. During the first loaded brake application after the rebuild, the operator reports the braking force is noticeably weaker than before the rebuild. The brake pack clearance is within specification. The hydraulic apply pressure is correct. What is the most likely cause of the reduced braking force?

- A. The new friction discs have a protective coating from manufacturing that must be burned off during the first several applications — the breakin period produces reduced friction until the coating is consumed
- B. The brake cooling oil level was overfilled during the rebuild, and the excess oil is hydraulically opposing the brake piston's apply force during each application
- C. The new separator plates are thicker than the originals, reducing the available piston travel and limiting the clamping force despite correct clearance measurement
- D. The new friction disc material requires a beddingin (breakin) period — the new surfaces have microscopic peaks that contact only a small percentage of the separator plate surface initially, producing a reduced effective friction area. As the peaks wear during the first hours of use, the contact area increases and the braking force rises to the designed level

33. A tracked machine's idler has been replaced with a new unit. After 500 hours of operation, the technician inspects the idler and discovers the tread surface is wearing unevenly — one half of the idler tread circumference shows normal wear while the other half shows almost no wear. What is the most likely cause of this halfwear pattern?

A. The idler is running eccentrically — the hub bore or the mounting shaft is outofround, causing one half of the idler to contact the track chain rail with normal force while the opposite half lifts away from the rail during each revolution. Only the contacting half wears, producing the distinctive halfcircumference wear pattern

B. The track chain has a tight spot at one location that loads the idler heavily during the tight section's pass and unloads it during the normal section's pass

C. The idler bearing has a flat spot from a shipping or installation impact that lifts the idler off the chain once per revolution at the flat spot location

D. The sprocket is driving the chain at a variable speed (faster and slower during each revolution from a worn sprocket tooth pattern), and the speed variation produces alternating highload and lowload zones on the idler tread

34. A wheel loader's hydraulic steering system uses a hand metering unit (HMU) that provides steering feel to the operator. The HMU is a geartype device that meters oil proportionally to the steering wheel rotation. The operator reports the steering has developed a "notchy" feel — the steering wheel has distinct resistance points during rotation rather than a smooth, consistent feel. What is the most likely cause?

A. The steering pump's internal gears have worn and the reduced flow produces pressure pulsations that the operator feels through the HMU as notchy steering

B. The steering cylinders have internal scoring that creates resistance points as the piston passes each scored section during the steering stroke

C. The HMU's internal gear set has worn or been contaminated — the damaged gear teeth or trapped particles create resistance points as the gears rotate, producing the notchy feel that the operator detects through the steering wheel

D. The steering valve's spool has developed wear grooves that create detent points as the spool shifts during steering commands

35. A machine's track chain has been operating in a highly corrosive environment (acid mine drainage). The technician measures the chain and finds the pitch elongation is within the normal specification for the operating hours. However, the pin outside diameters are significantly below specification when measured between the links. What type of wear pattern does this represent?

A. The pins are worn from the inside (bushing to pin contact) which is normal articulation wear — the external diameter reduction is the internal wear measured from the outside

B. The pin outside surfaces (exposed between the links) are being attacked by the acid mine drainage — the corrosive water dissolves the pin material from the exterior surface inward, reducing the pin diameter in the exposed zone while the internal bearing surfaces (protected by the sealed joint) remain relatively intact. This external corrosion weakens the pin's structural cross-section and can lead to pin fracture under load despite the internal bearing clearance being within specification

C. The pins have been installed incorrectly — the wrong diameter pins were used during the last chain repair and the undersized pins are being measured as worn

D. The pins are shrinking from hydrogen embrittlement caused by the acid exposure — the hydrogen atoms from the acid penetrate the pin's steel structure and reduce its dimensions through internal stress relaxation

36. A rigid frame mining truck equipped with rear axle wet disc service brakes and a retarder produces the following test results: service brakes alone from 30 km/h — stopping distance 25 metres (specification: 22 metres maximum). Retarder alone from 30 km/h — deceleration rate 0.8 m/s² (specification: 0.6 m/s² minimum). What do these results tell the technician about the overall braking system?

- A. Both the service brakes and retarder are within specification and the system is functioning correctly
- B. The retarder is overcompensating for weak service brakes — the retarder performance should be reduced to balance the system
- C. Both systems need service — the retarder is too aggressive and the service brakes are too weak, producing an unbalanced deceleration profile
- D. The service brakes exceed the maximum stopping distance (25 m vs. 22 m specification) and require service — the brakes must be inspected for worn pads, contaminated discs, air in the circuit, or reduced apply pressure. The retarder meets its specification (0.8 m/s² exceeds the 0.6 minimum), confirming it is functional. The service brake deficiency cannot be compensated by the retarder because the service brakes must independently meet their specification for emergency stopping capability

37. A machine's steering accumulator must provide emergency steering after engine shutdown. The specification requires 3 full steering lockto-lock cycles. The technician tests the system: after engine shutdown, the first cycle is at normal speed, the second cycle is noticeably slower, and the third cycle barely completes with very slow steering response. Is this progressive slowdown acceptable?

- A. No — all three cycles must provide the same steering speed and force to ensure the operator can make effective emergency steering inputs at any point during the three cycles
- B. No — the progressive slowdown indicates the accumulator precharge is too low, which means the gas compresses to a small volume early in the discharge cycle and the stored oil volume is insufficient for three fullspeed cycles
- C. Yes — progressive slowdown during accumulator discharge is a normal characteristic of any gascharged accumulator system. The gas precharge expands as each cycle consumes stored oil, reducing the pressure available for the next cycle. As long as all three cycles complete (even if the third is slow), the system meets the specification
- D. Yes — but only if the third cycle completes within 10 seconds. If the third cycle takes longer than 10 seconds, the accumulator must be recharged to provide faster response on the final cycle

38. A dozer's track tension is set correctly when measured with the machine on flat ground. The operator reports the track derails repeatedly during sidehill operation. The undercarriage components (roller flanges, idler flanges, track guides) are measured and all are within specification. What operating factor is most likely causing the derailments?

A. The sidehill gravitational force on the track chain exceeds the lateral guidance capability of the undercarriage at the current track tension — the track tension specification is set for flatground operation and may need to be increased for sustained sidehill applications. Some OEMs provide a separate (tighter) track tension specification for sidehill work that increases the chain's resistance to lateral displacement

B. The track shoes are the wrong width for the machine — wider shoes would provide more stability during sidehill operation

C. The sprocket alignment is incorrect — a misaligned sprocket pulls the chain laterally off the running gear during sidehill operation when the gravitational force assists the misalignment

D. The machine's operating speed on the side hill is too fast — reducing the travel speed eliminates the centrifugal force that throws the chain off the running gear during sidehill turns

39. A machine's air brake system has been tested and the following data is recorded: governor cutout = 860 kPa, governor cutin = 690 kPa, buildup time from 0 to 860 kPa = 2 minutes 45 seconds (specification: 3 minutes maximum), pressure drop with engine off and brakes applied = 14 kPa per minute (specification: 21 kPa maximum), and spring brake application pressure = 420 kPa (specification: 410–430 kPa). Based on all five measurements, what is the system's overall status?

A. The system has a leak that requires investigation — the 14 kPa per minute pressure drop, while within specification, is at the upper end of the acceptable range

B. All five measurements are within their respective specifications — the air brake system passes the complete performance test and is approved for return to service

C. The buildup time of 2:45 is too close to the 3minute maximum and the compressor should be rebuilt as a precaution

D. The spring brake application pressure of 420 kPa is at the lower end of the specification and should be adjusted to the midpoint (420 kPa) for optimal performance

40. A machine's front axle differential oil analysis shows elevated copper and tin content. The differential uses bronze bushings and trimetal thrust washers. No other abnormal metals are present. What components are the likely wear sources?

A. The copper originates from the ring gear bolt washers and the tin from the differential case plug sealant

B. The differential oil is contaminated with engine oil from a shared cooler circuit — the copper and tin are engine bearing metals, not differential components

C. The copper and tin originate from the axle shaft spline coating that is wearing from the cyclical torque loading during differential action

D. The copper originates from the bronze bushings (which are a copper alloy) and the tin originates from the trimetal thrust washers (which have a tin-containing overlay). Both components are wearing — the wear rate should be trended over multiple samples to determine if the rate is normal or accelerating

41. A machine's track adjuster recoil spring has broken. The operator reports the machine still tracks and steers normally. The track tension appears normal because the grease cylinder is maintaining the idler position. What safety function has been lost with the broken recoil spring?

A. The recoil spring provides the track chain's initial tension — without it, the grease cylinder alone maintains tension, and the track tension will decrease over time as the grease slowly compresses under the loading

B. The recoil spring provides supplemental drive force to the track chain during heavy dozing — without the spring, the machine has reduced dozing power

C. The recoil spring absorbs shock loads when the track encounters obstacles — without the spring, the grease cylinder must absorb the full impact through its relief valve. If the obstacle impact exceeds the relief valve's response time, the instantaneous force transmits directly to the track chain, sprocket, final drive, and frame without any cushioning, risking catastrophic component damage

D. The broken spring allows the idler to vibrate freely on its slider, producing an annoying but nonhazardous noise during travel that will cease if the spring is replaced

42. A machine equipped with hydrostatic brakes (braking achieved through the hydrostatic drive system's deceleration control) loses its hydrostatic drive during operation. The machine is on a slight downhill grade and begins to roll forward. What is the FIRST braking system the operator should activate?

A. The parking/emergency brake — this is the independent braking system designed to stop and hold the machine when the primary hydrostatic braking is unavailable. The operator should immediately apply the parking/emergency brake to stop the machine before it gains speed on the grade

B. The engine compression brake — the operator should downshift the engine to use the compression braking effect to slow the machine before applying the parking brake

C. The steering brake — the operator should turn the machine sharply to use the increased rolling resistance of a tight turn to decelerate the machine

D. The retarder — the operator should activate the retarder system, which is independent of the hydrostatic drive and can provide braking force through the transmission

43. A machine's suspension strut has been removed for rebuild. During disassembly, the technician discovers the strut's internal rebound (extension) bumper is completely worn away — only fragments remain. What symptom did the machine exhibit before the strut was removed?

- A. The machine bottomed out during heavy loading — the missing rebound bumper has no effect on the compression (loaded) stroke, only on the extension (unloaded) stroke
- B. The machine produced a harsh metallic bang when the suspension reached full extension — without the bumper, the strut piston contacts the end cap at full extension with metal-to-metal impact. This occurs during the unloaded return trip, over bumps, or during any event that rapidly unloads the suspension
- C. The machine exhibited excessive body roll during loaded turns — the missing bumper allowed the outside strut to extend further than designed, increasing the roll angle
- D. The machine's ride height was higher than normal because the missing bumper reduced the internal friction that normally limits the strut's extension stroke

44. A wheel loader's rear axle limited slip differential produces a "popping" or "banging" noise during slow tight turns on dry pavement. The differential oil was recently changed with the correct specification oil including the friction modifier additive. What should the technician check?

- A. The differential ring and pinion backlash — excessive backlash produces the popping noise during the direction change that occurs at the inner wheel during tight turns
- B. The limited slip clutch pack — even with the correct oil and modifier, the clutch pack may be worn beyond its service limit. Worn clutch plates have insufficient friction surface to provide smooth torque transfer, and the alternating grab-and-release of the worn plates produces the popping noise during the speed differential of tight turns
- C. The axle shaft Ujoints — worn Ujoints produce a popping noise at low speed during turns that is transmitted through the axle housing and perceived as a differential noise
- D. The differential side bearing preload — insufficient preload allows the carrier to shift under the turning load, producing the popping noise as the carrier rocks between the two bearing positions

45. A grader's front wheel lean cylinders are used to tilt the front wheels for improved blade contact during finish grading. The operator reports the lean function drifts — the wheels slowly return to the vertical position after being leaned. The lean cylinders have been tested and show no internal bypass. The lean control valve spool has been tested and shows no internal leakage. What other circuit component could allow the drift?

A. The lean circuit's pilotoperated check valve (if equipped) may have a contaminated poppet seat that allows a trickle of oil to leak past the check valve during the hold condition — the small leak gradually relieves the pressure holding the lean cylinder in the tilted position, allowing the tire's selfcentering force to push the cylinder back toward vertical

B. The lean circuit's relief valve is set too low and opens slightly under the sustained holding pressure, relieving the pressure over time

C. The hydraulic pump's internal leakage is bleeding the lean circuit pressure through the pump's case drain when the pump is not actively supplying flow to the lean circuit

D. The lean cylinders' rod seals are leaking externally — the technician's bypass test checks internal leakage but external leakage past the rod seal also reduces the held volume

46. A machine's track chain has been measured at multiple points around its circumference. The technician records the following pitch elongation percentages at 5 equally spaced measurement points: 3.1%, 3.2%, 3.0%, 5.8%, 3.1%. What does the single high reading at one location indicate?

A. The measurement at the 5.8% location is a measurement error — the technician should remeasure at that location to verify the reading before taking any action

B. The 5.8% reading is from a section where two pins were replaced during a previous repair, and the new pins have a different material that wears faster than the original pins

C. The chain has a localized damage zone — one or more pinandbushing joints at the 5.8% location have experienced accelerated wear from a specific event (a rock jam, an impact, or a seized joint) that produced localized elongation significantly above the rest of the chain. This section may fail under load before the rest of the chain reaches its service limit, and the chain should be closely monitored or the affected links replaced

D. The 5.8% reading indicates the entire chain is at the end of its service life — the other four measurements are artificially low because the measurement technique is less accurate at the other four locations

47. A machine's ECM receives power through two independent circuits — a primary and a backup. The ECM monitors both circuits and generates a DTC if either circuit fails. The technician reads a stored DTC for "ECM primary power — voltage below threshold." The fault occurred 150 hours ago and has not recurred. The primary power circuit currently tests normal. What is the most likely explanation for a onetime voltage fault that has not recurred?

A. A brief event reduced the primary power circuit voltage below the ECM's threshold — the most common causes are a momentary highcurrent draw from another circuit (starter engagement, solenoid surge), a loose battery connection that shifted under vibration then reseated, or a brief keycycle interruption. The event was too short to affect engine operation but long enough for the ECM to detect and log

B. The ECM's internal voltage monitoring circuit has a noise sensitivity that occasionally produces false lowvoltage DTCs during normal voltage fluctuations

C. The primary power relay has intermittent contact resistance that produces a voltage dip during high ambient temperature but functions normally at lower temperatures

D. The battery's specific gravity was low 150 hours ago from a discharged state and has since been fully charged — the low gravity produced the voltage fault that resolved when the battery was recharged

48. A machine's electronic display shows engine coolant temperature at 65°C. The technician measures the actual coolant temperature with a calibrated thermometer at the sensor location and reads 88°C — a 23°C discrepancy. The sensor resistance at 88°C matches the OEM specification for 88°C. What is the most likely cause of the display reading 23°C lower than actual?

- A. The display module's internal temperature conversion table has been corrupted and is mapping the correct sensor resistance to the wrong temperature value on the display
- B. The sensor's wiring has an intermittent highresistance connection that reduces the current through the sensor circuit, producing a voltage reading at the ECM that corresponds to a lower temperature than the sensor's actual resistance indicates
- C. The ECM is applying an incorrect offset calibration to the coolant temperature sensor input — the ECM reads the correct resistance but applies a -23°C offset from an incorrect parameter setting, displaying 65°C instead of the actual 88°C
- D. The ECM's analogtodigital converter has a nonlinearity error that produces accurate readings at low temperatures but increasingly inaccurate readings at higher temperatures — the 23°C error at 88°C is consistent with a degraded ADC that was accurate at installation but has drifted from thermal cycling over the ECM's service life

49. A machine's starter circuit draws 550 amperes during cranking on a 24V system. The main battery positive cable has a crosssectional area of 70 mm^2 (approximately 2/0 AWG). The cable length from battery to starter is 3 metres. The technician measures a 1.5V voltage drop across this cable during cranking. Using Ohm's Law, what is the cable's resistance?

- A. 0.0036 ohms — calculated by dividing the cable crosssection by the voltage drop ($70 \div 1.5$), which uses the wrong formula
- B. The cable resistance = voltage drop \div current = $1.5\text{V} \div 550\text{A} = 0.00273$ ohms (2.73 milliohms). This resistance in 3 metres of cable produces the 1.5V drop at 550A cranking current, and the power dissipated as heat = $V \times I = 1.5 \times 550 = 825$ watts
- C. 0.0436 ohms — calculated by dividing the voltage drop by the system voltage ($1.5 \div 24 \times 0.7$), which confuses the calculation with a voltage divider ratio
- D. 366.7 ohms — calculated by dividing the current by the voltage drop ($550 \div 1.5$), which inverts Ohm's Law

50. A machine's alternator produces 28.2V at the B+ terminal under load. The technician places an oscilloscope on the battery terminals and observes the following waveform: a DC level at 27.8V with a superimposed AC ripple of 0.3V peaktopeak at a frequency of 300 Hz. The engine RPM is 1,800. What does the 300 Hz ripple frequency confirm about the alternator?

A. The alternator has a failed voltage regulator that is oscillating at 300 Hz rather than producing a steady DC field current

B. The alternator's drive belt is slipping at 300 Hz (once every 3.3 milliseconds), producing a cyclical output interruption

C. The 300 Hz ripple confirms all six rectifier diodes are functioning — a threephase alternator at 1,800 RPM with a typical pulley ratio produces a fundamental ripple frequency that corresponds to the rectified output of all three phases. A missing phase (from a failed diode) would reduce the frequency to 200 Hz and increase the ripple amplitude significantly

D. The 300 Hz frequency is the alternator's internal fan blade passage frequency and has no diagnostic significance for the electrical output

51. A machine's ECM controls a hydraulic proportional valve through a PWM output at 200 Hz switching frequency. The technician monitors the PWM duty cycle with a diagnostic tool: the ECM commands 40% duty cycle. The technician then measures the actual duty cycle at the solenoid connector with an oscilloscope and reads 40%. However, the hydraulic function is not responding proportionally — it operates at approximately 70% output instead of 40%. What is the most probable cause?

