

PRACTICE EXAM 7: RED SEAL 421A

SIMULATION (135 QUESTIONS)

1. A technician is dispatched to repair a hydraulic hose failure on a machine that has spilled approximately 80 litres of hydraulic oil onto the ground at a remote construction site. After completing the hose repair, what regulatory obligation must be addressed regarding the spilled oil before leaving the site?

A. No action is required for spills under 100 litres on a construction site — the natural ground absorption process is considered an approved remediation method

B. Spread absorbent material over the spill area and leave it in place for the next rainfall to wash the absorbed oil into the surrounding soil naturally

C. Contain and clean up the spill using approved absorbent materials, collect the contaminated soil and absorbent for proper disposal, and report the spill if it exceeds the provincial reportable quantity threshold

D. Dig a trench downhill from the spill to prevent the oil from reaching any watercourse, and cover the spilled area with clean fill material before departing

2. A technician is performing a pre-use inspection on a nylon lifting sling (web sling) before using it to lift a transmission. The technician notices several small cuts on the sling's surface that expose the inner fibres, and the webbing has a stiff, hard texture in one section. What is the correct assessment?

A. The sling must be removed from service — exposed inner fibres from cuts and stiffened webbing from chemical or heat exposure both indicate the sling's structural integrity is compromised and it cannot be used for lifting

B. The small cuts are cosmetic damage to the protective outer cover only and do not reduce the sling's load rating — the inner loadbearing fibres are a different material

C. The sling may be used for loads up to 50% of its rated capacity to account for the surface damage — the exposed fibres indicate approximately half the webbing crosssection remains intact

D. The stiffened section can be softened by soaking the sling in warm soapy water for 30 minutes, which restores the fibre flexibility and returns the sling to its full rated capacity

3. A new apprentice technician is assigned to assist with a task that requires handling a chemical product. The apprentice asks the senior technician what training is required before working with the chemical. Under WHMIS 2015, what is the employer's obligation?

A. The apprentice requires no additional training — WHMIS 2015 training is provided through the apprenticeship schooling program and is valid for all workplaces

B. The employer must provide sitespecific WHMIS 2015 education and training that covers the hazards of the specific products used at that workplace, how to read labels and SDSs, and the workplace's specific safe handling procedures

C. The apprentice may begin working with the chemical immediately if supervised by a trained technician who provides verbal instructions before each task

D. The senior technician may provide the WHMIS training verbally during the lunch break and sign the apprentice's training record to confirm completion

4. A maintenance crew is performing a major repair on a diesel engine inside a partially enclosed maintenance bay. The engine has been removed from the machine and is mounted on an engine stand. The crew plans to run the engine on the stand for a postrepair breakin procedure. What hazard must be controlled before running the engine indoors?

A. Noise exposure — the engine must be enclosed in a sounddampening barrier to reduce the noise level below 85 dBA before the breakin run begins

B. Fire risk — the engine fuel supply must be connected through a fire-rated bulkhead fitting and a fire extinguisher must be positioned within arm's reach of the operator

C. Vibration — the engine stand must be bolted to the concrete floor to prevent the stand from walking across the bay during the break-in run

D. Exhaust gas exposure — the engine exhaust must be ducted to the outside or a local exhaust extraction system used to prevent carbon monoxide and diesel exhaust accumulation in the enclosed bay

5. A technician is working alone in a remote location servicing a machine. The employer's safe work procedures require a check-in protocol for lone workers. The technician has missed the scheduled check-in by 30 minutes. What should the employer's response be according to standard loneworker protocols?

A. Wait an additional 30 minutes for the technician to check in — a one-hour grace period is standard before initiating any emergency response for a missed loneworker check-in

B. Send a text message to the technician's mobile phone and wait for a reply — cellular communication attempts satisfy the check-in verification requirement

C. Initiate the employer's escalation procedure — attempt to contact the technician by all available means, and if contact cannot be established within the defined response time, dispatch assistance to the technician's known location

D. Log the missed check-in and address it at the next safety meeting — isolated missed check-ins are a training issue, not an emergency response trigger

6. A heavy equipment shop has designated a battery charging area with proper ventilation, an eyewash station, and acid-resistant flooring. A technician is charging a set of flooded lead-acid batteries. During charging, one battery begins producing an audible bubbling sound and the electrolyte level is visibly low. What is the immediate concern?

- A. The low electrolyte exposes the battery plates to air, which accelerates plate sulfation, and the bubbling indicates hydrogen gas production — the technician must add distilled water to cover the plates before continuing the charge, and verify ventilation is adequate to prevent hydrogen accumulation
- B. The bubbling sound indicates the battery has reached full charge and the charger should be disconnected to prevent overcharging and plate damage
- C. The low electrolyte indicates an internal battery crack that is allowing acid to leak from the case — the battery must be removed from the charger and disposed of immediately
- D. The bubbling is a normal indication that the battery is accepting charge at the maximum rate and the electrolyte level will return to normal as the battery approaches full charge

7. A technician must transfer a large, heavy hydraulic pump from the shop floor to a workbench using a manual chain hoist mounted on an overhead monorail. Before beginning the lift, what critical information must the technician verify about the chain hoist?

- A. The chain hoist's most recent load test date, which must be within the last 12 months to confirm the hoist is certified for lifting at its rated capacity
- B. The chain hoist's chain length, which must be sufficient to reach the pump on the floor and raise it to the workbench height without reaching the chain stop limit
- C. The chain hoist's hook latch condition, which must be intact to prevent the sling from sliding off the hook during the lateral monorail travel to the workbench
- D. The chain hoist's rated capacity, which must exceed the weight of the pump and rigging combined — and the monorail beam and mounting hardware must also be rated for the load

8. A technician observes that a compressed gas cylinder in the shop has been stored without its valve protection cap. The cylinder is a full oxygen cylinder stored next to the welding station. What specific risk does the missing valve cap create?

- A. The open valve allows oxygen to leak into the shop atmosphere, increasing the oxygen concentration and creating an enriched environment that accelerates combustion
- B. Dust and debris enter the valve opening and contaminate the regulator when it is eventually attached, causing inaccurate pressure readings during gas delivery
- C. If the cylinder is knocked over and the valve breaks off, the pressurized gas escapes from the narrow opening at extreme velocity, converting the heavy cylinder into an uncontrolled projectile
- D. The ultraviolet light from the nearby welding arc degrades the valve seat material when the cap is not installed, causing the valve to leak when a regulator is connected

9. A technician is cleaning parts in a solvent tank. The technician's hands are bare because the solvent "doesn't feel irritating." The product SDS lists the solvent as a skin sensitizer and a chronic health hazard. Why is the technician's lack of PPE dangerous despite the absence of immediate irritation?

- A. Solvents evaporate quickly from bare skin and the rapid cooling effect masks the chemical burn that is occurring beneath the surface of the skin tissue
- B. The solvent is absorbing through the skin into the bloodstream without causing immediate pain or visible damage, producing cumulative internal organ damage over time, and the skin sensitization may trigger a severe allergic reaction to future exposures
- C. The solvent is dissolving the skin's natural oil barrier and will cause delayed contact dermatitis within 24–48 hours of the unprotected exposure event
- D. The solvent vapour from the open tank is being inhaled at a higher rate because the technician's hands are wet with the product, which increases the surface area for vapour generation

10. A technician is replacing a highpressure hydraulic fitting on a machine. The old fitting was secured with thread sealant tape (Teflon tape). The replacement fitting is an Oring face seal (ORFS) type. Should the technician apply thread sealant tape to the new ORFS fitting?

A. No — ORFS fittings seal by compressing an Oring against a flat machined face, not through thread sealing. Applying tape to the threads can prevent the fitting from reaching the correct torque, interfere with Oring compression, and introduce tape fragments into the hydraulic circuit

B. Yes — all hydraulic fittings require thread sealant tape regardless of the seal type to provide a backup seal in case the primary Oring seal fails under pressure

C. No — but a liquid anaerobic thread sealant should be applied instead, which provides both a thread seal and a threadlocking function that prevents the fitting from loosening under vibration

D. Yes — but only one wrap of tape should be used on ORFS fittings compared to the three wraps used on NPT fittings, to prevent overthickening the thread area

11. A diesel engine has been operating with a persistent 15% fuel dilution in the engine oil (confirmed by oil analysis) for the last two sampling intervals. The engine is not exhibiting any driveability symptoms. What is the longterm risk of continued operation with this fuel dilution level?

A. Fuel dilution above 5% causes the oil to form an emulsion that clogs the oil filter bypass valve, eventually starving the turbocharger bearing of oil

B. Fuel dilution at 15% increases the oil's viscosity above the pump's maximum rating, overloading the oil pump drive gear and causing pump failure

C. Fuel dilution at this level has no measurable effect on engine life — modern synthetic oils are formulated to tolerate up to 20% fuel content without degradation

D. The fuel thins the oil below its designed viscosity, reducing the oil film strength at all bearing surfaces — the resulting metaltometal contact accelerates main bearing, rod bearing, cam bearing, and piston pin wear progressively until a catastrophic failure occurs

12. A technician is measuring the free play (backlash) in a gear-driven engine timing train during an overhaul. The measured backlash between the crankshaft gear and the idler gear is 0.40 mm. The OEM specification is 0.05–0.15 mm. What is the consequence of this excessive backlash?

- A. The excessive backlash changes the compression ratio of the engine because the camshaft position shifts relative to the crankshaft by the amount of the gear lash
- B. The timing train will produce a metallic rattling noise at idle that disappears under load, but the timing accuracy is not affected because the gears always drive in one direction
- C. The excessive backlash produces gear noise and allows timing variation — during load reversals (deceleration, compression braking), the gears move through the lash gap, producing impact loading and allowing the camshaft timing to shift momentarily
- D. The backlash has no functional consequence — gear timing trains are designed to operate with progressively increasing backlash throughout their service life

13. A diesel engine is equipped with a unit injector system where the camshaft mechanically actuates each injector through a rocker arm. After replacing a camshaft during an engine overhaul, the engine produces noticeably more combustion noise and smoke than before the repair. What is the most likely cause?

- A. The replacement camshaft has a different base circle diameter than the original, which changes the effective valve lash on all cylinders simultaneously
- B. The replacement camshaft has a different injection lobe profile — either higher lift or different timing than the original — producing an injection event that differs from the ECM's programmed fuel map
- C. The replacement camshaft bearings are tighter than the worn original bearings, creating higher friction that reduces the camshaft's rotational speed relative to the crankshaft
- D. The timing gears were not aligned to the correct timing marks during installation, and the camshaft is operating one tooth off its designed position relative to the crankshaft

14. A technician discovers that the engine oil in a diesel engine has turned a milky grey colour. The coolant level has dropped by 2 litres and the oil level has risen above the full mark. There are no external leaks. What is the most probable cause and what is the immediate risk?

A. Coolant is entering the engine oil through an internal leak path — the milky oil has lost its lubricating properties and the contaminated oil will destroy bearing surfaces rapidly. The engine must be shut down immediately and not restarted until the leak source is identified and repaired, and the oil system is flushed

B. The oil has been overfilled with the wrong oil type, which has a different colour base stock that produces the grey appearance when mixed with the existing oil

C. Condensation from operating in cold, humid conditions has mixed with the oil to produce the milky appearance — running the engine at operating temperature for 30 minutes will evaporate the moisture and restore normal oil colour

D. The fuel return circuit has a leak that is routing diesel fuel into the crankcase, diluting the oil and producing the colour change and level increase observed on the dipstick

15. A heavy equipment diesel engine is equipped with an intake manifold heater (grid heater or flamestart system) for cold weather starting. The heater operates for a fixed period during the preheat cycle before cranking begins. In extremely cold conditions (-35°C), the engine still fails to start even with the preheat cycle. What additional system would improve coldstart capability?

A. A turbocharger preoiler that circulates warm oil through the turbocharger bearings before cranking, reducing the drag that cold oil creates on the turbocharger shaft

B. A higheroutput starter motor that cranks the engine faster, producing higher compression temperature from the increased piston speed during the compression stroke

C. An engine block heater that preheats the coolant and block casting, raising the cylinder wall temperature above the threshold where compression heat alone cannot achieve autoignition in the extreme cold

D. A fuel tank heater that warms the diesel fuel above its cloud point, preventing the wax crystals in cold fuel from clogging the primary filter during cranking

16. A technician is performing a valve lash adjustment on a sixcylinder diesel engine. The service manual specifies setting the lash with the engine at room temperature. The technician adjusts the valves with the engine warm — it was shut down 10 minutes ago. What effect does adjusting valve lash on a warm engine have?

A. Warm valve adjustment produces a lash setting that is slightly tighter than the cold specification because the valve stem has expanded, reducing the actual gap

B. Warm valve adjustment produces a lash setting that is wider than the cold specification because the rocker arm has expanded more than the valve stem

C. Temperature has no effect on valve lash because the thermal expansion of all valve train components is equal and selfcancelling in the lash dimension

D. Warm valve adjustment produces a tighter effective lash at operating temperature because the components have not yet reached their full thermal expansion — the lash will tighten further as the engine reaches full operating temperature, potentially preventing the valves from fully closing

17. A technician is investigating an engine that consumes excessive crankcase oil but shows no blue smoke in the exhaust. Compression and leakdown tests are within specification. The turbocharger is not leaking. Where should the technician look for the oil consumption source?

A. The crankcase ventilation system — if the CCV system is routing oil mist to the intake at an excessive rate due to a failed separator, the oil enters the combustion chamber through the intake manifold and is burned at a rate that produces no visible smoke

B. The cylinder head drainback passages — if a passage is blocked, oil pools on the head and overflows into the intake or exhaust ports during engine operation

C. The exhaust manifold gasket — a failed gasket allows oil from the cylinder head oil gallery to seep onto the hot manifold surface, where it vaporizes without entering the exhaust stream

D. The valve cover gasket — oil leaking externally from the valve cover is dripping onto the exhaust manifold and burning off before it reaches the ground, producing an oil smell but no visible leak

18. A technician is diagnosing a common rail diesel engine that starts normally but develops a severe misfire under load. Injector backleak tests, compression tests, and valve lash checks are all within specification. The ECM shows no active fault codes. What less common fuel system fault could produce this symptom?

A. The fuel tank pickup tube has a small crack above the fuel level that draws air only when the fuel level is below half tank — but the symptom appears at any fuel level

B. A highpressure fuel line has a hairline crack that seeps fuel only under the peak injection pressures generated during heavyload operation — the leak reduces the pressure pulse at the injector below the minimum required for proper atomization

C. The fuel cooler (if equipped) has an internal restriction that limits fuel flow under heavy demand, starving the HP pump during peak load conditions

D. The fuel return line from the rail to the tank has a kink or restriction that creates backpressure on the injector returns, interfering with injector closing and causing the misfire

19. A technician observes that an engine's exhaust backpressure reading is 25 kPa at rated load. The OEM maximum specification is 7 kPa. The DPF was recently cleaned and the DOC appears unrestricted. What other component could be causing the excessive backpressure?

A. The turbocharger's compressor housing is restricted by oil coke deposits from a previous turbo seal failure, creating resistance on the exhaust side through the shaft connection

B. The EGR valve is stuck in the fully open position, routing a large percentage of the exhaust back into the intake and creating a secondary restriction path

C. The exhaust manifold has accumulated carbon deposits that are restricting the exhaust flow before it reaches the turbocharger turbine inlet

D. A crushed, kinked, or internally collapsed exhaust pipe between the DPF outlet and the tailpipe is restricting exhaust flow downstream of the aftertreatment system — the DPF and DOC are clean but the pipe beyond them is the restriction

20. A technician performs an infrared temperature measurement on the exhaust manifold runners of a sixcylinder engine at idle. Five runners read between 280°C and 310°C, while one runner reads only 150°C. What does the cold runner indicate?

A. The exhaust valve on that cylinder is open and leaking compression, which reduces the combustion temperature and therefore the exhaust gas temperature in that runner

B. The fuel injector on that cylinder is overfuelling and the excess fuel is absorbing combustion heat as it vaporizes, producing a lower exhaust temperature reading

C. The cylinder served by the cold runner is producing significantly less combustion energy than the others — the cylinder is either not receiving fuel, has no compression, or has a severely retarded injection timing that produces incomplete combustion

D. The thermocouple in the infrared thermometer is producing an inaccurate reading on one surface due to the difference in emissivity between the cold and hot manifold sections

21. A technician discovers that a diesel engine's coolant contains visible metallic particles when a sample is drained into a white container. The particles are bright copper colour. What is the most likely source?

A. The oil cooler core is failing — the copperalloy tubes inside the oiltocoolant heat exchanger are eroding from coolant velocity, cavitation, or electrolysis, releasing copper particles into the cooling circuit

B. The water pump impeller is made of copper alloy and is eroding from cavitation damage at the impeller blade tips during highspeed operation

C. The radiator core tubes are copperbrazed construction and the brazing material is dissolving from the exhaust gas contamination in the coolant from a head gasket breach

D. The cylinder liner anticavitation compound (DCA) has reacted with the coolant inhibitor package to precipitate a coppercoloured compound that mimics metallic particles

22. A technician replaces the exhaust manifold gasket on a diesel engine. After the repair, the engine produces a ticking noise from the manifold area that is proportional to engine RPM and loudest immediately after a cold start. The noise diminishes after the engine warms up. What is the cause?

A. The replacement gasket is thicker than the original, changing the exhaust port alignment and creating a turbulence-induced noise at the port entry that decreases as the gasket compresses at operating temperature

B. One of the exhaust manifold bolts was not torqued to specification, allowing a small gap that seals as the manifold thermally expands at operating temperature

C. The ticking noise is exhaust gas escaping through the newly machined manifold surface before the gasket has fully seated — the gasket requires 50 operating hours to achieve its final seal compression

D. One or more exhaust manifold bolts are not properly torqued or the manifold is warped — the cold manifold has a gap that leaks exhaust gas, and thermal expansion of the manifold closes the gap as the engine warms, eliminating the leak and the noise

23. A diesel engine has been in service for 15,000 hours. Oil analysis trends show slowly increasing lead content over the last five samples. All other wear metals are stable. What is the most probable wear source for the increasing lead?

A. The crankshaft main bearing journals have developed microscopic surface cracks that are releasing lead particles from the journal's induction-hardened surface layer

B. The overlay layer on the engine's trimetal connecting rod or main bearing shells is wearing — the outer lead-tin overlay is the softest and first layer to wear through on trimetal bearings, releasing lead into the oil

C. The piston pin bushings contain lead as a bearing surface material and are wearing at the pin-bushing interface under the combustion loading

D. The camshaft bearings are releasing lead from their bearing surface as the cam lobes generate cyclical impact loads on the bearing during each valve opening event

24. A technician is inspecting the intake valves on a diesel engine during a cylinder head overhaul. Several valves show a buildup of hard, black carbon deposits on the valve tulip and stem in the port area. The engine has a history of chronic lowload operation. What effect do these deposits have?

