PRACTICE EXAM 10: RED SEAL 421A SIMULATION (135 QUESTIONS)

1. A technician is replacing a hydraulic cylinder on the boom of a telehandler. The boom is fully lowered and resting on cribbing. The engine is shut down and locked out. Before disconnecting the hydraulic lines, the technician must relieve trapped pressure. The machine has no accumulator on the boom circuit. What is the correct depressurization procedure?

A. Open the reservoir filler cap to relieve system pressure — the open cap vents the reservoir to atmosphere and allows any trapped pressure to escape through the return line

B. Cycle the boom control lever several times with the engine off to bleed residual pressure from the cylinder circuits — the control valve shifts allow trapped oil to return to the reservoir through the valve's internal passages

C. Loosen the breather cap on the hydraulic reservoir and wait 15 minutes for any thermally expanded oil to equalize pressure naturally through the internal relief circuits

D. Crack the cylinder hose fittings immediately — with the boom resting on cribbing and the engine off, there is no stored energy in the circuit and the lines can be disconnected without depressurization

2. A technician is assigned to repair a machine operating in a landfill environment. The machine is parked on unstable fill material that includes household waste, construction debris, and potentially hazardous materials. What sitespecific hazard must the technician assess before beginning work?

A. The noise level of adjacent compaction equipment — the landfill's heavy equipment produces noise above 85 dBA that requires double hearing protection before any repair work begins

B. The wind direction — the technician must position the machine so the prevailing wind blows landfill gases away from the work area before beginning any engine compartment repair

C. The landfill gas composition — methane and hydrogen sulfide from decomposing waste can accumulate in lowlying areas and inside machine compartments, creating explosion and toxic exposure hazards

D. The ground stability, potential for subsurface voids, the presence of landfill gas (methane/hydrogen sulfide), and the possibility of contaminated materials requiring specialized PPE — the unstable fill, gas exposure, and hazardous material contact are all hazards specific to the landfill environment

3. A technician discovers that a fall protection harness stored in the shop has been contaminated with hydraulic oil. The webbing is saturated and has a strong petroleum odour. The hardware (buckles, Drings) appears undamaged. Can this harness be returned to service after cleaning?

A. Yes — wash the webbing with warm soapy water, rinse thoroughly, and hang to air dry. Once the webbing is dry and pliable, the harness is serviceable

B. Yes — but only after the webbing is tested for tensile strength by a certified testing laboratory to verify the petroleum contamination has not degraded the fibre strength

C. No — petroleum products degrade the synthetic fibres used in fall protection webbing, reducing tensile strength below the rated capacity. The degradation may not be visible or detectable by touch. The harness must be removed from service and destroyed to prevent reuse

D. No — but only the contaminated webbing sections need to be replaced. The metal hardware can be transferred to new webbing by a certified harness repair technician

4. A technician is working on a machine that requires a test drive on a public road to verify a repair. The technician's driver's licence allows operation of standard vehicles but does not include a heavy equipment endorsement for public road travel. What must the technician do?

A. The technician cannot legally operate the machine on a public road without the proper licence endorsement — the machine must be transported on a lowbed trailer operated by a licensed transport driver, or a licensed operator must perform the test drive

B. The technician can operate the machine on a public road for distances under 1 km without a special endorsement because the travel is classified as maintenance testing

C. The technician can operate the machine on a public road if a licensed operator rides in the cab as a supervisor during the test drive

D. The technician can operate the machine on a public road if the employer provides written authorization and the machine displays a slowmoving vehicle triangle

5. A heavy equipment shop has installed a new overhead bridge crane rated at 10 tonnes. Before the crane is used for the first time, what must be completed?

A. The crane operator must read the manufacturer's operating manual and sign a documentation form confirming they have read and understood the crane's controls and capacity

B. The crane must be load tested and certified by a qualified inspector, all operators must be trained and certified for that specific crane type, and the crane's inspection schedule and maintenance log must be established before any lifting operations begin

C. The crane must be registered with the provincial workplace safety authority and assigned a unique identification number before any load is suspended

D. The shop floor must be loadrated by a structural engineer to confirm the building foundation can support the combined weight of the crane, its maximum load, and the dynamic forces during lifting operations

6. A technician is using an oxyacetylene cutting torch to remove a seized bolt from a machine frame. During the cutting operation, a hot slag particle lands on a nearby hydraulic hose. The technician notices a small flame on the hose surface. What is the correct immediate action?

A. Continue cutting the bolt and address the hose fire after the cut is complete — stopping midcut creates a thermal stress point in the frame that is harder to manage than a small surface flame

B. Alert all personnel in the immediate area and evacuate the shop before attempting to fight the fire because hydraulic oil fires escalate rapidly beyond extinguisher capacity

C. Use the acetylene torch to burn the small flame off the hose surface — the direct torch flame will consume the localized fire and cauterize the hose surface

D. Stop cutting immediately, shut off the torch, and extinguish the hose fire using the fire extinguisher staged at the work area — then inspect the hose for damage and replace it if the outer cover has been compromised by heat or flame

7. A technician is replacing a drive belt on a machine. The engine is shut down and locked out. The technician removes the belt guard, loosens the tensioner, and removes the old belt. While installing the new belt, the technician notices the belt guard mounting bolt holes are slightly elongated from vibration. What should the technician do about the guard before completing the job?

A. Repair or replace the belt guard before returning the machine to service — the guard is a safety device that prevents contact with the rotating belt and pulleys. Elongated mounting holes allow the guard to shift or detach during operation, defeating its protective function

B. Install the guard with largerdiameter bolts that fill the elongated holes and restore a tight fit without replacing the guard

C. Document the elongated holes on the work order for the next scheduled maintenance and reinstall the guard using the existing bolts — the guard will remain functional until the holes are repaired

D. Leave the guard off until replacement parts arrive — the machine can operate temporarily without the belt guard if the operator is informed of the missing guard

8. A technician is preparing to weld a repair on a machine's structural frame. The weld procedure specification (WPS) calls for E7018 lowhydrogen electrodes stored in a rod oven at 120°C. The technician opens a new sealed can of E7018 electrodes. Must these electrodes still be placed in the rod oven before use?

A. No — factorysealed cans protect the electrodes from moisture and the electrodes can be used directly from a freshly opened sealed can without reconditioning

B. No — E7018 electrodes are coated with a moistureresistant flux that does not require oven storage under any circumstances

C. Yes — regardless of the sealed can, the WPS requires all E7018 electrodes to be stored in a rod oven at the specified temperature before use. Once the can is opened, the electrodes are exposed to atmospheric moisture and must be placed in the oven to maintain the lowhydrogen condition required for structural welding

D. Yes — but only if the ambient relative humidity exceeds 50%, which is the threshold at which E7018 electrodes begin absorbing atmospheric moisture through their packaging

9. A technician discovers a frayed wire rope sling during a preuse inspection. Six visible broken wires are found in one rope lay length. The sling's rejection criteria specify a maximum of five broken wires in one lay length. The technician needs the sling to complete the current lift. Can the sling be used "just this once"?

A. Yes — the onewire excess is within a commonly accepted field tolerance of ±2 wires for heavy equipment lifting applications

B. No — a sling that meets or exceeds any single rejection criterion must be removed from service immediately, regardless of the urgency of the lift. There is no "onetime exception" for condemned rigging. An alternative sling rated for the load must be found before the lift proceeds

C. Yes — if the technician wraps the frayed area with electrical tape to prevent the broken wires from snagging and further unravelling during the lift

D. No — but the sling can be returned to service after the frayed section is cut out and the remaining length is reterminated with new thimbles and swaged ferrules

10. A technician must replace a hydraulic fitting on a machine that is parked on a slope. The machine cannot be moved to flat ground. What specific precaution must be taken regarding the machine's position on the slope before the technician begins working?

A. Position the toolbox uphill of the machine to prevent tools from rolling downhill into the work area during the repair

B. Park a service truck directly behind the machine as a barrier to prevent rollback if the brakes fail while the technician is working under the machine

C. Ensure the work area is roped off with caution tape to prevent other personnel from walking through the area while the machine is parked on the slope

D. The machine must be secured against movement with wheel chocks, blocked frame rails, or other positive mechanical restraints — in addition to the parking brake — before the technician positions themselves near or under the machine on the slope

11. A diesel engine's oil analysis report shows a sudden spike in silicon content — from a baseline of 8 ppm to 52 ppm in a single sampling interval. All other wear metals are stable. What is the most likely source of the elevated silicon?

A. The silicon spike indicates a coolant leak into the oil — silicatebased coolant corrosion inhibitors contain silicon that transfers to the oil through the leak path

B. A new siliconebased gasket sealant was used during a recent repair and the excess sealant is dissolving into the circulating oil

C. The elevated silicon confirms dirt ingestion — silicon (from sand, soil, or dust) has entered the engine through a compromised air filtration system, a damaged intake duct, or an improperly sealed air filter element

D. The silicon originates from the engine's cylinder liner antiscuff coating that is wearing through at an accelerated rate during the breakin period

12. A diesel engine is running rough and producing white smoke at idle. The technician performs a glow plug current test and finds that 3 of 4 glow plugs draw zero current. The engine coolant temperature sensor reads 82°C. How are the nonfunctional glow plugs related to the white smoke complaint?

A. The nonfunctional glow plugs are unrelated to the white smoke at 82°C — the glow plug circuit is disabled by the ECM above approximately 40°C because the engine is warm enough for reliable autoignition. The white smoke has a different cause such as a coolant leak, incorrect timing, or low compression on one or more cylinders

B. The glow plugs are the direct cause — even at 82°C, the glow plugs remain energized to assist combustion and their failure produces incomplete combustion that generates white smoke

C. The nonfunctional glow plugs have created carbon deposits in the prechambers that are now smouldering at operating temperature, producing the white smoke observed at idle

D. The glow plug failures have damaged the glow plug control module, which shares a ground circuit with the fuel injection timing circuit — the shared ground fault has retarded injection timing, producing the white smoke

13. A technician is measuring the crankshaft main journal diameter on a diesel engine during an overhaul. The micrometer reads 89.952 mm. The OEM standard journal diameter is 90.000 mm with a wear limit of 89.960 mm. What does this measurement indicate?

A. The journal is within the standard specification — the 0.048 mm undersize reading is within the normal manufacturing tolerance of ±0.050 mm for crankshaft main journals

B. The journal is at the exact wear limit and the crankshaft can be returned to service with standard bearings if all other journals are within specification

C. The journal has worn beyond the wear limit — at 89.952 mm (0.040 mm below the 89.960 mm wear limit), the crankshaft must be reground to the next available undersize and fitted with corresponding undersize bearings

D. The crankshaft has been previously reground to a standard undersize of 0.050 mm — the technician should verify by checking for regrind markings on the crankshaft counterweight

14. A Tier 4 Final diesel engine equipped with a DPF has been operating at idle for 6 consecutive hours in a mine staging area. The ECM initiates an active DPF regeneration. The engine RPM increases and the exhaust temperature rises to 600°C. What risk does this automatic regeneration create in the staging area?

A. The high exhaust temperature during regeneration can ignite the diesel fuel vapour that has accumulated around the exhaust outlet from the extended idle period

B. The hightemperature exhaust can contact nearby combustible materials on the ground — dry vegetation, spilled fuel, paper debris, or rubber mats — and start a fire in the staging area

C. The automatic regeneration consumes significant fuel and the engine's fuel level may drop below the minimum sensor level, triggering a fuel system fault and engine shutdown during the regeneration cycle

D. The elevated engine RPM during regeneration produces vibration that can loosen the machine's parking brake mechanism, creating a rollaway hazard in the staging area

15. A diesel engine has been running with a coolant leak for an extended period. The leak has been repaired. The technician now discovers the engine oil has a thick, dark sludge on the dipstick and inside the valve cover. What has formed in the oil system and what must be done before the engine returns to service?