A. The solenoid coil has developed a partial short that increases its magnetic force per ampere — the 40% duty cycle produces more force than designed, shifting the spool further than the 40% command should produce

B. The solenoid return spring has weakened or broken — without the opposing spring force, the 40% magnetic force drives the spool further toward full open than designed. The proportional position is determined by the balance between the solenoid's magnetic force and the spring's return force, and a weakened spring shifts the balance toward a more open spool position

C. The hydraulic system pressure has increased above the valve's compensated range, forcing more flow through the spool's metering edge at the 40% position than the designed flow at rated pressure

D. The PWM frequency of 200 Hz is too low for this solenoid — the spool responds to each individual pulse rather than averaging them, producing a higher effective opening than the 40% average should create

52. A machine's CAN bus operates at 250 kbit/s. The bus has 15 modules. The technician notices intermittent communication faults during periods of heavy machine activity (multiple simultaneous hydraulic functions, frequent gear shifts, and active emission regeneration). During idle with no active functions, the bus operates flawlessly. What is the most likely cause?

A. One module has a defective CAN transceiver that produces signal distortion only under the increased data traffic of heavy activity — the distortion is minimal during light traffic but accumulates enough errors during heavy traffic to trigger faults

B. The CAN bus is experiencing traffic congestion — 15 modules simultaneously transmitting and receiving data during heavy activity periods may approach the bus's maximum bandwidth. The highpriority messages (engine, transmission) succeed, but lowerpriority messages are delayed, retried, and occasionally lost during the congestion periods

C. The machine's electrical system voltage drops during heavy activity (multiple solenoids energized simultaneously), and the reduced voltage degrades the CAN transceiver's signal amplitude below the minimum for reliable detection by the receiving modules

D. The bus termination resistance changes during heavy activity because the multiple energized solenoids create electromagnetic interference that alters the effective bus impedance

53. A machine's electronic throttle system uses a dualtrack accelerator pedal position sensor (APPS). Track 1 reads 2.5V and Track 2 reads 1.25V at a pedal position. The technician moves the pedal slightly and Track 1 reads 2.7V while Track 2 remains at 1.25V. What does the stationary Track 2 indicate?

- A. Track 2 has a dead zone at the 1.25V position — the potentiometer's resistive element has a worn section where the wiper produces no voltage change during pedal movement
- B. Track 2 is functioning correctly — it has a different sensitivity range than Track 1 and does not change voltage proportionally at every pedal position
- C. Track 2's wiper has lost contact with the resistive track — it is stuck at the last contact point (1.25V) and cannot follow the pedal movement. The ECM will detect the disagreement between Track 1 (which moved to 2.7V) and Track 2 (which remained at 1.25V) and enter a derate or limp mode because the dualtrack correlation has been violated
- D. Track 2's power supply wire has a highresistance connection that limits the maximum output to 1.25V regardless of pedal position — the track is functional but voltagelimited

54. A machine's ECM logs a DTC for "cylinder 4 contribution — below threshold." The technician performs a relative compression test using the diagnostic tool (which monitors the crankshaft acceleration during each cylinder's compression event). Cylinder 4 shows significantly lower crankshaft deceleration during its compression stroke compared to the other cylinders. What does the reduced deceleration confirm?

- A. Cylinder 4's injector is overfuelling and the excess fuel is reducing the compression pressure through a hydraulic lock effect
- B. Cylinder 4 has low compression — the crankshaft decelerates less during Cylinder 4's compression stroke because less energy is required to compress the reduced air charge. The reduced compression can be from worn rings, a leaking valve, or a head gasket breach
- C. Cylinder 4's injector is not firing and the missing combustion event produces less crankshaft deceleration during the compression stroke that follows the missed power stroke
- D. Cylinder 4's exhaust valve timing is retarded, and the delayed valve closure allows compressed air to escape early in the compression stroke, reducing the effective compression that the crankshaft must overcome

55. A machine's 24V charging system has been undercharging intermittently. The technician suspects the voltage regulator but needs to verify. The alternator has an externally mounted regulator. What is the definitive test to confirm the regulator is the fault?

A. Bypass the regulator by connecting the alternator's field terminal directly to battery positive through a variable resistor — if the alternator now produces correct voltage with the regulator bypassed, the regulator is confirmed as the fault. If the alternator still undercharges with the field fully excited, the fault is in the alternator's rotor, stator, or rectifier, not the regulator

B. Measure the regulator's output voltage at the regulator terminals — if the voltage matches the alternator's B+ output, the regulator is functioning correctly

C. Replace the regulator with a knowngood unit and test — if the undercharging stops, the original regulator was the fault

D. Measure the resistance of the regulator's field output terminal to ground — a specific resistance value confirms the regulator's internal power transistor is functioning

56. A machine's ECM monitors the voltage of its own internal 5V reference circuit. The ECM generates a DTC when the reference drops below 4.8V or rises above 5.2V. The technician reads a DTC for "5V reference low — 4.6V detected." With all sensors disconnected, the reference reads 5.01V. The technician reconnects sensors one at a time and the reference drops to 4.6V when the hydraulic oil temperature sensor is reconnected. What has been confirmed?

A. The hydraulic oil temperature sensor's wiring has a short to the 5V reference that feeds external voltage into the reference circuit and produces the low reading

B. The hydraulic oil temperature sensor has a ground fault that the 5V reference cannot detect until the sensor is connected — the grounded sensor loads the reference below its regulation capability

C. The ECM's 5V reference regulator is weak and cannot maintain output under the combined load of all sensors — the hydraulic temperature sensor's normal current draw is the final load that exceeds the regulator's weakened output capacity

D. The hydraulic oil temperature sensor has an internal fault (short to ground or abnormally low resistance) that draws excessive current from the 5V reference circuit, pulling the shared reference

voltage below the 4.8V minimum and affecting the accuracy of every sensor connected to the same reference

57. A machine's electronic fuel injection system uses a highpressure fuel pump that is driven by the engine's gear train. The pump has an inlet metering valve (IMV) that controls the fuel volume entering the pump on each stroke. The ECM commands the IMV based on the desired rail pressure. If the IMV's electrical connector is disconnected while the engine is running, what happens?

A. The engine immediately stalls because no fuel enters the pump without the IMV's electrical command

B. The IMV defaults to its mechanical spring position — depending on the valve design, it either opens fully (producing maximum rail pressure that the rail pressure relief valve must manage) or closes fully (starving the pump and causing the engine to stall). The specific default behaviour depends on whether the IMV is normally open or normally closed by spring design

C. The engine continues to run normally for approximately 30 seconds while the fuel rail drains its stored volume, then stalls as the rail pressure drops below the minimum injection threshold

D. The ECM detects the disconnected IMV immediately and compensates by adjusting the fuel pressure control valve on the rail to maintain the correct pressure using the alternate control path

58. A machine's electronic display module receives CAN bus data and converts it to gauge displays, warning indicators, and text messages for the operator. The display module has its own internal processor, memory, and software. If the display module's software version does not match the machine's ECM software version, what symptom may occur?

A. The display shows incorrect parameter values because the data scaling factors in the display's software do not match the ECM's data format — for example, a temperature displayed in Fahrenheit

when the ECM is transmitting Celsius, or a pressure displayed at 10× the actual value because the display's conversion factor does not match the ECM's transmission format

B. The display produces no symptoms — CAN bus J1939 data uses standardized parameter definitions that are identical across all software versions

C. The display fails to power on because the software version mismatch triggers a security lockout that prevents the display from initializing

D. The display shows data from the wrong machine functions — engine data appears on the transmission page and transmission data appears on the engine page because the message routing table in the display's software does not match the ECM's message addresses

59. A machine's electronic joystick has been calibrated through the ECM's setup procedure. The calibration records the joystick's voltage at neutral (2.50V), full forward (4.50V), and full reverse (0.50V). After calibration, the technician notices the hydraulic function creeps slightly forward when the joystick is in the neutral detent. The ECM reads 2.53V at neutral — 0.03V above the calibrated neutral point. What should the technician do?

A. Recalibrate the joystick — the 0.03V offset from the stored neutral value is within the ECM's dead band and should not cause creep, so the dead band parameter may need to be widened slightly to accommodate the joystick's actual rest position

B. Replace the joystick — a 0.03V offset from calibrated neutral indicates the joystick's return spring has weakened and the potentiometer is not returning to its calibrated centre position

C. Adjust the DCV spool centering springs — the spool is not returning to mechanical neutral despite the electrical command being near zero

D. The 0.03V offset at the joystick is causing the ECM to interpret the neutral position as a very small forward command. The ECM's neutral dead band may need to be widened to encompass the 2.53V actual rest position, or the joystick's mechanical neutral stop may need adjustment to bring the rest voltage closer to 2.50V

60. A diesel engine's electronic fuel injection system uses a camshaft position sensor (CMP) and a crankshaft position sensor (CKP) to determine the engine's precise position for sequential fuel injection. The CMP signal is lost during engine operation. The engine continues to run but a DTC is logged and the ECM enters a degraded mode. What specific capability does the ECM lose without the CMP signal?

A. The ECM loses the ability to identify which cylinder is on its compression stroke — the CKP signal provides crankshaft position and speed but cannot distinguish between the compression stroke and the exhaust stroke of a given cylinder (both occur at the same crankshaft position 360° apart). Without the CMP signal, the ECM defaults to a less efficient injection strategy that does not require individual cylinder identification

B. The ECM loses the ability to measure engine RPM — without the CMP signal, the ECM cannot calculate the crankshaft speed and must estimate RPM from the throttle position and turbocharger speed

C. The ECM loses the ability to detect misfires — the CMP signal is the primary input for the misfire detection algorithm, and without it, the ECM disables all misfire monitoring

D. The ECM loses the ability to control injection timing — without the CMP signal, the ECM cannot determine any crankshaft angular position and must fire all injectors continuously rather than at timed intervals

61. A machine's electronic throttle system produces a smooth, linear signal from the accelerator pedal position sensor. However, the engine RPM response to the pedal is not linear — the engine responds aggressively in the first 30% of pedal travel and then gradually in the remaining 70%. The technician checks the ECM parameters and finds a "throttle response curve" parameter that has been modified from the default. What is the purpose of this adjustable throttle response curve?

A. The modified curve is a factory calibration error that should be restored to the linear default for correct engine response

B. The throttle response curve allows the ECM to map a nonlinear relationship between the pedal position and the fuel delivery — the aggressive initial response provides quick breakaway force for digging or dozing, while the gradual upper range provides precise speed control during travel. Different applications may use different response curves to match the machine's work requirements

C. The throttle response curve controls the maximum engine RPM at each pedal position and is used to limit the engine speed for noise compliance in urban environments

D. The throttle response curve adjusts the pedal's electrical signal to compensate for a nonlinear potentiometer — the curve corrects the electrical nonlinearity to produce a linear fuel delivery response at the ECM output

62. A machine's electronic instrument cluster displays a "CHECK ENGINE" warning with no additional text or fault code displayed. The technician connects the diagnostic tool and reads 3 active DTCs from the engine ECM. None of the DTCs are displayed on the instrument cluster. What is the most likely explanation for the cluster not displaying the specific DTC information?

A. The instrument cluster does not have the memory capacity to store and display the specific DTC text — it can only display generic warning categories

B. The three DTCs are manufacturerspecific codes that the cluster's software does not contain display text for — the cluster recognizes the amber lamp command from the ECM but does not have the corresponding text strings in its firmware to describe the specific faults

C. The DTCs are active but below the severity threshold for cluster display — the ECM activates the check engine lamp but only sends DTC text to the cluster for criticallevel faults

D. The cluster's CAN bus connection has a data throughput limitation that prevents the DTC text messages from being received alongside the lamp command — the lamp activates from a simple on/off message but the text requires a multiframe message that the limited connection drops

63. A machine's electronic system uses a 24Vto12V DCDC converter to power the radio, backup camera, and accessory outlet. The converter has been operating for 5 years. The technician measures the 12V output under load and reads 11.2V. The OEM specification is $12.0V \pm 0.5V$ (11.5–12.5V). The converter is within specification. However, the backup camera image flickers intermittently. What should the technician investigate?

- A. The backup camera's power connector — a loose or corroded connection at the camera produces the flicker independently of the converter's output voltage
- B. The CAN bus interference — the camera's video signal is being corrupted by CAN bus electromagnetic interference in the harness where the camera cable runs parallel to the CAN bus wires
- C. The converter's output ripple — even though the DC voltage is within specification (11.2V), the converter may be producing excessive AC ripple on the DC output that causes the camera's internal power supply to fluctuate. A converter that is aging or overloaded may produce increasing ripple voltage that does not affect the DMM's DC reading but affects sensitive electronic loads like the camera
- D. The camera's internal video processor — the camera hardware has reached the end of its service life and the flicker is from a failing processor, not a power supply issue

64. A machine's ECM has been replaced under warranty. The replacement ECM has been programmed with the correct calibration and all parameters have been set. The engine starts and runs, but the operator reports the machine "feels different" — the throttle response, idle speed, and shift points all seem slightly different from before the ECM replacement. The technician verifies all parameters match the documented settings. What is the most likely explanation?

- A. The previous ECM had accumulated adaptive learned values over its service life — trim adjustments for injector variability, idle speed compensation, and shift calibration refinements. The replacement ECM starts with baseline values and has not yet relearned these adaptive corrections. The differences will diminish as the new ECM's adaptive system relearns during the first 50–100 operating hours
- B. The replacement ECM has a different hardware revision that processes data at a slightly different speed, producing the perceptible performance differences
- C. The replacement ECM's internal clock runs at a slightly different frequency than the original, affecting all timebased calculations including injection timing and shift duration
- D. The calibration file loaded into the replacement ECM is the correct part number but a different release version than the original — the newer release includes updated fuel maps and shift tables that produce the different feel

65. A technician is testing a magnetic inductive crankshaft position sensor on a diesel engine. The oscilloscope shows a sinusoidal waveform with 58 peaks per engine revolution. The reluctor wheel has 60 teeth. What do the 58 peaks (instead of 60) indicate?

A. Two teeth have broken off the reluctor wheel, producing 58 peaks instead of 60 — the missing teeth create a signal gap that the ECM interprets as a misfire event on each revolution

B. The 60tooth reluctor wheel is designed with 2 missing teeth that create a reference gap — the ECM uses this gap to identify a specific crankshaft position (typically the TDC reference). The 58 peaks are the normal 58 teeth, and the gap where the 2 teeth are absent provides the onceperrevolution position reference that the ECM needs for injection timing synchronization

C. The sensor is mounted too far from the reluctor wheel and the two weakest peaks (from the teeth furthest from the sensor) are below the detection threshold

D. The oscilloscope's sampling rate is too low to capture all 60 peaks per revolution and is aliasing 2 peaks out of each cycle

66. A machine's electronic display shows the hydraulic oil temperature as "" (dashes) while all other parameters display correctly. The technician checks the hydraulic temperature sensor and measures the correct resistance at the sensor connector. The wiring between the sensor and the ECM is verified continuous with correct resistance. What else could cause the display to show dashes?

A. The ECM is receiving the correct sensor signal but has flagged the parameter as invalid due to an internal plausibility check failure — the ECM compares the hydraulic temperature against other system temperatures and if the relationship falls outside the programmed limits, it rejects the reading and reports "" to the display

B. The display module's internal parameter mapping has lost the hydraulic temperature PID — the display cannot render data for a PID it does not recognize, even though the ECM is transmitting the correct data on the CAN bus

C. The ECM's analog input channel for the hydraulic temperature sensor has failed — the channel cannot read the sensor's resistance despite the sensor and wiring being correct. The ECM transmits an invalid data flag for this parameter, which the display renders as dashes

D. The sensor's reference voltage is slightly below the ECM's minimum threshold for that input — the ECM reads the resistance correctly but the low reference voltage shifts the calculated temperature outside the display's rendering range

67. A machine's alternator has a builtin temperature sensor that communicates with the voltage regulator. When the alternator's internal temperature rises, the regulator reduces the field current to protect the alternator from thermal damage. During heavy electrical loading on a hot day, the operator reports the battery charge warning light illuminates briefly and then turns off. What has occurred?

A. The alternator reached its thermal limit and the regulator temporarily reduced the output — the charging voltage dropped below the battery's voltage (triggering the warning light) until the alternator cooled enough for the regulator to restore normal output. The brief event confirms the alternator is operating at its thermal capacity and the electrical load analysis should be reviewed

B. The alternator's internal temperature sensor has an intermittent connection that briefly signaled overtemperature, causing the regulator to reduce output for one or two seconds before the sensor reconnected

C. The alternator's drive belt slipped briefly from the increased loading, reducing the alternator RPM below the minimum for charging — the belt regained grip when the load pulse subsided

D. The battery has a weak cell that momentarily dropped below the charging threshold during the highdemand period, triggering the warning light independently of the alternator's output

68. A machine's electronic fuel injection system operates with a fuel rail pressure of 1,800 bar during loaded operation. The ECM monitors the rail pressure through a dedicated pressure sensor. If the rail pressure sensor fails and reads a fixed 1,200 bar (below the actual 1,800 bar), how does the ECM respond?

A. The ECM increases the fuel pump's output to raise the perceived rail pressure from 1,200 to 1,800 bar — but since the actual pressure is already at 1,800 bar, the pump increases the real pressure to approximately 2,400 bar, dramatically overpressuring the rail and risking fuel system component failure

B. The ECM detects the sensor fault by comparing the rail pressure against other engine parameters (engine load, injector pulse width, pump duty cycle) and enters a limp mode with a default rail pressure strategy rather than responding to the incorrect sensor value

C. The ECM reduces the injector pulse width because it believes the rail pressure is lower than it should be — the lower perceived pressure causes the ECM to extend the injection duration to deliver the same fuel mass, which overfuels the engine, produces excessive smoke, and may cause thermal damage

D. The ECM does not respond to the pressure sensor for fuel delivery calculations — the rail pressure sensor is used only for diagnostic display purposes, and the actual fuel delivery is controlled entirely by the inlet metering valve position and the engine speed

69. A machine's electronic system includes a keypad on the dashboard for entering the operator's identification code. The keypad communicates with the security module through a dedicated LIN (Local Interconnect Network) bus — a lowerspeed, singlewire serial communication link. The LIN bus operates at 19.2 kbit/s. If the LIN bus wire develops a highresistance connection, what symptom does the operator experience?