- A. The deposits improve the valve's heat transfer by increasing the surface area exposed to the incoming air charge, which helps cool the valve
- B. The deposits have no operational effect because they are downstream of the combustion chamber and do not interact with the sealing surfaces
- C. The deposits restrict airflow through the intake port, reduce the cylinder's volumetric efficiency, and may prevent the valve from seating properly if deposits accumulate on the seat area — causing compression loss and potential valve burning
- D. The deposits protect the valve surface from the erosive effects of the highvelocity intake air charge and actually extend the valve's service life

25. A diesel engine equipped with a wastegate turbocharger produces the correct boost pressure at rated load and RPM, but produces 20% more boost than specified at low RPM during lightload acceleration. The engine is overfuelling at low RPM. What is the most likely cause?

- A. The wastegate actuator diaphragm or capsule has developed a leak — the actuator cannot open the wastegate at low boost pressures, and the wastegate remains closed until higher pressures physically force it open, producing excessive lowRPM boost that the ECM compensates for by overfuelling
- B. The turbocharger bearing housing drain is partially restricted, causing oil to accumulate and create additional resistance that keeps the turbo spinning faster than designed at low RPM
- C. The charge air cooler has a partial restriction that increases the boost pressure reading at the intake manifold sensor without actually increasing the air mass entering the cylinders
- D. The turbocharger compressor wheel has been replaced with a unit from a larger turbo, increasing the compressor's flow capacity beyond the engine's air demand at low speed

26. A technician is performing a cylinder cutout test on a misfiring sixcylinder diesel engine using the OEM diagnostic software. When cylinder 4 is disabled (injector turned off), the engine's rough idle smooths out slightly rather than roughening further. What does this indicate?

A. Cylinder 4's injector is mechanically stuck open and is delivering fuel continuously — disabling the injector command has no effect because the injector is already bypassing the ECM's control

B. Cylinder 4 is contributing negatively to engine operation — it may be misfiring, firing late, or producing a combustion event that opposes the normal power stroke, and removing its contribution improves overall engine balance

C. The cylinder cutout test is inconclusive — the slight improvement could be caused by the reduced total fuel volume, which leans the remaining cylinders and improves their combustion

D. Cylinder 4's compression is zero and the open cylinder is acting as an air pump that generates a vacuum pulse opposing the normal crankshaft rotation rhythm

27. A diesel engine's SCR system requires the exhaust gas temperature to be above a minimum threshold (typically 200°C) before the DEF dosing begins. During prolonged idle operation, the exhaust temperature remains below this threshold. What consequence does this have for the emission system?

A. The DEF pump runs continuously even though dosing is not occurring, consuming the pump's service life without performing any emissionreduction function

B. The SCR catalyst cools below its lightoff temperature and must be reheated during the next load event, causing a temporary increase in visible exhaust smoke

C. The ECM commands an active DPF regeneration to raise the exhaust temperature above the SCR threshold and enable DEF dosing during the idle period

D. The SCR system cannot reduce NOx emissions during the idle period — if the machine idles for extended periods, the cumulative NOx emissions exceed the programmed threshold and the ECM triggers a progressive power derate to force the operator to increase load

28. A technician is testing a diesel engine's glow plug system. The glow plugs should draw approximately 6 amperes each on a fourcylinder engine. The technician measures the total circuit current at 12 amperes during the glow cycle. What does this indicate?

A. Two of the four glow plugs are not drawing current — either the plugs have opencircuit heating elements or their supply wiring is interrupted, leaving two cylinders without coldstart combustion assistance

B. The glow plug controller is functioning correctly — the 12ampere reading represents the normal average current after the initial inrush period has passed

C. All four glow plugs are operating but at reduced power because the battery voltage has dropped below the minimum threshold during the highcurrent glow cycle

D. The glow plug relay contacts have developed high resistance that limits the total circuit current to 12 amperes regardless of how many plugs are functioning

29. A diesel engine's exhaust gas recirculation (EGR) cooler has been replaced three times in 10,000 operating hours due to internal coolanttoexhaust leakage failures. What root cause should be investigated to prevent a fourth failure?

A. The coolant is the wrong specification — the coolant chemistry is attacking the EGR cooler's internal tube material, causing premature corrosion that leads to tube perforation

B. The EGR valve is opening too far, routing excessive exhaust volume through the cooler and creating thermal shock from the hot gas contacting the cold coolant tubes

C. The cooling system's thermal cycling (rapid heating and cooling of the EGR cooler tubes during load transitions) is causing fatigue cracking of the tube material — the root cause is a thermostat that allows excessive coolant temperature variation or an EGR valve calibration that exposes the cooler to extreme temperature differentials

D. The EGR cooler mounting brackets are transmitting engine vibration to the cooler housing, causing the internal tubes to fatiguedcrack at their attachment welds

30. A diesel engine's intake manifold pressure sensor reads 102 kPa (approximately atmospheric pressure) at idle. At rated load and RPM, the reading increases to 250 kPa. A technician notes the 250 kPa reading is an absolute pressure reading. What is the actual boost pressure above atmospheric?

A. The actual boost pressure above atmospheric is approximately 148 kPa — calculated by subtracting the atmospheric baseline (102 kPa) from the absolute reading (250 kPa) to determine the gauge pressure

B. The actual boost pressure above atmospheric is approximately 148 kPa (250 kPa absolute minus 102 kPa atmospheric = 148 kPa gauge) — this represents the boost pressure relative to the atmospheric conditions at the test location

C. The actual boost pressure is 250 kPa because the manifold pressure sensor already compensates for atmospheric pressure in its calibration

D. The actual boost pressure cannot be determined from an absolute pressure reading without knowing the barometric pressure from a separate sensor mounted outside the intake system

31. A large mining truck is equipped with a retarder system that provides braking force during loaded downhill travel. The retarder is operated through a separate hand lever. During a loaded descent, the operator notices the retarder effectiveness decreases over the course of the grade. The retarder oil temperature gauge shows the temperature is approaching the maximum limit. What should the operator do?

A. Release the retarder and apply the service brakes to slow the truck — the service brake discs are designed to absorb sustained heat loading that the retarder cannot manage

B. Reduce speed using the service brakes in combination with a lower gear range to reduce the speed at the top of the grade, then reengage the retarder at the reduced speed where it can manage the lower heat generation rate

C. Increase the engine RPM by downshifting to a lower gear — higher engine speed increases the retarder pump flow and restores the retarding force lost to the hot oil

D. Pull to the side of the haul road and park until the retarder oil cools below the operating limit before continuing the descent at the same speed and gear range

32. A technician is performing a steer axle inspection on a motor grader. The kingpin is measured for wear by placing a dial indicator on the bottom of the axle beam and lifting the tire off the ground with a jack. The dial indicator shows 3 mm of vertical movement. The OEM maximum allowable vertical play is 1.5 mm. What component is worn?

- A. The kingpin thrust bearing — which carries the vertical load of the machine at the steer knuckle — has worn, allowing the knuckle and wheel assembly to move vertically on the kingpin
- B. The tie rod end ball joints have worn, allowing the entire steering linkage to move vertically when the wheel is lifted
- C. The wheel hub bearing inner race has migrated inward on the spindle, producing the apparent vertical play at the tire that is measured at the axle beam
- D. The kingpin upper and lower bushings have worn oval, producing both vertical and lateral play that the dial indicator registers as vertical movement

33. A technician inspects a track chain that has been operating in a corrosive saltwater environment (coastal construction). The chain shows unusually rapid pin and bushing wear despite correct track tension and regular lubrication intervals. What is the accelerating factor?

- A. The salt water has dissolved the track shoe grouser tips, changing the ground engagement angle and increasing the load on the pin and bushing interfaces
- B. The salt water is entering the chain joints through the seal failures that the corrosion has caused, washing out the lubricant and creating an abrasive saltwater slurry inside the joints
- C. The salt crystals that dry on the chain surface increase the friction coefficient between the track and the rollers, which pulls the chain tighter during travel and increases wear
- D. Saltwater corrosion attacks the pin and bushing surfaces directly, creating surface pitting that accelerates wear — the corroded surfaces cannot maintain the lubricant film and the pitting acts as stress risers that propagate cracks under cyclical loading

34. A technician is performing a brake pad inspection on a hydraulic disc brake caliper. The outboard pad is worn to 3 mm while the inboard pad still has 8 mm of friction material remaining. What does this uneven wear pattern indicate?

A. The caliper is mounted incorrectly — the mounting bolts are too tight on one side, preventing the caliper from floating to centre itself over the rotor

B. The brake rotor has excessive lateral runout (wobble) that pushes the outboard pad into contact more frequently than the inboard pad during each revolution

C. The caliper slide pins or slider mechanism are seized or corroded — the caliper cannot float to equalize pad contact, so the outboard pad is forced against the rotor while the inboard pad barely contacts

D. The outboard pad is made of a softer friction material than the inboard pad due to a manufacturing mixup in the pad set

35. A wheel loader's front tires consistently show more wear on the outer edge of both tires. No feathering pattern is present. Toe alignment is within specification. What alignment parameter is the most likely cause?

A. Excessive positive camber — both front wheels are tilted outward at the top, concentrating the machine's load on the outer edge of the contact patch and producing the outeredge wear pattern

B. Excessive toeout is causing the tires to scrub sideways, but the wear pattern is concentrated on the outer edge rather than the feathering pattern that toeout normally produces

C. Insufficient caster angle is allowing the tires to wander during travel, creating intermittent outeredge contact that wears the outer tread faster than the centre

D. The front axle oscillation pivot has seized, locking the axle in a slight outward tilt that concentrates load on the outer tread edge of both front tires

36. An operator reports that the air brake system on a machine takes significantly longer to build pressure from startup to operating pressure than it did previously. The governor cutin and cutout pressures are within specification. What is the most likely cause?

A. The air tanks have accumulated internal rust scale that reduces their effective volume, requiring the compressor to produce more total air to fill the remaining volume

B. The air compressor has lost pumping efficiency — worn piston rings, worn cylinders, or damaged valves reduce the compressor's output per revolution, requiring more time to fill the system volume to cutout pressure

C. The air dryer purge cycle has been adjusted to cycle more frequently, and each purge event depletes a portion of the stored air that the compressor must replace

D. The governor's cutin pressure has drifted downward, which makes the total pressure range (cutin to cutout) wider and requires more compressor cycles to traverse

37. A tracked excavator's undercarriage measurement shows the right track's bottom roller tread wear is 30% greater than the left track's bottom rollers. Both tracks have identical operating hours and track tension. What operating pattern could explain this asymmetric wear?

A. The right track's final drive is producing higher torque output than the left, pressing the track chain against the bottom rollers with greater force during operation

B. The machine is routinely oriented with the right side positioned in deeper or softer material during excavation, causing the rightside undercarriage to carry more load per hour than the left

C. The right track chain has stretched more than the left, causing the chain to ride higher on the roller tread surface and concentrate wear on a narrower contact band

D. The machine is consistently working on a righthand side slope (right side downhill) or routinely swinging to the right, which places a disproportionate load on the right undercarriage components and accelerates their wear

38. A technician is bleeding the air from a machine's hydraulic brake system after replacing a caliper. The bleeder screws on each caliper have a specific opening sequence that starts at the caliper furthest from the master cylinder. After completing the bleeding procedure, the pedal still feels spongy. What should the technician check?

A. The master cylinder reservoir cap vent is blocked, preventing air from entering the reservoir as fluid is pumped out through the bleeder screws during the bleeding process

B. The brake fluid viscosity is incorrect — using a fluid with a lower viscosity than specified produces a spongy pedal feel that mimics trapped air in the circuit

C. The bleeder screws were not opened far enough during the procedure, restricting flow and preventing the air bubbles from being pushed out of the caliper bore

D. Air may be trapped in a high point in the brake line routing, a junction fitting, or the master cylinder itself — areas that the standard bleeder screw sequence does not purge, requiring additional techniques such as gravity bleeding or pressure bleeding

39. A dozer operator reports the machine is difficult to steer to the left but steers normally to the right. The machine uses a hydrostatic drive with independent left and right track motors. Charge pressure and main pump pressures are within specification on both sides. What should be investigated?

A. The left track motor — if the motor has excessive internal leakage, it cannot develop the same retarding force as the right motor during left turns, requiring the pump to work harder to create the speed differential needed for the turn

B. The left steering control valve spool has a broken centering spring that prevents it from returning fully to neutral, causing a constant slight leftturn command that the operator must counteract

C. The right track tension is significantly tighter than the left, creating higher rolling resistance on the right side that makes left turns easier and right turns more difficult

D. The left track's final drive brake is partially dragging, creating resistance that counteracts the hydraulic steering effort during left turns while having no effect during right turns

40. A technician is adjusting the toe alignment on the front axle of a wheel loader. The machine has two tie rods — one connecting each steering knuckle to the center link. The technician adjusts the left tie rod but not the right. What problem does this create?

A. The steering wheel position will be centred when the wheels are pointing straight ahead, but the Ackermann geometry will be incorrect because only one side was adjusted

B. The steering wheel will be offcentre when the machine is travelling straight — both tie rods must be adjusted equally (half the total correction on each side) to maintain the steering wheel's centred position during straight travel

C. The toe alignment will be correct but the turning radius will be different between left and right turns because the steering arc geometry has been changed on one side only

D. Only one wheel's toe angle was changed, so the total toe measurement at the front of both tires will not match the specification — both tie rods must be adjusted to bring the fullaxle toe within specification

41. A rigidframe mining truck has a rear axle oil cooler that uses engine coolant to cool the final drive oil. The technician notices the rear axle oil level has increased above the full mark and the oil appears milky. What has failed?

A. The rear axle breather vent has been submerged in a water crossing, allowing water to be drawn into the axle housing through the breather during the postcrossing cooldown

B. The rear axle housing drain plug gasket has deteriorated and is allowing rainwater to seep into the housing during washdown operations

C. The engine cooling system pressure is forcing air into the axle oil through a leaking oil cooler tube, which aerates the oil and produces the milky appearance

D. The rear axle oil cooler has an internal tube failure — engine coolant at higher pressure than the axle oil is leaking through the failed tube into the axle oil circuit, raising the level and producing the milky emulsion

42. A technician measures track shoe grouser height on a dozer and finds the grousers are worn to 60% of their original height. The track chain is at 50% wear. The undercarriage is SALT type. What is the recommended action?

A. Replace the track shoes only — the shoes have worn faster than the chain and can be replaced independently to restore ground engagement without replacing the serviceable chain

B. Replace both the shoes and the chain simultaneously — the mismatched wear rates indicate a system problem that will cause the new shoes to wear prematurely on the existing chain

C. Rotate the shoes 180 degrees so the unworn edge of each grouser becomes the leading edge, extending the shoe service life without requiring replacement

D. No action required — the shoes and chain are both within their service limits and neither component requires service until the 80% wear threshold is reached

43. A technician discovers that a wheel loader's steering accumulator bladder has ruptured. The operator reports no change in steering feel during normal operation. When would the failed accumulator's absence become apparent?

A. The failed accumulator becomes apparent only if the engine stalls or the steering pump fails — the accumulator provides the stored energy for emergency steering, and without it, the operator would have zero steering capability after pump flow ceases

B. The failed accumulator becomes apparent during aggressive steering manoeuvres when the pump cannot keep up with the high flow demand

C. The failed accumulator becomes apparent during cold starts when the pump cannot generate sufficient flow to fill both the steering circuit and the accumulator simultaneously

D. The failed accumulator is never apparent to the operator — the accumulator provides only a dampening function that smooths pressure pulsations in the steering circuit

44. A technician is inspecting brake chamber pushrod travel on an air brake equipped machine using the applied stroke method. With a full brake application (approximately 690 kPa), the pushrod stroke on one chamber measures 55 mm. The maximum allowable stroke for this Type 24 chamber is 57 mm. The brake is within specification but close to the limit. What does this indicate about the brake condition?

A. The brake is correctly adjusted and the measurement confirms the automatic slack adjuster is maintaining the stroke within the OEM specification range

B. The brake linings are significantly worn — the pushrod must travel 55 mm (close to the 57 mm limit) before the shoes contact the drum, leaving very little remaining lining material before the brake exceeds the adjustment limit

C. The brake drum has been machined oversize during a previous service, increasing the shoetodrum clearance and requiring more pushrod stroke to achieve shoe contact

D. The air chamber diaphragm has stretched from age, absorbing stroke internally before transmitting force to the pushrod, producing a reading that overestimates the actual shoetodrum clearance

45. A technician discovers that the multipiece rim on a large OTR tire has a visible crack in the lock ring. The tire is currently inflated and mounted on the machine. What is the immediate required action?

A. Remove the machine from service, deflate the tire from maximum distance using a remote valve tool or extension hose, and do not approach the rim assembly until the tire is fully deflated and the valve core has been removed

B. Spray the cracked area with soapy water to check for air leakage — if no bubbles appear, the crack is nonstructural and the tire can continue in service until the next scheduled maintenance

C. The cracked lock ring must be replaced, but the tire can remain inflated during the ring change because the bead and flange provide adequate retention without the lock ring

D. Mark the crack with paint and monitor it at each preshift inspection — lock ring cracks that do not extend more than 25% of the ring circumference are within the acceptable service limit

46. A technician measures the nitrogen precharge on a hydropneumatic suspension strut at ambient temperature of 25°C. The reading is 2,500 kPa. The OEM specification states 2,750 kPa at 20°C. Before concluding the strut is undercharged, what must the technician account for?

A. The pressure gauge accuracy tolerance — most field gauges are $\pm 5\%$, which means the 2,500 kPa reading could be as high as 2,625 kPa, still below specification

B. The time since the machine was last operated — the strut requires 24 hours at rest before the gas pressure stabilizes to a measurable value

C. The ambient temperature is higher than the specification's reference temperature, which causes the nitrogen pressure to read higher than it would at 20°C — but the measured 2,500 kPa is still below the 2,750 kPa specification even after temperature correction upward, confirming the strut is undercharged

D. The temperature difference — at 25°C, the gas pressure is higher than it would be at 20°C. The technician must use the OEM temperature correction chart to calculate what the current 2,500 kPa reading equates to at the 20°C reference before comparing to the specification

47. A technician measures 24.2 volts at the battery terminals on a machine with the engine off and all loads disconnected. The machine has been sitting for 48 hours. This is a 24V system with two 12V batteries in series. What state of charge does the total OCV represent?

A. Approximately 75% — a fully charged 24V series bank reads approximately 25.2–25.4V OCV after a 48hour rest. The 24.2V reading indicates the bank is approximately threequarters charged and should be charged and tested before returning to service

B. The battery bank is fully charged — 24.2V is within the normal range for a 24V system after an extended rest period

C. The battery bank is completely discharged — any reading below 25.0V on a 24V bank confirms total depletion of both batteries

D. The OCV reading is meaningless without a load test — open circuit voltage cannot indicate state of charge on leadacid batteries

48. A heavy equipment machine has two identical alternators driven by a single engine — one charges the primary 24V system and the other charges a secondary 12V system for auxiliary equipment. Both alternators are belt-driven from the crankshaft. The 24V alternator produces correct charging voltage but the 12V alternator charges at only 11.8V at idle. The belt is tight. What should be checked?