A. The sludge is a coolantoil emulsion (also called mayonnaise) that formed from the prolonged coolant contamination — the engine oil system must be flushed with a suitable flushing oil to remove the emulsion from all galleries, passages, and bearing surfaces before fresh oil and filters are installed

B. The sludge is normal carbon buildup from extended operation between oil changes and requires no additional action beyond a standard oil and filter change

C. The sludge is oxidized oil that has broken down from the elevated operating temperature caused by the coolant leak — the oil system is selfcleaning and the sludge will dissolve when fresh oil is installed

D. The sludge is a mixture of combustion soot and fuel dilution that accumulated during the period of reduced cooling — a double oil and filter change at 25hour intervals will clear the sludge

16. A diesel engine's turbocharger has been replaced. During the first start after installation, the technician must prelubricate the turbocharger bearing housing before cranking the engine. Why is this prelubrication step critical?

A. The new turbocharger's bearings must be seated against their thrust surfaces before the exhaust gas spins the shaft — prelubrication provides the hydraulic force to push the bearings into their operating position

B. A new turbocharger's bearing housing is dry from manufacturing and shipping — without prelubrication, the first few seconds of engine operation spin the turbine shaft at high speed on dry bearings, causing immediate scoring and dramatically shortened bearing life

C. Prelubrication fills the oil drain cavity inside the turbocharger to create a seal between the compressor housing and the bearing housing, preventing boost pressure from leaking into the crankcase during the first start

D. Prelubrication is only required on journalbearing turbochargers, not on ballbearing turbochargers — the ball bearings are factorygreased and do not require external oil during the initial start

17. A diesel engine equipped with a variable geometry turbocharger produces a fault code for "VGT actuator stuck." The technician commands the VGT through its full range using the diagnostic tool and the actuator moves smoothly from fully open to fully closed with no sticking or hesitation. The fault code clears and does not return during the test. What is the most likely explanation for the intermittent fault?

A. The VGT actuator has a temperatureresensitive binding point — the actuator sticks when the exhaust housing is at full operating temperature but operates freely when tested at the cooler temperature present during the diagnostic test

B. The diagnostic tool commands the actuator at a slower rate than the ECM's normal operating commands — the actuator can follow the slow test command but cannot keep up with the faster ECM commands during normal operation

C. The VGT's feedback sensor (position sensor or speed sensor) has an intermittent fault that incorrectly reports the vanes as stuck when the physical mechanism is functioning correctly — the fault is in the sensor signal, not the actuator

D. The VGT's vane ring is carbonfouled — during normal operation, the hot exhaust carbon bonds the vanes to the unison ring momentarily. During the diagnostic test, the lower temperature and the mechanical force of the commanded actuation breaks the carbon bond. The fault will return during normal operation when the carbon reaccumulates

18. A technician discovers that a diesel engine's intake manifold has a thin film of oil on its internal surfaces. The engine uses a closed crankcase ventilation (CCV) system that routes blowby gases back to the intake. Under what condition is this oil film considered normal versus indicating a problem?

A. Any oil film in the intake manifold indicates excessive blowby — the CCV system should separate all oil mist from the blowby gas before it enters the intake

B. An oil film in the intake manifold always indicates the turbocharger compressor seal has failed, allowing oil from the bearing housing to enter the intake stream through the compressor housing

C. A thin oil mist film is normal — the CCV system cannot remove 100% of the oil vapour from the blowby gas, and a light residue is expected. A heavy oil coating, pooled oil, or visible oil dripping from the intake indicates excessive blowby, a failed CCV separator, or a turbocharger seal failure

D. Oil in the intake manifold is always a warranty claim issue regardless of quantity — the OEM's emission certification requires a completely dry intake manifold at all times

19. A diesel engine's electronic fuel injection system uses injector trim codes (IQA codes) that are unique to each injector. These codes are printed on the injector body and programmed into the ECM during installation. What do these trim codes compensate for?

A. Each injector has slight manufacturing variations in its internal clearances, nozzle flow rate, and opening pressure — the trim codes allow the ECM to adjust the pulse width for each individual injector to deliver the exact fuel quantity commanded, compensating for these manufacturing tolerances

B. The trim codes encode the injector's maximum fuel delivery capacity so the ECM can limit the fuel command to prevent any individual injector from being overdriven beyond its physical capability

C. The trim codes encode the injector's recommended replacement interval in operating hours so the ECM can generate a maintenance reminder when each injector reaches its service life limit

D. The trim codes encode the injector's solenoid coil resistance so the ECM can adjust its driver output voltage to deliver the correct current through each injector regardless of coil resistance variation

20. A diesel engine produces a brief puff of blue smoke at startup after sitting overnight, then runs cleanly with no smoke for the rest of the operating day. What is the most common cause of this symptom?

A. Fuel is leaking past the injector tips into the combustion chambers during the overnight sit period and burns off as blue smoke during the first few combustion cycles

B. The crankcase ventilation check valve is stuck open, allowing oil vapour to migrate from the crankcase into the intake manifold during the overnight sit — the accumulated vapour burns as blue smoke at startup

C. The air compressor is passing oil into the intake through a failed unloader valve, and the oil accumulates in the intake during the idle periods between compressor loaded cycles

D. Valve guide seals have hardened with age and no longer seal tightly when the engine is cold — during the overnight sit, oil seeps past the hardened seals and pools on top of the intake and exhaust valves. At startup, this pooled oil burns as a puff of blue smoke until the oil is consumed

21. A technician is performing an overhead valve adjustment on a diesel engine. The service manual specifies setting the intake valve lash at 0.30 mm and the exhaust valve lash at 0.51 mm. Why is the exhaust valve lash specification wider than the intake?

A. The exhaust valves operate at lower temperatures than the intake valves, and the wider lash compensates for the reduced thermal expansion of the cooler exhaust components

B. The exhaust valves and their associated components (stem, guide, seat, rocker arm) operate at significantly higher temperatures than the intake components — the wider cold lash compensates for the greater thermal expansion that occurs when the engine reaches operating temperature, ensuring the exhaust valves still close fully when hot

C. The exhaust valve rocker arms have a different lever ratio than the intake rocker arms, and the wider lash produces the same effective valve opening as the tighter intake lash

D. The exhaust valves require more closing force to seal against the higher exhaust pressure, and the wider lash provides the additional spring preload needed to hold the valves firmly on their seats during the exhaust stroke

22. A diesel engine has been overhauled and the technician is performing the initial breakin procedure. The OEM breakin procedure specifies varying the engine load between 50% and 75% of rated output for the first 2 hours, avoiding sustained fullload operation. Why does the breakin procedure restrict the load range?

A. The fresh gaskets and seals require a gradual thermal cycling period to achieve their final seal compression — sustained fullload heat would overcompress the gaskets before they have seated properly

B. The new fuel injectors must calibrate their IQA trim through the ECM's adaptive learning, which requires varied load conditions to sample the full operating range within the first 2 hours

C. The new piston rings must seat against the cylinder wall by gradually wearing the microscopic surface peaks (plateau honing) into a gastight seal — the varied load provides alternating compression pressures that promote even ring seating without overloading the unmated surfaces

D. The new turbocharger's bearings require gradual loading to distribute the oil film evenly across the full bearing surface before highspeed operation concentrates the load on a narrow bearing zone

23. A diesel engine's fuel system includes a water separator (fuelwater separator) in the primary fuel circuit. The separator has a clear bowl with a drain valve at the bottom. During a routine inspection, the technician observes a layer of water approximately 25 mm deep in the bottom of the bowl. What action is required?

A. Drain the water from the bowl using the drain valve — the separator is functioning as designed by collecting the water from the fuel before it reaches the highpressure system. The water must be drained to prevent it from rising to the level where it overflows into the secondary fuel filter and reaches the injection system

B. Replace the entire fuelwater separator assembly — the presence of water indicates the separator element has failed and is allowing water to pass through to the secondary filter

C. No action required — a 25 mm water level is within the normal operating range for a fuelwater separator and the bowl can hold up to 50 mm before draining is necessary

D. Drain the fuel tank completely and replace all fuel — the presence of water in the separator indicates the bulk fuel supply is contaminated beyond the separator's capacity to manage

24. A diesel engine's coolant system is being flushed after a coolant contamination event. The technician has drained the system and refilled it with clean water for the flush cycle. After running the engine for 30 minutes at operating temperature, the technician drains the flush water and discovers it has a slight green tint. What does this indicate?

A. The green tint is from the engine block's internal casting residue that dissolves in the flush water and is of no concern

B. Residual contaminated coolant remains in passages, heater circuits, heat exchangers, and low points of the system that did not drain completely during the initial drain. The system requires additional flush cycles until the drain water runs clear to confirm all contaminated coolant has been removed

C. The green tint is from copper corrosion products that dissolved into the flush water from the water pump impeller and the oil cooler tubes during the 30minute run

D. The flush water has reacted with the coolant system's DCA (supplemental coolant additive) that is embedded in the internal surfaces and cannot be removed by flushing — the tint will persist regardless of additional flush cycles

25. A diesel engine equipped with a common rail fuel system develops a hardstart condition only when the ambient temperature is above 35°C. The engine starts normally in cooler conditions. There are no fault codes. What temperaturerelated fuel system condition could cause this?

A. The common rail's pressure control valve is thermally expanding in the hot ambient, changing its seat geometry and allowing rail pressure to bleed below the starting threshold during hot cranking

B. The fuel injectors' nozzle tips expand in the hot ambient and the tighter tiptoseat clearance restricts fuel flow during cranking, reducing the fuel delivery below the starting requirement

C. The ECM reduces the starting fuel delivery quantity in hot ambient to prevent overfuelling the warm engine, and the reduced quantity is insufficient for reliable starting in the specific conditions

D. The fuel in the supply lines absorbs ambient heat and may reach temperatures that cause vapour formation in the lowpressure fuel circuit — the vapour displaces liquid fuel from the lines, creating an airlock condition that prevents the highpressure pump from receiving adequate liquid fuel during cranking

26. A diesel engine's exhaust system includes a diesel oxidation catalyst (DOC). The DOC uses a platinum and palladium catalyst surface to oxidize carbon monoxide (CO) and hydrocarbons (HC) in the exhaust stream. What happens to these pollutants inside the DOC?

A. The DOC filters CO and HC particles out of the exhaust stream and traps them in the catalyst substrate until they are burned off during a regeneration event

B. The DOC breaks CO and HC molecules apart into their constituent atoms, which are then released as free carbon and hydrogen gas through the exhaust outlet

C. The DOC converts CO to CO_2 (carbon dioxide) and HC to CO_2 and H_2O (water) through an exothermic oxidation reaction — the DOC lowers the activation energy required for these oxidation reactions to occur at exhaust temperatures

D. The DOC absorbs CO and HC into the catalyst metal surface and stores them permanently — the catalyst must be replaced when its storage capacity is exhausted

27. A diesel engine equipped with a highpressure common rail system is producing a rough idle with a cylinder balance deviation showing one cylinder contributing less power than the others. The technician performs an injector buzz test (electrical actuation test) using the diagnostic tool. All injectors click audibly when buzzed. Does this test confirm the injectors are functioning correctly?

A. Yes — the audible click confirms the injector solenoid is operating and the injector is delivering fuel as commanded by the ECM

B. No — the buzz test only confirms the injector's solenoid valve operates electrically (the coil generates magnetic force and the armature moves). It does not confirm the injector's nozzle is atomizing correctly, the delivery quantity is accurate, the injector is not leaking internally, or the return flow is within specification

C. Yes — the buzz test confirms both electrical operation and fuel delivery because the injector cannot click without fuel passing through the nozzle orifice

D. No — the buzz test is unreliable on common rail injectors and should only be used on mechanical injector systems where the click corresponds to the needle lifting off its seat

28. A diesel engine has a coolant leak that the technician has traced to the exhaust gas recirculation (EGR) cooler. The coolant is leaking from the EGR cooler into the exhaust stream and is visible as

white steam from the tailpipe. What additional damage should the technician inspect for beyond the EGR cooler failure?