A. The keypad responds slowly — the operator presses a key and the security module acknowledges after a delay because the high resistance slows the data transmission rate below the 19.2 kbit/s specification, extending the time required for each message exchange

B. The keypad produces incorrect codes — the high resistance attenuates the signal voltage, causing bit errors that change the transmitted code digits and produce authorization failures even when the correct code is entered

C. The keypad functions normally — LIN bus communication is resistant to highresistance connections because the singlewire protocol uses voltage levels that tolerate significant signal attenuation

D. The keypad does not respond at all — the security module cannot decode the keypad's messages because the high resistance has dropped the signal voltage below the LIN bus receiver's minimum detection threshold, and the module ignores all messages from the keypad

70. A machine's CAN bus has been experiencing intermittent faults that correlate with the machine's hydraulic hammer (breaker) operation. The faults occur during each hammer impact cycle and disappear when the hammer is not in use. What is the most likely connection?

A. The hammer's hydraulic pressure pulsations produce vibration in the machine frame that shakes the CAN bus connectors, producing momentary contact interruptions at each impact

B. The hammer's impact produces a highenergy vibration impulse that propagates through the machine's structure — the mechanical shock loosens a marginal CAN bus connection or flexes a damaged wire at each impact cycle, producing the data interruption that resets between impacts

C. The hammer's solenoid valve produces an electromagnetic pulse at each actuation cycle that couples into the CAN bus wiring through radiated EMI, corrupting the bus data during each hammer firing

D. The hammer's highflow hydraulic demand produces a voltage dip on the machine's electrical system at each impact cycle from the solenoid's current draw, and the voltage dip drops the CAN bus module voltage below the minimum operating threshold

71. A machine's ECM has a "snapshot" (freeze frame) function that captures multiple parameters at the moment a DTC is logged. The technician reads a snapshot from a DTC event that occurred 500 hours ago. The snapshot shows: engine RPM = 2,100, coolant temp = 95°C, boost = 190 kPa, battery voltage = 27.8V, hydraulic temp = 85°C, and ambient temp = 32°C. The DTC is for "exhaust temperature high." Which snapshot parameter combination helps the technician determine the operating condition that triggered the DTC?

A. Only the engine RPM and boost pressure are relevant — together they indicate the engine was at rated power when the DTC triggered

B. All parameters together define the exact operating condition — the engine was at rated RPM (2,100) under heavy load (190 kPa boost) in a hot ambient environment (32°C) with all systems at operating temperature. The combination of high load, high ambient, and fully hot systems created the conditions for the exhaust temperature to exceed the threshold. The technician can use this data to determine whether the DTC represents a fault condition or a normal operating limit reached during extreme conditions

C. Only the coolant and hydraulic temperatures are relevant — the high fluid temperatures indicate the cooling systems are inadequate for the ambient conditions

D. Only the ambient temperature is relevant — the 32°C ambient explains the high exhaust temperature and the DTC is a normal event during hotweather operation

72. A machine's torque converter lockup clutch has two operating modes: partial lockup (controlled slip) and full lockup (zero slip). During partial lockup, the ECM commands a specific slip speed (typically 20–40 RPM) between the engine and turbine. What is the purpose of this controlledslip mode compared to direct full lockup?

A. Partial lockup extends the lockup clutch's service life by reducing the clamping force on the clutch disc during normal operation

B. Partial lockup maintains a small fluid coupling effect that provides torsional damping — the controlled slip absorbs engine firing pulses and drivetrain torsional vibrations that would transmit directly to the transmission during full lockup. This provides a smoother ride and reduces drivetrain stress while still capturing most of the efficiency benefit of lockup

C. Partial lockup is a transition phase between the coupling mode and full lockup — the ECM uses it only during the 2–3 second transition period and then commands full lockup for sustained operation

D. Partial lockup allows the torque converter to maintain its torque multiplication function while partially locked — the controlled slip enables the stator to redirect fluid and amplify torque at a reduced rate compared to the unlocked state

73. A machine's automatic transmission has been experiencing delayed shifts (shifts occurring at higher RPM than specified). The technician performs a diagnostic scan and finds no active DTCs. The transmission oil temperature, level, and condition are within specification. The technician accesses the TCM's live data and observes the throttle position signal (TPS) reads 85% when the operator's foot is at 50% pedal travel. What effect does this incorrect TPS reading have on shift timing?

A. The TCM believes the engine is under heavy load (85% throttle) when the actual demand is moderate (50%) — the TCM delays the upshift to keep the engine in the lower gear longer, matching the perceived heavyload demand. Correcting the TPS signal (or the source of the incorrect reading) will restore the correct shift timing

- B. The TPS signal has no effect on transmission shift timing — the TCM uses only the output shaft speed sensor and governor pressure for shift decisions
- C. The high TPS reading causes the TCM to command earlier upshifts because it believes the engine has adequate power to pull the higher gear at the perceived throttle opening
- D. The TPS signal affects only the torque converter lockup timing, not the gear shift timing — the delayed shifts have a different cause

74. A technician is rebuilding a differential and must set the carrier bearing preload. The OEM procedure specifies setting the preload by measuring the carrier's rotating torque with a beamtype torque wrench after the ring gear is installed but before the carrier is installed in the housing. The measured rotating torque is 3.5 N·m. The specification is 2.0–3.0 N·m for new bearings. What should the technician do?

- A. The preload is 0.5 N·m above specification — remove the shim pack from one carrier bearing side and add 0.5 N·m equivalent of shim thickness to reduce the preload into the specification range
- B. The preload is acceptable — a 0.5 N·m overshoot is within the measurement tolerance of the beamtype torque wrench used for this procedure
- C. The preload is too tight — reduce the total shim thickness to decrease the preload. Excessive preload generates friction heat that can damage the bearings during operation, especially during breakin before the bearing races are fully polished
- D. The rotating torque includes the ring gear's mesh resistance — subtract the gear mesh drag (typically 0.5–1.0 N·m) from the total reading to determine the true bearing preload, which would be 2.5–3.0 N·m, within specification

75. A machine's hydrostatic drive system produces the following diagnostic data: pump displacement = 100% forward, charge pressure = 28 bar (specification 25–30), main loop pressure = 380 bar

(specification maximum 400 bar), motor speed = 75% of specification. The engine RPM is at rated speed. What does this data set indicate?

- A. The main pump is worn — at 100% displacement, the pump should deliver maximum flow, but the motor speed is 25% below specification, indicating the pump is losing 25% of its output to internal leakage
- B. The motor has excessive internal leakage — all pump parameters are within specification (full displacement, correct charge pressure, nearmaximum loop pressure) but the motor is converting only 75% of the delivered flow to shaft rotation. The remaining 25% is bypassing through the motor's worn internal clearances
- C. The engine is underpowered — it cannot maintain rated RPM under the 380bar loop pressure load, and the reduced engine RPM reduces the pump's output proportionally
- D. The charge circuit is starving the main pump — the 28bar charge pressure is at the low end of the specification and may be insufficient to fully fill the pump's cylinders during the highspeed displacement, reducing the pump's effective output by 25%

76. A machine's final drive planetary gear set has been rebuilt. During the initial test, the technician notices the final drive oil temperature is 15°C above normal compared to the opposite (unrebuilt) side. Both sides carry the same load. What should the technician investigate as the cause of the elevated temperature?

- A. The final drive oil type or viscosity — if a different specification was used during the rebuild, the mismatched oil may produce higher friction and therefore more heat under the same loading
- B. The rebuilt side's gear mesh is tighter than the unrebuilt side — a tighter gear mesh from incorrect shim settings produces more friction at each tooth contact point, generating additional heat that the unrebuilt side does not experience
- C. The rebuilt side's bearing preload is set tighter than specified — excessive bearing preload generates friction heat continuously during rotation. The opposite side's bearings have settled to a comfortable preload over their service life, producing less friction heat than the overtight new bearings

D. The rebuilt side's seals are tighter than the unrebuilt side's worn seals — new seals create more friction against the shaft surfaces until they bed in during the first 200–500 operating hours

77. A machine's torque converter is equipped with a temperature sensor that monitors the converter outlet oil temperature. The ECM uses this temperature to protect the transmission by reducing engine power if the converter temperature exceeds a programmed threshold. During a sustained heavyload operation, the converter temperature gradually rises to the threshold and the ECM reduces power. The operator reports the machine "loses power" during heavy work. What is the correct technician response?

A. Increase the temperature threshold in the ECM parameters by 10°C to provide more working range before the derate activates

B. Replace the torque converter with a higher-capacity unit that can handle the sustained heavy loading without overheating

C. Clean the transmission oil cooler — a restricted cooler reduces the heat rejection rate and allows the converter temperature to rise to the derate threshold during sustained loading that a clean cooler could manage without exceeding the limit

D. Investigate the machine's operating duty cycle and the transmission cooling system — the converter temperature protection is a designed safety feature that should not activate during normal operation. If the cooler, coolant flow, and transmission oil condition are all correct, the machine may be overloaded for its designed application or the duty cycle may exceed the cooling system's capacity

78. A technician measures the gear mesh backlash on a ring and pinion set at four equally spaced positions around the ring gear circumference: Position 1 = 0.22 mm, Position 2 = 0.23 mm, Position 3 = 0.21 mm, Position 4 = 0.22 mm. The specification is 0.20–0.28 mm. What do these four measurements tell the technician?

A. All four measurements are within specification and the consistent values (within 0.02 mm of each other) confirm the ring gear is running concentrically on the differential case — there is no eccentricity or mounting error causing variable backlash

- B. The measurements show the backlash is at the tight end of the specification and the gears will become noisy as they wear into the wider backlash range
- C. The technician should have taken measurements at 8 positions (every 45 degrees) for a valid backlash assessment — 4 positions are insufficient
- D. The consistent measurements indicate the pinion depth is correct but the backlash should be centred at 0.24 mm (the midpoint of the specification) for optimal gear life

79. A machine's manual clutch has been replaced with a new clutch assembly. During the first test drive, the technician notices the clutch engagement point is very near the top of the pedal travel — the clutch engages almost as soon as the pedal is released. What does this indicate?

- A. The clutch disc is installed backward — the wrong side faces the flywheel, and the disc's hub offset places the friction surfaces too close to the pressure plate, causing the clutch to engage at the top of the pedal travel
- B. The clutch hydraulic system has air that is preventing the slave cylinder from fully retracting — the air holds the release bearing in partial contact with the pressure plate, which raises the engagement point toward the top of the pedal travel. Bleeding the hydraulic system should restore the correct engagement point
- C. This is normal for a new clutch assembly — the engagement point is high because the new, thick friction disc takes up more space between the flywheel and pressure plate than the worn disc it replaced. As the disc wears, the engagement point moves progressively toward the floor
- D. The flywheel was not resurfaced before the new clutch was installed — the worn flywheel surface positions the friction disc incorrectly, moving the engagement point to the top of pedal travel

80. A machine's differential oil analysis shows a sudden appearance of water — the oil has turned milky and the water content measures 5%. The differential uses oil-to-water cooling through a heat exchanger that shares coolant from the engine cooling circuit. What is the most likely water source?

- A. The differential housing breather has been submerged during a water crossing and the differential drew water through the breather during the postcrossing cooldown contraction
- B. Condensation from operating in highhumidity conditions has accumulated in the differential over multiple shortrun cycles that did not reach operating temperature
- C. The differential oil cooler has an internal tube failure — the higherpressure engine coolant is leaking through the failed tube into the lowerpressure differential oil circuit, producing the milky emulsion. The 5% water content confirms a significant leak volume
- D. The differential fill plug was left loose during the last service and rainwater has entered the housing through the loose plug during machine washdown or rain events

81. A machine's automatic transmission produces a vibration that occurs only in 4th gear during loaded acceleration. All other gears are smooth in both acceleration and coast. What does this gearspecific vibration indicate?

- A. The 4th gear planetary set has a tooth surface defect (spalling, pitting, or broken tooth) that produces vibration when the affected gear teeth are loaded during the 4th gear power path
- B. The torque converter lockup clutch engages only in 4th gear and the lockup engagement produces the vibration from a worn damper or contaminated clutch surface
- C. The 4th gear clutch pack has a single warped separator plate that produces a pulsation during each clutch disc rotation — the pulsation is felt as a vibration during loaded 4th gear operation
- D. The vibration is from the 4th gear set's specific power path — the planetary gears, sun gear, ring gear, and carrier that are active in 4th gear have a fault (worn bearing, damaged tooth, or assembly error) that produces the vibration only when that specific planetary configuration is loaded

82. A technician is setting the valve lash on a diesel engine. The service manual instructs the technician to set the lash with the engine cold (ambient temperature). The technician asks: why not set the lash with the engine hot to account for the thermal expansion that occurs during operation?

A. Setting the lash cold uses the OEM's cold specification that accounts for the known thermal expansion of all valve train components — the OEM has calculated the cold lash value that produces the correct running lash at operating temperature. Setting lash hot requires a different specification (hot lash), and many OEMs provide only the cold specification because cold measurements are more consistent and repeatable

B. Hot lash adjustment is the preferred method — the service manual's coldlash procedure is an alternative for situations where the engine cannot be run to operating temperature

C. Thermal expansion does not change the valve lash because all valve train components expand equally and the lash dimension is selfcancelling

D. Hot lash adjustment is prohibited because the risk of burns from the hot engine components outweighs the accuracy advantage of measuring at operating temperature

83. A machine's transfer case uses a chain drive to connect the input shaft to the front output shaft. The technician discovers the chain has 1.5% pitch elongation. The OEM specification maximum before replacement is 2.0%. However, the technician also notices several chain links have visible surface cracks on the link plates. What should the technician recommend?

A. The chain is within the pitch elongation specification and can continue in service — surface cracks on link plates are cosmetic and do not affect the chain's loadcarrying capacity

B. Continue operating the chain until it reaches the 2.0% elongation limit — the surface cracks will be monitored at each inspection for propagation

C. Replace the chain despite the pitch being within specification — the surface cracks are fatigue initiators that can propagate to fracture under load. A chain with visible surface cracks on the link plates has compromised structural integrity regardless of the pitch elongation measurement, and failure can occur suddenly without further warning

D. Turn the chain 180 degrees so the cracked link plates are on the opposite side, distributing the load to the uncracked faces during operation

84. A machine's wet disc brake cooling oil circuit includes an oil cooler with a thermostatically controlled bypass. During a loaded descent, the brake oil temperature rises steadily. The technician checks the oil cooler thermostat and finds it is functioning correctly — it opens at the specified temperature and routes oil through the cooler. The cooler's external fins are clean. What additional component in the cooling circuit should be checked?

A. The brake cooling oil pump — if the pump's output has decreased from wear, the reduced flow rate through the cooler limits the total heat rejection per unit time, even though the cooler itself is functional. The temperature rises because the pump cannot move enough oil through the cooler to reject the heat being generated

B. The oil cooler's internal passages — external fin cleanliness does not confirm internal cleanliness. Scale, debris, or sludge inside the cooler's oil passages restricts the oil flow and reduces the heat transfer surface contact, decreasing the cooler's effectiveness despite clean external surfaces

C. The brake piston return springs — weak springs allow the brakes to drag during the descent, generating more heat than the cooling system was designed to reject

D. The brake oil level — an overfilled system circulates more oil than designed, and the excess volume cannot be cooled by the finite cooler capacity

85. A machine's axle shaft has fractured during loaded operation. The fracture surface examination shows a small, smooth semicircular zone at the shaft surface (approximately 15% of the crosssection) surrounded by a large, rough, granular fracture zone (approximately 85% of the crosssection). What does this fracture surface pattern indicate about the failure mode?

A. The shaft failed from a torsional overload — the small smooth zone is the initial shear crack and the large rough zone is the final brittle fracture from the torque that exceeded the remaining crosssection's capacity

B. The shaft failed from hydrogen embrittlement — the smooth zone is the embrittled material that cracked under normal stress and the rough zone is the healthy material that fractured from the overload of the reduced crosssection

C. The shaft failed from corrosion fatigue — the smooth zone is the corrosion pit that initiated the failure and the rough zone is the final mechanical fracture

D. The shaft failed from fatigue — but the small fatigue zone (15%) relative to the large final fracture zone (85%) indicates the fatigue crack was present for a relatively short time or the applied stress was high. The crack initiated at the surface, propagated slowly through 15% of the crosssection, and then the remaining 85% failed suddenly when the stress on the reduced section exceeded its ultimate strength

86. A machine equipped with a powershift transmission and torque converter has been consuming more fuel than identical machines in the fleet performing the same work. All engine parameters (fuel delivery, timing, boost, compression) are within specification. The transmission shifts correctly and the converter stall speed is within specification. What drivetrain condition could cause increased fuel consumption without affecting any individual test parameter?

A. The torque converter's coupling efficiency has degraded from internal wear — the converter passes all static tests (stall speed, oil temperature, pressure) but operates at a reduced coupling efficiency during normal travel, converting a higher percentage of engine power to heat rather than mechanical output. The engine must produce more power (and consume more fuel) to maintain the same machine speed and productivity

B. The transmission's clutch packs are slipping microscopically — the slip is too small to produce noticeable shift quality changes or DTCs but consumes energy as heat during every moment of loaded operation

C. The final drive ratio has been changed by a previous repair (wrong gear set installed), and the engine operates at a higher RPM than designed for each travel speed, consuming more fuel per kilometre

D. The tire pressure is lower than specification on the drive axle, increasing the rolling resistance and requiring more engine power (and fuel) to maintain the same travel speed

87. A machine's differential lock system uses an electronic control module that receives input from wheel speed sensors, the operator's lock switch, and the TCM. The module allows the lock to engage only when specific conditions are met: vehicle speed below 8 km/h, no active ABS event, and the transmission in a forward gear. The operator presses the lock switch at 5 km/h in forward gear with no ABS activity, but the lock does not engage. There are no DTCs in the differential lock module. What should the technician investigate?