A. The 12V alternator's drive belt tension should be increased beyond the standard specification because the 12V alternator requires more belt grip than the 24V unit

B. The 12V alternator's bearings are seized and the lower-than-normal charging voltage is caused by the alternator shaft not spinning at the correct speed

C. The 12V alternator's voltage regulator, field circuit, stator output, and rectifier should be tested — the low voltage at idle indicates the alternator cannot produce its rated output and the fault is within the 12V alternator or its control circuit

D. The 12V system battery is fully charged and the alternator is correctly reducing its output to 11.8V to prevent overcharging the auxiliary battery bank

49. A machine's CAN bus termination resistance measures 120 ohms instead of the expected 60 ohms. What does this indicate?

A. Both termination resistors have increased in value from 120 ohms to 240 ohms each, producing a parallel total of 120 ohms instead of the expected 60 ohms

B. An additional termination resistor has been added to the bus, reducing the total impedance below the 60ohm specification and producing the 120ohm reading through a complex impedance interaction

C. The CAN bus has a short between CANH and CANL that is adding a low-resistance path in parallel with the termination resistors, pulling the reading up to 120 ohms

D. One of the two 120ohm termination resistors has failed open — only one resistor remains in the circuit, reading its full 120 ohms instead of the 60ohm parallel combination of two 120ohm resistors

50. A technician discovers that a previous repair replaced a 15ampere blade fuse in a solenoid circuit with a 30ampere fuse "because the 15ampere fuse kept blowing." The circuit has been operating with the 30ampere fuse for several hundred hours without issue. What hazard does this create?

A. The 30ampere fuse allows the solenoid to draw twice its rated current, which has been progressively overheating the solenoid coil and will eventually cause the coil to short and fail

B. The 30ampere fuse defeats the circuit's overcurrent protection — the wiring in this circuit is rated for 15ampere protection and may now overheat and cause a fire if the original fault (that was blowing the 15ampere fuse) returns or a new fault develops

C. No hazard exists — the 30ampere fuse provides adequate protection for the circuit because fuse sizes are selected based on the wire gauge, which is the same in both cases

D. The 30ampere fuse produces a higher voltage drop than the 15ampere fuse, reducing the solenoid's operating voltage and causing it to perform sluggishly

51. A technician measures the voltage at a fuel injector connector during an active ECM command. The DMM reads a steady 24V DC. However, the ECM should be delivering a PWM signal at 75% duty cycle. Why does the DMM show 24V DC instead of a PWM reading?

A. A standard DMM set to DC volts averages the PWM signal and displays the average voltage — at 75% duty cycle, the average is 75% of 24V = 18V, but the DMM autoranging rounds to 24V because it reads the peak voltage instead

B. The DMM does not have PWM measurement capability — it averages the switching signal and displays the RMS equivalent. The technician must use a DMM with duty cycle or frequency measurement mode, or an oscilloscope, to see the actual PWM waveform

C. The ECM has defaulted to continuous 24V output instead of PWM because it has detected a fault in the injector circuit and is commanding maximum fuel delivery as a limp-home strategy

D. The wiring between the ECM and the injector has a short to battery voltage that is overriding the ECM's PWM signal with a constant 24V supply from the vehicle electrical system

52. A technician replaces a failed wheel speed sensor on an ABS-equipped machine. After installation, the ABS warning light remains on and a DTC for that sensor is active. The technician confirms the sensor is the correct OEM part number and is connected properly. What is the most likely installation error?

A. The replacement sensor was shipped without a magnet and must have a separate magnet installed in the sensor bore before it can produce a signal

B. The ABS module requires a sensor registration procedure through the OEM diagnostic software before it will accept a replacement sensor on any channel

C. The sensor orientation is incorrect — the sensor must be clocked to a specific rotational position in the mounting bore to align its sensing element with the reluctor tooth path

D. The sensor air gap to the reluctor wheel is incorrect — the sensor is either too far from or too close to the reluctor teeth, producing a signal that is outside the ABS module's acceptable amplitude range

53. A machine's ECM has a keepalive memory (KAM) circuit that maintains adaptive learned values, DTCs, and clock functions while the machine is shut down. The KAM circuit draws 15 milliamps from the battery. The machine will be parked for 90 days. Will the KAM drain the batteries?

A. No — 15 mA is insignificant over 90 days and the batteries will maintain adequate charge to start the machine when it returns to service

B. Yes — 15 mA continuously for 90 days consumes approximately 32 Ah of battery capacity ($0.015\text{A} \times 2,160$ hours). On a typical 210 Ah battery bank, this represents approximately 15% of total capacity, and combined with the battery's natural self-discharge rate, the bank may be below starting threshold after 90 days

C. No — the ECM's internal power management system disconnects the KAM circuit after 72 hours of inactivity and the battery drain drops to zero

D. Yes — but only if the machine is parked in cold temperatures. At warm temperatures, the battery's self-recharge rate from chemical activity exceeds the 15 mA drain

54. A machine has three pressure sensors connected to the same ECM. Sensors 1 and 3 produce correct readings. Sensor 2 reads 0.0V at all times regardless of applied pressure. The technician measures 5.0V reference and good ground at the sensor 2 connector with the sensor disconnected. What is the fault?

A. The ECM's internal signal conditioning circuit for sensor 2 has failed and cannot process the incoming signal regardless of its value

B. The wiring between the ECM and sensor 2 has a short to ground on the signal wire that pulls the signal to 0V regardless of what the sensor produces

C. Sensor 2 has failed internally — the sensing element has either opencircuited or shorted to ground, producing a fixed 0V output. The correct reference and ground at the disconnected connector confirm the wiring is intact

D. The sensor 2 signal wire in the harness has a short to the 5V reference wire, which should produce 5V rather than 0V — this rules out a signal wire fault

55. A technician is diagnosing an intermittent starter engagement issue. The engine sometimes cranks normally and sometimes produces a loud grinding noise from the starter area before engaging. What is the most likely cause?

A. The battery voltage is borderline — on cold mornings the voltage drops below the solenoid's minimum pullin threshold, causing the pinion to engage slowly and grind against the ring gear

B. The starter solenoid's pullin winding is failing intermittently, causing the pinion to extend partway before the main contacts close, resulting in the pinion contacting the ring gear teeth at an angle

C. The flywheel ring gear has damaged or missing teeth in one section — when the engine stops with the starter pinion aligned with the damaged section, the next start attempt produces grinding as the pinion cannot fully mesh

D. The starter drive mechanism (Bendix or overrunning clutch) is worn — the pinion does not fully extend or retract consistently, sometimes engaging the ring gear cleanly and sometimes catching on the tooth faces at an incorrect engagement depth

56. A technician is testing a machine's charging system under load. With the engine at rated RPM and all electrical loads turned on, the alternator produces 27.5V at 95% of its rated current. The alternator's rated output is 150 amperes. This means the alternator is producing 142.5 amperes. What concern does this operating point raise?

A. The alternator is operating near its maximum continuous output — running at 95% of rated capacity continuously generates excessive heat, shortens brush and bearing life, and leaves no reserve for additional loads or coldweather starting demands. The electrical load analysis should be reviewed and the alternator may need to be upsized

B. No concern — alternators are designed to operate continuously at their rated output and 95% is well within the design margin

C. The alternator should be replaced immediately — operating above 90% of rated output indicates the alternator is failing and cannot be trusted for continued service

D. The high output indicates the batteries are severely discharged and are pulling the alternator to nearmaximum output to recover — once the batteries are fully charged, the alternator output will drop to a normal level

57. A technician is troubleshooting an ECMcontrolled proportional solenoid that should produce variable flow based on the ECM's PWM command. The solenoid is commanded at 50% duty cycle but produces either full flow or zero flow — there is no proportional control. The solenoid coil resistance is within specification. What is the most likely cause?

A. The ECM's PWM output driver has failed and is producing either fullon or fulloff signals instead of the variable duty cycle — the driver transistor has failed into a switching mode

B. The solenoid's internal spool is sticking in either the fully open or fully closed position due to contamination, varnish, or mechanical binding — the spool cannot hold an intermediate position despite receiving the correct proportional electrical command

C. The PWM frequency is incorrect — the ECM is switching the solenoid at a frequency that does not match the solenoid's electrical time constant, causing the spool to respond to each individual pulse rather than averaging them into a proportional position

D. The solenoid return spring has broken, eliminating the mechanical force that opposes the electrical force and determines the proportional position — without the spring, the spool slams fully open when any command is present and fully closed when the command is removed

58. A technician is diagnosing a machine with a flickering check engine light that illuminates for exactly 1 second and then turns off for exactly 3 seconds, repeating this pattern continuously. No other symptoms are present. What does this regular pattern most likely indicate?

A. The ECM is performing a selfdiagnostic routine that produces the flashing pattern as a visual confirmation that the diagnostic cycle is active

B. The alternator is producing AC ripple at a frequency that causes the ECM to reset its check engine light output at the ripple frequency

C. A wiring fault is producing a short circuit that energizes the light for 1 second until the thermal overload protection in the circuit opens, then closes again after 3 seconds of cooling

D. The ECM is flashing a diagnostic blink code — some systems communicate fault codes by flashing the check engine light in a defined pattern when a specific code storage condition exists or when the system enters a diagnostic mode

59. A heavy equipment machine's electronic throttle operates through a throttle position sensor (TPS) and a foot pedal position sensor (APPS) connected to the ECM. The ECM compares the two signals for validity. If the TPS reads 4.2V but the APPS reads only 2.1V at full throttle (both should read approximately 4.5V at full throttle), what does the ECM do?

A. The ECM averages the two signals (3.15V) and commands the engine to operate at the average throttle position regardless of the disagreement

B. The ECM selects the higher signal (4.2V) and operates normally because the higher reading ensures the operator's fullthrottle intent is honoured

C. The ECM detects the signal disagreement exceeding the allowable correlation window and enters a derate or limp mode — it will not honour the higher signal because it cannot determine which sensor is correct

D. The ECM uses only the foot pedal (APPS) signal for throttle control and ignores the TPS entirely, because the APPS is the primary operator input device

60. A technician needs to perform an accurate battery load test on a 12V battery rated at 900 CCA. The load test applies a load equal to 50% of the CCA rating for 15 seconds. What is the pass/fail criterion?

A. The battery passes if the voltage remains above 9.6V (at 21°C) after 15 seconds under the 450ampere load — a voltage below 9.6V at the end of the 15second period indicates the battery cannot deliver its rated current and must be replaced

B. The battery passes if the voltage remains above 12.0V during the entire 15second test — any voltage below 12.0V indicates an internal cell fault

C. The battery passes if the voltage drops to exactly 0V at the end of the test — this confirms all cells discharged equally and no individual cell has failed

D. The battery passes if the voltage recovers to 12.0V within 30 seconds after the load is removed — the recovery speed indicates the battery's ability to accept a recharge

61. A technician is tracing a wiring fault in a machine's cab. The schematic shows a ground wire running from a sensor connector to a ground bolt on the cab floor. The technician measures the resistance from the sensor ground pin to the frame and reads 5.2 ohms. What does this indicate?

- A. The ground circuit has excellent continuity — any resistance below 10 ohms is acceptable for a sensor ground circuit in heavy equipment applications
- B. The ground circuit has excessive resistance — a clean, tight ground connection should measure less than 0.5 ohms. The 5.2ohm resistance will produce an unwanted voltage drop in the ground path that shifts the sensor's output reading and may cause incorrect ECM calculations
- C. The measurement is inconclusive — resistance checks on ground circuits are not valid because the circuit must be tested under load using the voltage drop method to identify the fault
- D. The 5.2ohm reading is the sensor's internal resistance being measured in series with the ground wire resistance, producing a combined reading that cannot be separated without disconnecting the sensor

62. A machine's telematics system is transmitting operational data to the fleet management server. The fleet manager reports the machine's fuel consumption data is significantly higher than the same model machines in the fleet. The machine is operating normally with no complaints. What should the technician investigate first?

- A. The engine's actual fuel consumption rate to verify whether the telematics data is correct — if it is, the engine may have a fault that is consuming more fuel than identical machines
- B. The telematics module's firmware version — an outdated firmware may be calculating fuel consumption using an incorrect algorithm
- C. The machine's operating pattern — the machine may be performing a different duty cycle (more idle time, heavier loads, steeper grades) than the fleet average that explains the higher fuel consumption without an engine fault
- D. The fuel level sensor calibration — an inaccurate sensor produces incorrect fuel level readings that the telematics system converts to incorrect consumption calculations

63. A technician measures the current draw of a hydraulic solenoid valve using a clamp-on ammeter. The solenoid is commanded on at 100% duty cycle. The ammeter reads 2.8 amperes. The OEM specification for this solenoid is 2.0 amperes at rated voltage. What does the elevated current draw indicate?

- A. The solenoid coil has developed a partial internal short between windings — the reduced resistance from the shorted turns allows more current to flow than the intact coil's designed impedance would permit
- B. The system voltage is higher than the rated voltage, which proportionally increases the current through the fixed-resistance coil according to Ohm's Law
- C. The solenoid spool is mechanically stuck and the coil is drawing additional current to generate the magnetic force needed to overcome the sticking resistance
- D. The clamp-on ammeter is not calibrated correctly and is producing a reading that is 40% higher than the actual current flowing through the circuit

64. A technician is diagnosing a CAN bus fault. The diagnostic tool cannot communicate with any module on the machine. The technician measures the voltage between CANH and CANL at the diagnostic connector with the system powered on. The reading is 0.0V (no differential voltage). What does this indicate?

- A. All modules on the bus have simultaneously entered sleep mode and are not transmitting, producing no measurable differential voltage on the bus
- B. The CAN bus is functioning normally in the recessive state — 0.0V between CANH and CANL is the expected idle voltage when no module is actively transmitting
- C. The diagnostic connector has a fault — the CAN bus pins in the connector are shorted together, equalizing the voltage and producing a 0V differential at the measurement point
- D. The CAN bus is nonfunctional — either both CAN lines are shorted together (equalizing the voltage), both lines are shorted to the same potential (ground or power), or the bus has no power. A functioning bus would show approximately 2.0V average differential between CANH and CANL during active communication

65. A technician is checking the operation of a magnetic pickup speed sensor on a transmission output shaft. The sensor is connected to the TCM and produces a signal used for shift control and speedometer display. The technician connects an oscilloscope and observes a clean sinusoidal waveform at idle. During acceleration, the waveform develops irregular amplitude variations — some peaks are noticeably shorter than others. What could cause this?

- A. The TCM is introducing noise into the sensor circuit through a shared ground connection that carries switching noise from the transmission solenoids
- B. The transmission output shaft bearing has developed play, allowing the shaft to wobble slightly at higher speeds and vary the sensor to reluctor gap during rotation
- C. The irregular amplitudes are normal — magnetic pickup sensors produce naturally varying peak voltages as the reluctor teeth pass at different velocities during acceleration
- D. The sensor's permanent magnet is weakening from age and the reduced magnetic field cannot maintain consistent signal amplitude at higher rotational speeds

66. A technician replaces the cab wiring harness on a heavy equipment machine. After installation, multiple circuits function correctly but the radio produces an audible buzzing that increases with engine RPM. The radio worked correctly before the harness replacement. What is the most likely cause?

- A. The replacement harness uses an unshielded radio power supply wire that runs parallel to the alternator output cable — the alternator's electromagnetic field induces noise into the unshielded radio supply wire
- B. The radio's internal antenna amplifier was damaged during the harness installation when the antenna cable was disconnected and reconnected
- C. The new harness's radio power wire is routed near or bundled with the alternator output wire or other high-current switching circuits — electromagnetic interference from these wires is coupling into the radio supply, producing the RPM-proportional buzz
- D. The replacement harness has a ground wire for the radio that is one gauge smaller than the original, and the increased ground resistance allows alternator ripple to appear on the radio's power input

67. A machine's ECM logs a DTC for "Injector 3 circuit — current below expected." The injector resistance measures within specification. The ECM connector is confirmed clean and tight. What should the technician check next?

A. The voltage supply to the injector driver circuit — if the supply voltage to the ECM's injector driver module is low, the driver cannot produce the expected current even though the injector coil resistance is correct

B. The harness wiring between the ECM and injector 3 — a highresistance connection (corroded splice, damaged terminal, or partially broken wire) limits the current flow below the ECM's expected threshold while the injector coil itself tests normally when measured in isolation

C. The ECM software version — an incorrect calibration file may contain an injector current threshold that does not match the actual injectors installed in the engine

D. The injector's internal control valve mechanism — a mechanical failure in the valve reduces the backEMF that the ECM's current monitoring circuit uses to determine current flow

68. A machine's keyswitch has three positions: OFF, RUN, and START. In the RUN position, the technician measures 24V at the starter solenoid "S" (signal) terminal. This means the starter could potentially engage while the engine is running. What is the most likely cause?

A. The keyswitch is internally defective — the RUN position contacts are bridging to the START terminal inside the switch, sending voltage to the solenoid S terminal when only the RUN circuit should be energized

B. The neutral safety switch has failed in the closed position, completing the starter circuit through an alternate path that bypasses the keyswitch START position

C. The starter solenoid has an internal short between its main terminals and the S terminal that is backfeeding voltage from the running engine's charging circuit

D. The wiring harness has a chafed spot where the starter signal wire contacts the ignition (RUN) circuit wire, crossconnecting the two circuits

69. A heavy equipment machine is equipped with a 24Vto12V voltage converter (DCDC converter) that powers a 12V auxiliary circuit from the 24V main system. The 12V circuit (radio, backup camera, accessory outlet) works intermittently. The 24V input to the converter is confirmed at a steady 27.8V. What should be checked?

- A. The 12V load circuits for a short to ground that causes the converter to overload and shut down intermittently until it cools and resets
- B. The converter's internal fuse — if equipped — and the converter's output voltage under load to determine if the converter is failing under demand
- C. The 24V battery bank — an imbalanced battery can produce intermittent voltage dips that the converter cannot track, causing the 12V output to drop out momentarily
- D. The converter's output voltage while the loads are connected and operating — the converter may be failing under load, producing intermittent output that drops below the 12V loads' minimum operating voltage, even though the 24V input is stable

70. A technician is using an oscilloscope to analyze the charging system on a machine with a threephase alternator. The scope shows the typical threephase rectified DC waveform, but one of the three phase humps is missing — the waveform shows only two peaks per cycle instead of three. What does this indicate?

- A. One phase of the stator winding has an open circuit or one pair of rectifier diodes has failed — the alternator is producing only twothirds of its rated output because one phase is not contributing to the total output
- B. The drive belt is slipping on the alternator pulley at the specific RPM being tested, causing one phase to drop out during the slip event
- C. The alternator's voltage regulator is overcompensating for one phase and suppressing its output to balance the total voltage output across all three phases
- D. One of the three stator windings has a short to ground that is bypassing its output directly to the alternator housing rather than through the rectifier

71. A technician is repairing a wire that has been severed in the engine compartment. The technician uses a buttsplice crimp connector, then covers it with adhesivelined heatshrink tubing. After the repair, the technician notices the heatshrink tubing has not fully sealed around the wire insulation at one end — a small gap is visible where the wire enters the tubing. What is the consequence of this incomplete seal?