A. The turbocharger — coolant mist in the exhaust stream can deposit on the turbine blades and cause corrosion or thermal shock that damages the turbine wheel over time

B. The intercooler — coolant that passes through the EGR valve can enter the intake manifold and contaminate the intercooler, reducing its heat exchange efficiency

C. The fuel injectors — coolant that enters the intake through the EGR circuit is ingested into the cylinders during the intake stroke, where it can cause hydraulic lock damage to injector tips and piston crowns

D. The DPF — the coolant entering the exhaust stream passes through the DOC and deposits on the DPF substrate. The coolant's glycol and silicate content poisons the DPF catalyst coating and clogs the ceramic pores, reducing the DPF's filtration and regeneration capability

29. A technician is diagnosing a diesel engine that runs but cannot reach full rated power. The boost pressure at rated RPM and full load is 15 kPa below specification. The turbocharger appears functional — no play in the shaft and the compressor wheel spins freely. What should be checked before condemning the turbocharger?

A. The intake and exhaust system for restrictions — a clogged air filter, a collapsed intake hose, an exhaust restriction (DPF, kinked pipe), or a charge air cooler leak reduces the effective airflow through the turbocharger and limits the achievable boost, even with a mechanically sound turbo

B. The engine timing — retarded injection timing reduces the exhaust gas energy available to drive the turbocharger, limiting the boost pressure the turbo can develop at rated speed and load

C. The engine's compression — low compression on multiple cylinders reduces the engine's ability to generate the exhaust gas volume and temperature needed to spin the turbocharger to its rated speed

D. The fuel quality — lowcetane fuel produces a slower burn rate that releases exhaust energy later in the cycle, after the exhaust valve has opened wider, which reduces the effective exhaust pulse energy at the turbine

30. A diesel engine's oil analysis trending shows a gradual increase in sodium and potassium over four consecutive samples. All other wear metals are stable. Iron, copper, lead, aluminum, and tin are at normal trending levels. What is the most likely source of the increasing sodium and potassium?

A. Sodium and potassium are common components of the corrosion inhibitor additive package in engine coolant — the gradual increase over multiple samples indicates a small, slow coolant leak into the oil system that is introducing coolant additives into the oil at a rate too slow to produce visible contamination on the dipstick

B. Sodium and potassium originate from the oil's own additive package and the increasing levels indicate the additives are breaking down from thermal stress

C. Sodium and potassium are atmospheric contaminants that enter the engine through the air intake and accumulate in the oil over multiple drain intervals

D. Sodium and potassium originate from the DEF (diesel exhaust fluid) system — a leak in the DEF dosing circuit is allowing urea solution to contaminate the exhaust system and migrate into the oil through the EGR circuit

31. A technician is performing a steer axle inspection on an articulated dump truck. The articulation joint uses upper and lower pivot pins with tapered roller bearings. The technician measures vertical play at the articulation point by jacking the front frame and measuring movement with a dial indicator. The measured play is 1.5 mm. The OEM specification maximum is 0.5 mm. What is the consequence of this excessive play?

A. The excessive play produces a rattling noise during travel over rough terrain but has no effect on the machine's steering precision or structural loading

B. The excessive play allows the steering cylinders to overextend during articulation, potentially pushing the cylinders past their stroke limit and damaging the cylinder seals

C. The excessive play increases the tire wear on the front axle by changing the effective caster angle during steering inputs, producing a scrubbing action on the front tires

D. The front and rear frames can shift vertically relative to each other during loaded operation — this misalignment produces uneven loading on the articulation pins, accelerates bearing wear, stresses the frame structures at the articulation joint, and reduces steering precision

32. A large mining truck's front suspension uses nitrogenoveroil struts. The technician measures the strut extended length (ride height) with the truck empty on flat ground. The left strut measures 685 mm and the right strut measures 720 mm. The OEM specification is 700 ± 15 mm for empty ride height. What do these measurements indicate?

A. Both struts are within specification and no adjustment is needed — 685 mm is within the lower tolerance (700 − 15 = 685) and 720 mm is within the upper tolerance (700 + 15 = 715) — however, 720 exceeds 715

B. The left strut is at the extreme lower limit of specification and the right strut exceeds the upper limit — the left strut may be low on nitrogen or oil, and the right strut may be overcharged or have a mechanical issue preventing full compression

C. The 35 mm difference between left and right sides indicates the truck frame is twisted from a structural overload and the struts themselves are functioning correctly

D. The left strut needs additional nitrogen to raise it to the 700 mm nominal height, and the right strut needs oil removed to lower it to 700 mm

33. A tracked machine's undercarriage has been measured and the technician determines the track chain requires a pinandbushing turn (rebushing). This procedure rotates the pins 180 degrees in the link bores so the unworn side of the pin and bushing contact surfaces become the new bearing surfaces. At what wear percentage should this procedure typically be performed?

A. At approximately 50% pin and bushing wear — turning at 50% exposes the unworn side while sufficient material remains on both the turned and unturned surfaces to provide a second wear life approximately equal to the first

B. At approximately 80% pin and bushing wear — turning at 80% maximizes the first wear period before requiring the service intervention

C. At approximately 70% wear — but only if the track links and shoes are also at 70% wear so all components can be serviced simultaneously to minimize machine downtime

D. Pin turning can be performed at any wear percentage because the unworn surface always provides the same second wear life regardless of when the turn is performed

34. A wheel loader operates on a paved surface in a lumber yard. The operator reports the machine feels "bouncy" during loaded travel — the machine oscillates vertically after hitting a bump and the oscillation takes several cycles to dampen. The tires are solid rubber (nonpneumatic). What is the most likely cause?

A. The solid rubber tires have no pneumatic damping — unlike airfilled tires that absorb and dampen road impacts through air compression, solid tires transmit virtually all impact energy directly to the machine's frame and suspension, producing the sustained oscillation after each bump

B. The front axle oscillation pivot has seized, transferring all bump energy directly to the cab through the rigid frame connection

C. The hydraulic accumulator on the steering circuit has lost its precharge, and the lost damping from the accumulator allows the steering system to oscillate in response to road impacts

D. The loader's boom is in the raised position during travel and the elevated centre of gravity amplifies the vertical oscillation from road impacts

35. A heavy equipment machine's air brake system has been serviced and the technician performs a final brake test. The compressor builds system pressure from zero to the governor cutout pressure (860 kPa) in 4 minutes. The OEM specification requires buildup from zero to cutout in a maximum of 3 minutes. What does the extended buildup time indicate?

A. The governor cutout pressure setting has drifted high, requiring the compressor to generate more pressure than specified and therefore taking longer to reach the elevated cutout point

B. The air system has a leak that is consuming air during the buildup, reducing the net air volume being stored in the reservoirs per unit time and extending the buildup duration

C. The compressor drive belt is slipping at higher pressures, reducing the compressor's RPM and therefore its output volume during the final portion of the buildup cycle

D. The compressor output is insufficient — either the compressor has lost pumping efficiency (worn valves, worn cylinders), the system has a leak that is consuming air during the buildup, or the total system volume has increased (additional reservoirs or larger chambers). All three conditions reduce the net air stored per unit time and extend the buildup

36. A technician is adjusting the preload on a wheel hub bearing set (tapered roller bearings). The OEM procedure specifies tightening the adjusting nut to 270 N·m while rotating the hub, then backing the nut off to the nearest castellation and installing the cotter pin. What is the purpose of rotating the hub during tightening?

A. Rotating the hub seats the bearing rollers against the cup (outer race) surfaces and distributes the lubricant evenly across all roller contact areas — this ensures the bearing preload measurement reflects the actual running condition rather than a dry or partially seated state

B. Rotating the hub prevents the rollers from being crushed in a single position by the tightening force — the rotation distributes the load across all rollers simultaneously

C. Rotating the hub confirms the bearing is not binding at the specified torque — if the hub becomes difficult to rotate before reaching the specified torque, the bearing is damaged or contaminated

D. Rotating the hub generates heat from friction that expands the races to their operating temperature, allowing the technician to set the preload at the hot condition rather than the cold condition

37. A machine's hydraulic power steering produces adequate steering force in both directions but the steering wheel does not return to centre when released after a turn. The steering valve centering springs have been verified as functional. What should the technician investigate?

A. The steering cylinder rod seals — if the seals are binding on the rod, the friction prevents the steering linkage from returning to centre under the centering spring force alone

B. The steering pump's internal relief valve — if the relief is set too low, the pump cannot produce the pressure needed to overcome the steering friction during the returntocentre movement

C. The front axle geometry — insufficient caster angle reduces the selfcentering force generated by the tire contact patch trailing behind the steering axis, preventing the wheels from naturally returning to the straightahead position under the force of gravity and road contact

D. The steering accumulator — a depleted accumulator cannot provide the stored energy needed to assist the centering springs in returning the steering to centre

38. A machine's emergency/parking brake is tested and holds the machine on the specified 15% grade. The brake is then tested for dynamic stopping capability from 10 km/h — the machine is driven at 10 km/h and the emergency brake is applied. The machine requires significantly more stopping distance than specification. Why can a brake pass the static holding test but fail the dynamic stopping test?

A. The static test and dynamic test load different brake components — the static test loads the friction material's holding friction while the dynamic test loads the thermal capacity and the actuating mechanism's speed

B. Static friction (holding a stationary load) produces a higher friction coefficient than kinetic friction (stopping a moving load). The brake generates enough force to hold the machine stationary but not enough to decelerate it from 10 km/h within the specified distance — the brake actuation force or friction material is inadequate for dynamic stopping

C. The 15% grade produces less resistive force on the brake than the kinetic energy of the machine moving at 10 km/h — the brake does not encounter its capacity limit during the static test but is overwhelmed by the kinetic energy during the dynamic test

D. The brake oil or air is heated by the dynamic application and the thermal expansion reduces the clamping force during the dynamic stop, while the static test does not generate any heat

39. A technician is inspecting the idler on a tracked excavator and discovers the idler tread surface is cupped (concave) rather than flat. What does this wear pattern indicate?

A. The idler bearings have failed and the idler is running eccentrically, wearing a concave pattern into the tread as the worn bearing allows the idler to orbit offcentre

B. The track chain has been running with incorrect tension — the chain sag allows the chain to whip against the idler tread during travel, concentrating wear at the centre of the tread and producing the cupped profile

C. The idler tread hardness is softer in the centre than at the edges from a heat treatment inconsistency during manufacturing, and the softer centre wears faster than the harder edges

D. The track chain has been operating at excessive tension — the overtensioned chain pulls the idler tread against the link rails with excessive force, and the concentrated centre loading wears the tread into the cupped (concave) profile faster than the edges

40. A rigidframe mining truck has an automatic traction control system (TCS) that uses the ABS wheel speed sensors to detect drive wheel spin. When spin is detected, the TCS applies the brake on the spinning wheel to transfer torque to the nonspinning wheel through the open differential. What limitation does this brakebased TCS have compared to a mechanical locking differential?