A. The wheel speed sensor signals — if one or more sensors are reading inaccurately, the module may calculate a speed above 8 km/h from the incorrect sensor data even though the actual speed is 5 km/h

B. The operator's lock switch — the switch may have failed electrically (open circuit) and cannot send the engage command to the module despite the operator's physical button press

C. The differential lock actuator — the solenoid or hydraulic actuator that physically engages the lock may have failed, preventing engagement even though the module has accepted all input conditions and is commanding the lock to engage. The module may not generate a DTC for a mechanical failure if it cannot electronically detect the actuator's physical position

D. The transmission's CAN bus communication — the lock module requires the TCM to confirm the transmission is in a forward gear through a CAN message. If the CAN connection between the TCM and the lock module is interrupted, the lock module cannot verify the forward gear condition and blocks engagement

88. A machine's driveshaft has a measured runout (wobble) of 0.5 mm when rotated slowly on Vblocks. The OEM specification maximum runout is 0.3 mm. The driveshaft has no visible damage. What is the consequence of operating with this excessive runout?

A. The 0.5 mm runout is unlikely to produce any noticeable symptom — the difference between 0.3 mm and 0.5 mm is too small to generate perceptible vibration at normal operating speeds

B. The excessive runout produces a onceperrevolution vibration that is proportional to the driveshaft's rotational speed. At low speed, the vibration may be imperceptible, but at higher travel speeds, the centrifugal force generated by the offcentre mass amplifies the vibration to a level that accelerates Ujoint wear, transmission output bearing wear, and differential pinion bearing wear

C. The excessive runout produces a vibration only at the driveshaft's critical speed — at all other speeds, the 0.5 mm runout is dynamically balanced by the driveshaft's natural flex

D. The excessive runout increases the driveshaft's torsional vibration frequency, which may conflict with the engine's firing frequency and produce a resonant condition during specific RPM ranges

89. A machine's A/C system has been operating normally for 3 years. The operator reports cooling performance has gradually decreased over the past 6 months. The technician connects manifold gauges and reads: lowside 35 PSI (specification 25–30 PSI), highside 280 PSI (specification 200–250 PSI). Both sides are above normal. What is the most likely cause?

A. The system is overcharged — excess refrigerant increases the pressure throughout the system. The high lowside pressure indicates too much refrigerant is flooding the evaporator, and the high highside pressure indicates the condenser is handling more refrigerant mass than designed

B. The condenser is restricted (dirty fins, blocked airflow, failed fan) — inadequate heat rejection causes the highside pressure to rise above normal. The elevated highside pressure feeds through the expansion device and raises the lowside pressure as well, because the metering device cannot maintain the designed pressure differential against the elevated supply pressure

C. The compressor has a failed reed valve — the valve leak allows highpressure gas to bypass back to the low side internally, raising the lowside pressure while the high side also rises because the pump is recycling gas instead of compressing fresh vapour

D. The expansion valve is stuck partially open — the excess flow floods the evaporator (high lowside) and the compressor works harder to compress the excess gas (high highside)

90. A machine's cab HVAC system uses a blower motor that operates at 4 speeds. The operator reports that Speed 1 (low) and Speed 4 (high) work correctly, but Speeds 2 and 3 are inoperative — the blower jumps directly from low to high with no intermediate speeds. What is the most likely cause?

A. The blower motor has two internal windings — one for low speed and one for high speed — and the intermediate speeds are produced by a combination of both windings. If one winding has an open connection, only the remaining singlewinding speeds function

B. The blower motor speed controller uses a resistor pack with individual resistors for each speed. The resistors for Speeds 2 and 3 have failed open — the circuit cannot produce the intermediate voltage drops needed for those speeds, while Speed 1 (full resistance) and Speed 4 (no resistance, direct power) remain functional

C. The HVAC control module's output driver for Speeds 2 and 3 has failed — the module can only command the low and high relay circuits, not the intermediate speed relays

D. The blower motor's commutator has flat spots at the positions corresponding to Speeds 2 and 3 — the motor cannot start from these positions but runs normally at the low and high positions where the commutator contacts are intact

91. A machine's A/C compressor clutch is measured at 0.8 mm air gap between the clutch plate and the pulley face. The OEM specification is 0.4–0.6 mm. What is the consequence of this excessive air gap?

A. The clutch may slip during engagement — the increased air gap reduces the magnetic force available to pull the clutch plate against the pulley because magnetic force decreases exponentially with distance. The weakened magnetic grip may be insufficient to hold the clutch plate against the compressor's torque load, especially during highdemand conditions

B. The clutch engages too aggressively — the larger air gap allows the plate to accelerate further before contact, producing a harder impact that wears the clutch face faster than normal

C. The excessive gap has no operational consequence — the air gap is a shipping specification that applies only to new compressors and does not require field adjustment

D. The clutch produces an audible click during each engagement — the larger gap produces a louder impact noise but does not affect the clutch's holding capacity

92. A machine's cab pressurization system operates with the HVAC blower pushing fresh air into the cab through the filtration system. The technician measures 65 pascals of positive pressure with the cab sealed (doors and windows closed). The operator then opens a small sliding window for ventilation. What happens to the cab pressurization?

A. The positive pressure is maintained at 65 pascals because the blower increases its output to compensate for the open window

B. The positive pressure drops to zero because any opening in the cab shell allows the pressurized air to escape — the cab cannot maintain positive pressure with any window or door open

C. The positive pressure drops proportionally to the size of the window opening — the 65 pascals may drop to a lower but still positive value if the window opening is small relative to the blower's total airflow capacity. However, the reduced pressure may fall below the OEM minimum specification, allowing dust to enter through other gaps and seals that the positive pressure normally holds closed

D. The positive pressure increases because the open window creates a Venturi effect that draws additional air through the filtration system

93. A machine's dieselfired auxiliary heater has been operating correctly for 4 years. The heater now fails to start — the operator presses the start button and the heater's glow plug cycles, the fuel pump activates, but no flame is established. After the start attempt, the heater locks out. What is the most likely cause of the noflame condition?

A. The glow plug has weakened from 4 years of thermal cycling and cannot reach the temperature needed to ignite the fuelair mixture during the start sequence

B. The combustion air blower has slowed from a worn motor bearing, reducing the airflow below the minimum needed to support combustion — the fuel enters the chamber but cannot ignite without adequate air for the fueltoair ratio to reach the flammable range

C. The heater's flame sensor has failed and cannot detect the flame even if it ignites — the controller shuts off the fuel after the start timeout because it receives no flame confirmation

D. The fuel metering pump is delivering fuel (audible pump operation) but the fuel quality has degraded from contaminated fuel or a blocked fuel filter — the pump moves mechanically but delivers insufficient fuel for ignition

94. A machine's A/C system uses an orifice tube (fixed expansion device) instead of a TXV. The system is properly charged. During operation on a 35°C day, the technician observes frost forming on the suction line between the evaporator outlet and the compressor inlet. What does this frost indicate?

A. The orifice tube is partially restricted from debris — the restricted flow reduces the refrigerant mass entering the evaporator, causing the small amount of refrigerant that does enter to evaporate completely inside the evaporator and continue to absorb heat (superheat) in the suction line. The superheated suction line is colder than the dew point and forms frost

B. The system is functioning correctly — frost on the suction line in 35°C ambient confirms the A/C is operating at maximum efficiency by utilizing the full evaporator and suction line surface for heat absorption

C. The compressor is oversized for the system — the excess pumping capacity pulls the lowside pressure below the freezing point of the condensate on the suction line surface, producing frost on the exterior

D. The system is undercharged — the reduced refrigerant mass in the evaporator evaporates completely before reaching the evaporator outlet, and the superheated vapour continues to be very cold in the suction line. The lowpressure, lowtemperature suction gas drops the line's external surface below the dew point, forming frost

95. A machine's HVAC evaporator core has failed from internal corrosion. The corrosion is concentrated on the tube surfaces where the liquid refrigerant enters the evaporator from the expansion device. What environmental factor most commonly causes this type of internal evaporator corrosion?

A. Moisture in the refrigerant system — water that was not removed during evacuation or that entered through a leak combines with the refrigerant to form hydrochloric or hydrofluoric acid. The acid attacks the aluminum evaporator tubes, and the corrosion concentrates at the coldest point (the expansion device outlet) where the moisture condenses out of the refrigerant stream and concentrates the acid attack

B. The refrigerant itself corrodes the aluminum tubes over time — all A/C refrigerants contain trace amounts of chlorine that attack aluminum alloy surfaces during normal operation

C. The evaporator's external condensate (water from dehumidification) penetrates through the aluminum tube walls from the outside surface inward through a process called crevice corrosion

D. The compressor oil degrades from thermal cycling and the acidic oil attacks the evaporator tubes from the inside at the coldest location where the degraded oil condenses

96. A machine's exhaust aftertreatment system's DEF dosing injector has failed. The injector is removed and the technician discovers the nozzle tip is blocked with white crystalline deposits. What caused the deposit formation that blocked the injector?

A. The deposits are calcium carbonate from hard water that was added to the DEF tank to dilute the urea concentration

B. The deposits are from a DEF quality issue — the DEF has higher than specified mineral content that crystallizes at the hot nozzle tip during the injection cycle

C. The deposits are urea crystallization (polyurea) from the DEF itself — the nozzle tip is exposed to exhaust heat when DEF is not flowing, and the residual DEF on the nozzle tip decomposes into crystalline deposits that progressively block the orifice. A failed coolant circuit that should cool the injector tip between injection cycles is the most common root cause

D. The deposits are from the diesel fuel's sulfur content — sulfur compounds from the exhaust react with the DEF at the hot nozzle tip and form crystalline sulfate compounds that block the orifice

97. A machine operates in a cold climate where temperatures routinely reach -30°C . The machine is equipped with an engine block heater, an oil pan heater, and a battery blanket heater — all connected to shore power when the machine is parked overnight. The operator reports that one morning, only the battery blanket heater was functioning — the block heater and oil pan heater had no power. What is the most likely cause?

A. The shore power outlet has a 15ampere circuit breaker that has tripped from the combined current draw of all three heaters exceeding the breaker's capacity — the battery blanket heater (lowest wattage)

remained on because it was on a separate circuit or was the only heater below the tripped breaker's position in the circuit

B. The block heater and oil pan heater share a common extension cord that has developed an open circuit from a damaged plug, severed wire, or frozen connector — the battery blanket heater is on a separate cord that remains functional

C. The engine coolant has frozen and the block heater's thermal protection has tripped to prevent overheating the dry heater element — the oil pan heater has also tripped because the frozen coolant has caused the oil temperature to drop below the heater's minimum operating threshold

D. The block heater's heating element has burned out from age, and the oil pan heater's thermostat has failed in the off position — both failures are independent and coincidental

98. A hydraulic system's main pump has been rebuilt and reinstalled. During the initial no-load test, the pump produces rated flow at rated RPM with the system relief blocked. The technician then loads the system by stalling a cylinder and observes the pressure reaches only 200 bar before the flow drops to zero. The system relief is set at 280 bar. What is the most likely cause?

A. The system relief valve has drifted from 280 to 200 bar and is opening prematurely

B. The cylinder's internal piston seal is bypassing massively, consuming all pump flow at 200 bar without building further pressure

C. The pump produces full flow at zero pressure but cannot maintain flow as pressure increases — the rebuilt pump has an internal leak (a damaged valve plate, an improperly installed barrel, or a worn swashplate) that bypasses fluid at a rate proportional to pressure. At 200 bar, the internal bypass equals the pump's full displacement, and no net flow reaches the system

D. The rebuilt pump's pressure compensator was set to 200 bar instead of 280 bar during the rebuild — the compensator destrokes the pump at 200 bar, reducing the flow to zero at the compensator setting rather than at the relief valve setting

99. A hydraulic motor on a winch produces a steady whining noise during loaded lowering operations. The noise is not present during hoisting (raising). The counterbalance valve and the motor have been tested individually and both pass their specifications. What is the most likely noise source?

A. The counterbalance valve is correctly holding the load but its pilotoperated poppet is vibrating at a specific frequency during the metered flowthrough that occurs during lowering — this flowinduced vibration produces the whining noise that is absent during hoisting when the counterbalance is fully open from the direct supply flow

B. The motor is cavitating during lowering because the loadinduced motor rotation (the load drives the motor faster than the supply flow) creates a suction on the supply side that drops below the oil's vapour pressure

C. The winch drum brake is dragging during lowering and the friction between the drum and the brake band produces the whining noise that is not present during hoisting when the brake is fully released

D. The motor's internal check valve (anticavitation valve) is chattering during the lowering operation as it attempts to supplement the supply flow with oil drawn from the case drain to prevent cavitation on the motor's supply side

100. A hydraulic system's pump displacement is 110 cm³/rev. The pump is driven at 1,800 RPM. The system pressure is 250 bar. The pump's volumetric efficiency at this pressure is 92% and its mechanical efficiency is 90%. What is the pump's actual flow output and input power requirement?

A. Theoretical flow = $(110 \times 1,800) \div 1,000 = 198$ L/min. Actual flow = $198 \times 0.92 = 182.2$ L/min. Hydraulic power output = $(250 \times 10^5 \text{ Pa} \times 182.2 / 60,000) \div 1,000 =$ approximately 75.9 kW. Input power = hydraulic output \div mechanical efficiency = $75.9 \div 0.90 = 84.3$ kW required from the engine

B. The actual flow is 198 L/min (volumetric efficiency does not affect flow) and the input power is 82.5 kW (calculated from theoretical flow \times pressure \div 60,000)

C. The actual flow is $198 \times 0.90 = 178.2$ L/min (using mechanical efficiency for flow) and the input power is 74.3 kW

D. The calculations cannot be performed without knowing the pump's overall efficiency, which is not provided

101. A machine's hydraulic system uses a closedcentre loadsensing pump with an LS differential of 20 bar. During simultaneous operation of the boom (200 bar load) and the swing (150 bar load), the pump supply pressure should be 220 bar (highest load + LS differential). The technician measures the pump supply at 220 bar. The boom operates at normal speed but the swing is slower than specification. What is the cause of the slow swing speed?

- A. The swing motor has excessive internal leakage that consumes flow without producing proportional shaft speed
- B. The swing circuit's DCV spool is receiving the 220 bar supply pressure, but the spool's metering edge must create a 70 bar pressure drop ($220 - 150$) to meter the flow to the 150bar swing motor. This excessive pressure drop across the metering edge wastes energy as heat but should still pass adequate flow. The slow swing is more likely caused by the DCV spool's metering area being too small for the required flow, or the spool not opening fully from a pilot pressure deficit
- C. The pump cannot supply adequate flow for both functions simultaneously — the combined flow demand exceeds the pump's maximum output at 220 bar supply pressure
- D. The LS shuttle check valve is stuck and is reporting the swing circuit's 150 bar to the pump instead of the boom's 200 bar — the pump is producing only 170 bar ($150 + 20$), which is insufficient for the boom but adequate for the swing. However, the question states the boom operates normally, which contradicts this explanation

102. A machine's air brake system has a dualcircuit foot valve (treadle valve). The primary circuit supplies the rear brakes and the secondary circuit supplies the front brakes. During a brake test, the technician applies the brakes fully and measures: primary delivery pressure = 690 kPa, secondary delivery pressure = 520 kPa. Both should deliver equal pressure at full application. What is the most likely cause of the low secondary pressure?

- A. The secondary circuit's relay valve is restricting the air delivery to the front brake chambers, limiting the delivered pressure below the foot valve's output
- B. The front brake chambers are larger than the rear chambers and the increased volume reduces the delivered pressure — the foot valve cannot supply the larger volume at the same pressure as the smaller rear chambers
- C. The treadle valve's secondary piston seal has failed — the seal leak allows air to escape from the secondary circuit's pressure chamber inside the foot valve, reducing the delivered pressure to the front brakes while the primary circuit (with intact seals) delivers full pressure

D. The secondary circuit's foot valve has an internal restriction from contamination that limits the maximum delivered pressure to 520 kPa — the secondary side of the treadle valve must be cleaned or the valve replaced

103. A hydraulic system's return line filter has been changed at the correct interval. However, the replacement filter element has a 25micron rating instead of the OEMspecified 10micron rating. The machine operates normally with no immediate symptoms. What is the longterm consequence of this coarser filtration?

A. No consequence — the 25micron filter provides adequate protection for the system's components and the difference between 10 and 25 microns is insignificant in a heavy equipment hydraulic system

B. The 25micron filter operates at a lower pressure drop than the 10micron element, which actually improves the system's efficiency by reducing the return line backpressure

C. Particles between 10 and 25 microns circulate freely through the system — these particles are in the critical wear size range for most hydraulic components (pumps, motors, valves) and the coarser filtration allows accelerated internal wear that shortens component life. The damage accumulates progressively and may not be apparent until a component fails prematurely

D. The 25micron filter clogs faster than the 10micron element because it captures a wider range of particle sizes — the increased dirt-holding demand exhausts the element's capacity before the scheduled change interval

104. A machine's hydraulic system operates at 300 bar maximum working pressure. The system's main relief valve has been set correctly at 330 bar (10% above working pressure). A technician discovers the relief valve's cracking pressure has drifted to 310 bar — only 10 bar above the maximum working pressure. Is this a concern?

A. Yes — a relief valve setting only 10 bar above the maximum working pressure leaves insufficient margin for pressure spikes from load transients, cylinder stall conditions, and dynamic impulses. The valve may open briefly during normal working conditions, producing heat, flow loss, and potential instability in the actuator function. The valve should be readjusted to the 330 bar specification

B. No — the relief valve is still above the 300 bar working pressure and provides adequate overpressure protection

C. No — the 10bar margin is sufficient because hydraulic system pressures are controlled by the pump compensator and the relief valve only opens during a compensator failure

D. Yes — but the concern is only the increased heat generation from the relief valve opening more frequently, not a safety or performance issue

105. A hydrostatic drive machine is tested and the following data is recorded: pump displacement = 100%, engine RPM = 1,800 (rated), charge pressure = 27 bar (specification 25–30), main loop pressure forward = 350 bar, motor case drain = 18 L/min (specification maximum 8 L/min), machine speed = 60% of rated. What does the motor case drain flow confirm?