- A. The gap allows the crimp connector to move inside the tubing and potentially work loose under vibration, creating an intermittent open circuit at the splice
- B. The gap allows moisture to wick along the wire strands into the crimp connector — over time, the moisture corrodes the copper strands inside the crimp, progressively increasing the connection's resistance until the circuit fails
- C. The incomplete seal reduces the splice's mechanical strength because the heatshrink tubing provides the primary strain relief that prevents the wire from pulling out of the crimp terminal
- D. The gap has no consequence because the adhesivelined heatshrink has already sealed the crimp connector internally even if the outer tube has not fully shrunk at one end

72. A technician performs a torque converter stall test and obtains a stall RPM that is 300 RPM above the OEM specification. The engine has been independently verified as producing its rated power output. What does the high stall RPM indicate?

- A. The torque converter stator clutch has failed and is freewheeling in both directions, eliminating the torque multiplication phase and reducing the converter's resistance to engine rotation
- B. The transmission has an internal clutch pack that is slipping — the turbine is not being held as firmly by the transmission, allowing the engine to spin the pump faster than designed at stall
- C. The torque converter is the correct unit but has been installed backward on the flywheel, reversing the pump and turbine rotation and reducing the fluid coupling resistance
- D. The transmission oil viscosity is lower than specified from fuel dilution or incorrect oil type, reducing the fluid's resistance to shearing inside the converter

73. A machine's powershift transmission produces a metallic grinding noise in 3rd gear only. First, second, and fourth gears are quiet. The 3rd gear clutch pressure tests within specification. What component specific to 3rd gear should be inspected?

A. The 3rd gear clutch piston seal — a leaking seal allows the clutch to slip under load, producing a friction-generated grinding sound

B. The 3rd gear friction disc splines — damaged internal splines produce a grinding noise as the disc attempts to lock to the hub during engagement

C. The planetary gear set components that are active in 3rd gear — a damaged planet gear, broken planet pin, or failed planet gear needle bearing produces the noise only when that specific planetary member is carrying the load in 3rd gear

D. The 3rd gear band servo — a seized servo piston produces a grinding noise as it attempts to apply the band against the drum surface

74. A driveshaft has been removed and reinstalled during a transmission repair. After reinstallation, the machine produces a vibration at all travel speeds that was not present before the repair. The Ujoints are new and the driveshaft was marked before removal. What was likely done incorrectly?

A. The driveshaft was reinstalled with the yoke ears out of phase — the marks on the shaft were not aligned during reassembly, rotating one yoke relative to the other by 90 degrees and creating an uncancelled velocity variation

B. The new Ujoints are a different cross-spider dimension than the originals, producing a clearance difference that introduces a vibration at all speeds

C. The driveshaft balance weight was dislodged during removal and did not return to its original position during reinstallation

D. The transmission output shaft seal was damaged during reinstallation, allowing fluid to leak onto the driveshaft and create an imbalance from the oil weight

75. A machine equipped with a limited slip differential produces a strong pulsing sensation through the steering wheel during lowspeed tight turns on dry pavement. The gear oil was changed recently. What is the most probable cause?

A. The differential carrier bearings are worn and produce the pulsing under the lateral load of the tight turn

B. The new gear oil does not contain the limited slip additive (friction modifier) required for the limited slip clutch pack — without the modifier, the clutch packs grab and release cyclically during the speed differential required for turning

C. The limited slip clutch pack has seized completely, locking both axle shafts together and preventing any speed differential — the tires alternate between grip and slip as the machine tries to turn

D. The ring and pinion backlash has shifted from gear oil expansion, producing the pulsing vibration during lowspeed turns

76. A technician is measuring the endplay of a transmission input shaft during a rebuild. The measured endplay is 0.08 mm. The OEM specification is 0.15–0.30 mm. What is the consequence of the insufficient endplay?

A. Insufficient endplay causes the input shaft to expand into the bearing under operating temperature, creating a condition called bearing preload that generates excessive friction heat and can cause premature bearing failure

B. The tight endplay will loosen naturally during the first 100 hours of operation as the thrust washers bed into their seats

C. Insufficient endplay causes the clutch disc to drag on the flywheel because the input shaft pulls the disc forward against the flywheel surface

D. The endplay specification is a manufacturing reference only and has no functional consequence in normal operating conditions

77. A machine's transfer case uses a chain to connect the input shaft to the front axle output shaft. The technician inspects the chain and measures 2% pitch elongation. The OEM maximum is 1.5%. However, the transfer case has no tensioner — the chain runs on fixed position sprockets. How is the elongation affecting operation?

- A. The elongated chain has no effect because the fixed sprocket positions maintain constant chain tension regardless of elongation
- B. The chain rides higher on the sprocket teeth, concentrating stress on the tooth tips and causing accelerated tooth wear
- C. The elongated chain produces excessive noise during engagement but has no effect on torque transmission or component wear
- D. The excess slack from elongation produces a clunking noise during load reversals and increases the risk of the chain skipping teeth on the sprocket during high torque events, which can cause catastrophic transfer case failure

78. A technician observes that the flywheel housing on a diesel engine has a dowel pin alignment system that precisely positions the transmission bell housing relative to the engine. One dowel pin is missing. The transmission was reassembled without noticing the missing pin. What symptom will this produce?

- A. The misaligned bell housing allows the transmission input shaft to run off centre relative to the crankshaft, producing vibration, accelerated pilot bearing wear, and potential input shaft bearing failure from the cyclical radial loading
- B. The missing dowel allows the transmission to rotate slightly on the flywheel housing during heavy torque events, producing a clunking noise during load reversals
- C. The missing dowel has no operational consequence because the mounting bolts alone provide adequate alignment between the engine and transmission
- D. The missing dowel causes the clutch disc to wobble on the input shaft spline because the disc cannot centre without the reference datum that the dowel provides

79. A machine's differential ring gear has developed a tooth surface defect known as "spalling" — small chips of hardened surface material have flaked off several gear teeth. What causes spalling and what is the consequence?

A. Spalling is caused by the gear oil's viscosity being too high, which prevents adequate lubrication film from forming at the tooth contact point

B. Spalling results from incorrect gear mesh pattern that concentrates the contact load on a small area of the tooth face, causing localized surface fatigue

C. Spalling is caused by surface fatigue from cyclical contact stress exceeding the material's endurance limit — the hardened surface cracks and chips from repeated loading, and the resulting rough surface accelerates wear of both the affected and mating gear teeth

D. Spalling is caused by abrasive particles in the gear oil that score the tooth surface and create initiation points for the surface material to flake under subsequent loading

80. A hydraulic retarder equipped machine has a retarder apply solenoid that the ECM commands based on the operator's retarder lever position. The ECM monitors the retarder's output shaft speed sensor to verify the retarder is actually producing the commanded braking force. If the actual speed reduction does not match the commanded level, what does the ECM do?

A. The ECM increases the retarder solenoid command to compensate for the reduced effectiveness, pushing more oil into the retarder housing to restore the designed braking force

B. The ECM logs a retarder efficiency fault and continues operating at the current level without making any adjustment to the retarder command

C. The ECM reduces engine power to lower the speed independently of the retarder, compensating for the retarder's reduced effectiveness through engine derate

D. The ECM may increase the retarder command, apply the engine brake, and/or alert the operator — the specific strategy depends on the OEM's programmed response, but the system will attempt to maintain safe speed control through whatever means are available

81. A machine's powershift transmission has been rebuilt. During the initial test drive, the technician notices the transmission shifts from 2nd to 3rd and then immediately back to 2nd, and this hunting pattern continues. What is the most likely cause?

A. The governor pressure signal at the 23 shift point is at the exact threshold where the shift valve oscillates between the two states — the cause is typically a misadjusted governor, an incorrect governor gear, or a valve body calibration issue

B. The 3rd gear clutch pack has no friction material installed — the clutch engages briefly from oil resistance alone, then slips and the transmission defaults back to 2nd

C. The transmission oil temperature is too cold for the oil to flow through the cooler circuit, and the backpressure from the cold oil is preventing 3rd gear from achieving full engagement pressure

D. The torque converter lockup clutch is engaging in 3rd gear and the resulting RPM drop triggers the TCM to downshift to 2nd, then the lockup releases and the cycle repeats

82. A technician is installing a new set of axle shaft seals on a wheel loader. The seal has a springloaded rubber lip that contacts the axle shaft surface. The technician applies grease to the seal lip before installation. Why is this prelubrication important?

A. The grease provides initial lubrication to the seal lip until the axle oil reaches the seal and establishes a normal lubrication film — without prelubrication, the dry seal lip runs against the dry shaft surface for the first several revolutions, generating heat that can damage the new seal immediately

B. The grease fills the spring channel and prevents the garter spring from falling off the seal lip during the pressin installation process

C. The grease softens the rubber lip material, making it more pliable and easier to press into the bore without cocking or damaging the seal housing

D. The grease provides a visible indicator that the seal is installed correctly — grease visible on the shaft surface after the seal is pressed in confirms the lip is oriented toward the oil side

83. A machine's wet clutch produces a burnt smell after a heavy work cycle. The clutch functions normally and no slipping is detected during operation. What is the most likely cause of the smell?

A. The clutch oil cooler bypass valve is stuck closed, forcing all oil through the cooler at all times and overcooling the clutch, which produces a characteristic smell from the coldthickened oil

B. A small amount of friction material wear debris has accumulated in the clutch housing sump and is overheating when it contacts the hot clutch oil during heavyload cycles

C. The clutch oil has been in service beyond its change interval and the degraded oil is producing the burnt odour when heated to peak temperature during heavy clutch loading — the oil's thermal stability has declined from oxidation

D. The clutch apply piston seal is leaking, causing the clutch to microslip under heavy load for brief periods that are too short to detect as slip but generate enough heat to produce the smell

84. A technician is testing a hydrostatic drive motor's case drain flow. The OEM specification states the maximum allowable case drain flow at rated pressure is 8 L/min. The measured case drain flow is 15 L/min. What does this confirm?

A. The motor's charge circuit check valve is stuck open, diverting charge flow through the motor housing and out the case drain rather than into the working loop

B. The case drain line has a restriction downstream of the measurement point that is creating backpressure and producing an artificially high flow reading at the measurement port

C. The motor is within specification — case drain flow increases proportionally with motor speed and the 15 L/min reading is normal at the RPM at which the test was conducted

D. The motor has excessive internal leakage — fluid is bypassing through the motor's worn internal clearances at nearly double the acceptable rate, reducing the motor's torque output and generating excess heat

85. A machine equipped with a manual clutch has the clutch adjusted to the correct free play specification at the pedal. The operator reports the clutch does not fully disengage — the machine creeps forward when the clutch pedal is fully depressed in gear. What could cause this despite correct free play?

A. The clutch disc has warped from heat, and the warped section maintains contact with the flywheel even when the pressure plate is fully released — the residual friction from the warped disc drags the input shaft

B. The clutch disc friction material has swollen from oil contamination, increasing the disc thickness beyond the pressure plate's release travel capability

C. The pilot bearing has seized, preventing the input shaft from stopping even when the clutch disc is fully released — the seized bearing drives the input shaft from the flywheel rotation

D. The flywheel face has excessive runout (wobble) that pushes the clutch disc back into partial contact with the pressure plate during portions of each revolution

86. A machine's final drive planetary gear set uses a sun gear, three planet gears, and a ring gear. During inspection, one planet gear shows significantly more wear on its teeth than the other two. All three planet gears have equal operating hours. What is the most likely explanation?

A. The worn planet gear was manufactured from a different material batch with lower hardness than the other two gears

B. The worn planet gear's needle bearing has failed, causing the gear to rotate erratically on its pin and generating uneven loading on its teeth compared to the other two

C. The planet gear carrier has a distorted pin bore that holds the worn gear's pin at a slight angle, causing the gear's teeth to mesh unevenly with the sun and ring gear

D. The worn gear is positioned at the planet carrier's heavy spot (imbalance point), which subjects it to higher centrifugal loading during rotation than the other two gears

87. A technician discovers that a torque converter has been replaced with a unit that has a different stall torque ratio than the original. The original converter had a 2.5:1 stall torque ratio, and the replacement has a 1.8:1 ratio. What operational difference will the operator notice?

A. The machine will have less tractive effort during initial acceleration and when working in heavy material because the converter multiplies engine torque less — the 1.8:1 ratio produces less breakaway force than the original 2.5:1 ratio

B. The machine will be faster at travel speed because the lower stall ratio reduces the converter's fluid drag during the coupling phase

C. The machine will consume less fuel because the lower stall ratio reduces the energy wasted as heat during the torque multiplication phase

D. The operator will notice no difference because the transmission's gear ratios compensate for any change in converter torque ratio

88. A machine's automatic transmission produces a whining noise in all gear ranges that changes pitch with output shaft speed. The noise is present in both forward and reverse. Transmission oil level and condition are correct. What is the most probable noise source?

A. The transmission pump — its internal gears produce a whining noise proportional to pump speed, which changes with engine RPM not output shaft speed

B. The torque converter — internal turbulence produces a whining noise that changes with turbine speed, which is proportional to output shaft speed

C. The transmission output shaft bearing or the final drive input components — a bearing or gear that rotates at output shaft speed in all ranges and both directions is the most likely source

D. The transmission governor — the governor spins at output shaft speed and its internal weights produce a whining noise that changes pitch with speed variation

89. An air conditioning system has been diagnosed with a restricted condenser. The restriction causes the highside pressure to rise above normal while the lowside pressure drops below normal. What is the physical explanation for the lowside pressure drop?

A. The restricted condenser prevents adequate heat rejection, causing the refrigerant to remain partially in vapour state as it leaves the condenser — the expansion device receives a mixture of liquid and vapour instead of pure liquid

B. The restricted condenser causes the compressor to work harder, which draws suction more aggressively on the low side and reduces the evaporator pressure

C. The expansion device compensates for the high condenser pressure by reducing its opening, which restricts the flow to the evaporator and causes the lowside pressure to drop from insufficient refrigerant mass flow

D. The restricted condenser reduces the total mass flow rate of refrigerant through the system — less refrigerant reaches the evaporator per unit time, reducing the evaporating pressure on the low side

90. A technician is testing the cab pressurization on a machine operating in a dust environment. The specification requires a minimum of 50 pascals positive pressure inside the cab. The technician measures 10 pascals. The pressurization fan is running at full speed. What should be investigated?

A. The HVAC blower motor speed controller — a failing controller reduces the fan speed below its maximum despite appearing to be at full speed based on the selector position

B. The cab air intake filter — a heavily loaded filter restricts the airflow into the cab despite the fan running at maximum speed, reducing the volume of fresh air entering and therefore the positive pressure achieved

C. The cab heater core — a blocked heater core restricts the airflow through the HVAC housing even in cooling mode, reducing the total air volume delivered to the cab

D. The cab structure — the door seals, window seals, panel seals, and any penetrations (wiring, hoses) that have deteriorated, leaving excessive leak area that allows the positive pressure to escape faster than the fan can build it

91. A technician is recovering refrigerant from an A/C system and the recovery machine stops at 50% of the expected charge weight. The system has not been opened and there are no visible oil stains or leak evidence. What is the most likely explanation?

A. The system has had a slow leak that has lost approximately 50% of its charge over an extended period — slow leaks may not leave visible evidence, especially in locations such as the evaporator core inside the HVAC housing or the compressor shaft seal

B. The recovery machine is not functioning correctly and cannot extract the remaining refrigerant — the machine's compressor is failing and cannot pull the lowpressure gas from the system

C. The remaining 50% of the charge is trapped in the evaporator as liquid that will not transfer to the recovery tank under the current ambient temperature conditions

D. The system was originally charged at 50% of specification by a previous technician who used the sight glass method instead of weighing the charge

92. A machine's A/C compressor is equipped with a pressure relief valve that opens at approximately 2,800 kPa (400 PSI). During operation on a hot day, the operator reports hearing a brief hissing sound from the engine compartment, followed by reduced cooling for several minutes before cooling returns. What is occurring?

A. The receiverdrier is releasing trapped moisture through its overpressure vent at peak load conditions on hot days

B. The compressor clutch is disengaging from highpressure switch activation, not the relief valve — the hissing is the sudden release of pressure from the clutch electrical connector

C. The pressure relief valve is opening briefly to vent excessive highside pressure — the lost refrigerant reduces cooling until the system equilibrates. Repeated events will progressively deplete the charge

D. The expansion valve is cavitating under the highpressure conditions and the sound is hydraulic noise from the expansion device, not a relief event

93. A technician is diagnosing a cab HVAC system where the A/C compressor cycles on and off rapidly — approximately 4 seconds on, 2 seconds off, continuously. What is the most common cause of this rapid cycling?

A. The evaporator thermostat has failed in a position where its set point is very close to the current evaporator temperature, causing continuous cycling around the narrow deadband

B. Low refrigerant charge — the reduced refrigerant mass causes the lowside pressure to drop below the lowpressure switch cutout during each compressor run cycle. The switch opens (compressor off), pressure equalizes above the cutin (compressor on), and the cycle repeats rapidly

C. The compressor clutch coil is overheating from continuous operation and the thermal protection circuit inside the coil is cycling the clutch to prevent coil damage

D. The condenser fan relay is defective and cycling the fan on and off, which causes the highside pressure to oscillate and trigger the highpressure switch cutout

94. A machine's cab heating system uses a hot water valve that is opened and closed by an electric actuator controlled by the cab temperature controller. The operator reports the cab temperature oscillates — the cab heats to uncomfortable warmth, then cools to an uncomfortable chill, in a repeating cycle. What is the most likely cause?

A. The coolant temperature at the heater core inlet is fluctuating because the engine thermostat is cycling open and closed at an abnormal rate

B. The cab temperature sensor that provides feedback to the controller has failed or is reading inaccurately — without correct temperature feedback, the controller overshoots in both directions

C. The hot water valve actuator is functioning correctly but the heater core has an internal restriction that delays the heat response, causing the controller to overcompensate in each direction

D. The temperature controller has a defective control algorithm that cannot hold a steady temperature setting — the controller must be replaced with an updated unit

95. A machine's A/C system uses a variable displacement compressor that adjusts its output based on system demand. The advantage of this design is that the compressor runs continuously without cycling the clutch on and off. The operator reports the A/C provides adequate cooling but produces an annoying low-frequency vibration in the cab that was not present before. What is the most likely cause?

- A. The variable displacement mechanism inside the compressor has stuck at a displacement that creates a resonant vibration at the current engine RPM
- B. The compressor mounting bracket bolts have loosened, allowing the compressor to vibrate on its mounts and transmit the vibration through the bracket to the cab structure
- C. The compressor's internal wobble plate or swash plate is worn, producing an imbalance at the operating displacement that transmits vibration through the compressor body to the belt and engine — the vibration changes frequency with engine RPM
- D. The compressor drive belt is worn and the reduced belt section is producing a vibration pulse at the belt's rotational frequency

96. A technician replaces the heater hoses on a machine's cab heating system. After the repair, the heater produces no heat despite both hoses being hot at the engine connections. At the cab, the inlet hose is hot but the outlet hose is ambient temperature. What does this indicate?