A. The brakebased TCS reacts slower than a mechanical lock because the electronic detection, processing, and brake application sequence requires more time than the instantaneous mechanical engagement of a lock

B. The brakebased TCS can only transfer torque equal to the braking force applied to the spinning wheel — it cannot transfer the full differential torque capacity like a mechanical lock

C. The brakebased TCS wears the brake components on the spinning side during every activation, creating asymmetric brake wear that requires more frequent service than a machine with a mechanical lock

D. The brakebased TCS converts the spinning wheel's kinetic energy to heat in the brake rather than transferring it to the nonspinning wheel — the system wastes energy during every activation, reduces the total available tractive effort compared to a mechanical lock, and generates heat that limits the system's duration of operation before thermal protection deactivates the TCS

41. A technician replaces the steering cylinder on a wheel loader. After installation, the steering turns smoothly in both directions but the turning radius is noticeably larger than before the repair (the machine cannot turn as tightly). What is the most likely cause?

A. The replacement steering cylinder has a shorter stroke than the original, limiting the maximum angular displacement of the steered wheels and increasing the turning radius

B. The replacement cylinder has the correct stroke length but the rod end was connected to the wrong hole on the steering arm — a different attachment point changes the effective lever arm and limits the maximum steering angle

C. The new cylinder's internal cushions are restricting the last portion of the stroke, preventing the cylinder from reaching full extension on each side

D. The new cylinder's piston seals are tighter than the worn original, creating friction that the steering pump cannot overcome at the end of the stroke range

42. A machine equipped with wet disc brakes has its brake oil sampled as part of a scheduled oil analysis program. The analysis shows a sudden increase in copper content from 15 ppm (previous sample) to 85 ppm. What is the most likely source?

A. The copper increase indicates the brake disc separator plates (steel reaction plates) are releasing copper from their surface plating as the plating wears through during normal brake operation

B. The copper originates from the machine's hydraulic pump, which shares the brake oil circuit — the pump's bronze bushing is wearing and releasing copper into the common oil circuit

C. The copper originates from the bronze friction disc material in the brake pack — the sudden increase indicates the brake disc friction material is wearing at an accelerated rate and the brake pack should be inspected for excessive wear, contamination, or inadequate cooling

D. The copper is a contaminant introduced during the oil sampling process — the sampling equipment uses copper fittings that shed particles into the sample bottle

43. A tracked dozer's sprocket segments are bolted to the hub rather than being a onepiece sprocket. What is the advantage of this segmented sprocket design compared to a solid onepiece sprocket?

A. The segmented design allows the sprocket to flex under chain load, distributing the torque more evenly across all teeth and reducing the peak stress on individual teeth

B. The segmented design allows the sprocket to be replaced without removing the track chain — individual worn segments can be unbolted and replaced while the chain remains on the machine, significantly reducing undercarriage service downtime

C. The segmented design weighs less than a solid sprocket of the same size, reducing the final drive's rotating mass and improving fuel efficiency during travel

D. The segmented design allows individual segments to be rotated to a different position on the hub when one section wears, distributing the wear across the full circumference before replacing any segments

44. A technician is bleeding the air from a machine's hydraulic brake circuit after a caliper replacement. The bleeding procedure specifies starting at the caliper furthest from the master cylinder and working toward the closest. After completing the specified bleeding sequence, the pedal is firm but the frontright brake produces no braking force during a test. What is the most probable cause?

A. The replacement caliper has an internal passage that is blocked from a manufacturing plug or shipping cap that was not removed during installation — the caliper receives no hydraulic pressure despite the firm pedal, because the blockage is downstream of the bleeding circuit and the bleeder screw exhausts air from the line without confirming the caliper bore is receiving fluid

B. The caliper was installed on the wrong side (left caliper on the right mount) and the bleeder screw is at the bottom instead of the top, trapping air in the caliper bore that cannot be bled from the lowmounted bleeder

C. The brake line to the frontright caliper has a kink that restricts flow under the slow bleeding flow rate but would allow flow under the higher dynamic pressure of a brake application

D. The frontright caliper was bled first instead of last, and the earlybled caliper reintroduced air from the subsequently bled calipers through the common master cylinder circuit

45. A machine's track adjuster uses a grease cylinder with a relief valve. The relief valve protects the track and undercarriage from damage when the machine encounters a large obstruction. How does the relief valve protect the undercarriage?

A. The relief valve limits the maximum grease pressure in the adjuster, preventing the recoil spring from being compressed beyond its design limit during normal tensioning

B. When the track encounters an obstruction that suddenly tightens the chain beyond the relief valve's cracking pressure, the valve opens and allows grease to escape from the adjuster cylinder, permitting the recoil spring to compress and the idler to move rearward — absorbing the shock load and preventing catastrophic damage to the chain, sprocket, final drive, or frame

C. The relief valve bleeds grease slowly from the adjuster during normal operation, maintaining a constant track tension regardless of chain elongation from wear

D. The relief valve opens when the machine reverses direction, momentarily loosening the track to prevent the chain from binding around the sprocket during the directional change

46. A machine's front axle uses kingpintype steering knuckles with tapered roller bearings on the upper and lower kingpin positions. During inspection, the technician discovers the lower kingpin bearing cup (outer race) has spun in the axle bore — the cup has rotated in the housing and the bore is now enlarged. What caused the cup to spin?

A. The kingpin nut was overtorqued, pressing the bearing cone (inner race) against the cup with excessive force that exceeded the bore's interference fit

B. The axle bore was not manufactured to the correct interference fit tolerance — the bore was too large for the cup OD, and the repeated steering loads gradually worked the cup out of its position until it began to rotate freely

C. The bearing was installed without the proper cup driving tool and the cup was cocked during installation, creating an uneven contact between the cup and the bore that reduced the effective pressfit area below the minimum needed to prevent rotation under load

D. The bearing grease broke down and allowed the rollers to skid rather than roll, creating a torque on the cup that exceeded the pressfit friction and caused the cup to rotate in the bore

47. A technician measures the voltage at a fuel injector connector during cranking. The DMM reads 0V. The ECM is confirmed powered and receiving a crank signal. What is the most likely reason the injector receives no voltage during cranking?

A. The ECM uses a fuel prime strategy that delays injector firing for the first 3–5 engine revolutions during cranking to build adequate rail pressure before commanding fuel delivery — the 0V reading is normal during this initial prime period

B. The injector is a lowside switched device — the ECM provides ground (not voltage) to fire the injector. The supply voltage is present at all times from a separate fused power circuit. The DMM should be measuring the supply side, not the ECM control side, to verify injector power

C. The camshaft position sensor signal is missing — without the cam signal, the ECM cannot determine which cylinder is on its compression stroke and will not fire any injector. The ECM uses the crank signal for RPM only and requires the cam signal for injection sequencing

D. The ECM's internal injector driver has failed open and cannot deliver the switching signal to the injector, even though the ECM is powered and receiving the crank signal

48. A machine's 24V electrical system uses a fusible link in the main alternator output wire. The fusible link melts and the machine loses charging capability. What condition causes a fusible link to melt?

A. The fusible link melted from age — fusible links have a limited service life and must be replaced at scheduled intervals regardless of the circuit's operating condition

B. Normal charging current exceeded the fusible link's amperage rating due to a cold battery that drew excessive charging current during the first minutes of operation

C. The machine was jumpstarted from a 24V external source with the polarity reversed — the reverse current through the alternator exceeded the fusible link's rating

D. A short circuit downstream of the fusible link drew current exceeding the link's rated capacity — the most common cause is a direct short in the charging circuit wiring between the alternator output and the battery positive terminal, or an alternator with internally shorted rectifier diodes that allow excessive current flow

49. A machine's ECM logs a DTC for "injector 2 circuit open." The technician measures the injector 2 coil resistance at the injector connector and reads 0.6 ohms — within the OEM specification of 0.5–0.8 ohms. The fault code persists after clearing. What should the technician check next?

A. The fuel rail pressure — low rail pressure can prevent the injector from opening electrically, which the ECM interprets as an open circuit because it cannot detect the inductive kickback that confirms the injector fired

B. The injector's internal control valve mechanism — a seized valve prevents the plunger from responding to the solenoid's magnetic force, which the ECM detects as an open circuit condition

C. The wiring and connectors between the ECM and the injector connector — the injector coil is intact (0.6 ohms at the injector), but the harness between the ECM and the injector may have an open wire, a corroded splice, or a damaged pin that interrupts the circuit before the current reaches the injector

D. The ECM's internal memory — the DTC may be a stored historical code that the ECM cannot clear through the standard clear procedure and requires a full ECM reset to erase

50. A machine's dashboard warning system uses three indicator levels: yellow (caution), red (warning), and flashing red (critical). A yellow engine oil pressure indicator illuminates during idle but turns off when the engine RPM is raised above 1,200 RPM. What does this indicate?

A. The oil pressure switch has failed and is producing a false signal at idle voltage that clears when the alternator raises the system voltage at higher RPM

B. The engine oil pressure at idle is below the yellow warning threshold but above the red (critical) threshold — the pressure rises above the yellow threshold when RPM increases. This may indicate a worn oil pump, worn bearings, low oil level, or incorrect oil viscosity that produces inadequate pressure at idle

C. The oil pressure sensor's electrical circuit has a wiring fault that produces a lowvoltage reading at the sensor connector during idle — the higher alternator output at elevated RPM compensates for the wiring fault and produces a normal reading

D. The yellow indicator functions as a selftest light that illuminates during idle as part of the ECM's lamp check sequence and is not connected to an actual oil pressure reading

51. A technician discovers that a machine's CAN bus has been repaired by a previous technician who twisted the CANH and CANL wires together without shielding or proper connector restoration. The repair appears functional — the diagnostic tool communicates with all modules. What longterm risk does this improper repair create?

A. The twisted splice creates a signal reflection point that will eventually cause bit errors as the bus traffic increases during multimodule communication events

B. The unshielded splice is vulnerable to electromagnetic interference — the exposed twisted wires can pick up EMI from the machine's alternator, solenoids, and highcurrent switching circuits, causing intermittent communication errors that worsen over time as corrosion increases the splice resistance

C. The twisted wires create an impedance mismatch at the splice point that reduces the bus's maximum communication distance, potentially causing the most remote module to drop off the bus intermittently

D. The unshielded, unprotected splice is vulnerable to moisture ingress, corrosion, vibrationinduced fatigue, and EMI — any of these conditions can produce intermittent communication faults that are difficult to diagnose because the splice appears functional during static testing but fails under the machine's operating environment

52. A machine's electronic throttle system has a dualtrack accelerator pedal position sensor (APPS) — two independent potentiometers in the same housing that produce different voltage ranges. Track 1 outputs 0.5–4.5V and Track 2 outputs 0.25–2.25V. Why does the system use two tracks with different voltage ranges?

A. The dual tracks provide redundancy — if one track fails, the ECM uses the other for throttle control. The different voltage ranges allow the ECM to distinguish between the two tracks and detect a fault where one track's signal is inadvertently crossconnected to the other track's circuit

B. Track 1 controls the engine RPM and Track 2 controls the transmission shift timing — the different voltage ranges prevent crosstalk between the two independent control functions

C. The two tracks measure different pedal travel ranges — Track 1 covers 0–50% pedal travel and Track 2 covers 50–100% pedal travel, providing higher resolution across the full range

D. Track 1 provides the primary throttle signal and Track 2 provides a temperature compensation signal that the ECM uses to correct the primary signal for pedal temperature variation

53. A machine's battery voltage reads 24.8V with the engine off and all loads disconnected (48hour rest). The machine has two 12V batteries in series. What state of charge does this total voltage represent?

A. Approximately 100% — a fully charged 24V battery bank reads 25.2–25.4V, and the 24.8V reading indicates the bank is at approximately 100% charge

B. Approximately 85% — the 24.8V reading is between the 100% charge level (25.2V) and the 50% charge level (24.0V), placing the bank at approximately 85% state of charge

C. The voltage reading cannot indicate state of charge without knowing the battery's CCA rating — state of charge is determined by load testing, not open circuit voltage

D. Approximately 50% — a 24V bank at 50% charge reads approximately 24.8V, and the batteries require immediate charging before any load is applied

54. A machine's alternator charges the 24V battery system through a charge wire that runs from the alternator B+ terminal to the battery positive bus bar. The technician measures a 0.8V voltage drop on this charge wire at full alternator output (150A). Using Ohm's Law, what is the resistance of this wire?