A. The motor case drain flow at 18 L/min (more than double the 8 L/min maximum) confirms the motor has excessive internal leakage — fluid is bypassing through the motor's worn clearances at a rate that consumes more than 40% of the pump's output without producing shaft rotation. The motor must be rebuilt or replaced

B. The elevated case drain is caused by the high loop pressure (350 bar) which naturally increases the internal leakage through normal motor clearances proportionally to pressure

C. The motor case drain line has a restriction that is creating backpressure and the 18 L/min reading is artificially high from the restricted drain line's pressure effect on the flow meter

D. The elevated case drain originates from the main pump's internal leakage, not the motor — the pump's case drain routes through the motor before reaching the measurement point

106. A machine's hydraulic cylinder extends at normal speed but retracts very slowly. The DCV, pump, and return circuit have been verified as correct. The cylinder has been bypassed and shows no internal leakage. What remaining component could cause the slow retraction?

A. The cylinder rod seal has excessive friction from an improperly installed wiper seal that creates drag during the retract stroke but does not affect the extend stroke because the extend force is greater than the retract force

B. The cylinder's rod end supply hose has a partial restriction — a collapsed internal liner, a kinked hose, or a contaminated fitting limits the flow entering the rod end during retraction while the cap end supply path (used during extension) is unrestricted. The restricted rod end supply reduces the maximum retract speed

C. The cylinder's cushion (snubber) valve on the rod end is stuck in the restricted position, limiting the exhaust flow from the rod end during the full retraction stroke instead of only at the end of stroke

D. The cylinder rod has bent slightly and the bend creates interference with the rod seal gland during the retract stroke — the rod drags through the tight spot, slowing the retraction

107. A machine's pneumatic system includes an air dryer with a purge cycle that activates during each governor unload (compressor cutout) event. The purge cycle blasts stored dry air backward through the desiccant cartridge to remove captured moisture. The technician notices the purge cycle is not occurring — the governor unloads the compressor correctly but no purge blast is heard. What is the consequence?

A. The desiccant becomes saturated with moisture because it is never regenerated — saturated desiccant passes moisture through to the downstream brake system. The moisture accumulates in reservoirs, valves, and chambers, producing corrosion, seal degradation, and freeze risk in cold weather

B. The failed purge has no immediate consequence — the desiccant has a 500-hour capacity before saturation and the purge cycle is a maintenance enhancement that extends the desiccant life beyond the base capacity

C. The failed purge allows the compressor to unload too quickly, reducing the total air stored per governor cycle and extending the buildup time between cycles

D. The failed purge causes the air dryer housing to pressurize above the downstream reservoir pressure, which backfeeds air into the compressor discharge and damages the compressor's discharge valves

108. A hydraulic accumulator on a machine's steering circuit has been tested and the precharge is correct. The system provides the specified 3 emergency steering cycles after engine shutdown. However, the technician notices the steering becomes sluggish (slower than normal) approximately 2 seconds before the engine stalls during an engine failure simulation. What does this 2second sluggish period indicate?

A. The steering pump's output drops below the minimum for normal steering response during the 2 seconds between the engine beginning to stall and the engine stopping completely — during this period, the pump produces reduced flow at the declining engine RPM, and the accumulator does not supplement the pump because the system pressure has not yet dropped below the accumulator's discharge threshold. The 2second slug is the transition period between pumppowered steering and accumulatorpowered emergency steering

B. The accumulator's precharge is too high, preventing the accumulator from discharging until the system pressure drops significantly below normal

C. The steering priority valve is restricting flow during the engine stall event because the declining pump output triggers the priority valve to reduce steering flow to protect the steering circuit from total flow loss

D. The HMU (hand metering unit) has worn internal gears that produce sluggish response under the reduced flow conditions of the engine stall period

109. A machine's hydraulic system has a variable displacement axial piston pump. The pump's compensator is adjusted to destroke the pump at 250 bar. The technician measures the system pressure during a loaded lift cycle and observes the pressure rises to 250 bar as the cylinder stalls, but then the pressure drops to 230 bar and oscillates between 230 and 250 bar approximately twice per second. What is occurring?

A. The compensator spool is hunting — the pump destrokes at 250 bar (as designed), but the pressure then drops below the compensator's reseal point (230 bar) and the pump strokes back up. The cycle repeats as the compensator alternately destrokes and restores the pump. This hunting is caused by a worn or contaminated compensator spool that cannot find a stable intermediate position between full stroke and full destroke

B. The pump has a mechanical fault — one or more pistons are not sealing correctly and leak intermittently, producing the 20bar pressure fluctuation

C. The relief valve is chattering at 250 bar, alternately opening and closing as the pressure fluctuates around its set point

D. The cylinder's piston seal is bypassing intermittently, consuming flow in 2second pulses that the pump must replace, producing the pressure oscillation

110. A hydraulic system's flow divider splits pump output between the steering circuit and the implement circuit. The technician discovers the flow divider's compensator spool is stuck, and 70% of the pump flow is going to the implements while only 30% reaches the steering. What is the safety concern?

A. The steering circuit receives only 30% of its designed flow — the steering speed is reduced and the operator may not be able to steer the machine fast enough to avoid an obstacle or maintain control on a slope. Emergency steering capability is also compromised because the accumulator charge rate is reduced from the lower steering flow

B. The implement circuit receives excessive flow that may damage the implement cylinders from the increased extension speed

C. The unbalanced flow creates asymmetric pressure loading on the pump that accelerates the pump's bearing wear

D. The excess implement flow causes the implement relief valve to open during every function actuation, generating excessive heat

111. A machine's air brake system uses a park/emergency brake valve with three positions: released (full air to spring brake chambers), applied (zero air to spring brake chambers), and emergency (rapid exhaust of air from spring brake chambers). The technician tests the valve and discovers the emergency position does not exhaust air faster than the applied position — both positions produce the same exhaust rate. What has failed?

- A. The park/emergency valve's quickrelease orifice is blocked — the emergency position normally opens an additional largediameter exhaust path that dumps the air from the spring brake chambers much faster than the standard applied position's exhaust path. The blocked orifice forces the emergency exhaust through the same path as the applied exhaust, producing identical exhaust rates
- B. The spring brake chambers have internal restrictions that limit the maximum exhaust rate regardless of the valve position — the chambers themselves are the flowlimiting component
- C. The air supply line to the park brake valve is undersized, limiting the maximum flow rate through the valve regardless of which exhaust port is activated
- D. The park/emergency valve's internal seal has failed, equalizing the pressure between the applied and emergency exhaust paths and producing the same flow rate in both positions

112. A machine's hydraulic system oil has been analyzed and the following contaminants are identified: 200 ppm water, ISO cleanliness code 21/19/16, and acid number (AN) of 2.5 (new oil AN is 0.5). The OEM condemning limits are: water 500 ppm maximum, ISO cleanliness 18/16/13, acid number 4.0 maximum. Which contaminant requires the most immediate attention?

- A. The ISO cleanliness code (21/19/16) exceeds the specification (18/16/13) by approximately 8× at the largest particle size — the solid particle contamination is the most immediately damaging contaminant because the particles are actively wearing the pump, motor, valve, and cylinder components during every operating minute. Water and acid number are within their condemning limits but should be monitored
- B. The water content (200 ppm) requires the most attention because water is the most destructive contaminant in a hydraulic system
- C. The acid number (2.5 vs. 4.0 limit) requires the most attention because the elevated acid is corroding the system's internal metal surfaces

D. All three contaminants are equally critical and the oil must be changed immediately to address all three simultaneously

113. A machine's hydraulic cylinder has a rod that is 80 mm in diameter and a bore of 120 mm. The system operates at 250 bar. The technician needs to calculate the cylinder's extend force and retract force to verify it meets the application requirement. What are the forces?

A. Extend force = $250 \text{ bar} \times (\pi/4 \times 120^2) \text{ mm}^2 = 250 \times 11,310 \text{ mm}^2 = 2,827,500 \text{ N} \approx 283 \text{ kN}$ (using bore area). Retract force = $250 \text{ bar} \times (\pi/4 \times (120^2 - 80^2)) \text{ mm}^2 = 250 \times (11,310 - 5,027) = 250 \times 6,283 = 1,570,750 \text{ N} \approx 157 \text{ kN}$ (using annular area)

B. Both forces are 283 kN — the rod area does not affect the retract force because the rod is inside the cylinder

C. Extend = 283 kN, Retract = 126 kN — using only the rod area for retraction (incorrect)

D. Extend = 283 kN, Retract = 157 kN — but the units are wrong: the actual forces are in kN, not N, and the conversion from bar \times mm² must include the factor of 10 (1 bar = 0.1 N/mm²). Extend = $0.1 \times 250 \times 11,310 = 282,750 \text{ N} \approx 283 \text{ kN}$. Retract = $0.1 \times 250 \times 6,283 = 157,075 \text{ N} \approx 157 \text{ kN}$

114. A machine's hydraulic system uses a pilotoperated check valve (POCV) to hold the boom in the raised position. The POCV requires a pilot pressure ratio of 4:1 to open — meaning the pilot pressure must equal at least 25% of the loadholding pressure. The boom cylinder holds 200 bar. What minimum pilot pressure is required to open the POCV?

A. 800 bar — calculated by multiplying the load pressure by the 4:1 ratio (200×4)

B. 25 bar — calculated by dividing the load pressure by a factor of 8, using the wrong formula

C. 50 bar — calculated by dividing the load pressure (200 bar) by the pilot ratio (4:1) = $200 \div 4 = 50$ bar. The pilot pressure must be at least 50 bar to generate enough force on the pilot piston to overcome the 200bar load holding the main poppet closed

D. 200 bar — the pilot pressure must equal the load pressure to open any pilotoperated check valve

115. A hydraulic system's tankmounted suction strainer has a magnetic element. During a routine service, the technician removes the strainer and examines the magnetic element. The magnet has a thin, uniform coating of fine metallic fuzz. Is this a concern?

A. Yes — any metallic material on the suction strainer magnet indicates a system failure that requires immediate investigation

B. A thin, uniform coating of fine metallic fuzz is normal for a hydraulic system operating within its designed parameters — the magnet captures the small amount of ferrous wear debris produced by the normal wear of pumps, motors, cylinders, and valves during each service interval. A concern arises only when the debris is excessive (thick accumulation), contains large particles (chunks, flakes), or has changed significantly from the previous service

C. No concern — suction strainer magnets always accumulate metallic debris and the accumulation rate has no diagnostic value

D. Yes — the metallic fuzz indicates the suction strainer mesh has failed and is shedding wire fragments from its own screen material

116. A machine's hydraulic system includes a pressurecompensated variable displacement pump. The compensator maintains a constant pressure regardless of flow demand. During operation, the technician notices the system pressure fluctuates by ± 15 bar around the 250bar set point. What does this fluctuation indicate?

A. The ± 15 bar fluctuation is a normal characteristic of a pressurecompensated pump — the compensator uses a proportional control spool that modulates the pump displacement continuously, and the 15bar band represents the normal response bandwidth of the control system

B. The compensator spring has weakened and cannot maintain a stable set point — the weakened spring allows the pump to oscillate between the compensated and decompensated states

C. The pump's swashplate control servo has a worn seal that allows the control pressure to leak, producing intermittent loss of swashplate position control that manifests as the pressure fluctuation

D. The ± 15 bar fluctuation indicates the compensator spool is contaminated or has developed a wear groove that prevents it from finding a stable equilibrium position — a healthy compensator should maintain the set point within $\pm 3-5$ bar under steady state conditions

117. A machine's hydrostatic drive system has a flushing (shuttle) valve that exchanges a small amount of hot loop oil with cool charge oil during each directional change. The flushing valve has stuck open in the forwardflush position. What symptom does this produce?

A. The forward loop runs cooler than normal because the flushing valve continuously replaces hot forwardloop oil with cool charge oil — but the reverse loop runs hotter than normal because it never gets flushed

B. The machine cannot travel in reverse because the open flushing valve diverts all reverse loop flow through the cooler instead of to the motor

C. The machine operates normally in both directions — the flushing valve's flow rate is too small to affect the drive performance, and the only consequence is slightly elevated oil temperature from the reduced cooling efficiency

D. The forward loop is continuously flushed (cooled) while the reverse loop receives no flushing — the reverse loop oil degrades faster from the accumulated heat, and the asymmetric cooling may produce different oil temperatures between the forward and reverse operating directions

118. A machine's hydraulic system has two parallelconnected cylinders that lift a heavy attachment. Both cylinders should extend at the same rate to keep the attachment level. The operator reports the attachment tilts to one side during lifting — one cylinder extends faster than the other. Both cylinders are the same size and receive oil from the same DCV work port. What is the most likely cause?

A. One cylinder has lower internal friction than the other — the lowerfriction cylinder extends faster because it presents less resistance to the hydraulic flow

B. One cylinder has higher internal leakage (bypassing piston seals) than the other — the leaking cylinder loses a portion of its supply flow through the internal bypass, extending slower than the tight cylinder. The flow follows the path of least resistance, preferentially feeding the lowerleakage cylinder

C. The supply hoses to the two cylinders are different lengths — the longer hose creates more pressure drop, reducing the flow to that cylinder and causing it to extend slower

D. The DCV spool has an asymmetric wear pattern that directs more flow to one work port than the other

119. A machine's air brake system's compressor has been replaced. After the replacement, the technician performs a system test and discovers the air dryer's purge cycle is excessively long — approximately 15 seconds instead of the normal 5 seconds. The governor settings are correct. What is the most likely cause of the extended purge?

A. The replacement compressor has a higher output capacity than the original — the larger compressor fills the system to the governor cutout faster, and the higher stored pressure at cutout produces a longer purge duration because more air is available for the purge cycle

B. The replacement compressor's unloader mechanism is slow to respond, allowing the compressor to continue producing air after the governor signals the unload — the additional air extends the purge duration

C. The replacement compressor has a larger unloader port that allows more air to flow backward through the compressor during the purge cycle, extending the purge duration — this is a design difference that does not affect the air dryer's regeneration effectiveness

D. The air dryer's purge valve has been contaminated during the compressor installation and is not closing promptly after the purge — the extended purge is a valve fault, not a compressor characteristic

120. A machine's hydraulic pump is producing a highpitched screaming noise during loaded operation. The noise is not present during noload running. The pump is a variable displacement axial piston type. The suction strainer is clean, the oil level is correct, and the oil temperature is within specification. What is the most likely cause of the loaded only screaming noise?

A. The pump's compensator is oscillating at a high frequency during loaded operation, producing the screaming noise as the swashplate vibrates between the compensated and fullstroke positions under the fluctuating load demand

B. The pump's internal valve plate is worn and the highpressure oil is bypassing between the barrel and the valve plate at a specific frequency that produces the screaming noise — the bypass only occurs under loaded conditions when the pressure differential across the valve plate is high

C. The pump's drive shaft bearing has a defect that produces noise only under the radial loading created by the highpressure reaction force during loaded operation — at noload, the bearing is unloaded and operates quietly

D. The pump is cavitating under load — the highpressure discharge creates a corresponding high vacuum on the suction side that exceeds the oil's ability to fill the cylinders at the pump's rotational speed. The screaming is the sound of vapour bubbles forming and collapsing inside the pump's cylinder bores during each suction stroke

121. A machine's hydraulic DCV uses a proportional pilot solenoid to shift the main spool. The solenoid receives a PWM signal from the ECM at 150 Hz. The technician monitors the solenoid current with a clamp ammeter and reads 0.8A at a 50% duty cycle command. At 75% duty cycle, the ammeter reads 1.0A. The OEM specification shows the solenoid should draw 0.6A at 50% and 0.9A at 75%. Both readings are above specification. What could cause the elevated current at both duty cycle settings?

A. The solenoid coil has developed shorted turns — the reduced coil inductance from the shorted turns allows more current to flow at any given duty cycle, producing the elevated readings at both test points

B. The system supply voltage is higher than nominal — at 28V instead of 24V, the solenoid draws proportionally more current at each duty cycle setting according to Ohm's Law

C. The solenoid spool is mechanically binding, and the binding resistance causes the solenoid to draw more current as it works harder to move the stuck spool

D. The PWM frequency has drifted from 150 Hz to a lower frequency, allowing more current to flow during each longer onpulse

122. A machine's hydraulic system's oil cooler has been operating with a partially restricted airside (the cooling fins are 40% blocked with debris). The system has been running at 10°C above the normal operating temperature for approximately 1,000 hours. What progressive damage may have occurred to the hydraulic system during this extended elevatedtemperature operation?

A. No progressive damage — a 10°C elevation above normal is within the hydraulic system's designed thermal tolerance and produces no measurable effect on component life

B. The elevated temperature has accelerated the oil's oxidation rate — the depleted antioxidant additives have allowed acids to form that attack seal materials, producing progressive seal hardening and eventual leakage across multiple components. The reduced oil viscosity from the elevated temperature also decreases the oil film thickness at all wearing surfaces, accelerating pump, motor, and cylinder wear

C. The elevated temperature has only affected the oil — changing the oil now restores full system protection and no component damage has occurred

D. The elevated temperature has caused the hydraulic hoses to deteriorate faster than normal — the rubber compounds degrade at elevated temperatures, reducing the hoses' burst pressure and fatigue life

123. A mining excavator's boom has been in service for 25,000 hours. The OEM's structural integrity management plan recommends a comprehensive NDE inspection at this milestone. The inspection identifies a 25 mm long indication at a critical weld toe that was not present at the previous inspection (at 20,000 hours). What is the most significant piece of information this finding provides?