- A. The heater core is completely blocked — hot coolant enters at the inlet but cannot flow through the core to reach the outlet, so no heat is transferred to the cab air and the outlet hose remains at ambient temperature
- B. The outlet hose was connected to the wrong port on the machine and coolant is flowing out of the heater core into the overflow tank rather than back to the engine
- C. The heater core is functioning correctly and the cool outlet hose indicates the core is extracting maximum heat from the coolant, which is the normal operating condition for a properly functioning heater
- D. An air lock in the heater core is preventing coolant from circulating through the core — the hot inlet hose confirms coolant reaches the core entrance but the air lock prevents it from flowing through

97. A machine's HVAC system includes an incab air quality sensor that monitors CO₂ concentration. When the CO₂ level exceeds a threshold, the system automatically switches from recirculation mode to fresh air mode. What is the safety purpose of this automatic switching?

A. Elevated CO₂ causes the operator to become drowsy and inattentive — the automatic switch to fresh air replaces the highCO₂ recirculated air with fresh outside air, maintaining the operator's alertness and cognitive function

B. Elevated CO₂ indicates the cab filter has reached its service limit and the system switches to fresh air to bypass the loaded filter and maintain adequate airflow

C. The CO₂ sensor detects combustion gas infiltration from the engine exhaust, and the switch to fresh air mode activates a secondary filtered intake that removes the combustion gases

D. Elevated CO₂ causes corrosion of the cab's electronic components and the fresh air mode reduces the moisture content associated with the high CO₂ concentration

98. A variable displacement piston pump has nine pistons. During operation, only a portion of the pistons are actively displacing fluid at any given moment while the others are in the suction (intake) phase. What is the minimum number of pistons that must be in the discharge phase simultaneously to maintain smooth (low pulsation) flow output?

A. Three pistons — onethird of the total piston count produces flow at any given moment while the remaining twothirds are in the intake stroke

B. One piston — the pump's valve plate timing ensures that at least one piston is always on the discharge stroke, providing a minimum continuous flow

C. Five pistons — more than half must be in the discharge phase to overcome the suction force of the remaining four pistons during the intake phase

D. The pump design ensures piston overlap — at any given moment, four to five pistons are simultaneously in the discharge phase while the others are in the suction phase. This overlap is what produces the characteristically smooth output of axial piston pumps

99. A hydraulic system's main relief valve is set at 280 bar. A technician installs a pressure gauge at the pump outlet and observes the pressure never exceeds 210 bar during any operation, including stalling a cylinder against its stop. What does this indicate?

A. The system is functioning correctly — 210 bar is the load-induced working pressure, and the 280bar relief setting is the overpressure protection that the system should never reach during normal operation

B. The pump is worn and cannot generate pressure above 210 bar regardless of the relief valve setting — the pump needs to be tested independently

C. The relief valve has drifted from its 280bar setting down to 210 bar and is opening prematurely, limiting the maximum system pressure. The cylinder stall test should produce relief valve pressure if the pump is capable

D. The relief valve is functioning correctly because stalling a cylinder does not actually load the system to relief pressure — only a deadheaded pump test loads the system to relief

100. A technician discovers a hydraulic cylinder with a chrome rod that has a visible circumferential scratch around its entire circumference. The scratch is approximately 0.3 mm deep. What is the most likely cause and what is the consequence?

A. A foreign particle trapped at the rod seal lip has scored the rod during a single stroke cycle — the circumferential scratch cuts the seal lip on every subsequent stroke, producing an external leak that worsens progressively and allows contamination to enter on the return stroke

B. The scratch is a manufacturing feature — the chrome plating process produces a circumferential polishing line at the point where the rod was chucked during the finishing operation

C. The rod has been bent and the high spot contacts the seal during each stroke, creating the circumferential scratch from the rotational wiping of the bent section against the seal

D. The cylinder cushion plunger has been improperly adjusted and the rod decelerates too rapidly at end of stroke, creating a scuffing mark from the metallic contact at the cushion engagement point

101. A hydraulic motor drives a winch drum on a crane. The motor supply circuit includes a counterbalance valve. During a lowering operation, the operator reports the load descends at an inconsistent speed — sometimes faster, sometimes slower — despite maintaining a constant lever position. What is the most likely cause?

A. The counterbalance valve pilot signal is fluctuating due to a loose pilot line connection or a worn shuttle valve that supplies the pilot, causing the valve to open and close erratically and producing inconsistent lowering speed

B. The motor has a worn cylinder barrel that changes its displacement during each revolution, creating a speed variation that is proportional to the motor's rotational position

C. The winch drum's mechanical brake is dragging intermittently due to a weak return spring that allows the brake to partially engage during lowering at random intervals

D. The hydraulic pump's compensator is hunting — the pump is cycling between high and low displacement, producing flow variations that reach the motor as speed fluctuations during the lowering operation

102. A hydrostatic transmission on a crawler dozer produces full speed in forward but only half speed in reverse. Charge pressure is correct. Forward and reverse pressures at the pump test ports are both within specification when measured during their respective loaded operations. What should be tested next?

A. The pump servo — if the servo cannot move the swashplate to full angle in the reverse direction due to a physical stop or internal restriction, the pump produces reduced displacement in reverse

B. The forward motor — if the motor has excessive internal leakage, it would affect both directions equally since the same motor is used for forward and reverse

C. The charge circuit filter — a restricted charge filter would reduce charge pressure, but the question states charge pressure is correct

D. The reverse crossport relief valve — if it is set lower than the forward relief, it limits the maximum reverse pressure and therefore the maximum reverse speed, but the question states both pressures are within specification at the test ports. The motor case drain flow should be measured to check for motor internal leakage that allows fluid to bypass rather than drive the motor

103. A hydraulic excavator's swing function overshoots the target position by approximately 30 degrees when the operator releases the joystick from full swing speed. The swing motor has a crossport relief valve on each port. What adjustment would reduce the overshoot?

A. Reduce the swing crossport relief valve settings — lower relief pressure limits the maximum pressure available to sustain swing momentum after the supply stops, allowing the relief valves to absorb the kinetic energy more aggressively and stop the swing faster

B. Increase the swing motor displacement to provide greater resistance to the rotating mass, which decelerates the upper structure more quickly

C. Increase the pilot pressure to the swing control valve to provide a stronger centring return force that closes the spool faster when the joystick is released

D. Install a larger accumulator on the swing circuit to absorb the kinetic energy of the decelerating upper structure and convert it to stored hydraulic pressure

104. A machine's hydraulic return line filter has a 10micron absolute rating. The technician needs to replace the element but only 10micron nominal elements are available. What is the difference between absolute and nominal filter ratings?

A. There is no functional difference — "absolute" and "nominal" are marketing terms used by different filter manufacturers for the same filtration specification

B. A nominal rating is less precise — a 10micron nominal filter allows a significant percentage of particles larger than 10 microns to pass, while a 10micron absolute filter stops 98.7% (Beta 1000) or more of particles at or above 10 microns

C. An absolute rating applies to the filter in new condition only, while a nominal rating applies throughout the filter's entire service life including its loaded state

D. A nominal filter has a finer actual filtration capability than an absolute filter of the same stated micron rating because the nominal specification includes a safety factor

105. An air brake system's governor is being tested. The technician observes the compressor building pressure normally to 860 kPa, at which point the governor should signal the compressor to unload. Instead, the pressure continues to climb to 930 kPa before the governor unloads the compressor. What does this indicate?

- A. The governor is functioning correctly — a 70 kPa variation from the specification is within the governor's normal adjustment tolerance and does not require correction
- B. The air dryer is creating additional restriction that delays the governor's pressure sensing, causing it to read the actual system pressure approximately 70 kPa late
- C. The reservoir check valve between the governor and the air tank is restricting the pressure signal to the governor, causing the governor to sense a lower pressure than the actual tank pressure
- D. The governor cutout setting has drifted high — the governor is not unloading the compressor until 930 kPa instead of the specified 860 kPa, which overpressures the system beyond the designed operating range and must be readjusted

106. A hydraulic cylinder extends at the correct speed but retracts at approximately 1.5 times the extension speed. The cylinder has a 100 mm bore and a 70 mm rod. Is this speed difference normal?

- A. No — a properly functioning cylinder should extend and retract at the same speed regardless of bore and rod dimensions because the DCV meters equal flow to both ports
- B. Yes — the rodend has a smaller effective area (piston area minus rod area) than the capend. With the same flow entering the smaller rodend chamber, the piston must travel faster to accept the same volume per unit time, producing the higher retraction speed
- C. No — the higher retraction speed indicates the capend piston seal is bypassing, reducing the effective capend resistance and allowing the rodend pressure to push the piston back faster than normal
- D. Yes — but only if the circuit includes a regenerative function that adds the capend exhaust flow to the pump supply during retraction, increasing total flow to the rod end

107. A technician is diagnosing a hydrostatic drive complaint where the machine has lost power in both forward and reverse. The charge pressure is low at 12 bar (specification is 25–30 bar). The charge relief valve has been tested and is correct. What should be checked next?

A. The charge pump — if the charge pump has lost volumetric efficiency from internal wear, it cannot produce the required charge flow to maintain the specified pressure, resulting in low charge pressure that affects both forward and reverse drive performance

B. The main pump servo — a failed servo prevents the pump from reaching full displacement in either direction

C. The loop flushing valve — a stuckopen flushing valve diverts excessive charge flow through the flush circuit

D. Both crossport relief valves — if both have drifted below specification, they limit the maximum working pressure in both directions

108. A hydraulic system includes two cylinders connected in a series circuit — the rod end of cylinder A is connected to the cap end of cylinder B. Both cylinders have the same bore and rod dimensions. When the pump supplies fluid to the cap end of cylinder A, both cylinders extend. What is special about the flow relationship in this series connection?

A. Both cylinders receive identical flow and operate at identical speed regardless of load because the series connection ensures equal flow distribution

B. Cylinder B always extends faster than cylinder A because the fluid exiting cylinder A's rod end has been pressurized and enters cylinder B's cap end with additional energy

C. Both cylinders must have different bore sizes to function in series — two identical cylinders cannot be connected in series because the rodend output of cylinder A is less than the capend input requirement of cylinder B

D. The rodend output flow of cylinder A is less than the pump's input to cylinder A (because the rod occupies volume). Cylinder B receives this reduced flow, so cylinder B extends slower than cylinder A unless a makeup circuit supplies the difference

109. A hydraulic pressure gauge reads 200 bar. The gauge has a $\pm 2\%$ fullscale accuracy rating and a 400bar fullscale range. What is the actual pressure range that the 200bar reading could represent?

A. 196 to 204 bar — the $\pm 2\%$ accuracy is applied to the reading itself, producing a ± 4 bar uncertainty at the 200bar indicated value

B. 198 to 202 bar — the $\pm 2\%$ accuracy is applied to a fixed base value of 100 bar, producing a ± 2 bar uncertainty at any reading on the scale

C. 192 to 208 bar — the $\pm 2\%$ fullscale accuracy applies to the gauge's 400bar fullscale range, producing a fixed ± 8 bar uncertainty at any reading. The actual pressure could be anywhere from 192 to 208 bar

D. 190 to 210 bar — the $\pm 2\%$ accuracy is doubled for readings in the middle of the gauge range because the gauge mechanism is least accurate at midscale

110. A hydraulic motor on a conveyor drive is supplied with 120 L/min of flow. The motor displacement is 500 cm³/rev. What is the theoretical motor speed?

A. 60,000 RPM — calculated by multiplying flow rate by motor displacement instead of dividing

B. 240 RPM — calculated as $(120 \text{ L/min} \div 500 \text{ cm}^3) \times 1,000 = (120,000 \text{ cm}^3/\text{min} \div 500 \text{ cm}^3/\text{rev}) = 240$ RPM theoretical output speed

C. 4.17 RPM — calculated by dividing motor displacement by flow rate in litres without unit conversion

D. 600 RPM — calculated by dividing the flow rate by 0.2 (the decimal equivalent of 500 cm³ expressed in litres) rather than by 0.5

111. A machine has a hydraulic accumulator precharged to 100 bar nitrogen. The system operating pressure cycles between 150 bar and 250 bar during normal operation. The technician checks the precharge and finds it at 60 bar. What is the consequence of the low precharge?

- A. The accumulator provides more stored oil volume because the nitrogen occupies less space at the reduced precharge, leaving more room for oil
- B. The accumulator bladder or piston moves through a larger stroke range during each pressure cycle, which accelerates bladder fatigue and reduces accumulator life
- C. The low precharge has no operational consequence as long as the system pressure remains above the precharge pressure at all times during operation
- D. The accumulator's bladder is at risk of being crushed against the gas valve when system pressure compresses the lowcharge gas to a very small volume — the bladder can be extruded into the gas valve opening, causing immediate bladder failure. Additionally, the accumulator stores less usable oil volume per cycle

112. A technician is measuring the flow from a hydraulic pump at rated RPM and zero backpressure. The measured flow is 148 L/min. The pump displacement is 85 cm³/rev and the engine RPM is 1,800. The theoretical flow is 153 L/min ($85 \times 1,800 \div 1,000$). What is the pump's volumetric efficiency at zero pressure?

- A. 96.7% — calculated as $(148 \div 153) \times 100 = 96.7\%$. This represents the pump's mechanical losses (friction, incomplete filling) at zero load because no pressureinduced internal leakage exists at zero backpressure
- B. 103.4% — calculated as $(153 \div 148) \times 100$, indicating the pump is producing more than theoretical output
- C. 85% — calculated by dividing the displacement by the flow rate, which produces a ratio that does not represent volumetric efficiency
- D. 91.5% — calculated by subtracting the flow loss (5 L/min) from 100 and expressing the result as a percentage

113. A hydraulic system operates a large press cylinder that must hold position under load for extended periods (minutes) without the pump running. What circuit component is required to achieve this?

- A. A flow control valve in the cylinder supply line that restricts flow to zero when the pump is off, preventing the oil from leaving the cylinder
- B. A pressure relief valve set at the maximum loadholding pressure that maintains backpressure in the cylinder when the pump stops
- C. A pilotoperated check valve in each cylinder work port that blocks flow in the held direction until commanded to open — the check valve maintains the loadholding pressure in the cylinder indefinitely regardless of pump state
- D. An accumulator connected to the cylinder supply port that maintains pressure on the cylinder after the pump stops, replacing any leakage through the DCV spool

114. An air brake system is tested and the following results are obtained: service brake application with the engine running and system at full pressure — the stopping distance is within specification. Service brake application with the engine off and the system at full pressure — the stopping distance is significantly longer than specification. What does this discrepancy indicate?

- A. The brake booster (power assist) is contributing to the braking force when the engine is running by providing vacuum or hydraulic assist — when the engine is off, the power assist is lost and the brakes rely on air pressure alone
- B. The engine compression provides additional retarding force during the enginerunning test that is absent in the engineoff test, which inflates the enginerunning result
- C. The air compressor is actively supplementing the stored air volume during the enginerunning test, maintaining higher application pressure throughout the stop — with the engine off, the stored air depletes during the stop and pressure drops
- D. The engine is equipped with an exhaust brake that activates automatically during service brake application when the engine is running, providing additional retarding force that is unavailable with the engine off

115. A hydraulic pump produces excessive noise immediately after a cold start but the noise disappears after approximately 15 minutes of operation at low load. What is the most likely cause?

- A. The pump's internal clearances are at their widest when cold, allowing more internal leakage noise that diminishes as the components warm and expand to their operating clearances
- B. The cold hydraulic oil is too viscous for the pump to draw through the suction line efficiently — the high inlet restriction causes cavitation that produces the noise. As the oil warms and thins, the suction restriction decreases and the cavitation ceases
- C. The pump drive coupling has a worn elastomeric element that is stiff in cold conditions and produces noise until the element warms and softens to its normal flexibility
- D. The reservoir air breather is frozen closed from overnight condensation, creating a vacuum in the reservoir that restricts the pump inlet — the breather thaws after the engine compartment warms

116. A machine's hydraulic DCV uses a closedcentre spool design with a loadsensing (LS) feedback port. When the operator moves the joystick, the spool meters flow to the actuator and simultaneously sends a pressure signal through the LS port to the pump controller. What information does this LS signal convey to the pump?

- A. The LS signal tells the pump controller the highest active load pressure in the circuit — the pump adjusts its output to maintain a fixed margin (LS differential) above this pressure, ensuring adequate flow is available to the actuator at all load conditions
- B. The LS signal tells the pump the total flow demand of all active circuits, allowing the pump to match its displacement to the combined flow requirement
- C. The LS signal tells the pump the actuator's position so the pump can preposition its displacement for the next expected command from the operator
- D. The LS signal tells the pump the operator's joystick position, allowing the pump to match its displacement directly to the operator's input without measuring the actual load

117. A technician is performing a hydrostatic drive system diagnostic. Both the left and right track motors operate at the same reduced speed, and the system is noisier than normal. Charge pressure is at the low end of specification (22 bar, specification is 20–28 bar). Main loop pressures are correct. What is the most likely cause of the reduced speed?

- A. Both drive motors have simultaneously developed excessive internal leakage, which is statistically unlikely and would produce asymmetric symptoms
- B. The main pump has worn and its reduced volumetric efficiency produces less flow to both motors at the same rate — the noise is from the pump's internal wear surfaces
- C. The charge pump is worn and producing marginal charge pressure — while still within specification, the low charge pressure is insufficient to adequately replenish the loop flow lost to case drain leakage at both motors, starving the main pump inlet and causing cavitation noise and reduced output flow
- D. The flushing valve is stuck open, diverting excessive flow from the loop through the cooler, which reduces the flow available to the motors in both directions

118. A hydraulic system's oil analysis shows a sudden increase in water content — from the normal 0.02% to 0.8%. The system has not been opened for service recently. What is the most likely source of the water contamination?

- A. Condensation from thermal cycling in the reservoir — the daily temperature variation causes atmospheric moisture to condense inside the reservoir headspace and mix with the oil
- B. A failed reservoir breather cap that no longer contains a desiccant element, allowing humid air to enter the reservoir during the thermal breathing cycle without moisture removal
- C. A failed heat exchanger (oil cooler) that uses water or coolant as the cooling medium — an internal tube failure allows the higherpressure coolant to leak into the lowerpressure hydraulic oil circuit
- D. A failed hydraulic oil cooler (oilto coolant type) — the higherpressure coolant side has breached an internal tube, allowing coolant to enter the hydraulic oil circuit. This produces a sudden increase in water content that corresponds to the volume of coolant entering through the failure

119. A hydraulic cylinder must lift a 50,000 N load. The available system pressure is 200 bar. Using the force formula ($F = P \times A$), what is the minimum piston bore diameter required?

A. Approximately 25 cm² piston area → approximately 56 mm bore diameter — but this provides zero safety margin above the minimum force needed to hold the load stationary

B. Required area = $F \div P = 50,000 \text{ N} \div 20,000,000 \text{ Pa} = 0.0025 \text{ m}^2 = 25 \text{ cm}^2$. Bore diameter = $\sqrt{(25 \div 0.7854)} = \sqrt{31.83} =$ approximately 56.4 mm minimum bore. In practice, a larger bore (e.g., 63 mm or 70 mm standard size) is selected to provide a working margin above the minimum

C. 100 mm bore — calculated by dividing the force by the pressure without converting units, producing an inflated diameter

D. 40 mm bore — calculated using the radius instead of the diameter in the area formula, producing a bore that is undersized by half

120. A machine's hydraulic system has an inline pressurecompensated flow control valve set to deliver 30 L/min to a cylinder. The pump produces 100 L/min. What happens to the remaining 70 L/min of pump output?