A. 18.75 ohms — calculated by dividing the system voltage (24V) by the current (150A), which produces the total circuit resistance rather than the wire resistance

B. 120 watts — calculated by multiplying voltage drop by current, which produces the power dissipated in the wire rather than the wire resistance

C. 0.0053 ohms — calculated by dividing the voltage drop (0.8V) by the current (150A), which gives the resistance of the charge wire that produces the 0.8V drop at 150A current flow

D. 187.5 ohms — calculated by dividing the alternator voltage (28V) by the current (150A), which produces the total charging circuit impedance rather than the wire resistance

55. A machine's ECM has a watchdog timer — an internal hardware circuit that monitors the ECM's processor. If the processor fails to reset the timer within a predetermined interval, the watchdog assumes the processor has frozen and performs a forced reset. What symptom would the operator notice if the watchdog timer is repeatedly resetting the ECM?

A. The engine briefly cuts out and restarts every few seconds — each watchdog reset forces the ECM through its initialization sequence, which briefly interrupts fuel injection until the ECM completes its startup checks and resumes normal operation

B. The dashboard displays a steady "ECM FAULT" warning but the engine continues to operate normally because the watchdog reset occurs faster than the engine can respond to the brief power interruption

C. The engine enters limp mode permanently because the repeated resets prevent the ECM from completing its full initialization sequence and loading its normal operating calibration

D. The operator notices no symptom — the watchdog reset is an internal electronic event that occurs in microseconds and does not affect the ECM's external outputs

56. A machine has multiple ground points — the battery negative connects to the engine block, the engine block connects to the frame via a ground strap, and the cab connects to the frame via a separate ground strap. The technician discovers the enginetoframe ground strap has broken. What symptoms will this broken ground strap produce?

A. No symptoms — the engine block is grounded through the transmission and drivetrain to the frame, providing an alternate ground path

B. The starting circuit draws full cranking current through the transmission and drivetrain to reach the frame ground, producing slow cranking and potential damage to transmission bearings and drivetrain seals from the current flow through their greaselubricated surfaces

C. The alternator output voltage increases because the broken ground strap creates a higherresistance ground path that the voltage regulator compensates for by increasing field current

D. All enginemounted electrical devices (alternator, sensors, solenoids, ECM) lose their ground reference and produce erratic behaviour — the reduced ground path forces current through unintended paths such as throttle cables, hydraulic lines, and control linkages that can produce arcing, bearing damage, and signal interference

57. A machine's starter solenoid has two windings: a pullin winding and a holdin winding. When the key is turned to START, both windings energize simultaneously. The pullin winding generates a strong magnetic force to engage the pinion and close the main contacts. Once the main contacts close, what happens to the pullin winding?

A. The pullin winding continues to operate alongside the holdin winding for the entire cranking duration to maintain maximum engagement force on the pinion

B. The pullin winding is shortcircuited by the closing of the main contacts — both ends of the pullin winding are now at battery voltage (one end from the solenoid terminal, the other from the closed main contacts), so no current flows through it. Only the holdin winding maintains the solenoid in the engaged position

C. The pullin winding opens from a thermal fuse that protects it from sustained highcurrent draw — the fuse opens after the pinion is engaged and the holdin winding takes over

D. The pullin winding reverses polarity when the main contacts close, creating a magnetic field that opposes the holdin winding and requires both windings to balance for stable engagement

58. A machine's ECM monitors the crankshaft position sensor signal for misfires by tracking the angular acceleration of the crankshaft between firing events. A misfiring cylinder produces less angular acceleration than a normally firing cylinder. What parameter does the ECM compare to detect this variation?

A. The peak voltage amplitude of the CKP signal — a misfiring cylinder produces a lower peak signal because the crankshaft decelerates through the firing position

B. The frequency of the CKP signal — a misfiring cylinder causes the crankshaft to slow momentarily, reducing the signal frequency at that point in the rotation

C. The time interval between successive CKP signal edges (teeth) — a normally firing cylinder accelerates the crankshaft, producing shorter intervals between teeth during its power stroke. A misfiring cylinder does not accelerate the crank, producing longer intervals that the ECM detects as a misfire event

D. The waveform shape of the CKP signal — a misfiring cylinder produces a distorted signal waveform that the ECM's patternrecognition algorithm identifies as different from the normal firing signature

59. A machine's CAN bus has 12 modules connected. During operation, the technician notices that CAN bus error frames are being generated at an increasing rate according to the diagnostic tool's bus health monitor. No individual module has flagged a fault code. What is the significance of the increasing error frame rate?

A. The increasing error rate is normal during heavy multimodule communication periods — the bus protocol generates error frames as a flowcontrol mechanism when traffic volume exceeds a threshold

B. The error frames indicate a network traffic congestion issue — too many modules are attempting to transmit simultaneously, and the bus arbitration is producing errors during the collision resolution process

C. The increasing error rate is a diagnostic nonissue — CAN bus protocol generates error frames as part of its normal selfcheck process, and the rate increases with engine RPM as the modules send data more frequently

D. The increasing error frame rate indicates a developing hardware fault on the bus — a degrading connection, a failing transceiver in one module, or increasing EMI is producing signal integrity issues that will eventually escalate to communication loss if not diagnosed and corrected

60. A machine's engine ECM and transmission ECM share data over the J1939 CAN bus. The engine ECM sends a "percent load at current speed" message to the transmission ECM. The transmission ECM uses this data to determine shift timing. If the engine ECM sends an incorrect (too low) load value, what symptom will the operator notice?

A. The transmission shifts to a higher gear earlier than expected because the TCM believes the engine is lightly loaded and upshifts sooner — the operator feels the engine lug (drop RPM and struggle) after the premature upshift because the actual load is higher than the TCM was told

B. The transmission shifts to a lower gear earlier than expected because the TCM compensates for the perceived low load by selecting a gear ratio that provides more engine braking

C. The transmission holds each gear longer than expected because the TCM receives the low load signal and waits for the load to increase before commanding the upshift

D. The transmission shifts normally — the TCM uses only the output shaft speed sensor for shift timing and ignores the engine load data from the J1939 bus

61. A technician is installing a replacement ECM on a machine. The replacement ECM is a new unit that requires programming with the machinespecific calibration file and parameter settings. After programming, the technician starts the engine. The engine runs but the idle speed is 150 RPM higher than normal and several parameters are at default values. What step was likely missed?

A. The replacement ECM was programmed with the correct calibration but the machine's individual parameter settings — including idle speed, fan control map, tire size, implement calibrations, and security codes — were not transferred from the old ECM's saved configuration to the replacement unit

B. The replacement ECM requires a 24hour operating period for its adaptive learning to reestablish all parameters from baseline through normal operation

C. The calibration file loaded into the replacement ECM is the correct model but a different software version that produces slightly different default values for all parameters

D. The replacement ECM's hardware revision is incompatible with the machine's wiring harness, producing the parameter differences from the electrical signal mismatches

62. A machine's instrument cluster includes an hour meter that records engine operating hours. The technician discovers the hour meter has stopped incrementing even though the engine runs normally. All other cluster functions operate correctly. What is the most likely cause?

A. The hour meter's internal quartz crystal has failed and the meter cannot track time regardless of the engine running signal

B. The hour meter circuit has lost its input signal — the signal that tells the meter the engine is running (typically from the oil pressure switch, alternator Rterminal, or ECM data) has failed or been interrupted, so the meter does not recognize the engine is operating

C. The hour meter has reached its maximum count and has rolled over to zero, which the display interprets as an error and freezes the reading

D. The hour meter requires a periodic calibration reset through the diagnostic software that was not performed at the last service — the meter stops after a programmed interval to force the operator to report for service

63. A machine equipped with an integrated GPS/GNSS (Global Navigation Satellite System) grade control system has lost positioning accuracy. The system normally provides ±15 mm vertical accuracy. The operator reports the accuracy has degraded to ±150 mm. What should the technician investigate?

A. The GPS antenna cable — a damaged cable, a loose connector, or a corroded antenna mount can attenuate the satellite signal below the receiver's minimum threshold for highaccuracy positioning, forcing the receiver to use a loweraccuracy positioning mode

B. The machine's electrical system — alternator ripple or CAN bus noise can interfere with the GPS receiver's internal clock and degrade the position calculation accuracy

C. The GPS receiver's internal battery — a depleted backup battery causes the receiver to lose its satellite almanac data, requiring a full coldstart acquisition that produces reduced accuracy until the almanac is refreshed

D. The GPS antenna location — if the antenna has been moved or obstructed (by a newly installed canopy, camera mast, or aftermarket accessory), the satellite signal reception is degraded and the positioning accuracy suffers

64. A technician is measuring the current draw of a glow plug circuit on a 4cylinder diesel engine. Each glow plug should draw 6A. The total circuit current measures 24A during the glow cycle. What does this confirm?

A. Only three of four glow plugs are operating — the total should be 6 × 4 = 24A, but the measurement indicates one plug is drawing zero and the other three are drawing 8A each to compensate

B. All four glow plugs are drawing their rated current — 6A × 4 = 24A total, confirming all four plugs are functioning correctly

C. The glow plug relay is failing and allowing excess current to pass — the specification calls for 18A total (6A × 3 plugs, with one plugcontrolled off for emissions), and the 24A reading indicates the relay has welded contacts

D. The measurement is inconclusive — the technician must measure each individual glow plug's current draw separately to confirm all four are operating, because one plug drawing 12A (shorted) and three plugs drawing 4A each would also total 24A

65. A machine's ECM stores a snapshot of multiple sensor readings (freeze frame data) when a DTC is triggered. A technician reads a freeze frame for DTC "boost pressure low." The freeze frame shows intake air temperature at −5°C and ambient temperature at 25°C. What does this discrepancy between IAT and ambient temperature suggest?

A. The intake air temperature sensor has failed and is reading a fixed low value (−5°C) that does not reflect the actual intake air temperature — this incorrect reading is likely the cause of the boost pressure DTC because the ECM is using the false −5°C to calculate a boost target that does not match the actual operating conditions

B. The −5°C IAT reading is correct — the charge air cooler is cooling the compressed intake air below ambient temperature, which is normal for a highly efficient CAC operating in moderate ambient conditions

C. The freeze frame captured the data during a brief transient condition that has since resolved and does not reflect the current sensor status

D. The IAT sensor is reading correctly and the ambient temperature sensor has failed high — the actual ambient is closer to −5°C and the 25°C ambient reading is incorrect

66. A machine's electronic display shows parameter IDs (PIDs) that the technician can scroll through in a live data view. The technician observes that the "engine percent load" PID reads 95% while the machine is performing a lightload task (travelling unloaded on flat ground). Normal percent load for this condition should be approximately 30–40%. What could cause the elevated load reading?

A. The throttle position sensor is producing an incorrect signal that the ECM interprets as a highload demand — the ECM fuels accordingly and the percent load reflects the actual fuel delivery rate rather than the external work being performed

B. The percent load PID is calculated from fuel consumption — any condition that increases fuel usage (malfunctioning injector, incorrect timing, excessive parasitic loads from a seized component, or a failing hydraulic pump) increases the percent load reading even when the external work demand is low

C. The percent load PID is based on the turbocharger boost pressure — elevated boost from a stuckclosed wastegate or VGT produces a high percent load reading that does not reflect the actual engine mechanical load

D. The ECM calculates percent load from exhaust temperature — the exhaust temperature sensor has drifted high, producing a calculated load value that is significantly above the actual mechanical load on the engine

67. A machine's electronic system includes a body controller module (BCM) that manages cab functions: lights, wipers, horn, HVAC blower, and window controls. The BCM communicates with the main J1939 bus through a gateway. The technician discovers all BCMcontrolled functions are inoperative. The gateway module is functioning correctly (engine and transmission communicate normally). What is the most likely cause?