A. The indication's exact size, which determines whether it exceeds the acceptance criteria for the weld joint

B. The indication's depth (surface or subsurface), which determines the appropriate repair method

C. The fact that the indication is new (not present at 20,000 hours) — this confirms the indication is a growing fatigue crack, not a static fabrication defect. A growing crack will continue to propagate and must be addressed before it reaches a critical size. The growth rate (25 mm in 5,000 hours) also allows the engineer to estimate the remaining life before the crack reaches a critical dimension

D. The indication's orientation relative to the weld, which determines whether it is a transverse crack (perpendicular to the weld, more dangerous) or a longitudinal crack (parallel to the weld, less dangerous)

124. A machine's bucket has wear plates (liner plates) installed on the internal floor and sidewall surfaces. During inspection, the technician discovers several wear plate mounting bolts have sheared. The wear plates are still partially attached but have shifted from their original position. What is the primary concern?

- A. The shifted wear plates expose the bucket's base metal to direct abrasion from the loaded material — the unprotected areas will wear through the bucket shell rapidly, potentially causing a structural failure or a hole in the bucket floor. The sheared bolts must be replaced and the wear plates repositioned to restore full coverage before the machine returns to heavyload operation
- B. The sheared bolt fragments inside the bucket will contaminate the loaded material and damage downstream processing equipment
- C. The shifted wear plates increase the bucket's weight asymmetrically, changing the centre of gravity and potentially exceeding the machine's rated tipping load
- D. The sheared bolts indicate the bucket has been overloaded and a structural inspection of the bucket's main welds is required before any bolt replacement is performed

125. A machine's quick coupler has been in service for 10,000 hours. During an inspection, the technician measures the coupler's front hook (cradle) and rear lock pin bores and finds both have worn 3 mm beyond the OEM specification. The coupler still holds the current attachment securely during a visual check. What is the technician's recommendation?

- A. The coupler is functioning correctly and can continue in service — the 3 mm wear is within the extendedservice tolerance for a coupler with this operating hour count
- B. The worn coupler bores reduce the positive retention force on the attachment pins — even though the coupler holds the attachment during a static visual check, the worn bores allow the pins to shift under the dynamic digging and lifting loads of normal operation. The coupler must be rebuilt (bore remachined and fitted with wear bushings) or replaced before the machine returns to service
- C. The coupler should be monitored at each preshift inspection — the current wear does not pose a safety risk but the wear rate should be tracked to plan the replacement timing
- D. The coupler can be returned to service after welding buildup material into the worn bores and remachining to the original dimensions

126. A machine's operator cab has developed a persistent vibration that the operator feels through the seat and controls. The vibration is present at all engine speeds and all machine operating conditions. The engine and drivetrain vibration levels measured at the frame are within specification. What should the technician investigate?

A. The engine mounts — worn or broken engine mounts allow the engine vibration to transmit directly to the frame, producing the cab vibration at all operating conditions

B. The drivetrain universal joints — worn Ujoints produce a vibration that is proportional to driveshaft speed, which changes with engine speed, contradicting the "all engine speeds" characteristic

C. The cab mounting system — the cab's isolation mounts (rubber bushings, spring mounts, or viscous mounts) may have deteriorated, allowing the frame's normal vibration level (which is within specification) to transmit directly to the cab without the designed isolation. The cab amplifies and transmits the vibration to the operator

D. The hydraulic pump — a pump vibration that is present at all speeds and conditions would also be detectable at the frame, which contradicts the withinspecification frame measurements

127. A machine's attachment quick coupler has a secondary locking mechanism that the operator must verify before operating the attachment. The operator is trained to perform a "tilt test" — tilting the attachment forward to verify the coupler locks hold the attachment against the tilting force. What does this tilt test verify that a visual inspection alone cannot?

A. The tilt test verifies the coupler locks can sustain a dynamic load — the tilting force simulates the forces the attachment experiences during digging and lifting. A visual inspection confirms the locks are in the engaged position, but the tilt test confirms the locks can actually hold the attachment against a force that would disengage a poorly locked coupler

B. The tilt test verifies the hydraulic supply to the coupler locks is functioning — the hydraulic pressure must be maintained during the tilt to keep the locks engaged

C. The tilt test verifies the coupler's structural integrity — the tilting force loads the coupler's welds and identifies any structural cracks that would fail under load

D. The tilt test verifies the attachment's pin dimensions are correct for the coupler — an undersized pin passes a visual inspection but slips out of the coupler under the tilting force

128. A mining excavator has a structural crack in the stick (dipper arm) that has been repaired by welding. The repair weld was verified by NDE immediately after welding. Six months later (approximately 3,000 operating hours), the machine is due for its routine NDE inspection. Should the repaired weld receive any special attention during this followup inspection?

A. No — the repair weld was verified by NDE at the time of repair and does not require any additional attention beyond the standard inspection scope

B. No — repair welds are not included in the routine inspection program because they are inspected under a separate repair verification process

C. Yes — but only if the operator has reported any symptoms such as unusual noise, vibration, or visible cracking near the repair location

D. Yes — the repaired weld should be specifically reinspected because repair welds in highstress locations are more susceptible to crack reinitiation than original welds. The heataffected zone of the repair, the weld toe geometry, and the surrounding base metal should all be examined to verify no new indications have developed since the repair

129. A machine's ROPS structure is made of rectangular hollow section (RHS) steel tubing. During an inspection, the technician discovers that water has been entering the ROPS tubes through unsealed bolt holes at the mounting base. The trapped water has corroded the inside of the tubes at the base — the wall thickness at the corrosion zone is unknown without removing the ROPS for inspection. What is the concern?

A. Internal corrosion at the ROPS tube base is the most critical type of ROPS damage because the base is the higheststress location during a rollover — the tubes experience maximum bending stress at their

connection to the frame. Any wall thickness reduction from corrosion at this location directly reduces the ROPS's energy absorption capacity, potentially below the certified rating

B. Internal corrosion in ROPS tubes is cosmetic only because the structural strength of hollowsection tubing depends on the external dimensions, not the wall thickness

C. The trapped water will freeze in cold weather and the ice expansion will split the tube from the inside — the ice damage is a greater concern than the corrosion

D. The concern is limited to the mounting bolt torque — the corroded bolt holes may not maintain the specified clamping force, and the bolts should be retorqued to restore the connection

130. A technician is installing a new set of wear edges on a wheel loader bucket. The wear edges are bolted and reversible (they can be flipped when one face is worn). The technician notices the bolt holes in the new wear edges are slotted rather than round. What is the purpose of the slotted holes?

A. The slotted holes allow the wear edge to be positioned precisely relative to the bucket cutting edge — the technician can slide the wear edge forward or backward in the slots to align it with the bucket's profile before tightening the bolts, accommodating minor variations in bucket dimensions and previous repair history

B. The slotted holes allow the wear edge to float under impact loading — the edge shifts slightly with each impact, distributing the load across the bolt pattern rather than concentrating the impact force at fixed bolt locations

C. The slotted holes are a manufacturing cost reduction — slots are faster to produce than precision round holes

D. The slotted holes compensate for the different bolt hole spacing between various bucket manufacturers — the universal slot pattern fits multiple bucket models without requiring custom drilling

131. A machine's operator seat heightadjustment mechanism has failed in the fully raised position. The operator is a shorterstatured individual who normally operates with the seat at the lowest setting. Operating with the seat in the fully raised position forces the operator to look over the instrument panel at an unnatural angle and reach further for the controls. What safety concern does this create beyond ergonomic discomfort?

- A. The raised seat position moves the operator's head closer to the ROPS upper cross member, reducing the survival space during a rollover event
- B. The raised seat position changes the operator's eye point relative to the windows, mirrors, and rear camera display — the altered sight lines reduce the operator's visibility of the work area, blind spots, and surrounding personnel, increasing the risk of struckby incidents and contact with other equipment or infrastructure
- C. The raised seat position increases the operator's exposure to cab vibration because the higher seating position amplifies the frame vibration through the longer lever arm between the seat base and the operator's head
- D. The raised seat position reduces the operator's ability to operate the foot pedals effectively because the longer leg extension changes the pedal force angle and reduces the maximum braking force the operator can apply

132. A hybrid excavator's energy storage system uses a lithiumion battery pack rated at 20 kWh. The machine's swing motorgenerator captures 5 kWh of regenerative energy during each operating hour. The battery's roundtrip efficiency (energy out ÷ energy in) is 92%. How much useful energy does the battery return to the swing motor per operating hour from the captured regenerative energy?

- A. The battery returns $5 \text{ kWh} \times 0.92 = 4.6 \text{ kWh}$ per hour — the 8% loss (0.4 kWh) is dissipated as heat inside the battery during the charge and discharge cycles. This net energy recovery supplements the diesel engine's output, reducing the total fuel consumption proportionally to the 4.6 kWh of electrical energy that replaces dieselgenerated mechanical energy
- B. The battery returns 5 kWh per hour — the roundtrip efficiency applies only to external charging from shore power, not to internally generated regenerative energy
- C. The battery returns $5 \div 0.92 = 5.43 \text{ kWh}$ per hour — the battery amplifies the captured energy through its chemical conversion process
- D. The battery returns $20 \text{ kWh} \times 0.92 = 18.4 \text{ kWh}$ per hour — the full battery capacity is cycled during each operating hour

133. A batteryelectric machine's HV battery pack has experienced a cell venting event — one cell has released gas through its safety vent. The BMS has isolated the pack and the machine is shut down. The technician observes a strong chemical odour near the battery enclosure. What is the correct immediate response?

A. Open the battery enclosure to inspect the vented cell and determine whether the event has stabilized or is progressing toward thermal runaway

B. Reconnect the battery pack to allow the BMS to perform its diagnostic routine and determine the severity of the venting event through the internal monitoring circuits

C. Apply water to the battery enclosure exterior to cool the pack and prevent the venting event from escalating to thermal runaway

D. Evacuate all personnel from the immediate area, establish a safety perimeter, do not open the battery enclosure, and contact the OEM's emergency response team — a cell venting event indicates internal cell failure that may escalate to thermal runaway (fire, explosion, toxic gas emission). The chemical odour confirms electrolyte has been released, which is both toxic and flammable. Only trained HV emergency response personnel should approach and assess the battery

134. A fleet operator is evaluating the maintenance cost advantage of batteryelectric machines over diesel equivalents. The electric machine has no engine, no transmission, no torque converter, no exhaust aftertreatment system, and no engine oil, coolant, or filters. However, the electric machine has HV battery packs, electric motors, power electronics, and a cooling system for the battery thermal management. What is the NET maintenance advantage when both the eliminated and the added maintenance items are considered?

A. The net maintenance advantage is zero — the electric machine's battery thermal management, HV system inspections, and power electronics maintenance cost approximately the same as the diesel machine's engine, transmission, and aftertreatment maintenance

B. The batteryelectric machine has a significant net maintenance cost reduction — the eliminated engine, transmission, torque converter, and aftertreatment maintenance (oil changes, filter replacements, coolant service, injector service, DPF cleaning, DEF system service) represents a much larger recurring cost than the added HV system inspections and battery thermal management. Electric motors have virtually no wear items, and the power electronics require minimal maintenance

C. The batteryelectric machine has higher net maintenance cost because the HV battery pack replacement cost (at end of battery life) exceeds the total engine and transmission maintenance cost over the same period

D. The net maintenance advantage depends entirely on the battery pack's warranty coverage — with a full-life warranty, the electric machine costs less; without warranty, it costs more

135. A hybrid machine's energy management system determines the optimal split between diesel and electric power for each operating condition. During a loading cycle, the system monitors the instantaneous power demand and the battery's state of charge. At 90% SOC, the system aggressively supplements diesel power with electric power (to use the stored energy). At 20% SOC, the system minimizes electric power use and allows the diesel to recharge the battery through the motorgenerator. What determines the "crossover" SOC at which the system transitions from netelectricconsumer to netelectricproducer?

A. The crossover SOC is fixed at 50% in all hybrid machines — the system uses electric power above 50% SOC and recharges below 50%

B. The crossover SOC is determined by the operator through a dashboard selector switch that allows the operator to prioritize either fuel savings (higher crossover = more electric use) or battery preservation (lower crossover = less electric use)

C. The crossover SOC is dynamically calculated by the energy management controller based on the current duty cycle, ambient temperature, battery health (SOH), remaining work duration, and the diesel engine's current fuel efficiency point — the controller continuously optimizes the crossover to minimize total energy cost while maintaining the battery within its optimal operating range for longevity

D. The crossover SOC is set by the OEM during factory calibration and cannot be changed in the field — it is a fixed parameter based on the battery chemistry's optimal cycling range

Practice Exam 13: Answer Key and Explanations

1. D — A 12,000 kg lift using a mobile crane requires a written lift plan that documents the load weight, rigging configuration, crane capacity at the specific working radius, ground conditions, overhead obstructions, wind limits, and the step-by-step procedure. The plan must be reviewed and signed by the crane operator and supervising technician before rigging begins. This is a regulatory requirement for critical lifts in Canadian jurisdictions.

2. A — Compressed air directed at the body can penetrate the skin and enter the bloodstream (air embolism), rupture eardrums, and drive particles into the eyes and skin at injurious velocities. Using compressed air for personal cleaning is prohibited in most Canadian jurisdictions regardless of the regulated nozzle pressure. The hazards extend well beyond noise exposure alone.

3. C — A drained hydraulic reservoir meets the definition of a confined space: enclosed area with limited entry/exit, not designed for continuous human occupancy, and potential for oxygen-deficient or toxic atmosphere from residual oil vapour. A confined space entry permit, atmospheric testing, ventilation, a rescue plan, and a standby attendant are required before the technician enters.

4. B — The fusible link is the parts washer's primary fire suppression mechanism. If the solvent ignites, the fusible link melts at a predetermined temperature and the lid closes automatically, smothering the fire by cutting off the oxygen supply. With the link disabled, the lid cannot close, the fire burns freely with unlimited oxygen, and it can spread to adjacent combustibles and escalate beyond hand-held extinguisher capacity.

5. D — Loss of fine motor control from cold-induced numbness increases the risk of injury from slipping tools and compromises the quality of precision work. The technician may fail to detect tactile feedback such as a cross-threaded fastener, an improperly seated fitting, or an O-ring that has rolled during installation. The technician must warm up in a heated enclosure until hand dexterity is fully restored.

6. A — Pressure gauge needle vibration during a static hold test indicates an active leak in the test circuit. Each leak pulse drops the pressure slightly and each hand-pump stroke restores it, producing the oscillation the needle follows. The test cannot produce a valid 5-minute pressure hold until the leak is located and eliminated. A valid test shows a stable, motionless needle.

7. C — A through-thickness fatigue crack at a weld toe in a high-stress structural zone requires engineering assessment before any repair. The crack's root cause, the repair procedure, the NDE verification requirements, and the post-repair inspection criteria must be determined by a qualified structural engineer or the OEM. A field weld repair without engineering direction may not address the root cause and could fail catastrophically.

8. B — Operating a hydraulic track press at near-maximum capacity against a seized pin risks sudden pin release — the stored energy in the hydraulic system can eject the pin as a projectile. The technician should stop increasing force, apply penetrating oil, and use localized heat to expand the link bore and break the corrosion bond, reducing the required extraction force before continuing.

9. A — Each probe puncture creates a small hole in the wire insulation that allows moisture ingress to the copper conductor. Over time, moisture wicks along the conductor strands through the puncture, corroding the copper and increasing circuit resistance until the circuit becomes intermittent. The puncture sites should be sealed with liquid electrical tape or heat-shrink to prevent this progressive corrosion.

10. D — Working near a running engine requires identifying all rotating components — fan, belts, pulleys, driveshafts — and ensuring no loose clothing, jewelry, lanyards, or tools can contact any rotating part. All guards that can remain in place during the diagnostic must be installed, and the technician must maintain clearance from all unguarded components throughout the procedure.

11. C — The simultaneous rapid increase in both iron and silicon confirms dirt ingestion. Silicon from airborne dust is entering the engine through a compromised intake system (torn filter, loose clamp, cracked duct). The abrasive dust particles dramatically accelerate wear on iron components — liners, rings, and gears — producing the correlated iron increase. The intake system must be inspected immediately.

12. B — A nozzle opening pressure 70 bar below specification allows the injector to open earlier in the injection cycle at a lower pressure. The longer injection duration produces larger fuel droplets that atomize poorly, burn inefficiently, produce excessive smoke, and reduce power from the affected cylinder. The larger droplets may also wash the oil film from the cylinder wall, accelerating liner wear.

13. A — A common rail fuel leak at 1,600 bar produces a nearly invisible, high-velocity fuel jet capable of penetrating skin and underlying tissue (hydraulic injection injury). This is the same mechanism as a hydraulic oil injection injury. The technician must never use hands to feel for leaks on a running common rail system. A piece of cardboard held near the suspected area safely detects the jet.

14. D — The lead-tin overlay is the outermost sacrificial layer of a tri-metal connecting rod bearing. A spike from 3 to 28 ppm in one sampling interval confirms the overlay is being removed at an accelerated rate. If uncorrected, the overlay will wear through to the copper intermediate layer within the next interval, and the copper spike will follow. The cause must be identified before bearing failure occurs.

15. B — The ECM believes the engine is at high altitude where less oxygen is available. The ECM reduces the fuel delivery and the boost pressure target to match the perceived thin air. At the actual sea level altitude, the engine has full oxygen available but the ECM artificially limits the fuel delivery, producing less than rated power.

16. C — The radial play exceeds the OEM specification (0.12 mm vs. 0.08 mm maximum). The excess play allows the compressor and turbine wheels to contact their housings during transient conditions — rapid acceleration, deceleration, or side-loading from rough terrain. A catastrophic wheel contact event destroys the turbocharger and sends debris into both the intake system and exhaust after-treatment.

17. A — The two-stage design provides a more gradual transition from bypass to radiator cooling. The primary valve begins partial radiator flow at 82°C, and the secondary valve increases to full flow at 90°C. This progressive flow increase reduces thermal shock on the radiator core and produces a more stable engine temperature with less cycling than a single valve that transitions abruptly.

18. D — Isolated aluminum in diesel engine oil most commonly originates from piston skirt wear. The gradual increase over four consecutive samples suggests progressive scuffing on one or more pistons. Possible causes include insufficient piston-to-bore clearance, inadequate oil cooling from a blocked piston cooling jet, or a lubrication deficiency at the piston-to-liner interface.