A. The excess 70 L/min flows through the flow control valve's bypass port back to the reservoir — the valve meters 30 L/min to the cylinder and diverts the excess to tank, maintaining the set flow regardless of pump output or load pressure

B. The pump automatically destrokes to produce only 30 L/min when the flow control valve is active, reducing power consumption

C. The excess flow builds pressure in the supply line until the main relief valve opens and dumps the 70 L/min to tank as waste heat

D. The excess flow is stored in the system accumulator until the cylinder requires additional flow during a highspeed extend cycle

121. A technician is inspecting a hydraulic hose routing on a machine and notices a hose that is twisted along its length — visible by the misalignment of the layline (printed identification stripe) that should run straight along the hose. What hazard does a twisted hose create?

- A. A twisted hose produces internal turbulence that increases the pressure drop across the hose, reducing the available pressure at the actuator
- B. The twist produces no operational hazard — the hose's internal flow characteristics are unaffected by external twist because the bore remains circular
- C. A twisted hose has reduced internal diameter from the torsional compression of the reinforcement layers, which restricts flow below the hose's rated capacity
- D. The twist produces torsional stress on the hose reinforcement that dramatically reduces the hose's fatigue life and pressure rating — pressure cycling under twist accelerates failure at the fitting connection points where the stress concentrates

122. A machine's air brake system has a dualcircuit brake valve (treadle valve). The primary circuit operates the rear brakes and the secondary circuit operates the front brakes. During a brake test, the technician observes that applying the pedal produces immediate rear brake application but the front brakes apply with a noticeable delay. What is the most likely cause?

- A. The dual brake valve's primary piston moves before the secondary piston in all designs — a slight delay between primary and secondary circuit activation is a normal operational characteristic
- B. The secondary circuit has a restriction — either a partially blocked line, a malfunctioning relay valve, or a contaminated quickrelease valve — that delays the air pressure delivery to the front brake chambers compared to the unrestricted primary circuit
- C. The front brake chambers are a larger Type designation than the rear chambers and require more air volume to fill, producing the perceived application delay
- D. The secondary circuit's check valve between the reservoir and the brake valve has a higher cracking pressure than the primary circuit's check valve, restricting the initial flow to the secondary side of the treadle valve

123. A mining excavator's boom has been in service for 40,000 operating hours. The OEM recommends a comprehensive structural inspection program at this hour milestone. What type of inspection is most appropriate for detecting both surface and internal fatigue damage in the boom's critical weld zones?

A. A combination of magnetic particle testing (MT) for surface and nearsurface defects at all critical weld toes, supplemented by ultrasonic testing (UT) at selected highstress joints where internal defects may be developing — this multimethod approach provides the most complete assessment of the boom's structural integrity at the highhour milestone

B. Visual inspection only — at 40,000 hours, any significant fatigue crack would have grown large enough to be visible to a trained inspector without instrumented testing

C. Radiographic testing (RT) of all weld joints — Xray provides the most comprehensive singlemethod assessment and can detect both surface and deep internal defects in one pass

D. Dye penetrant testing (PT) of all weld joints — PT provides complete coverage for both surface and subsurface defects at a lower cost than UT or MT

124. A machine's bucket has been modified in the field by welding additional material to the bucket cheek plates to increase the bucket's width. The operator reports the bucket now digs unevenly and the machine's stick cylinder bleeds down under load. What has the modification caused?

A. The wider bucket increases the digging resistance, requiring more hydraulic force — the increased load exceeds the stick cylinder's holding pressure and causes it to drift

B. The additional weight from the welded material has shifted the bucket's centre of gravity outside the cylinder's designed load envelope

C. The welding heat has warped the bucket cheek plates, changing the bucket's geometry and causing it to dig at an angle rather than straight into the material

D. The increased bucket width and weight have exceeded the machine's rated bucket capacity — the stick cylinder cannot hold the heavier, wider bucket under load because the hydraulic force required exceeds the cylinder's design pressure at the increased lever arm

125. A technician is replacing a hydraulic thumb on an excavator. The new thumb is a different brand than the original but has the same mounting pin dimensions and hydraulic specifications. After installation, the technician discovers the thumb cylinder's hose connections are on the opposite side of the cylinder compared to the original. What must be done?

- A. Swap the supply and return hoses at the machine's auxiliary valve connections to reverse the cylinder's extend and retract functions to match the new thumb's orientation
- B. The hoses can be crossed at the cylinder connections without any modification to the machine's valve or hose routing
- C. The thumb must be returned and the correct brand installed — crossing hydraulic hoses creates a safety hazard because the operator's controls would operate in reverse
- D. The cylinder must be rotated 180 degrees on its mounting pin to position the hose connections on the same side as the original, and the hoses connected in the standard configuration

126. A technician is inspecting a loader's ROPS structure and discovers a crack at the base of one of the four ROPS mounting posts where it joins the frame. The crack is approximately 75 mm long. What action is required?

- A. Apply a cosmetic weld repair to the crack and continue operating — the three remaining intact posts provide adequate rollover protection
- B. Remove the machine from service immediately — any crack in a ROPS structural member or its mounting point compromises the entire ROPS certification and the structure must be assessed and repaired by an OEM authorized facility before the machine returns to operation
- C. Monitor the crack length at each daily pre-shift inspection and schedule a repair when the crack reaches 150 mm — below this threshold, the remaining cross-section is adequate
- D. Weld a reinforcement plate over the cracked area using a structural electrode and return the machine to limited-duty service until a permanent repair can be scheduled

127. A technician installs a new set of GET (ground engaging tools) on a mining excavator bucket. The new teeth are a selfsharpening design with a carbide insert on the cutting edge. After 200 hours of operation, the operator reports the teeth are wearing much faster than the previous set. What should the technician investigate?

A. The toothtoadapter fit — if the teeth are not fully seated on the adapters, the unsupported tooth rocks under digging load, concentrating wear on one face rather than the selfsharpening geometry that requires uniform loading

B. The digging material has changed since the previous set was installed — if the current material is more abrasive, any tooth design will wear faster regardless of the selfsharpening feature

C. The carbide insert quality — a manufacturing defect in the carbide may have produced inserts with inadequate hardness that wear at the rate of standard tooth material

D. The operator's digging technique — if the operator is using excessive crowd force that bends the teeth rather than cutting, the selfsharpening geometry is defeated and the tooth wears from abrasion rather than cutting

128. A quick coupler on an excavator has been flagged during a safety audit because the secondary locking indicator is not visible from the operator's seat. The coupler is functioning correctly and the locks are confirmed engaged. What must be addressed?

A. No action is required — the secondary lock indicator is a maintenance inspection feature and does not need to be visible from the operator's seat during normal operation

B. Install extended indicator flags or a camera system that allows the operator to visually confirm the secondary lock status from the cab — the operator must be able to verify coupler engagement without leaving the machine

C. The coupler must be replaced with a model that has an indicator visible from the cab — operating with an invisible indicator violates the safety audit requirement

D. Repaint the indicator in a highvisibility colour (fluorescent orange or yellow) so it is visible from the operator's seat under all lighting conditions

129. A heavy equipment machine's frame has been repaired by welding after a crack was discovered. The repair procedure included preheat, welding with the correct electrode, postweld stress relief, and NDE verification. Despite the correct procedure, the repaired area cracks again after 3,000 operating hours. What is the most likely reason for the repeated failure?

- A. The welder did not achieve adequate penetration during the repair weld, and the lack of fusion at the weld root acted as a stress riser that initiated a new crack
- B. The stress relief procedure did not achieve the correct temperature or hold time, leaving residual stresses in the weld zone that reduced the fatigue life below the 3,000hour threshold
- C. The 3,000hour life is typical for a repair weld in a highstress location and confirms the repair procedure was correct — repair welds in highfatigue areas rarely achieve the original service life
- D. The crack location is a highstress area with a designlevel fatigue load that exceeds the repaired material's endurance limit — the repair procedure was correct but the underlying cause (stress concentration, underdesigned section, or operating overload) was not addressed

130. A technician notices that a wheel loader's counterweight mounting bolts use a specific washer arrangement — a hardened flat washer under the bolt head and a Belleville (conical spring) washer between the flat washer and the frame surface. What is the purpose of the Belleville washer in this application?

- A. The Belleville washer maintains clamping force on the counterweight mounting bolts by compensating for thermal expansion, frame flex, and vibrationinduced bolt relaxation — the spring action keeps the bolt loaded even as the joint moves during operation
- B. The Belleville washer prevents the bolt head from damaging the frame surface by distributing the clamping force over a larger contact area
- C. The Belleville washer acts as a threadlocking device by maintaining constant friction between the washer face and the bolt head, preventing the bolt from rotating under vibration
- D. The Belleville washer is a loadindicating washer that flattens to a specific height when the correct bolt torque is achieved, providing a visual torque verification

131. A technician is repairing a damaged operator seat mounting rail on a compact track loader. The rail is cracked and one mounting bolt hole has elongated. The technician welds the crack and drills the elongated bolt hole oversize to accept a larger bolt. Is this repair acceptable?

A. Yes — the welded crack restores the structural strength and the larger bolt provides more clamping area than the original, which improves the mounting security

B. No — the seat mounting rail is part of the ROPS restraint system and any modification — including oversizing bolt holes and field welding — must be approved by the OEM or a qualified engineer. An unauthorized repair may not provide adequate restraint during a rollover

C. Yes — provided the welder uses a structural electrode rated for the rail material and the replacement bolt is the same grade as the original

D. No — the entire cab floor must be replaced because the seat mounting rail is welded to the floor structure and cannot be repaired independently

132. A hybrid machine's energy management controller decides in real time whether the diesel engine or the electric motor (or both) should power each function. During a repetitive digging cycle on a hybrid excavator, when is the electric motor most likely to be the sole power source?

A. During the power stroke (bucket curl and boom up) when maximum force is required to break the material and lift the loaded bucket

B. During the loaded swing phase when the upper structure rotates to the dump point — the constant-speed rotation at moderate torque is well suited to electric motor operation

C. During the engine start sequence when the electric motor cranks the diesel engine through the motor-generator unit before transitioning to engine-driven operation

D. During the swing deceleration and boom-down phases, the electric motor operates as a generator (not a motor) to capture regenerative energy — it functions as the sole power source during these phases by converting kinetic and potential energy to electricity for battery storage

133. A batteryelectric machine's BMS (Battery Management System) reports that one cell in a series string is consistently reading 0.15V lower than the average of all other cells during discharge. What does this indicate?

- A. The low cell has a manufacturing defect in its separator material that allows a microshort between the electrodes, slowly selfdischarging the cell
- B. The BMS voltage sensor for that cell has drifted out of calibration and is reading 0.15V low compared to the actual cell voltage
- C. The low cell has reduced capacity compared to the other cells in the string — it reaches its discharge cutoff voltage first, limiting the entire string's usable capacity and creating a potential imbalance that the BMS must manage to prevent overdischarge of the weak cell
- D. The 0.15V difference is within the normal manufacturing tolerance for lithiumion cells and does not indicate a problem with the cell or the string

134. A technician is performing a scheduled HV safety inspection on a hybrid machine. One inspection step requires measuring the insulation resistance between each HV conductor and the chassis with a 500V megohmmeter. The OEM minimum specification is 500 k Ω . One conductor measures 200 k Ω . What does this mean?

- A. The conductor's insulation resistance is well above the safety threshold and no action is required
- B. The conductor's insulation has degraded below the minimum specification — current can leak from this HV conductor through the weakened insulation to the chassis, creating a shock hazard. The damaged cable must be located and replaced before the HV system is reenergized
- C. The 500V megohmmeter test voltage has damaged the insulation and the low reading is an artifact of the test itself — the insulation was adequate before the test
- D. The measurement is only valid if the HV system is energized during the test — a deenergized measurement does not reflect the insulation's behaviour under actual operating voltage

135. A fleet manager is considering converting a portion of the heavy equipment fleet from diesel to batteryelectric. The mine operates at high altitude (3,000 metres). What advantage does a batteryelectric machine have over a diesel machine at high altitude?

A. A batteryelectric machine's electric motor produces the same power output at 3,000 metres as it does at sea level because electric motors are not affected by air density — a diesel engine at the same altitude loses approximately 10–15% of its rated power due to the reduced oxygen available for combustion

B. A batteryelectric machine's battery charges faster at high altitude because the reduced air pressure lowers the boiling point of the cooling fluid, improving heat rejection during charging

C. A batteryelectric machine's regenerative braking is more effective at high altitude because the thinner air reduces aerodynamic drag, allowing more kinetic energy to be captured by the regenerative system

D. A batteryelectric machine produces zero exhaust emissions, which eliminates the need for the highaltitude exhaust aftertreatment system modifications required for diesel machines at 3,000 metres

Practice Exam 7: Answer Key and Explanations

1. C — Environmental regulations require the responsible party to contain and clean up any oil spill, collect contaminated soil and absorbent for proper disposal at a licensed facility, and report the spill to the provincial environmental authority if the volume exceeds the reportable quantity threshold. Leaving oil on the ground or allowing it to migrate to waterways carries severe penalties.

2. A — Cuts that expose inner load-bearing fibres compromise the sling's structural integrity — the intact outer cover is part of the designed cross-section, not just a protective layer. Stiffened webbing indicates chemical exposure or heat damage that has degraded the synthetic fibre material. Either condition requires the sling to be immediately removed from service and destroyed to prevent reuse.

3. B — WHMIS 2015 requires employers to provide site-specific education and training to every worker who handles or works near hazardous products at that workplace. Training must cover the specific hazards of the products on-site, how to read the labels and SDSs for those products, and the workplace's specific safe work procedures. Previous training at other workplaces or schools does not substitute for site-specific training.

4. D — Running a diesel engine indoors produces carbon monoxide, nitrogen oxides, and diesel particulate matter. In a partially enclosed maintenance bay, these exhaust gases accumulate rapidly and can reach toxic or fatal concentrations within minutes. The exhaust must be ducted outside through a flexible tailpipe connection or captured by a local exhaust extraction system before the engine is started.

5. C — A missed lone-worker check-in triggers the employer's escalation procedure — the defined sequence of contact attempts followed by dispatch of assistance if contact cannot be established. Waiting beyond the defined response time or logging the event for later follow-up defeats the purpose of the check-in protocol, which exists to ensure rapid response if the worker is injured, incapacitated, or in danger.

6. A — The audible bubbling indicates the battery is gassing — producing hydrogen and oxygen through electrolysis of the water in the electrolyte. Low electrolyte exposes the plate tops to air, accelerating permanent plate sulfation on the exposed area. The technician must add distilled water to cover the plates before continuing the charge, and verify the ventilation system is adequately removing the hydrogen gas.

7. D — Before using any lifting device, the technician must verify its rated capacity exceeds the total load weight including the rigging hardware. Additionally, the overhead monorail beam and its mounting to the building structure must be rated for the same or greater load. An undersized hoist, beam, or mounting can fail catastrophically under load, causing the load to fall.

8. C — A compressed gas cylinder stored without its valve protection cap is vulnerable to valve damage from any impact — a falling tool, a bump from a forklift, or the cylinder tipping over. If the valve breaks off a full high-pressure cylinder, the escaping gas converts the heavy steel cylinder into an uncontrolled high-velocity projectile that can penetrate walls and cause fatal injuries.

9. B — A skin sensitizer and chronic health hazard may produce no immediate pain or visible damage — the solvent absorbs through the intact skin barrier into the bloodstream, accumulating in internal organs over time. The skin sensitization component means the worker may develop a severe allergic reaction to future exposures that were previously tolerated. The absence of immediate irritation does not mean the exposure is safe.

10. A — ORFS fittings seal through O-ring compression against a precision-machined flat face on the mating fitting. The threads serve only to pull the faces together — they are not the sealing element. Applying thread tape interferes with the correct torque-to-seat relationship, can prevent the O-ring from compressing fully, and tape fragments that enter the hydraulic circuit damage precision valve components.

11. D — Fuel dilution at 15% reduces the oil's viscosity far below its designed grade, which thins the lubricating film at every bearing surface in the engine. The resulting metal-to-metal contact accelerates wear at the main bearings, connecting rod bearings, camshaft bearings, and piston pin bushings. If

uncorrected, the progressive bearing wear leads to catastrophic failure — a spun bearing, seized crankshaft, or broken connecting rod.

12. C — Excessive timing gear backlash produces a metallic rattling noise from the gear impact as the teeth move through the lash gap during load reversals (deceleration, compression braking). More critically, the backlash allows the camshaft to shift momentarily relative to the crankshaft during these reversals, producing transient timing variations that affect injection timing accuracy and valve event precision.

13. B — After a camshaft replacement, increased combustion noise and smoke point to an injection event that differs from the ECM's fuel delivery map. A replacement camshaft with a different injection lobe profile — different lift height, different duration, or different timing relative to the base circle — produces an injection event that does not match the ECM's programmed expectations, causing excessive pressure rise rate (noise) and incomplete combustion (smoke).

14. A — Milky grey oil with a rising oil level and dropping coolant level confirms coolant is entering the engine oil through an internal leak — most commonly a failed head gasket, cracked head, or cracked liner seal. Coolant-contaminated oil loses its lubricating properties immediately. The emulsified oil cannot maintain an adequate film on bearing surfaces, and continued operation will destroy the bearings within hours. Immediate shutdown is mandatory.

15. C — An engine block heater pre-heats the coolant and block casting, raising the cylinder wall temperature well above the -35°C ambient. Warmer cylinder walls reduce the heat loss from the compressed air during the compression stroke, allowing the air temperature at TDC to remain above the fuel's autoignition point. The intake heater alone cannot overcome the extreme heat sink of a -35°C block.

16. D — Adjusting valve lash on a warm engine produces a setting that does not account for the additional thermal expansion that occurs between the warm measurement temperature and the full operating temperature. As the engine reaches full operating temperature, the components expand further, tightening the lash beyond the specification. Valves that were correctly set warm may not fully close at operating temperature, causing compression loss and potential valve burning.

17. A — The crankcase ventilation system routes oil mist from the crankcase to the intake manifold for re-combustion. If the CCV separator element has failed, it passes liquid oil and heavy oil mist directly to the intake instead of returning it to the sump. This oil enters the combustion chambers through the intake

ports and is burned at a rate that does not produce visible blue smoke but is sufficient to cause measurable oil consumption.

18. B — A hairline crack in a high-pressure fuel line is invisible at low injection pressures but opens under the extreme pressure peaks (1,600–2,500 bar) that occur during heavy-load injection events. The leak reduces the pressure pulse delivered to the affected injector below the threshold for proper atomization, producing the misfire under load. At idle and light load, the lower peak pressures do not open the crack.