A. The BCM has lost its power supply or ground connection — without power, the module cannot operate any of its output circuits regardless of the CAN bus status

B. The BCM's CAN bus connection to the gateway has failed — the module is powered but cannot receive commands from the operator switches (which may route through the CAN bus) or from the gateway

C. The BCM's internal fuse board has blown the main bus fuse, cutting power to all output circuits simultaneously while the module's processor continues to communicate on the CAN bus

D. The gateway module is blocking all commands to the BCM due to a configuration error introduced during the last software update — the gateway is functioning for engine and transmission data but has lost its BCM routing table

68. A machine's keyswitch circuit is protected by a 10A fuse. The technician discovers the fuse has blown repeatedly — three replacements in one week. Each time, the fuse blows when the key is turned to the RUN position. What should the technician do to locate the fault?

A. Install a circuit breaker in place of the fuse to identify the fault by observing which circuits lose power when the breaker trips — the cycling breaker allows the technician to systematically disconnect circuits until the breaker stops tripping

B. Install a higheramperage fuse (15A) to prevent the nuisance blowing while the machine is needed for production — the higher fuse provides more margin for the circuit's normal inrush current

C. Disconnect all loads on the RUN circuit one at a time and test with a new 10A fuse after each disconnection — when the fuse stops blowing, the last disconnected circuit contains the fault. This systematic isolation identifies the specific circuit that is drawing excessive current

D. Replace the keyswitch — repeated fuse blowing when the key is turned to RUN indicates the switch's internal contacts are arcing and producing a momentary highcurrent spike that exceeds the fuse rating

69. A machine's electronic system uses a 5V analog pressure sensor with a 0.5–4.5V output range. The sensor's output at zero pressure should be 0.5V (not 0V). Why is the sensor designed to output 0.5V at zero pressure rather than 0V?

A. The 0.5V baseline prevents the ECM's analogtodigital converter from resting at its zerobit floor, which improves the converter's accuracy in the lowvoltage range

B. The 0.5V baseline reduces the electrical noise sensitivity of the signal wire — a 0V signal is indistinguishable from a grounded (shorted) wire, but a 0.5V baseline allows the ECM to distinguish between a valid zeropressure reading (0.5V) and a faulted signal wire shorted to ground (0V)

C. The 0.5V baseline is an artifact of the sensor's internal Wheatstone bridge circuit — the bridge produces a residual voltage at zero pressure that cannot be eliminated during manufacturing

D. The 0.5V offset allows the ECM to use the same analog input channel for both the pressure sensor and a temperature sensor by timedivision multiplexing — the offset prevents the two signals from overlapping at the zero point

70. A technician is diagnosing a machine where the electric fuel pump (lowpressure transfer pump) runs continuously with the key on — even when the engine is off. The pump should operate only during cranking and while the engine is running, then shut off after 2 seconds if the engine does not start. What is the most likely cause?

A. The fuel pump relay has welded contacts — the relay's internal contacts have fused together from arcing, keeping the relay energized and supplying power to the pump regardless of the ECM's command

B. The ECM's fuel pump driver is stuck in the on state — the internal transistor has failed shorted and continuously grounds the relay coil circuit

C. The oil pressure switch (which provides a run signal to the fuel pump circuit on some systems) has failed in the closed position, signaling the ECM that the engine is running and the pump should remain active

D. The fuel pump circuit has a direct short to battery voltage downstream of the relay, bypassing the relay entirely and powering the pump from the constant battery supply regardless of key position or ECM command

71. A machine equipped with an electronic joystick control has developed a condition where one hydraulic function drifts slowly when the joystick is in the neutral (centred) position. The joystick's electrical output has been verified as exactly centred (2.50V on a 0.5–4.5V range). The ECM shows no active fault codes. What is the most likely cause?

A. The joystick's mechanical centering spring has weakened but the potentiometer happens to read exactly 2.50V at the new rest position — the electrical reading is correct but the physical joystick is not at true mechanical centre

B. The DCV pilot solenoid for that function has a small internal leak that allows a trickle of pilot pressure to reach the main spool even when the solenoid is commanded off — the residual pilot pressure shifts the main spool slightly off neutral, producing the slow drift

C. The ECM's digitaltoanalog converter has a zerooffset error that produces a nonzero solenoid command even when the joystick reads exactly 2.50V — the converter's baseline has drifted from calibration

D. The main DCV spool centering springs have weakened and the spool cannot return to exact centre against the flow forces in the neutral position — the spool rests slightly offcentre and allows a trickle of flow to the actuator

72. A technician is testing a torque converter lockup clutch. With the diagnostic tool, the technician commands the lockup clutch to engage. The RPM data shows the engine RPM and the turbine RPM become identical. Five minutes later, the turbine RPM begins to drop below engine RPM while the lockup is still commanded on. What does this indicate?

A. The lockup clutch has begun to slip — the friction material is either overheated, contaminated with oil from a seal failure, or worn to the point where it can no longer maintain a mechanical connection between the pump and turbine under the current load

B. The torque converter's stator oneway clutch has failed and the stator is now freewheeling, reducing the fluid coupling efficiency and producing the apparent RPM difference

C. The ECM has detected a fault and is partially releasing the lockup clutch to protect the transmission — the RPM split is an intentional ECM strategy

D. The turbine speed sensor has drifted out of calibration and is reading progressively lower than the actual turbine speed

73. A machine's differential has a whining noise that changes tone when the machine transitions from drive (acceleration) to coast (deceleration). What does this change in noise character indicate?

A. The differential carrier bearings are worn and the shift between drive and coast loading changes the bearing preload, producing different noise frequencies

B. The ring and pinion teeth are worn or incorrectly adjusted — the mesh loads the drive side of the teeth during acceleration and the coast side during deceleration, and the different contact patterns on worn teeth produce different noise characteristics

C. The ring and pinion gear mesh pattern shifts between the drive side (convex) and coast side (concave) of the tooth faces during the load transition — the different contact patterns on the two faces produce different noise characteristics, indicating the gear mesh contact is not centred correctly on both faces

D. The differential spider gears are worn and the axial play allows them to shift between the drive loading and the coast loading, producing different contact noise at each position

74. A machine equipped with a powershift transmission has been experiencing harsh shifts after the transmission oil was changed. The correct oil type and volume were used. What transmission oil property beyond type and viscosity should the technician verify?

A. The oil's pour point — if the pour point is higher than the operating temperature, the oil cannot flow through the valve body passages at the required rate for smooth shifts

B. The oil's friction modifier content — different oil manufacturers use different friction modifier packages, and the replacement oil's friction characteristics may not match the clutch pack material's designed engagement profile, producing the harsh shifts

C. The oil's flash point — a low flash point produces vapour bubbles inside the hot transmission housing that interfere with the clutch apply pressure ramp and produce harsh engagement

D. The oil's foaming tendency — the replacement oil may foam more readily than the original, and the compressible foam in the clutch apply circuit absorbs the modulation pressure that controls the shift smoothness

75. A technician is diagnosing a hydrostatic drive system where the machine has full speed in one direction but only 50% speed in the other. The charge pressure is correct. The pump servo test shows the pump reaches full displacement in both directions. What should be tested next?

A. The main pump's case drain flow in both directions — if the pump's internal leakage increases in one direction (from directionally biased valve plate wear), the pump produces less net output in that direction

B. The engine power — if the engine cannot produce full power in the highdemand direction, the pump's pressure compensator may be limiting the displacement to protect the engine

C. The forward and reverse crossport relief valves — the relief in the reducedspeed direction may be set lower than the other, limiting the maximum loop pressure and therefore the maximum motor speed in that direction

D. The drive motor's case drain flow — if the motor has increased internal leakage, it affects both directions equally. However, the motor's crossport relief in one direction may be stuck partially open, diverting a portion of the pump's output before it reaches the motor, reducing speed in that direction only

76. A machine's automatic transmission has a governor that produces a pressure signal proportional to the output shaft speed. This governor pressure acts on the shift valves to command upshifts. The governor pressure is measured at 50 kPa at 15 km/h. The OEM specification is 85 kPa at 15 km/h. What symptom does this low governor pressure produce?

A. The transmission upshifts at a higher vehicle speed than normal — the low governor pressure does not develop enough force on the shift valve to command the upshift until the machine reaches a higher speed where the governor finally produces the required pressure

B. The transmission upshifts at a lower vehicle speed than normal because the low governor pressure causes the shift valve to be more sensitive to the throttle pressure signal

C. The transmission shifts normally but the converter lockup clutch engages at a lower speed than specified because the lockup control uses the governor signal independently of the shift valves

D. The transmission remains in first gear and does not upshift because the governor pressure never reaches the minimum required to move the shift valve against the throttle pressure, regardless of vehicle speed

77. A machine's clutchtype limited slip differential produces a "chatter" noise during slow, tight turns. A new oil change was performed using the correct gear oil specification. What is the most likely cause?

A. The limited slip clutch pack has worn beyond its service limit and the reduced disc thickness produces insufficient clamping force for smooth torque transfer during the speed differential of a tight turn

B. The differential side bearing preload has been lost, allowing the carrier to shift under the turning load and producing the chattering noise from the bearing movement

C. The new gear oil, while correct in viscosity and API specification, does not contain the friction modifier additive required by the limited slip clutch pack — the modifier controls the slip characteristics of the clutch, and without it, the pack grabs and releases cyclically during the speed differential of tight turns

D. The ring and pinion backlash has shifted from the oil change process (removal and reinstallation of the differential cover disturbed the carrier bearing shim pack), producing the chatter during loaded turns

78. A technician discovers that a machine's driveshaft has been repaired by welding — a previously broken shaft was welded back together in the field. What is the safety concern with a welded driveshaft repair?

A. The weld may not withstand the torsional fatigue loading of the driveshaft, and a failure at the weld produces a shaft that separates into two pieces while spinning at high speed — the disconnected shaft section can cause catastrophic damage to the underside of the machine, breach the cab floor, or strike personnel near the machine

B. The weld changes the driveshaft's resonant frequency, producing a vibration at a specific RPM that damages the transmission output seal and the differential pinion seal

C. The weld adds mass to one side of the shaft, creating an imbalance that produces a speedproportional vibration that accelerates Ujoint wear at both ends

D. The welding heat has annealed the shaft material adjacent to the weld, softening the steel and reducing its torsional strength below the rated capacity for the application

79. A machine's final drive uses a twostage planetary reduction. Stage 1 has a ratio of 4.5:1 and Stage 2 has a ratio of 6.2:1. What is the total reduction ratio of the twostage system?

A. 10.7:1 — calculated by adding the two stage ratios (4.5 + 6.2)

B. 27.9:1 — calculated by multiplying the two stage ratios (4.5 × 6.2), which is the correct method for calculating the total ratio of seriesconnected gear reductions

C. 1.38:1 — calculated by dividing the second stage by the first stage (6.2 ÷ 4.5)

D. 13.85:1 — calculated by multiplying the two ratios and dividing by 2 ((4.5 × 6.2) ÷ 2)

80. A machine's transmission cooler circuit includes a thermostat that bypasses the cooler when the oil is cold. The technician discovers the thermostat is stuck in the bypass position — all oil bypasses the cooler regardless of temperature. After 4 hours of loaded operation, the transmission oil temperature has risen to 130°C. The OEM maximum is 110°C. What damage is occurring at this elevated temperature?