19. B — The DEF consumption rate is correct (ruling out dosing problems) and the post-SCR NO_x exceeds the specification. The SCR catalyst's conversion efficiency has degraded — the catalyst receives the correct ammonia supply but cannot convert the NO_x at the required rate. Degradation causes include thermal aging of the catalyst substrate, sulfur poisoning, or hydrocarbon contamination of the catalyst surface.

20. C — The electronically controlled thermostat allows the ECM to optimize the engine operating temperature for different conditions. The ECM runs the engine slightly cooler during heavy load (preventing overheating) and slightly warmer during light load (improving fuel efficiency and reducing emissions). A wax-element thermostat opens at a fixed temperature regardless of operating conditions.

21. D — The initial moisture event introduced mineral salts from the coolant into the connector housing. Even after drying, the salt residue remained on the terminal surfaces. Salt is hygroscopic — it absorbs atmospheric moisture and re-establishes the electrochemical corrosion process without requiring a new external moisture source. The connector should have been thoroughly flushed with contact cleaner during the initial repair.

22. A — A failed WIF sensor in the "no water detected" state allows water to accumulate in the fuel-water separator without the operator's knowledge. The water eventually overflows the separator and enters the secondary filter and the high-pressure injection system. Water corrodes precision injector components, erodes nozzle seats, and causes injector seizure — expensive damage the WIF warning was designed to prevent.

23. C — The regeneration burned the soot (carbon) but left behind ash — non-combustible metallic residue from engine oil additives that entered the DPF through normal oil consumption. Ash cannot be removed by regeneration. The ash narrows the wall-flow channels, producing a baseline restriction that increases over the DPF's service life and eventually requires professional off-machine cleaning.

24. B — The VGT is near its commanded position, but boost is 20 kPa below specification while back-pressure is 5 kPa above specification. The turbine creates the expected restriction but cannot convert that exhaust energy into proportional compressor output. This indicates the turbocharger's efficiency has decreased from internal losses — worn bearings, eroded wheel surfaces, or increased housing clearances.

25. D — Both readings are within specification, but the rate of increase is the critical diagnostic data point. The 25 L/min increase over 2,000 hours indicates accelerating ring or liner wear. Projecting this trend, the engine will exceed the 100 L/min limit within the next 400 hours. An oil analysis and compression test should be scheduled to verify the wear rate and plan the overhaul timing.

26. A — Without the oil cooler thermostat, all oil bypasses the cooler at all temperatures. The sustained elevated oil temperature over 500 hours has accelerated oxidation exponentially, depleted the additive package prematurely, and reduced the viscosity below the bearing film-strength threshold. Bearing surface damage may have occurred from inadequate lubrication at the reduced viscosity.

27. C — A disconnected CCV hose creates two simultaneous problems: the crankcase loses its ventilation path to the intake vacuum, so blowby gases pressurize the crankcase and push oil past external seals. Simultaneously, the open CCV port on the intake manifold admits unmetered air that can cause a lean condition, and the discharged oil mist contaminates the engine compartment.

28. D — Diesel fuel is entering the crankcase and diluting the oil. The most common cause is a leaking injector that allows fuel to wash past the piston rings, or a fuel system component that leaks fuel into an oil-wetted cavity inside the engine. The fuel-diluted oil has reduced viscosity and load-carrying capacity that will progressively damage bearing surfaces if not corrected.

29. A — Before removing the head, the technician must determine whether the crack has created secondary damage — specifically coolant contamination of the oil through a crack path connecting the water jacket to the combustion chamber or oil gallery. Checking the oil for coolant contamination and testing the coolant for combustion gas determines whether the repair scope extends beyond head replacement alone.

30. B — When governor gain is set too high, the governor overreacts to each speed deviation. The correction overshoots the target speed, which triggers a correction in the opposite direction. This cycle repeats as a rhythmic speed oscillation (surging) that the operator perceives as the engine RPM cycling above and below the target. Reducing the gain eliminates the surging.

31. B — Single-circuit operation reduces the total flow to the steering cylinders to approximately half of the normal two-circuit flow. The reduced flow fills the steering cylinders more slowly. Since the HMU meters oil proportionally to steering wheel rotation, the operator must turn the wheel more times to displace the same cylinder volume at the reduced flow rate.

32. D — New friction disc material has microscopic surface peaks that contact only a small percentage of the separator plate surface initially. The small initial contact area produces a reduced effective friction force. As the peaks wear during the first hours of use (bedding-in), the contact area increases progressively and the braking force rises to the designed level.

33. A — The half-circumference wear pattern confirms the idler is running eccentrically. The hub bore or the mounting shaft is out-of-round, causing one half of the idler to contact the track chain rail with full force while the opposite half lifts away from the rail during each revolution. Only the contacting half wears, producing the distinctive pattern.

34. C — The HMU's internal gear set has worn or been contaminated. Damaged gear teeth or trapped particles between the gears create distinct resistance points during rotation. The operator feels these resistance points through the steering wheel as a notchy, non-smooth rotation. The HMU should be flushed or replaced to restore smooth steering feel.

35. B — The pin outside surfaces exposed between the links are directly attacked by the acid mine drainage. The corrosive water dissolves the pin material from the exterior inward, reducing the pin diameter in the exposed zone. The internal bearing surfaces remain relatively intact because the sealed joints protect them from the acid. This external corrosion weakens the pin's structural cross-section and can lead to fracture under load.

36. D — The service brakes exceed the maximum stopping distance (25 m vs. 22 m specification) and must be serviced — worn pads, contaminated discs, air in the hydraulic circuit, or reduced apply pressure are likely causes. The retarder meets its specification independently. The service brakes must independently meet their specification because they are the primary emergency stopping system.

37. C — Progressive slowdown during accumulator discharge is a normal characteristic of any gas-charged accumulator. As each steering cycle consumes stored oil, the nitrogen pre-charge expands and the remaining pressure decreases. Each subsequent cycle operates at a lower pressure and therefore a slower steering speed. As long as all three cycles complete, the system meets the specification.

38. A — The track tension specification is set for flat-ground operation. During side-hill work, the gravitational force component acting laterally on the track chain can exceed the lateral guidance capability of the undercarriage at the standard tension setting. Some OEMs provide a separate tighter tension specification for sustained side-hill applications that increases the chain's resistance to lateral displacement.

39. B — All five measurements are within their respective OEM specifications: governor cut-out (860 kPa), cut-in (690 kPa), build-up time (2:45 vs. 3:00 max), pressure drop (14 vs. 21 kPa max), and spring brake application (420 kPa within 410–430). The system passes the complete performance test and is approved for return to service.

40. D — Copper originates from the bronze bushings (copper alloy) and tin from the tri-metal thrust washers (tin-containing overlay). Both components are wearing and releasing their characteristic metals into the oil. The wear rate should be trended over multiple samples to determine if the rate is normal for the operating hours or is accelerating and requires intervention.

41. C — The recoil spring absorbs shock loads when the track encounters obstacles — rocks, stumps, or uneven terrain. Without the spring, the grease cylinder's relief valve must absorb the full impact. If an obstacle impact exceeds the relief valve's response speed, the instantaneous force transmits directly to the chain, sprocket, final drive, and frame without any cushioning.

42. A — When the hydrostatic drive fails, the parking/emergency brake is the independent braking system designed specifically for this situation. The spring-applied, hydraulically released parking brake applies automatically when charge pressure is lost, or can be manually commanded by the operator. It is the first and most reliable braking system available when the primary hydrostatic braking is unavailable.

43. D — Without the rebound bumper, the strut piston reaches full extension and contacts the end cap with a harsh metallic bang — metal-to-metal impact with no cushioning. This occurs during unloaded return trips, over bumps, or during any event that rapidly unloads the suspension. The repeated impact also damages the strut's end cap and piston surfaces.

44. B — Even with the correct oil and friction modifier, a worn limited slip clutch pack has insufficient friction surface to provide smooth torque transfer. The worn plates alternate between grabbing (static friction) and releasing (kinetic friction) during the speed differential of tight turns, producing the popping or banging noise. The clutch pack must be inspected for wear.

45. A — The lean cylinders and DCV have been verified leak-free. A pilot-operated check valve in the lean circuit may have a contaminated poppet seat that allows a trickle of oil to leak past during the hold condition. The small leak gradually relieves the holding pressure, and the tire's self-centering force pushes the cylinder back toward vertical over time.

46. C — Four measurements cluster at 3.0–3.2% while one location reads 5.8%. The isolated high reading indicates localized damage at that section — a rock jam, an impact, or a seized joint that produced accelerated wear at that specific location. This section may fail under load before the rest of the chain reaches its service limit, and the affected links should be closely monitored or replaced.

47. A — A one-time voltage fault that has not recurred in 150 hours was most likely caused by a brief transient event: a momentary high-current draw from the starter or solenoid surge, a loose battery connection that shifted under vibration and reseated, or a brief key-cycle interruption. The event was too short to affect operation but long enough for the ECM to detect and log.

48. D — The sensor resistance is correct for 88°C and the wiring is verified. The ECM's internal ADC has developed a non-linearity error from thermal aging — it produces accurate readings at low temperatures but increasingly inaccurate readings at higher temperatures. The 23°C error at 88°C is consistent with a degraded ADC that was accurate at installation but has drifted over the ECM's service life.

49. B — Cable resistance = voltage drop ÷ current = $1.5\text{V} \div 550\text{A} = 0.00273$ ohms (2.73 milliohms). This resistance in 3 metres of cable produces the measured 1.5V drop at 550A cranking current. The power dissipated as heat in the cable = $V \times I = 1.5 \times 550 = 825$ watts — significant energy wasted as heat in the charging cable during each cranking event.

50. C — A three-phase alternator produces a rectified output with a ripple frequency determined by the number of diode pairs and the rotational speed. The 300 Hz ripple at 1,800 RPM confirms all six rectifier diodes are conducting. A failed diode would reduce the ripple frequency (typically to 200 Hz for a missing phase) and increase the ripple amplitude significantly, which is not observed.

51. A — The ECM commands 40% duty cycle, the solenoid receives 40%, but the hydraulic output is at 70%. The proportional valve's position is determined by the balance between the solenoid's magnetic force and the return spring's force. A solenoid coil with shorted turns has reduced inductance that allows more current and therefore more magnetic force per duty cycle, shifting the spool further than designed.

52. D — The CAN bus operates normally during light traffic but produces faults during heavy activity. The 250 kbit/s bus with 15 modules may approach its bandwidth limit during peak activity periods. Higher-priority messages succeed through the CAN arbitration process, but lower-priority messages are delayed, retried, and occasionally lost during congestion, producing intermittent communication faults.

53. C — Track 2's wiper has lost contact with the resistive track and is stuck at 1.25V. When the pedal moves, Track 1 changes (2.5V to 2.7V) but Track 2 remains at 1.25V. The ECM detects the disagreement between the two tracks — the dual-track correlation is violated — and enters a derate or limp mode as a safety measure because the redundant signal validation has failed.

54. B — The relative compression test measures the crankshaft's deceleration during each cylinder's compression stroke. Cylinder 4 decelerates less because less energy is required to compress its reduced air charge. The low compression can be from worn rings, a leaking valve, or a head gasket breach — the cylinder cannot trap and compress its full air charge.

55. A — The definitive regulator test bypasses the regulator by connecting the field terminal directly to battery positive through a variable resistor. If the alternator produces correct voltage with the regulator bypassed, the regulator is confirmed as the fault. If the alternator still undercharges with full field excitation, the fault is in the alternator's rotor, stator, or rectifier.

56. D — The 5V reference reads 5.01V with all sensors disconnected (healthy regulator) but drops to 4.6V when the hydraulic temperature sensor is reconnected. The sensor has an internal fault (short to ground or abnormally low resistance) that draws excessive current from the shared 5V reference, pulling it below the 4.8V minimum and affecting the accuracy of every sensor on the same reference.

57. B — The IMV's default position depends on its spring design. A normally open IMV defaults to full open without electrical command, allowing maximum fuel to enter the pump and producing maximum rail pressure. A normally closed IMV defaults to closed, starving the pump. The specific default behaviour and the ECM's response depend on the valve design — the technician must know the specific engine's IMV type.

58. C — If the display module's software version does not match the ECM's data format, the display may misinterpret the data scaling. For example, a temperature could display in the wrong units, or a pressure could display at a multiplied value because the display's conversion factors do not match the ECM's transmission format. J1939 standardization reduces this risk but version mismatches still occur.

59. D — The 0.03V offset causes the ECM to interpret the neutral position as a very small forward command — the voltage exceeds the stored neutral calibration point. The fix is either widening the ECM's neutral dead band to encompass the 2.53V rest position, or adjusting the joystick's mechanical neutral stop to bring the rest voltage closer to the calibrated 2.50V.

60. A — On a four-stroke engine, each cylinder's piston reaches TDC twice per cycle — once on the compression stroke and once on the exhaust stroke. The CKP signal alone cannot distinguish which TDC event is which because both occur at the same crankshaft position 360° apart. The CMP signal (rotating at half-crank speed) provides the additional reference that identifies the engine's cam cycle position. Without CMP, the ECM retains crankshaft timing from CKP but loses individual cylinder identification, forcing a degraded injection strategy.

61. B — The throttle response curve maps a non-linear relationship between pedal position and fuel delivery. The aggressive initial response provides quick breakaway force for digging or dozing applications, while the gradual upper range provides precise speed control during travel. Different applications (excavation, haul, grading) may use different response curves to match the work requirements.

62. C — The instrument cluster recognizes the amber lamp command from the ECM and illuminates "CHECK ENGINE," but the three active DTCs are manufacturer-specific codes that the cluster's software does not contain display text for. The cluster's firmware lacks the corresponding text strings to describe those specific fault codes.

63. D — The DC voltage (11.2V) is within specification, but the converter may be producing excessive AC ripple on the DC output from aging or overloading. The DMM reads average DC and does not detect the ripple. The ripple causes the camera's internal power supply to fluctuate, producing the flicker. An oscilloscope on the converter's output reveals the ripple amplitude.

64. A — The previous ECM accumulated adaptive learned values over its service life — injector trim corrections, idle speed compensation, and shift calibration refinements. The replacement ECM starts with baseline (default) values and has not yet re-learned these machine-specific corrections. The

differences will diminish as the new ECM's adaptive system re-learns during the first 50–100 operating hours.

65. B — The 60-tooth reluctor wheel is designed with 2 intentionally missing teeth that create a reference gap. The ECM uses this gap to identify a specific crankshaft position (typically the TDC reference for Cylinder 1). The 58 peaks per revolution are the 58 physical teeth, and the gap provides the once-per-revolution synchronization reference.

66. C — The sensor resistance is correct, the wiring is intact, but the display shows dashes for hydraulic temperature only. The ECM's analog input channel for this sensor has failed — it cannot read the sensor's resistance despite external verification. The ECM transmits an invalid data flag for this parameter, and the display renders the invalid flag as dashes.

67. D — The alternator reached its thermal protection limit. The internal temperature sensor signaled the regulator to reduce field current, dropping the output voltage below the battery voltage and triggering the charge warning light. When the alternator cooled sufficiently, the regulator restored normal output and the light extinguished. This confirms the alternator operates at its thermal capacity under the current load.

68. B — The ECM detects a sensor fault by comparing the rail pressure reading against other engine parameters — engine load, injector command, and pump duty cycle. The 1,200-bar reading does not correlate with the expected pressure at the current operating condition. The ECM enters a limp mode with a default rail pressure strategy rather than blindly increasing pump output to chase the incorrect reading.

69. A — The high-resistance connection on the LIN bus attenuates the signal voltage. The LIN receiver on the security module cannot reliably decode the attenuated messages — the reduced voltage margin between the logic-high and logic-low levels produces bit errors that corrupt the keypad's transmitted codes. The operator enters the correct code but the module receives a corrupted version.

70. C — The CAN bus faults correlate precisely with the hydraulic hammer's operation. The hammer's solenoid valve produces an electromagnetic pulse at each actuation that couples into the CAN bus wiring through radiated EMI. The high-energy solenoid switching generates transient electrical interference that corrupts CAN data during each hammer firing cycle.

71. B — All snapshot parameters together define the exact operating condition at the time of the DTC. The engine was at rated RPM under heavy load in a hot ambient environment with all systems at operating temperature. The technician uses this complete data set to determine whether the exhaust temperature exceeded the threshold due to a fault condition or because the machine reached a normal operating limit during extreme conditions.

72. C — Partial lockup maintains a controlled fluid coupling effect that provides torsional vibration damping. The 20–40 RPM controlled slip absorbs engine firing pulses and drivetrain torsional vibrations that would transmit directly to the transmission during full lockup. This provides a smoother ride and reduces drivetrain stress while capturing most of the efficiency benefit of lockup.

73. A — The TCM uses the throttle position signal to determine the engine load demand and adjust shift timing accordingly. At 85% TPS (perceived heavy load), the TCM delays upshifts to keep the engine in the lower gear longer for maximum power. The actual demand is only 50%, so the delayed shifts are unnecessary. Correcting the TPS signal restores correct shift timing.

74. D — The measured rotating torque of 3.5 N·m exceeds the 2.0–3.0 N·m bearing preload specification. However, the ring gear's mesh resistance contributes drag to the total reading. The gear mesh component (typically 0.5–1.0 N·m) must be accounted for. Subtracting the mesh drag from the total brings the bearing preload into the 2.5–3.0 N·m range, within specification.

75. B — The pump is at full displacement with correct charge pressure, the engine is at rated RPM, and the loop pressure is near the maximum (380 bar). All pump-side parameters are correct, yet the motor produces only 75% speed. The motor's worn internal clearances are bypassing approximately 25% of the delivered flow as internal leakage, which exits through the case drain as waste heat.

76. C — The rebuilt side runs 15°C hotter than the unrebuilt side under identical loading. The most common cause after a rebuild is excessive bearing preload from incorrect shim settings. Overtight bearings generate continuous friction heat during rotation. The unrebuilt side's bearings have settled to a comfortable preload over their service life, producing less heat.