19. D — With the DPF recently cleaned and the DOC unrestricted, the exhaust path through the after-treatment components is clear. The restriction must be downstream — a crushed, kinked, or internally collapsed exhaust pipe between the DPF outlet and the tailpipe. Internal collapse from heat damage or external impact is not always visible from outside the pipe and can only be confirmed by inspection or pressure testing of the downstream section.

20. C — The cold runner indicates that cylinder is producing significantly less combustion energy than the other five. The exhaust gas temperature from each cylinder is directly proportional to the energy released during combustion. A cylinder that is not receiving fuel (dead injector), has no compression (failed valves or gasket), or has severely retarded timing produces minimal heat — reading 130°C colder than normal.

21. A — Bright copper-coloured metallic particles in the coolant originate from copper-alloy components in the cooling circuit. The most common source is the oil cooler core, which uses copper or copper-alloy tubes. Erosion from coolant velocity, cavitation, or electrolytic (galvanic) corrosion between dissimilar metals in the cooling circuit attacks the tube surfaces, releasing copper particles into the circulating coolant.

22. D — A ticking noise from the exhaust manifold area after a gasket replacement that diminishes as the engine warms is the classic symptom of an exhaust leak that closes with thermal expansion. One or more manifold bolts may not have been torqued correctly, or the manifold may be warped. The cold manifold has a gap that leaks exhaust gas; as the manifold heats and expands, the gap closes and the leak — and noise — stop.

23. B — Tri-metal engine bearings have three layers: a steel backing, a copper-lead intermediate layer, and a soft lead-tin overlay on the surface. The overlay is the first layer to wear because it is the softest — designed to conform to minor surface irregularities and absorb contaminants. A slowly increasing

lead trend over multiple samples confirms the overlay is wearing through progressively, which is expected at high hours but warrants monitoring.

24. C — Carbon deposits on the intake valve tulip and stem restrict the airflow passage area into the cylinder, reducing volumetric efficiency and therefore power output. If deposits accumulate on the valve seat area, they prevent the valve from seating fully, creating a compression leak that worsens combustion quality. Severe deposits can hold the valve slightly open, leading to valve burning from constant exhaust gas exposure.

25. A — The wastegate actuator uses boost pressure to push against a spring and open the wastegate valve. If the actuator diaphragm has leaked, the spring force is no longer opposed by the correct boost signal. The wastegate remains closed at low RPM because the available boost pressure is too low to overcome even the weakened spring. Excessive boost develops because the wastegate cannot open to limit it.

26. B — In a normal cylinder cut-out test, disabling a healthy cylinder makes the engine rougher because one power impulse is removed. If disabling cylinder 4 makes the engine slightly smoother, that cylinder was contributing a negative or disruptive impulse — a misfire, a late combustion event, or an abnormal pressure pulse that was working against the engine's normal rotational balance.

27. D — When the exhaust temperature remains below the SCR system's minimum dosing threshold during extended idle, the ECM cannot inject DEF because the catalyst temperature is too low to convert ammonia to its active form. NO_x passes through the SCR unreduced. If the cumulative uncontrolled NO_x exceeds the emission system's programmed tolerance, the ECM initiates a progressive power derate per emission regulations.

28. A — Four glow plugs at 6 amperes each should draw 24 amperes total. A total circuit current of only 12 amperes confirms only two of the four glow plugs are drawing current. The other two have either open-circuit heating elements (failed plugs) or interrupted supply wiring. The two non-functioning cylinders will have reduced cold-start combustion assistance, which is often sufficient to prevent starting in cold conditions.

29. C — Repeated EGR cooler failures from internal tube cracking point to thermal fatigue as the root cause. The exhaust side of the cooler tubes experiences rapid temperature changes during load transitions — hot exhaust floods the tubes during load application and cold air enters during deceleration. If the cooling system allows excessive coolant temperature variation or the EGR valve

calibration exposes the cooler to extreme temperature differentials, the cyclical thermal stress fatigues the tube material.

30. B — The manifold pressure sensor reads absolute pressure — which includes atmospheric pressure. To determine the boost pressure above atmospheric (gauge pressure), the technician subtracts the atmospheric reading from the loaded reading: $250 \text{ kPa (absolute)} - 102 \text{ kPa (atmospheric)} = 148 \text{ kPa (gauge boost)}$. This 148 kPa represents the actual pressure increase that the turbocharger is producing above the ambient atmospheric baseline.

31. B — A retarder's effectiveness decreases as oil temperature rises because the thinning oil provides less shearing resistance. The correct operator response is to reduce the machine's speed before the grade using the service brakes and a lower gear selection. At the reduced speed, the retarder's heat generation rate drops to a level it can manage for the entire grade length.

32. A — Vertical play measured at the kingpin by lifting the wheel indicates the thrust bearing — which carries the vertical weight of the machine at each steer knuckle — has worn. The worn thrust surfaces allow the knuckle and wheel assembly to move vertically on the kingpin axis. This wear affects steering precision and produces clunking during bump impacts.

33. D — Salt-water corrosion directly attacks the hardened steel surfaces of the pins and bushings, creating surface pitting that prevents the lubricant film from forming properly. The corroded, pitted surfaces act as stress risers that initiate fatigue cracks under the cyclical loading of track chain articulation. The combination of corrosion and fatigue dramatically accelerates the wear rate beyond projections for non-corrosive environments.

34. C — A floating caliper design relies on the caliper sliding freely on its pins or guides to equalize pad contact on both sides of the rotor. If the slide mechanism is seized or corroded, the caliper cannot float — the hydraulic piston pushes the inboard pad against the rotor but the caliper cannot pull the outboard pad into equal contact. The outboard pad wears from the limited contact it does receive, while the inboard pad barely contacts.

35. A — Both front tires showing outer-edge wear without feathering — with toe within specification — points to excessive positive camber. Positive camber tilts the tops of both wheels outward, shifting the tire's load-bearing contact to the outer edge of the tread. This concentrated loading produces smooth outer-edge wear that is symmetrical between both front tires.

36. B — The governor cut-in and cut-out pressures are correct, confirming the pressure regulation cycle is normal. The prolonged build-up time indicates the compressor is producing less air volume per revolution than it should. Worn piston rings, worn cylinder bores, or damaged intake/discharge valves reduce the compressor's volumetric efficiency, requiring more revolutions (and therefore more time) to fill the system to cut-out pressure.

37. D — Asymmetric bottom roller wear with identical track tension and operating hours on both sides indicates one side is carrying a disproportionate load. Consistently working on a right-hand side slope or routinely swinging the upper structure to one side during every digging cycle places more machine weight and dynamic loading on the downhill undercarriage, accelerating roller tread wear on that side.

38. C — After completing the standard bleeder sequence, a spongy pedal indicates air remains trapped in a location the bleeders cannot reach. High points in the brake line routing, junction blocks, or the master cylinder bore can trap air pockets that the fluid flow during bleeding bypasses. Pressure bleeding (forcing fluid through the system under pressure) or gravity bleeding (allowing fluid to flow slowly under its own weight) can purge these trapped pockets.

39. A — A hydrostatic drive machine with correct charge and main pump pressures but difficulty steering in one direction isolates the fault to the motor or circuit on the affected side. If the left track motor has excessive internal leakage, it cannot develop the same retarding force as the right motor. During a left turn, the left motor must slow or stop — if it leaks internally, it continues freewheeling rather than decelerating.

40. B — When only one tie rod is adjusted, only one wheel's toe angle changes. The total toe may read correctly, but the steering wheel will be off-centre because the geometric centreline of the two wheels no longer aligns with the steering wheel's straight-ahead position. Both tie rods must be adjusted equally — splitting the total correction between both sides — to maintain a centred steering wheel.

41. D — The rear axle oil cooler transfers heat from the final drive oil to the engine coolant. An internal tube failure allows higher-pressure coolant to leak into the lower-pressure oil circuit, raising the oil level and producing the characteristic milky emulsion from coolant-oil mixing. The one-sided contamination confirms the failure is specific to that side's cooler.

42. C — The track shoes (60% worn) have worn faster than the chain (50% worn), but both are within their service limits. The shoes and chain are independent components — shoes can be replaced or serviced without replacing the chain. Installing new shoes on the existing serviceable chain restores ground engagement. Replacing the chain at 50% wear would waste 50% of its remaining service life.

43. A — A steering accumulator provides stored hydraulic energy for emergency steering when the engine-driven pump stops. During normal pump-driven operation, the accumulator's contribution is masked by the pump's continuous flow. The failed accumulator becomes apparent only when pump flow ceases — at that point, the operator discovers zero emergency steering capability, which is a critical safety deficiency.

44. B — A pushrod stroke of 55 mm approaching the 57 mm limit indicates the brake shoes have consumed most of their friction material. The long stroke reflects the distance the shoes must travel to contact the drum — as linings wear thinner, the shoes sit further from the drum and require more pushrod travel. The measurement indicates the linings are approaching their minimum thickness and replacement should be planned.

45. C — A cracked lock ring on a multi-piece rim under inflation pressure is an imminent life-threatening hazard. The crack weakens the ring's ability to retain the tire bead, and the ring can fracture and eject with lethal force at any moment. The machine must be removed from service, and the tire must be deflated from maximum distance using a remote valve tool before anyone approaches the rim assembly.

46. D — Gas pressure changes with temperature according to Gay-Lussac's Law. At 25°C (higher than the 20°C reference), the nitrogen pressure reads higher than it would at 20°C. The technician must use the OEM's temperature correction chart to calculate what the measured 2,500 kPa at 25°C equates to at the 20°C reference temperature before comparing it to the 2,750 kPa specification.

47. A — A fully charged 24V lead-acid battery bank (two 12V batteries in series) reads approximately 25.2–25.4V OCV after a 48-hour rest. A reading of 24.2V — approximately 1.0V below full charge — indicates the bank is at roughly 75% state of charge. The batteries should be charged and then load-tested to verify they can deliver their rated cranking current.

48. C — The 24V alternator produces correct output, confirming the engine drive speed is correct. The 12V alternator's low output at idle is therefore an internal alternator problem — the voltage regulator, field winding, stator, or rectifier must be tested to identify the component that is preventing the 12V unit from reaching its rated output. Belt drive and RPM are confirmed adequate by the 24V alternator's correct performance.

49. D — A CAN bus with two 120-ohm termination resistors in parallel should measure 60 ohms. A reading of 120 ohms confirms only one termination resistor is present — the other has failed open or is disconnected (possibly inside a module that has been removed or has lost power). The missing

termination causes signal reflections that corrupt data frames and produce communication errors across the entire network.

50. B — The original 15-ampere fuse was blowing because a fault in the circuit was drawing more than 15 amperes. The 30-ampere fuse does not fix the fault — it simply allows the fault current to flow without opening the fuse. The wiring in this circuit is rated for protection by a 15-ampere fuse. If the fault returns and the wire carries current above its rated capacity, the insulation melts, the wire overheats, and a fire can result.

51. A — A standard DMM set to DC volts does not display the switching characteristics of a PWM signal. It measures the average DC voltage, which may not clearly differentiate between a continuous 24V supply and a 75% duty cycle PWM signal. To verify PWM operation, the technician must use a DMM with a duty cycle or frequency measurement mode, or an oscilloscope that can display the actual switching waveform.

52. D — After confirming the correct part number and connection, the remaining installation variable is the sensor-to-reluctor air gap. If the gap is too wide, the sensor signal amplitude is too weak for the ABS module to process. If too narrow, the sensor may contact the reluctor. The gap must be set to the OEM specification using a feeler gauge or the sensor's built-in gap-setting mechanism.

53. B — A continuous 15 mA draw for 90 days (2,160 hours) consumes approximately 32.4 Ah ($0.015\text{A} \times 2,160\text{h}$). A typical 210 Ah battery also self-discharges at 2–5% per month from internal chemical reactions. Over 90 days, the combined KAM drain and self-discharge may deplete the battery below starting threshold. A battery maintainer or disconnect should be used for extended storage.

54. C — With correct 5V reference and ground confirmed at the disconnected connector, the wiring between the ECM and the sensor is intact. Sensors 1 and 3 produce correct readings, confirming the ECM's reference supply and ground bus are functioning. The isolated 0V output from sensor 2 with a confirmed-good supply circuit means the sensor itself has failed — its internal sensing element has either open-circuited or shorted to ground.

55. D — The starter drive mechanism (Bendix, overrunning clutch, or reduction drive) is responsible for extending the pinion into the ring gear before the motor engages at full torque. A worn drive mechanism that does not fully extend or retract consistently allows the pinion to partially engage — sometimes meshing cleanly and sometimes catching the ring gear tooth faces at an incorrect depth, producing the intermittent grinding.

56. A — Operating an alternator continuously at 95% of its rated output places the unit at the edge of its thermal design envelope. The sustained heat shortens brush life, degrades bearing lubricant, and stresses the rectifier diodes. Additionally, there is no reserve capacity for cold-weather starting loads or future accessory additions. The electrical load analysis should be reviewed and the alternator may need to be upsized.

57. B — A proportional solenoid that operates only at full-open or full-closed — with no intermediate positioning despite receiving a correct 50% PWM command — indicates the spool cannot hold a mid-position. Contamination, varnish buildup, or mechanical binding from a burr or foreign particle causes the spool to stick. The electrical command is correct but the spool's mechanical response is binary rather than proportional.

58. D — A precisely repeating flash pattern (1 second on, 3 seconds off) is too regular to be caused by a random wiring fault or an intermittent sensor signal. Many ECMs communicate fault codes by flashing the check engine light in a defined on/off pattern — a legacy diagnostic method that some systems retain alongside the modern digital DTC retrieval. The pattern should be referenced against the OEM's blink code chart.

59. C — The ECM cross-references the TPS and APPS signals for validity. When the two sensors disagree beyond the programmed correlation window (4.2V vs. 2.1V), the ECM cannot determine which sensor is correct. Rather than risk responding to a faulty signal, the ECM enters a protective derate or limp mode that limits engine output until the sensor disagreement is resolved.

60. A — A 12V lead-acid battery passes a load test if the terminal voltage remains above 9.6V (at 21°C/70°F) after 15 seconds under a load equal to 50% of the CCA rating. A voltage below 9.6V indicates the battery cannot sustain adequate voltage under the high-current demand of cranking and must be replaced or further tested after a full recharge.

61. B — A ground circuit resistance of 5.2 ohms is far above the maximum acceptable value of 0.5 ohms for a sensor ground. The excessive resistance produces an unwanted voltage drop in the ground path that shifts the sensor's signal voltage reading. The ECM interprets this shifted signal as a different parameter value than the sensor is actually reporting, causing incorrect control decisions.

62. C — Before investigating a technical fault, the technician should compare the machine's operating pattern to the fleet average. Different duty cycles — more idle time, heavier loads, steeper grades, longer haul distances — are the most common explanation for fuel consumption variations between identical

machines. Confirming or eliminating the duty cycle difference focuses the investigation on the correct root cause.

63. A — The solenoid coil's resistance determines the current it draws at a given voltage (Ohm's Law: $I = V/R$). A coil drawing 2.8A at the rated voltage instead of the specified 2.0A has a lower-than-designed resistance — indicating shorted turns inside the coil. The reduced resistance from the shorted windings allows excessive current to flow, which may overheat the coil and damage the ECM driver.

64. D — A functioning CAN bus with active module communication shows an average differential voltage of approximately 2.0V between CAN-H and CAN-L (CAN-H averaging ~3.5V and CAN-L averaging ~1.5V during dominant states). A 0.0V differential means no signal is present — both lines are at the same voltage, either from a short between them, a short to a common rail, or complete loss of bus power.

65. B — A magnetic pickup sensor's signal amplitude depends on the relative velocity between the sensor's magnetic field and the reluctor teeth AND the air gap distance. If the output shaft bearing has developed play, the shaft wobbles slightly at higher speeds, causing the reluctor wheel to vary its distance from the sensor during each revolution. The varying gap produces irregular signal amplitudes.

66. C — The radio's RPM-proportional buzz appeared only after the harness replacement, confirming the new harness routing is the cause. The radio's power supply wire is routed near or bundled with high-current switching circuits (alternator output, solenoid feeds) that produce electromagnetic interference. The EMI couples into the unshielded radio supply wire and produces the audible noise.

67. B — The injector coil resistance is within specification (eliminating the injector as the fault) and the ECM connector is clean (eliminating the ECM connection). The remaining variable is the harness wiring between the two — a corroded splice, damaged terminal, or partially broken conductor limits the current flow through the circuit below the ECM's expected threshold, even though the injector and ECM are individually functional.

68. A — In the RUN position, voltage should be present only on circuits designated for the RUN function — not on the START circuit. Voltage at the solenoid S terminal during the RUN position confirms the keyswitch has an internal fault where the RUN contacts are bridging to the START terminal, potentially engaging the starter while the engine is running and damaging the starter drive.

69. D — The 24V input is confirmed stable, so the converter is receiving adequate supply. The intermittent 12V output must be tested under load — the converter may be failing internally and unable to maintain its rated 12V output when the connected loads draw their operating current. A converter that produces correct voltage at no-load but drops out under demand has an internal fault.

70. C — A three-phase rectified DC waveform should show three evenly spaced humps per cycle. A missing hump confirms one of the three phases is not contributing output — either a stator winding has opened or a pair of rectifier diodes (one positive, one negative for that phase) has failed. The alternator produces only two-thirds of its rated output, which may be insufficient for the machine's electrical demand.

71. B — The incomplete heat-shrink seal leaves a gap where moisture can wick along the wire strands — capillary action draws water through the fine channels between the individual copper conductors into the crimp connection. This moisture initiates corrosion inside the crimp that progressively increases resistance until the circuit becomes intermittent or opens completely — an invisible failure inside an apparently intact repair.

72. B — Stall speed above specification with a verified-good engine indicates the transmission is not presenting the designed resistance to the converter. The most common cause is a slipping internal clutch pack — the turbine is not being held as firmly by the transmission, allowing the engine to overspeed the converter pump past its designed stall point. The specific clutch can be identified through a stall test in each gear range.

73. D — A metallic grinding noise isolated to a single gear range with correct clutch pressure points to a mechanical component specific to that range's power path. The planetary gear set components — planet gears, planet pins, planet gear needle bearings, sun gear, or ring gear — that are carrying the load in 3rd gear are the most likely source. A damaged tooth, broken pin, or failed needle bearing produces grinding under load.

74. A — Despite being marked before removal, the driveshaft was reinstalled with the yoke ears out of phase. The marks must be aligned so both yokes are in the same rotational plane — 90 degrees of misalignment between the two yokes produces a torsional velocity variation at each U-joint that does not cancel, creating a vibration at all speeds proportional to driveshaft RPM.

75. C — The limited slip clutch pack has seized completely from the incorrect gear oil. Without the friction modifier additive, the clutch plates have bonded to the separator plates through excessive friction. Both axle shafts are now locked together with no speed differential possible. The tires must slip

on the pavement during tight turns, producing the pulsing sensation as they alternate between grip and break-away.

76. B — The input shaft expands with temperature during operation. With only 0.08 mm endplay (less than the 0.15 mm minimum), the shaft will expand into the bearing as the transmission reaches operating temperature. This eliminates the running clearance, preloads the bearing, generates friction heat, and accelerates bearing wear that can lead to premature seizure.