A. The elevated temperature is accelerating the oxidation of the transmission oil — the oil's antioxidant additives are being consumed at an exponentially higher rate than at normal temperature, and the resulting oxidation produces acids and varnish that attack seals, clog passages, and reduce the oil's lubricating and hydraulic properties

B. The elevated temperature is causing the transmission case to expand beyond its design limit, which changes the internal bearing preloads and gear mesh patterns

C. The elevated temperature has no immediate effect on the transmission — the 130°C reading is within the acceptable shortterm operating range and the thermostat can be replaced at the next scheduled service

D. The elevated temperature is expanding the clutch friction disc material, producing a drag condition that generates additional heat in a selfescalating cycle that will result in clutch failure if not corrected

81. A hydrostatic drive machine produces full speed and power in both directions. However, the machine cannot hold position on a grade with the controls in neutral — it slowly rolls downhill. The parking brake is not applied. The technician measures the charge pressure at 28 bar (specification is 25–30 bar). What is the correct diagnosis?

A. The charge pressure is within specification and the hydrostatic system is not designed to hold a stationary load on a grade through hydraulic lock alone — internal leakage through the pump and motor clearances always allows slow drift under gravity loading when the pump is at zero displacement

B. The charge check valves are leaking, allowing loop pressure to bleed backward into the charge circuit when the pump is at zero displacement

C. The pump swashplate is not reaching true zero displacement — a slight residual angle produces a slow flow that drives the motor in the downhill direction

D. The motor's brake valve (counterbalance valve) has failed and cannot hold the load when the control valve is in neutral

82. A technician is measuring the output of a transmission oil pump during a bench test. The pump produces 35 L/min at the test speed. The OEM specification for a new pump at this speed is 38 L/min. What is the pump's condition?

A. The pump is severely worn and must be replaced — the 3 L/min deficit represents a catastrophic loss of pumping capacity that cannot support transmission operation

B. The pump is within acceptable limits — a 3 L/min reduction from the new specification represents approximately 8% wear, which is within the typical acceptable range of 10% for a transmission charge pump

C. The pump has reached its rebuild threshold — at 35 L/min, the pump is producing only 92% of its new output, which is below the typical 95% minimum for a serviceable pump

D. The bench test result cannot be compared to the OEM specification because the test speed may not exactly match the specification's test conditions — the pump must be tested at the exact OEMspecified RPM and temperature to produce a valid comparison

83. A machine's torque converter is producing a vibration that changes frequency with engine RPM. The vibration is present in all gear ranges and both forward and reverse. What is the most likely cause?

A. The torque converter's internal lockup clutch disc has broken into pieces that circulate inside the converter housing — the fragments impact the pump, turbine, and stator at varying frequencies that change with RPM

B. The torque converter pilot (hub) is not fully seated in the flywheel's pilot bore, causing the converter to run eccentrically at engine speed and produce a vibration that is proportional to RPM regardless of gear range or direction

C. The converter's stator oneway clutch has seized and the stator is locked in both directions, creating a hydraulic imbalance that produces the vibration

D. The pumptoflywheel mounting bolts have loosened, allowing the converter to shift on the flywheel under centrifugal force and produce an RPMproportional vibration

84. A machine's axle shaft has fractured. Postfailure examination of the fracture surface shows two distinct zones: a smooth, curved zone covering approximately 75% of the crosssection, and a rough, granular zone covering the remaining 25%. What does this fracture surface pattern indicate?

A. The fracture was caused by a single highimpact overload that exceeded the shaft material's ultimate tensile strength — the smooth zone represents the shear plane and the rough zone represents the final brittle fracture

B. The fracture is a fatigue failure — the smooth curved zone is the fatigue crack that propagated slowly over thousands of load cycles, and the rough granular zone is the final sudden fracture when the remaining crosssection could no longer carry the load

C. The fracture was caused by a manufacturing defect — the smooth zone represents a preexisting crack from the forging process that was filled with scale during heat treatment

D. The fracture is a torsional overload — the smooth zone represents the ductile deformation from the twisting force and the rough zone represents the final shear failure

85. A machine's transmission produces a metallic rattling noise only during deceleration (coast condition). The noise disappears during acceleration and neutral idle. What is the most likely cause?

A. The input shaft pilot bearing is worn — during acceleration, the engine drives the input shaft and the bearing is loaded in one direction. During deceleration, the drivetrain drives the engine and the loading reverses, shifting the worn bearing to its loose clearance zone and producing the rattle

B. The torque converter lockup clutch damper springs have weakened and cannot absorb the torsional reversals during deceleration — the loose springs rattle inside their pockets during each engine firing pulse

C. The transmission gear teeth are loaded on their drive face during acceleration and their coast face during deceleration — worn coastside tooth surfaces produce the rattle only during the deceleration loading

D. The exhaust brake is activating automatically during deceleration and the resulting backpressure produces vibration in the turbocharger that transmits through the engine to the transmission housing

86. A machine's differential pinion bearings are set with a specified preload. The technician measures the preload by checking the pinion rotating torque with a torque wrench. The measured rotating torque is 1.5 N·m. The OEM specification for used bearings is 1.0–2.0 N·m. Is the pinion bearing preload correct?

A. No — the specification of 1.0–2.0 N·m applies to new bearings. Used bearings typically settle to a lower preload as the rollers polish the races, and a usedbearing specification should be approximately 60–70% of the new specification

B. No — the pinion preload should be measured with a spring scale wrapped around the pinion nut, not with a rotating torque wrench, and the 1.5 N·m reading is in the wrong unit for the measurement method

C. Yes — but only if the measurement was taken without the pinion seal installed, because the seal's friction adds to the measured rotating torque and must be subtracted to determine the true bearing preload

D. Yes — the 1.5 N·m reading is within the specified range of 1.0–2.0 N·m for used bearings, confirming the bearing preload is correct for reinstallation without requiring shim or spacer adjustment

87. A machine has a hydrostatic transmission with a variabledisplacement pump and a fixeddisplacement motor. To increase the machine's maximum travel speed, the operator has requested the technician increase the pump's maximum displacement setting. What is the potential consequence of increasing the pump's maximum displacement?

A. Increasing the pump displacement increases the maximum flow to the motor, which increases the motor's speed and therefore the machine's travel speed — but the increased flow demand may exceed the engine's available power, causing the engine to lug or stall under load, and the higher motor speed may exceed the motor's and drivetrain's design limits

B. Increasing the pump displacement has no effect on travel speed — speed is determined by the motor displacement, not the pump displacement

C. Increasing the pump displacement increases the travel speed but proportionally reduces the tractive effort because the total power is divided between speed and force

D. Increasing the pump displacement increases both the travel speed and the tractive effort proportionally because the pump produces more flow and more pressure simultaneously

88. A machine's powershift transmission shifts smoothly in all ranges except the 34 shift, which produces a brief engine flare (RPM spike) before the shift completes. All other shifts are smooth. What does this isolated shift flare indicate?

A. The 3rd gear clutch pack is not releasing fast enough — the overlap between 3rd releasing and 4th applying is too short, and the engine briefly overspeeds during the gap between the two events

B. The 4th gear clutch pack has a hydraulic leak in its apply circuit — the clutch piston takes longer than designed to fill and clamp the disc pack, producing the engine flare during the delay between the 3rd gear release and the 4th gear full engagement

C. The governor pressure at the 34 shift point is at the transition threshold and the shift valve oscillates briefly between the 3rd and 4th gear positions before committing to 4th

D. The 34 shift solenoid has a slower response time than the other shift solenoids, delaying the 4th gear apply command relative to the 3rd gear release command

89. A machine's A/C system has been converted from R134a to R1234yf during a compressor replacement. The new system uses the same condenser, evaporator, and expansion valve but a new compressor designed for R1234yf. After charging with R1234yf to the OEMspecified weight, the system produces adequate cooling but the highside pressure is 15% lower than the R134a system's normal highside pressure. Is this a concern?

A. Yes — the lower highside pressure indicates the compressor is undersized for the system's condenser and the system will not perform adequately in hot ambient conditions

B. No — R1234yf operates at lower pressures than R134a by design. The 15% lower highside pressure is a normal characteristic of the different refrigerant's thermodynamic properties and does not indicate a system fault

C. No — R1234yf operates at slightly different pressures than R134a. The 15% lower highside is a normal characteristic of the refrigerant's properties, and if the system produces adequate cooling at the correct charge weight, the lower gauge readings are expected and not a concern

D. Yes — the condenser is oversized for the R1234yf charge and the excess condenser capacity is subcooling the refrigerant below its optimal operating range

90. A machine's cab heater uses a hotwater valve controlled by the operator's temperature control lever. The operator reports the temperature control has no effect — the cab is always at maximum heat regardless of the lever position. What is the most likely cause?

A. The hotwater valve has failed in the fully open position — hot coolant flows through the heater core at maximum rate regardless of the operator's temperature command, producing constant maximum heat output

B. The heater core has a bypass tube that routes coolant around the core, and the bypass tube has become blocked, forcing all coolant through the core at all times

C. The temperature blend door (if equipped) has stuck in the fullheat position, routing all airflow across the heater core regardless of the water valve position

D. The engine thermostat has stuck in the closed position, keeping the coolant temperature at maximum and overwhelming the temperature control valve's ability to regulate the heater output

91. A technician is checking the refrigerant charge level on a machine's A/C system using the manifold gauges. The system has been running for 20 minutes at rated RPM with maximum cooling selected. The lowside gauge reads 15 PSI (103 kPa) and the highside reads 120 PSI (827 kPa). The ambient temperature is 30°C. Compared to normal operating pressures for R134a (lowside 25–35 PSI, highside 200–250 PSI at 30°C ambient), both readings are significantly below normal. What is the most likely diagnosis?

A. The compressor has failed internally and cannot generate adequate pressure differential — but if this were true, the low side would be high (not low) because the compressor is not pulling the low side down

B. The condenser fan has failed — but this would produce a high highside pressure, not a low one

C. The expansion valve is stuck closed — restricting refrigerant flow to the evaporator, which starves the low side (low pressure) while the compressor pulls down the high side (low highside pressure from insufficient refrigerant mass flow through the system)

D. The system is significantly undercharged — insufficient refrigerant mass in the system produces low pressures on both sides because there is not enough refrigerant volume to develop normal operating pressures at any point in the circuit

92. A machine's cab air conditioning system uses an internal heat exchanger (IHX) — a tubeintube device that transfers heat between the highpressure liquid line and the lowpressure suction line. What is the purpose of this additional heat exchanger?

A. The IHX preheats the lowpressure suction gas with heat from the highpressure liquid line — this subcools the liquid (improving system efficiency by ensuring only liquid enters the expansion device) and superheats the suction gas (protecting the compressor from liquid slugging by ensuring only vapour enters the compressor inlet)

B. The IHX acts as a secondary condenser that provides additional heat rejection capacity when the main condenser cannot reject adequate heat during high ambient conditions

C. The IHX provides a controlled refrigerant metering function that supplements the expansion valve during highdemand cooling conditions

D. The IHX is a safety device that limits the maximum suction pressure to protect the compressor from highload conditions that could produce liquid refrigerant at the compressor inlet

93. A machine's dieselfired coolant heater produces a pulsing flame sound (combustion cycling on and off rapidly) during operation. The heater's exhaust shows intermittent smoke during the cycling. What is the most likely cause?

A. The fuel pump diaphragm has developed a crack that allows air to enter the fuel supply during the suction stroke — the airfuel mixture alternates between combustible and noncombustible ratios, producing the pulsing flame

B. The heater's combustion air blower is producing an inconsistent airflow that alternately enriches and leans the combustion mixture — a worn blower motor bearing, a dirty blower wheel, or a restricted air intake can produce the cycling

C. The heater's flame sensor is failing and intermittently signals the controller that no flame is present — the controller cycles the fuel supply off (no flame signal) and back on (flame detected) rapidly

D. The heater's fuel metering pump is worn and delivering inconsistent fuel volume per stroke — the varying fuel delivery produces alternating rich and lean cycles that cannot sustain a stable flame

94. A machine's HVAC system includes an automatic temperature control (ATC) function. The operator sets the desired cab temperature to 22°C. The ATC module controls the blend door position, blower speed, and compressor operation to maintain the set point. On a day when the ambient temperature is 22°C, the operator notices the system cycles the A/C compressor on and off every few minutes. Is this normal?