77. D — The converter temperature protection is a designed safety feature. The technician must investigate why it activates during the current duty cycle. If the cooler, coolant flow, and oil condition are correct, the machine may be overloaded for its designed application or the duty cycle exceeds the cooling system's designed capacity. Increasing the threshold defeats a safety protection.

78. A — All four measurements are within the 0.20–0.28 mm specification, and the consistency (within 0.02 mm of each other across 4 positions) confirms the ring gear is running concentrically on the differential case. There is no eccentricity or mounting error causing variable backlash around the circumference. The gear mesh is correctly set.

79. B — A high clutch engagement point (near the top of pedal travel) with a new clutch assembly typically indicates air in the hydraulic release system. The air prevents the slave cylinder from fully retracting, holding the release bearing in partial contact with the pressure plate fingers. Bleeding the hydraulic system removes the air and restores the correct engagement point.

80. C — The differential uses oil-to-water cooling with engine coolant as the cooling medium. The 5% water content and milky oil confirm a significant internal tube failure in the oil cooler. The higher-pressure engine coolant leaks through the failed tube into the lower-pressure differential oil circuit, producing the contamination.

81. D — A vibration occurring only in 4th gear during loaded acceleration isolates the fault to the specific planetary gear set, clutch pack, and bearing configuration that is active in the 4th gear power path. The gears, bearings, and clutch components that are loaded in other gears are eliminated because those gears are smooth.

82. A — Setting valve lash cold uses the OEM's cold specification that accounts for the known thermal expansion of all valve train components. The OEM has calculated the cold lash value that produces the correct running lash at operating temperature. Cold measurements are more consistent and repeatable because they eliminate the variables of non-uniform engine temperature and the time pressure of working on a hot engine.

83. C — The chain is within the pitch elongation specification (1.5% vs. 2.0% max), but the visible surface cracks on the link plates are fatigue initiators that can propagate to sudden fracture under load. A chain with surface cracks has compromised structural integrity regardless of the pitch elongation measurement. The chain should be replaced to prevent a catastrophic failure without warning.

84. B — The brake cooling oil pump controls the volume of oil flowing through the cooler. If the pump's output has decreased from wear, the reduced flow rate limits the total heat rejection per unit time — even though the cooler itself is clean and functional. The temperature rises because the pump cannot circulate enough oil through the cooler to match the heat generation rate.

85. D — The fracture surface shows a classic fatigue failure pattern. The small smooth zone (15%) is the fatigue crack that initiated at the surface and propagated slowly. The large rough zone (85%) is the final sudden fracture when the stress on the reduced remaining cross-section exceeded its ultimate strength. The small fatigue zone relative to the large final fracture indicates either a short crack life or high applied stress.

86. A — The torque converter's coupling efficiency has degraded from internal wear. The converter passes all static tests (stall speed, pressure, temperature) but operates at reduced efficiency during normal travel. A higher percentage of engine power is converted to heat rather than mechanical output during every moment of loaded travel. The engine consumes more fuel to maintain the same machine speed and productivity.

87. C — All electronic input conditions are met (speed, ABS, gear), no DTCs are present, but the lock does not engage. The differential lock actuator (solenoid or hydraulic piston) may have failed mechanically, preventing physical engagement despite the module commanding the lock. The module may not generate a DTC for a mechanical failure if it has no position feedback sensor to detect the actuator's physical state.

88. B — The 0.5 mm runout exceeds the 0.3 mm specification and produces a once-per-revolution vibration proportional to shaft speed. At higher travel speeds, the centrifugal force from the off-centre mass amplifies the vibration, accelerating wear on the U-joints, transmission output bearing, and differential pinion bearing. The progressive wear shortens the service life of every component in the driveline.

89. B — Both the high-side and low-side pressures are above normal. A restricted condenser (dirty fins, blocked airflow, or failed fan) prevents adequate heat rejection. The high-side pressure rises because the condenser cannot condense the refrigerant efficiently. The elevated high-side pressure feeds through the expansion device and raises the low-side pressure, because the metering device cannot maintain the designed pressure differential.

90. D — The blower motor speed controller uses a resistor pack with individual resistors for each intermediate speed. Speed 1 passes through all resistors (maximum resistance, lowest voltage to motor). Speed 4 bypasses all resistors (direct power). Speeds 2 and 3 each use specific resistors. The resistors for Speeds 2 and 3 have failed open, eliminating those intermediate speeds while Speed 1 and Speed 4 remain functional.

91. A — The 0.8 mm air gap exceeds the 0.4–0.6 mm specification. Magnetic force decreases exponentially with distance. The increased gap reduces the force available to pull the clutch plate against

the pulley. The weakened magnetic grip may be insufficient to hold the clutch plate against the compressor's torque load, causing slip during high-demand conditions.

92. C — The positive pressure drops proportionally to the window opening size. A small window opening may reduce the 65 pascals to a lower but still positive value. However, the reduced pressure may fall below the OEM minimum specification, allowing dust to enter through other gaps and seals that the higher positive pressure normally holds closed.

93. B — The fuel pump activates (audible operation) and the glow plug cycles, but no flame is established. The combustion air blower provides the air needed for the fuel-air mixture to reach the flammable range. A worn motor bearing slows the blower, reducing airflow below the minimum needed to support ignition. The fuel enters the chamber but cannot ignite without adequate air.

94. D — The system is undercharged. The reduced refrigerant mass evaporates completely before reaching the evaporator outlet. The superheated, very cold vapour continues through the suction line, dropping the line's external surface temperature below the ambient dew point and forming frost. Frost on the suction line with an orifice tube system is a classic undercharge symptom.

95. A — Moisture in the refrigerant system that was not removed during evacuation combines with the refrigerant to form hydrochloric or hydrofluoric acid. The acid attacks the aluminum evaporator tubes, and the corrosion concentrates at the coldest point — the expansion device outlet — where the moisture condenses out of the refrigerant stream and concentrates the acid attack on the tube surfaces.

96. C — The white crystalline deposits are urea crystallization (polyurea) from the DEF itself. The nozzle tip is exposed to exhaust heat when DEF is not being injected. The residual DEF on the tip decomposes into crystalline deposits. A failed coolant circuit that should cool the injector tip between injection events is the most common root cause — the overheated tip bakes the residual DEF into crystals.

97. B — The block heater and oil pan heater share a common extension cord that has developed an open circuit — a damaged plug, severed wire, or frozen connector. The battery blanket heater is on a separate cord that remains functional. The most common cause is a frozen or damaged outdoor extension cord connector that loses contact in extreme cold.

98. D — The pump produces full flow at zero pressure (confirming the displacement mechanism works) but cannot maintain flow as pressure increases. The pump's pressure compensator was set to 200 bar

during the rebuild instead of 280 bar. The compensator destrokes the pump at 200 bar, reducing the flow to zero. The compensator must be readjusted to 280 bar.

99. C — The counterbalance valve correctly holds the load during lowering by metering the flow through its pilot-operated poppet. During the metered flow, the poppet vibrates at a specific frequency — this flow-induced vibration produces the whining noise. During hoisting, the counterbalance valve is fully open from the direct supply pressure and no metering vibration occurs.

100. A — Theoretical flow = $(110 \times 1,800) \div 1,000 = 198$ L/min. Actual flow = $198 \times 0.92 = 182.2$ L/min. Hydraulic power output = $(250 \times 10^5 \times 182.2/60,000) \div 1,000 \approx 75.9$ kW. Input power = $75.9 \div 0.90 = 84.3$ kW. The engine must supply 84.3 kW to drive the pump at this operating condition.

101. B — The pump supply is correct (220 bar) and the boom operates normally. The swing circuit receives 220 bar supply but the DCV must create a 70 bar drop to meter flow to the 150-bar swing motor. The slow swing speed indicates the DCV spool's metering area is insufficient for the required flow rate, or the spool is not opening fully from a pilot pressure deficit.

102. D — The treadle valve delivers unequal pressures to the two circuits (690 vs. 520 kPa). The foot valve's secondary side has an internal restriction from contamination or a seal defect that limits the maximum delivered pressure. The secondary piston seal leak allows air to escape the pressure chamber, reducing the output. The valve must be cleaned or replaced.

103. C — Particles between 10 and 25 microns are in the critical wear size range for most hydraulic components. The coarser 25-micron filter allows these particles to circulate freely. The particles accelerate internal wear on pumps, motors, valves, and cylinders. The damage accumulates progressively over thousands of hours and may not be apparent until premature component failure.

104. A — A relief valve setting only 10 bar above the 300-bar working pressure provides insufficient margin for pressure spikes from load transients, cylinder stall conditions, and dynamic impulses. The valve may open briefly during normal working conditions, producing heat, flow loss, and actuator instability. The valve must be readjusted to the 330 bar specification.

105. D — The motor case drain at 18 L/min (more than double the 8 L/min maximum) confirms the motor has excessive internal leakage. Fluid bypasses through the worn clearances at a rate that consumes more than 40% of the pump's output. The leaked flow produces heat instead of shaft rotation, explaining the 60% machine speed. The motor must be rebuilt or replaced.

106. B — The cylinder extends normally (cap-end supply unrestricted) but retracts slowly (rod-end supply restricted). The rod-end supply hose has a partial restriction — a collapsed internal liner, a kinked hose, or a contaminated fitting limits the flow entering the rod end during retraction while the cap-end path is unrestricted.

107. C — Without the purge cycle, the desiccant is never regenerated. Saturated desiccant passes moisture through to the downstream brake system. The moisture accumulates in reservoirs, valves, and chambers, producing corrosion, seal degradation, and freeze risk in cold weather — the exact conditions the air dryer was designed to prevent.

108. A — During the 2 seconds between the engine beginning to stall and stopping completely, the steering pump produces declining flow at the dropping engine RPM. The accumulator does not supplement because the system pressure has not yet fallen below the accumulator's discharge threshold. The sluggish period is the transition between pump-powered steering and accumulator-powered emergency steering.

109. D — The compensator spool is hunting between the destroke and restore positions. The pump destrokes at 250 bar, the pressure drops below the reseal point (230 bar), and the pump strokes back up. A worn or contaminated compensator spool cannot find a stable intermediate position, producing the oscillation. Cleaning or replacing the compensator spool eliminates the hunting.

110. C — The steering circuit receives only 30% of its designed flow. The reduced steering speed compromises the operator's ability to steer quickly enough to avoid obstacles or maintain control on slopes. Emergency steering accumulator charge rate is also reduced from the lower flow, potentially extending the time required to build adequate emergency steering reserves.

111. B — The park/emergency valve's emergency position normally opens an additional large-diameter exhaust path for rapid air evacuation. The blocked quick-release orifice forces the emergency exhaust through the same standard-size path as the applied position, producing identical exhaust rates. The orifice must be cleared to restore the rapid emergency exhaust capability.

112. A — The ISO cleanliness code (21/19/16) exceeds the specification (18/16/13) by approximately 8× at the largest particle size category. Solid particle contamination causes immediate and ongoing wear damage during every operating minute. Water (200 ppm) and acid number (2.5) are within their condemning limits and less immediately destructive, though they should be monitored.

113. D — Extend force = $P \times \text{bore area} = 0.1 \times 250 \times (\pi/4 \times 120^2) = 25 \times 11,310 = 282,750 \text{ N} \approx 283 \text{ kN}$.
Retract force = $P \times \text{annular area} = 0.1 \times 250 \times (\pi/4 \times (120^2 - 80^2)) = 25 \times 6,283 = 157,075 \text{ N} \approx 157 \text{ kN}$.
The conversion factor 0.1 converts bar $\times \text{mm}^2$ to newtons (1 bar = 0.1 N/mm²).

114. C — The POCV pilot ratio of 4:1 means the pilot piston requires 25% of the load-holding pressure to generate enough force to unseat the main poppet. Minimum pilot pressure = load pressure \div pilot ratio = $200 \div 4 = 50 \text{ bar}$. The pilot system must generate at least 50 bar to open the POCV against the 200-bar load.

115. B — A thin, uniform coating of fine metallic fuzz on the suction strainer magnet is normal for a healthy hydraulic system. The magnet captures the small amount of ferrous wear debris produced by normal pump, motor, cylinder, and valve wear. A concern arises only when the debris becomes excessive, contains large particles, or changes significantly from the previous service interval.

116. A — A ± 15 bar fluctuation around the set point is a normal operating characteristic of a pressure-compensated pump. The compensator spool continuously modulates pump displacement in response to system demand, and the 15-bar band represents the normal control bandwidth. A healthy compensator maintains stability within approximately ± 3 – 5 bar only under perfectly steady-state conditions.

117. D — The flushing valve stuck open in the forward-flush position continuously routes forward-loop oil through the cooler, keeping the forward loop well-cooled. However, the reverse loop never receives flushing and its oil is never refreshed through the cooler. The asymmetric cooling produces different oil temperatures and degradation rates between the two operating directions.

118. B — Both cylinders receive oil from the same DCV port, but one cylinder has higher internal leakage (worn piston seals). The leaking cylinder loses supply flow through its internal bypass, extending slower than the tight cylinder. The flow preferentially feeds the lower-resistance cylinder, creating the speed differential that tilts the attachment.

119. C — The replacement compressor has a larger unloader port diameter than the original. During the governor's unload cycle, the larger port allows more air to flow backward through the compressor into the air dryer's purge circuit. The increased air volume extends the purge duration. This is a design difference between compressor models, not a malfunction.

120. D — The pump is cavitating under loaded conditions. The high-pressure discharge creates a corresponding suction demand. When the suction-side vacuum exceeds the oil's ability to fill the

cylinders at the pump's speed, vapour bubbles form in the cylinder bores and collapse violently during compression. The screaming noise is the characteristic sound of cavitation. The suction circuit must be checked for restrictions despite the strainer appearing clean.

121. A — The solenoid coil has developed shorted turns from insulation breakdown. The reduced number of effective turns decreases the coil's inductance, allowing more current to flow at any given duty cycle. The elevated current readings at both 50% and 75% duty cycle settings are consistent with a reduced-inductance coil from shorted turns.

122. B — Operating 10°C above normal for 1,000 hours has accelerated the oil's oxidation rate. The depleted antioxidant additives have allowed acids to form, attacking seal materials and causing progressive hardening. The reduced viscosity from elevated temperature also decreases the oil film thickness at all wearing surfaces, accelerating pump, motor, and cylinder wear throughout the system.

123. C — The most significant finding is that the indication is new — it was not present at the 20,000-hour inspection. This confirms it is a growing fatigue crack, not a static fabrication defect. The growth rate (25 mm in 5,000 hours) provides the data needed to estimate the remaining life before the crack reaches critical size and to determine the urgency of the repair.

124. A — The shifted wear plates expose the bucket's base metal to direct abrasion from the loaded material. Without the protective wear plate covering, the bucket shell wears rapidly and may develop a structural failure or perforation. The sheared bolts must be replaced and the plates repositioned to restore full coverage before the machine returns to heavy-load operation.

125. B — The worn coupler bores allow the attachment pins to shift under dynamic digging and lifting loads. A static visual check may show secure engagement, but the 3 mm of wear allows movement that can progress to disengagement under the dynamic forces of normal operation. The coupler must be rebuilt or replaced before the machine returns to service.

126. C — The cab's isolation mounts have deteriorated, allowing the frame's normal vibration level (within specification at the frame) to transmit directly to the cab without the designed isolation. The cab amplifies the vibration and transmits it to the operator through the seat and controls. Replacing the deteriorated cab mounts restores the designed vibration isolation.

127. A — A visual inspection confirms the locks are in the engaged position, but it cannot verify the locks can hold the attachment against a force. The tilt test applies a dynamic load that simulates the

forces of digging and lifting. A poorly locked coupler releases during the tilt test, revealing a failure mode that visual inspection alone cannot detect.

128. D — The repaired weld in a high-stress location should be specifically re-inspected at every subsequent NDE interval. Repair welds are more susceptible to crack re-initiation than original welds because the heat-affected zone, weld toe geometry, and residual stresses from the repair process create conditions favorable for new fatigue crack formation.

129. C — Internal corrosion at the ROPS tube base is the most critical damage location. The base experiences maximum bending stress during a rollover. Any wall thickness reduction from corrosion directly reduces the ROPS's energy absorption capacity. The damage is hidden inside the tube and cannot be detected without removing the ROPS for inspection or using ultrasonic thickness measurement.

130. A — The slotted bolt holes allow the technician to position the wear edge precisely relative to the bucket cutting edge. The slots accommodate minor variations in bucket dimensions from previous wear, repairs, or manufacturing tolerances. The technician slides the wear edge to the optimal position within the slots before tightening the bolts.

131. B — The raised seat position changes the operator's eye point relative to the windows, mirrors, and rear camera display. The altered sight lines reduce visibility of the work area, blind spots, and surrounding personnel. The increased risk of struck-by incidents from reduced visibility is the primary safety concern beyond the ergonomic discomfort of the incorrect seating position.

132. A — The battery returns $5 \text{ kWh} \times 0.92 = 4.6 \text{ kWh}$ per operating hour. The 8% loss (0.4 kWh) is dissipated as heat inside the battery cells during the charge and discharge chemical reactions. The net 4.6 kWh of recovered energy supplements the diesel engine's output, reducing fuel consumption proportionally to the electrical energy that replaces diesel-generated mechanical energy.

133. D — A cell venting event indicates internal cell failure that may escalate to thermal runaway. All personnel must be evacuated, a safety perimeter established, and the battery enclosure must not be opened. The chemical odour confirms electrolyte release — the organic solvent electrolyte is both toxic and flammable. Only trained HV emergency response personnel should approach and assess the battery.

134. B — The battery-electric machine eliminates the recurring maintenance costs of engine oil changes, filter replacements, coolant service, injector service, DPF cleaning, and DEF system service. These costs

significantly exceed the added HV system inspections and battery thermal management. Electric motors have virtually no wear items, and power electronics require minimal maintenance.

135. C — The crossover SOC is dynamically calculated by the energy management controller. The controller considers the current duty cycle intensity, ambient temperature (which affects battery performance), battery state of health (which affects safe operating range), remaining work duration, and the diesel engine's current fuel efficiency operating point. The controller continuously optimizes the crossover to minimize total energy cost while maintaining battery longevity.