77. D — In a transfer case without a tensioner, there is no mechanism to compensate for chain elongation. The excess slack from the 2% elongation produces a clunking noise during load reversals as the chain snaps tight in the new direction. More critically, the slack chain can skip teeth on the smaller sprocket during high-torque events, causing catastrophic chain and sprocket damage.

78. A — The dowel pins precisely position the transmission bell housing concentrically with the crankshaft centerline. A missing dowel allows the bell housing to shift off-centre by the bolt-hole clearance, causing the input shaft to run eccentrically relative to the crankshaft. This cyclic radial loading accelerates pilot bearing wear and can cause input shaft bearing failure from the continuous off-axis force.

79. C — Spalling is surface fatigue failure — the hardened tooth surface develops subsurface cracks from repeated contact stress that exceeds the material's endurance limit. These cracks propagate to the surface, and small chips of hardened material flake off. The resulting rough, pitted surface accelerates wear on both the affected teeth and the mating teeth, and the spalled area continues to grow as the stress concentration worsens.

80. D — The ECM's response to a retarder efficiency deficit depends on the OEM's programming. Common strategies include increasing the retarder solenoid command, activating the engine compression brake, requesting a downshift for engine braking, and alerting the operator. The system uses all available resources to maintain safe speed control.

81. B — A transmission that hunts between 2nd and 3rd gear indicates the shift command is oscillating at the exact threshold where the shift valve is balanced between the two states. A misadjusted governor, incorrect governor drive gear, or a valve body calibration issue produces a governor pressure signal that hovers at the 2-3 shift point rather than transitioning cleanly through it.

82. A — Pre-lubricating the seal lip with grease provides the initial lubrication film between the rubber lip and the metal shaft surface during the first revolutions of operation. Without this film, the dry rubber lip runs against the dry steel shaft, generating immediate friction heat that can damage the seal lip material and create a leak path before the axle oil reaches the seal contact area.

83. C — The wet clutch oil has been in service beyond its change interval. The oil's antioxidant additives have depleted, and the base oil has begun to oxidize from repeated thermal cycling. When heated to peak temperatures during heavy clutch loading, the degraded oil produces the characteristic burnt smell. The clutch is functioning correctly — the oil requires replacement.

84. D — The measured case drain flow of 15 L/min is nearly double the 8 L/min maximum specification. This confirms that high-pressure fluid is bypassing through the motor's worn internal clearances at an unacceptable rate. The bypassing fluid generates heat rather than producing output torque, reducing the motor's efficiency and the machine's drive performance.

85. B — With correct free play confirmed, the clutch pedal travel should be adequate for full disc release. Oil contamination on the clutch disc friction surfaces causes the material to swell, increasing the disc thickness beyond the pressure plate's designed release travel. When the release bearing fully retracts the pressure plate, the swollen disc still contacts the flywheel, dragging the input shaft.

86. C — Significantly more wear on one planet gear than the other two with equal operating hours indicates the worn gear's operating conditions differ from the others. A distorted carrier pin bore holds the affected gear's pin at an angle, causing its teeth to mesh unevenly with the sun and ring gear. The uneven mesh concentrates load on one face of each tooth, accelerating wear on that gear exclusively.

87. A — Torque multiplication ratio directly determines the converter's ability to amplify engine torque during the stall and multiplication phases. A 2.5:1 ratio multiplies engine torque by 2.5 times during stall — a 1.8:1 ratio multiplies by only 1.8 times. The operator will notice reduced breakaway force, slower initial acceleration, and less aggressive digging capability.

88. C — A whining noise that changes pitch with output shaft speed — present in all gear ranges and both directions — must originate from a component that rotates at output shaft speed regardless of gear selection or direction. The transmission output shaft bearing, output seal area, or the final drive input components meet this criterion. The pump turns at engine speed (not output speed) and the governor is only one of several possibilities.

89. B — A restricted condenser prevents adequate heat rejection from the refrigerant. The reduced heat rejection limits the rate at which refrigerant condenses from vapour to liquid in the condenser. With less liquid refrigerant available downstream, the expansion device receives less liquid per unit time, reducing the total mass flow rate of refrigerant into the evaporator. Less refrigerant evaporating in the evaporator produces lower low-side pressure.

90. D — The pressurization fan is at full speed, confirming the air-moving capacity is at maximum. With only 10 pascals achieved against a 50-pascal requirement, the air is escaping faster than the fan can pressurize the cab. The leak area must be identified — deteriorated door seals, window seals, panel gaskets, and any wiring or hose penetrations that have lost their sealing grommets are the most common leak sources.

91. A — The recovery machine stopped at 50% of the expected charge because there is only 50% of the charge remaining in the system. A slow leak — potentially from the evaporator core inside the HVAC housing, the compressor shaft seal, or a crimped fitting — has released refrigerant over an extended period. Slow leaks may not leave visible oil stains, especially in concealed locations.

92. C — The pressure relief valve on the compressor is opening briefly when the high-side pressure spikes above its set point on hot days under maximum cooling demand. Each opening vents a small amount of refrigerant, which temporarily reduces cooling capacity until the system equilibrates. Repeated events progressively deplete the charge. The root cause of the high-side pressure spike must be addressed.

93. B — Rapid compressor cycling (4 seconds on, 2 seconds off) is the classic symptom of a low refrigerant charge. The reduced refrigerant mass in the evaporator causes the low-side pressure to drop below the low-pressure switch cut-out during each brief run cycle. The compressor shuts off, pressure equalizes above the cut-in threshold, the compressor restarts, and the cycle repeats continuously.

94. D — The temperature controller uses the cab temperature sensor's feedback to determine whether to increase or decrease heat output. If the sensor is failed or reading inaccurately, the controller responds to false temperature data — overshooting in the heating direction because the sensor reports cold, then overcorrecting in the cooling direction when the accumulated heat finally registers. The oscillation continues because the feedback loop is broken.

95. C — A variable displacement compressor adjusts its internal displacement to match system demand. A worn swash plate, wobble plate, or internal control mechanism can produce an imbalance at certain

displacement settings that generates a low-frequency vibration. The vibration transmits through the compressor body, the mounting bracket, and the drive belt to the engine and cab structure.

96. A — A hot inlet hose with an ambient-temperature outlet hose confirms coolant reaches the core entrance but cannot flow through it to the outlet. The heater core is completely blocked — scale, debris, or a sediment plug inside the core prevents any coolant circulation. No heat transfer to the cab air can occur without coolant flow through the core.

97. B — When the cab is in recirculation mode, the same air is recirculated continuously. The operator's respiration consumes oxygen and produces CO₂, progressively raising the CO₂ concentration inside the sealed cab. Elevated CO₂ causes drowsiness, reduced alertness, and impaired cognitive function. The automatic switch to fresh air replaces the high-CO₂ cabin air with fresh outside air to maintain the operator's alertness.

98. D — An axial piston pump's design ensures multiple pistons are always in the discharge phase simultaneously through the overlap provided by the valve plate timing. With nine pistons, approximately four to five are on the discharge stroke at any instant while the others are on the intake stroke. This continuous overlap is the fundamental reason axial piston pumps produce characteristically smooth, low-pulsation flow output.

99. C — The system should reach 280 bar when a cylinder stalls against its stop — the pump continues to supply flow with no outlet, and pressure should rise to the relief valve setting. A maximum reading of 210 bar during a stall indicates either the relief valve has drifted down to 210 bar and is opening prematurely, or the pump cannot generate pressure above 210 bar. The relief valve must be tested and the pump evaluated.

100. A — A particle trapped at the rod seal lip is dragged around the full circumference of the rod as the cylinder cycles, cutting a continuous groove into the chrome surface. This circumferential scratch damages the seal lip on every subsequent stroke cycle, producing a progressive external leak. Additionally, the groove provides an entry path for contamination on the inward stroke.

101. B — A counterbalance valve holds the load by blocking return flow until a positive pilot signal commands it to open. If the pilot signal fluctuates — from a loose connection, a worn shuttle valve, or an erratic pilot supply — the counterbalance valve opens and closes inconsistently, producing variable lowering speeds despite constant operator input.

102. D — Full forward speed but half reverse speed with correct charge and loop pressures at the pump test ports suggests the motor is the issue. The case drain flow from the motor should be measured — excessive motor internal leakage allows fluid to bypass through worn clearances rather than driving the motor at full speed. The leakage affects reverse more than forward if the motor's wear pattern creates directionally biased bypass.

103. A — The swing cross-port relief valves determine the maximum pressure available to decelerate the swing mass. Reducing the relief setting means the valves open at a lower pressure, absorbing the swing's kinetic energy more aggressively. The swing decelerates faster and the overshoot is reduced. The trade-off is reduced maximum swing torque.

104. C — A 10-micron absolute filter stops 98.7% or more (Beta 1000) of particles at or above 10 microns. A 10-micron nominal filter allows a significant percentage of particles at and above 10 microns to pass — typical nominal filters may only capture 50–90% at the stated micron size. The nominal element provides substantially less protection for downstream components.

105. D — The governor should unload the compressor at 860 kPa. Operating to 930 kPa before unloading means the governor's cut-out setting has drifted high. This subjects all air system components to 70 kPa above their designed maximum operating pressure. The governor must be readjusted to the specified 860 kPa cut-out pressure.

106. B — A differential-bore cylinder (rod present on one side only) has a smaller effective area on the rod end than the cap end. When the same flow enters the smaller rod-end chamber, the piston must travel faster to accept that volume — $\text{speed} = \text{flow} \div \text{area}$. The approximately 1.5:1 speed ratio matches the area ratio between the cap end (78.5 cm²) and the rod end (approximately 40 cm²).

107. A — The charge relief valve has been verified correct, which eliminates the relief as the pressure-limiting cause. Low charge pressure with a correct relief setting means the charge pump is not producing adequate flow to maintain the specified pressure. Worn charge pump internals reduce volumetric efficiency, and the pump cannot displace enough fluid per revolution to sustain the specified pressure against the system's internal leakage demand.

108. D — In a series cylinder circuit, the rod-end output of cylinder A feeds the cap end of cylinder B. Because the rod occupies volume inside cylinder A's rod end, the output flow from A's rod end is less than the input flow to A's cap end. Cylinder B receives this reduced flow and therefore extends slower than cylinder A. A make-up circuit is needed to supply the flow deficit if equal speeds are required.

109. C — The $\pm 2\%$ accuracy specification on a 400-bar full-scale gauge means the potential error is $\pm 2\%$ of 400 bar = ± 8 bar at ANY point on the scale. At a 200-bar indication, the actual pressure could be anywhere from 192 to 208 bar. This fixed ± 8 bar uncertainty applies regardless of where on the scale the reading falls.

110. B — Motor speed (RPM) = Flow (L/min) \div Displacement (L/rev). Converting displacement: $500 \text{ cm}^3 = 0.5 \text{ L}$. Speed = $120 \div 0.5 = 240$ RPM theoretical output speed. This is the speed before accounting for the motor's volumetric efficiency, which would reduce the actual speed slightly below 240 RPM under load.

111. D — The 100-bar pre-charge has dropped to 60 bar. At system minimum pressure (150 bar), the low pre-charge gas compresses to a very small volume — potentially crushing the bladder against the gas valve opening, extruding it into the valve port and causing immediate bladder failure. Additionally, the accumulator stores less usable oil per pressure cycle because the gas occupies a different volume ratio.

112. A — Volumetric efficiency at zero pressure = (measured flow \div theoretical flow) $\times 100 = (148 \div 153) \times 100 = 96.7\%$. At zero back-pressure, there is no pressure-induced internal leakage — the 3.3% loss represents mechanical losses only (incomplete filling, timing port overlap). This baseline establishes the pump's mechanical health before pressure-related losses are measured.

113. C — A pilot-operated check valve in each cylinder work port blocks flow in the held direction until commanded to open by a pilot signal. The check valves maintain the load-holding pressure in the cylinder indefinitely — regardless of pump state, DCV spool leakage, or any other circuit condition. The cylinder holds position until the operator commands movement.

114. D — The engine running provides exhaust brake or engine compression braking force that supplements the service brakes during the test. When the engine is off, this supplemental retarding force is absent and the service brakes alone must produce all stopping force. The longer stopping distance reveals that the total system relies on engine retarding force to meet the specification.

115. B — Cold hydraulic oil has dramatically higher viscosity than oil at operating temperature. The thick oil resists flow through the suction line, creating a partial vacuum at the pump inlet. If the vacuum exceeds the oil's vapour pressure, the oil vaporizes locally inside the pump, producing cavitation noise. As the oil warms and thins, suction restriction decreases, the cavitation ceases, and the noise disappears.

116. A — The LS signal conveys the highest active load pressure to the pump controller. The pump adjusts its output to maintain a fixed pressure margin (LS differential, typically 15–25 bar) above this load pressure. This ensures adequate flow is available to push fluid through the DCV metering edges to the actuator at any load, while minimizing wasted energy by not maintaining pressure above what the current load requires.

117. C — Both tracks operating at equally reduced speed with normal loop pressures and low-end charge pressure points to the charge circuit as the common factor. A worn charge pump producing marginal charge flow cannot adequately replenish the loop flow lost to normal case drain leakage. The main pump's inlet side becomes slightly starved, producing the cavitation noise and reducing the total delivered flow equally to both motors.

118. D — A sudden increase in water content (from 0.02% to 0.8%) without any recent system opening points to a continuous external water source. A failed hydraulic oil cooler (oil-to-coolant type) allows higher-pressure coolant to leak into the lower-pressure oil circuit through a failed tube. The coolant volume entering the oil explains both the sudden water content increase and the contamination rate.

119. B — Required piston area = Force ÷ Pressure = 50,000 N ÷ 20,000,000 Pa (200 bar) = 0.0025 m² = 25 cm². Bore diameter = $\sqrt{(\text{Area} \div 0.7854)}$ = $\sqrt{(25 \div 0.7854)}$ = $\sqrt{31.83}$ = approximately 56.4 mm minimum. In practice, the next standard bore size above 56.4 mm (typically 63 mm or 70 mm) is selected to provide a working safety margin.

120. A — A pressure-compensated flow control valve meters the set flow (30 L/min) to the cylinder and diverts the excess flow through an internal bypass port back to the reservoir. The valve maintains the 30 L/min output regardless of variations in pump output or downstream load pressure, and the excess 70 L/min returns to tank at low pressure.

121. C — A twisted hose places torsional stress on the reinforcement wires that they were not designed to carry. The wire reinforcement is engineered for radial (pressure) loading, not torsional loading. Pressure cycling under twist fatigue the reinforcement at the fitting connection points where the stress concentrates, dramatically reducing the hose's fatigue life and increasing the risk of sudden failure.

122. B — A noticeable delay in front brake application with immediate rear brake application indicates a restriction in the secondary (front) circuit. A partially blocked line, restricted relay valve, or contaminated quick-release valve delays the air pressure delivery to the front chambers. The primary (rear) circuit has no restriction and applies at normal speed.

123. A — At 40,000 hours, the boom requires a comprehensive NDE program that combines MT (for surface and near-surface defects at all critical weld toes) with UT (for internal defects at high-stress joints). MT catches the majority of fatigue cracks that initiate at weld toes, while UT detects internal flaws such as laminations or lack-of-fusion that MT cannot reach. This multi-method approach provides the most complete assessment.

124. D — Widening the bucket increases the digging resistance (more material to cut) and moves the bucket's centre of gravity further from the stick pivot. The increased lever arm at the stick cylinder creates a higher holding force demand than the cylinder was designed for. At the increased load, the cylinder's internal seal bypass rate exceeds its ability to hold, producing the drift.

125. C — Crossing the hoses at either end reverses the cylinder's extend and retract functions relative to the operator's joystick input. This creates a serious safety hazard — the operator commands close and the thumb opens, or commands open and the thumb closes. Any hose crossing must be paired with a corresponding reversal at the machine's valve connections so the net operator command remains correct.

126. B — Any crack in a ROPS structural member or its mounting point compromises the entire ROPS assembly's ability to protect the operator during a rollover. The ROPS was tested and certified as a complete structural system — a crack at a mounting post base is a critical deficiency. The machine must be removed from service and the ROPS repaired by an OEM-authorized facility before returning to operation.

127. A — Self-sharpening tooth designs require the tooth to seat fully on the adapter so the digging forces load the cutting geometry evenly. If the tooth is not fully seated — from a worn adapter, contamination in the pocket, or a manufacturing tolerance mismatch — the unsupported tooth rocks under load, concentrating wear on one face rather than allowing the designed self-sharpening wear pattern to develop.

128. C — The quick coupler's secondary locking indicator must be visible from the operator's seat so the operator can verify engagement without leaving the cab. Installing extended indicator flags (bright-colored extensions on the existing indicator mechanism) or a camera focused on the indicator provides the visual confirmation required by the safety audit.

129. D — The crack recurred because the underlying cause was not addressed. The weld repair procedure was technically correct, but the location has a design-level stress concentration, an underdesigned cross-section, or the machine is being operated beyond its rated loads. Without

addressing the root cause — redesigning the section, adding reinforcement, or controlling the operating loads — the repair weld will fail at approximately the same interval.

130. A — Belleville (conical spring) washers maintain clamping force by compensating for joint relaxation from thermal expansion, frame flex during operation, and vibration-induced bolt stretch. The spring action keeps the bolt under tension even as the joint moves. Without the Belleville washer, counterweight mounting bolts would loosen progressively under the severe dynamic loading of excavation cycles.

131. B — The seat mounting rail is part of the ROPS restraint chain — the seat belt anchors to the seat, the seat mounts to the rail, and the rail connects to the cab floor structure. Any modification to this chain — including oversizing bolt holes (which reduces the rail's load-bearing cross-section at the hole) and field welding (which changes the metallurgy) — must be approved by the OEM or a qualified engineer to ensure adequate restraint in a rollover.

132. D — During swing deceleration and boom lowering, kinetic and potential energy are available for recovery. The electric motor-generator operates as a generator during these phases, converting the mechanical energy into electrical energy for battery storage. The motor-generator is not motoring (consuming energy) during these phases — it is generating, making it the sole power source converting mechanical energy to electrical energy for storage.

133. C — A cell consistently reading 0.15V lower than the string average during discharge has reduced capacity — it reaches its minimum safe voltage before the other cells. This weak cell limits the entire string's usable capacity because the BMS must stop discharge when any single cell reaches its cut-off voltage. The imbalance must be monitored and managed to prevent the weak cell from being over-discharged.

134. B — The measured insulation resistance of 200 k Ω is below the OEM minimum of 500 k Ω . This degraded insulation allows leakage current to flow from the HV conductor through the weakened insulation to the chassis, creating a ground fault hazard. The damaged conductor must be located and replaced before the HV system is re-energized.

135. A — Electric motors produce rated power output regardless of altitude because their performance depends on electrical input, not air density. A diesel engine at 3,000 metres loses approximately 10–15% of its sea-level power rating because the reduced atmospheric oxygen limits the fuel that can be burned per combustion cycle. The battery-electric machine maintains full performance at any altitude.