A. Yes — when the ambient temperature equals the set point, the ATC module cycles the compressor to dehumidify the cab air (which adds heat) and then stops the compressor when the cab reaches the set point. The cycling frequency increases when the ambient and set point are close because the system is

near its thermal equilibrium point and small changes in solar load or occupant heat produce rapid temperature swings

B. No — the ATC should completely disable the compressor when the ambient temperature matches the set point because no cooling is required at thermal equilibrium

C. No — the rapid cycling indicates the ATC module's temperature sensor has drifted and is reading incorrectly, causing the module to overcool and undercool alternately around the set point

D. Yes — but only if the cab is in recirculation mode, where the recirculated air temperature fluctuates more rapidly than fresh air mode

95. A machine's cab pressurization system draws fresh air through a cyclonic precleaner, a primary filter, and a HEPA filter in series. What is the correct filter service order?

A. Replace all three filters simultaneously at the same service interval to ensure consistent filtration performance and prevent contamination from a newly installed filter passing through the existing dirty downstream filters

B. Replace the HEPA filter first, then the primary filter, then clean the cyclonic precleaner — servicing in the reverse order of airflow prevents contamination from the dirty upstream filters from passing through the freshly installed downstream filters

C. Service the cyclonic precleaner at every scheduled service, replace the primary filter at the manufacturer's interval, and replace the HEPA filter only when the cab pressurization drops below the minimum specification — the precleaner and primary filter protect the HEPA filter, which has the longest service life and highest replacement cost

D. Replace the cyclonic precleaner and primary filter at every oil change interval, and inspect the HEPA filter visually for discoloration that indicates it has loaded beyond its capacity

96. A machine's A/C compressor has been replaced. The technician installs the new compressor, evacuates the system, and charges with the correct refrigerant weight. On the first startup, the compressor clutch engages but the compressor produces a loud metallic knocking noise. What is the most likely cause?

A. The new compressor was shipped with a full oil charge and the system was also charged with oil during assembly — the excess oil has flooded the compressor and the liquid oil is being compressed (hydraulic lock) during each piston stroke, producing the metallic knocking

B. The new compressor was shipped without oil and is running dry — the metaltometal contact between the pistons and the cylinder walls produces the knocking noise

C. The compressor mounting bolts are loose, allowing the compressor to vibrate against its bracket

D. The compressor clutch air gap is set too wide, causing the clutch to engage and disengage with each revolution and producing the repetitive knocking

97. A machine's exhaust aftertreatment system includes a DEF dosing module that injects DEF into the exhaust stream. The DEF line from the tank to the dosing module includes an electric heater to prevent DEF from freezing in cold weather (DEF freezes at −11°C). If the DEF line heater fails in −20°C ambient, what happens?

A. The DEF freezes in the line and no DEF can be delivered to the dosing module — the SCR system cannot reduce NOx, and the ECM initiates a progressive power derate per the emission compliance strategy until the heater is repaired and the DEF thaws

B. The DEF pump increases its pressure to force the partially frozen DEF through the line — the pump overcomes the restriction and delivers DEF at a reduced rate that partially maintains SCR function

C. The frozen DEF expands in the line and ruptures the DEF supply tube at its weakest point, producing a DEF leak that drains the tank and contaminates the machine's undercarriage

D. The ECM detects the frozen condition through the DEF temperature sensor and disables the SCR system cleanly without initiating a derate — the system resumes DEF dosing automatically when the ambient temperature rises above −11°C

98. A hydraulic system is equipped with a variabledisplacement piston pump that uses a pressure compensator to control output. The compensator is set to 250 bar. The technician measures the standby pressure (all DCVs in neutral) at 30 bar. During a cylinder stall test, the pressure reaches 250 bar. What does the 30bar standby pressure represent?

A. The 30 bar standby is the parasitic pressure loss from oil flowing through the system's internal leakage paths — the pump produces just enough flow to compensate for internal leakage, and the 30 bar is the pressure required to push this small flow through the circuit

B. The 30bar standby is the charge pressure maintained by a separate pilot circuit that keeps the pump's servo system primed

C. The 30bar standby is excessive — a properly functioning compensated pump should produce zero standby pressure when all DCVs are in neutral

D. The 30 bar standby is the pump's compensated standby pressure — the pump has destroked to minimum displacement and produces only enough flow to overcome internal leakage and maintain the system ready for the next command. This is the designed idle pressure that minimizes heat generation and power consumption when no function is active

99. A hydraulic cylinder extends fully in 8 seconds. The OEM specification is 5 seconds. The pump flow rate has been measured and is within specification. The system relief valve is set correctly. What should the technician check to explain the slow extension?

A. The cylinder's capend supply circuit for restrictions — a partially blocked hose, a contaminated check valve, a restricted fitting, or a flow control valve set too low can limit the flow reaching the cylinder and increase the extension time, even though the pump is producing correct total flow

B. The cylinder rod seals — worn rod seals allow oil to leak externally, reducing the effective flow entering the cap end

C. The hydraulic oil viscosity — thicker oil flows more slowly through the circuit and increases the extension time proportionally

D. The system accumulator — if the accumulator is absorbing a portion of the pump's flow during the extension cycle, less flow reaches the cylinder

100. A machine's hydraulic system includes a return line filter and a pressure line filter. The return line filter has a 10micron rating and the pressure line filter has a 6micron rating. Why are different micron ratings used for these two filter positions?

A. The pressure line filter protects the more sensitive control valves and actuators downstream, which require finer filtration. The return line filter catches the bulk contamination generated by the system's wear and external ingression at a coarser rating that provides lower restriction and longer element life

B. Both filters should be the same micron rating — using different ratings indicates a previous technician installed the wrong element in one location

C. The return line filter is finer (10micron) because it sees a higher flow rate and the finer filtration compensates for the higher velocity of particles through the element. The pressure filter is coarser (6micron) because the higher pressure compresses the particles and allows them to pass through a finer element

D. The pressure filter is finer because the highpressure oil is more damaging to components when contaminated — particles driven at 250 bar produce more damage than particles at 5 bar return pressure

101. A hydraulic motor drives a winch on a crane. The motor is equipped with a crossport relief on each work port and a counterbalance valve on the lowering port. During load lowering, the operator reports the load accelerates momentarily and then catches, producing a jerky lowering motion. What is the most likely cause?

A. The counterbalance valve's pilot signal is fluctuating — a loose pilot connection, a worn shuttle valve, or an erratic DCV pilot circuit produces an inconsistent pilot signal that alternately opens and closes the counterbalance valve during lowering

B. The winch drum brake is dragging intermittently — the brake applies and releases cyclically, producing the jerky motion independently of the hydraulic circuit

C. The crossport relief valve on the lowering side is set too close to the working pressure, and the relief alternately opens (accelerating the load) and closes (catching the load) as the pressure fluctuates around the relief setting

D. The motor's internal bypass creates a flow surge each time the pistons pass the valve plate transition zone — the cyclical flow variation produces the jerky lowering motion

102. A machine's air brake system compressor cycles on and off correctly at the governor cutin and cutout pressures. However, the technician notices the compressor's duty cycle (percentage of time loaded) is 65%. The OEM specification maximum duty cycle is 50%. What does the elevated duty cycle indicate?

A. The compressor is undersized for the machine's air demand — the air system consumes more air than the compressor can produce in 50% of its running time, requiring longer loaded periods to maintain system pressure

B. The governor cutin pressure has been adjusted too high, causing the compressor to cycle on before the system has used a significant volume of air — the frequent cycling produces the high duty cycle

C. The compressor is worn and producing less air per revolution than designed — the reduced output requires longer loaded periods to build the system back to cutout pressure

D. The system has an air leak or the air demand is higher than designed — the leak or demand consumes stored air faster than normal, dropping the pressure to the cutin point more quickly and requiring the compressor to run loaded for a greater percentage of time to maintain pressure

103. A hydraulic system uses a proportional pressurereducing valve to control a brake apply circuit. The valve is commanded to produce 50 bar downstream pressure from a 200 bar supply. The technician measures 75 bar downstream. What is the most likely cause?

A. The proportional valve's solenoid is receiving a higher command signal than intended — the ECM may be commanding a higher pressure than 50 bar due to an incorrect input signal or calibration error

B. The valve's proportional solenoid coil has developed a short that increases the magnetic force beyond the commanded level, pushing the valve further open and producing higher downstream pressure

C. The valve's spring is set incorrectly from a previous adjustment, adding a mechanical bias that increases the downstream pressure above the electrical command

D. The proportional valve's feedback orifice is partially blocked — the valve cannot sense the actual downstream pressure accurately and overcorrects by maintaining a higher pressure than commanded

104. A machine's hydraulic system operates at 280 bar working pressure. The system uses a 4bolt flange connection on the main pump outlet. The technician discovers one of the four flange bolts has sheared. The remaining three bolts are holding the flange under operating pressure. Can the machine continue operating while a replacement bolt is obtained?

A. Yes — three bolts provide 75% of the original clamping force, which is adequate for the operating pressure if the machine avoids maximumload conditions

B. No — the sheared bolt indicates the flange was subjected to a force that exceeded the bolt's design limit, and the remaining three bolts are overloaded by 33%. Operating the machine risks a cascading bolt failure that would produce a catastrophic highpressure hydraulic release — the machine must be shut down and repaired before any further operation

C. Yes — but only if the technician applies threadlocking compound to the remaining three bolts to prevent them from loosening under the additional load

D. No — but the flange can be temporarily clamped with an external chain or band clamp to distribute the load until the replacement bolt is installed

105. A hydraulic system's oil analysis shows an ISO cleanliness code of 22/20/17. The OEM specification for this system is 18/16/13. What does this discrepancy mean for the system?

A. The actual contamination level is close enough to the specification that no action is required — the 4codenumber difference represents a minor variation within the measurement tolerance

B. The system is underfiltered — the oil analysis laboratory has used a different standard than the OEM specification and the results cannot be directly compared

C. The system's oil contamination level exceeds the OEM specification by approximately 16 times at the largest particle size (each ISO code number increase represents a doubling of particle count). The system requires investigation to identify the contamination source, followed by filtration to bring the cleanliness to specification before continued operation damages components

D. The ISO cleanliness code measures only the water content of the oil and does not reflect particle contamination — the discrepancy indicates moisture contamination rather than solid particle contamination

106. A machine's hydraulic system includes a pilotoperated check valve (POCV) on the boom cylinder's capend port that locks the boom in the raised position. The operator reports the boom drifts down slowly over 30 minutes. The technician replaces the POCV with a new unit. The drift rate does not change. What should the technician investigate next?

A. The POCV installation — the new valve may have been installed backward, passing flow in the wrong direction

B. The DCV spool — internal leakage across the spool allows capend oil to bleed to tank through the spool clearance

C. The cylinder's internal piston seal — oil is bypassing across the piston from the highpressure cap end to the lowpressure rod end inside the cylinder

D. The boom cylinder's rod seal — external leakage past the rod seal is allowing oil to escape from the capend chamber, reducing the oil volume that holds the boom up

107. A hydrostatic transmission's main pump produces full displacement in both directions, confirmed by swashplate angle measurement. However, the machine's maximum travel speed is only 75% of specification in both directions. Charge pressure is correct. What should the technician test?

A. The drive motor — if the motor has excessive internal leakage, it converts a portion of the pump's output to heat rather than mechanical rotation, reducing the motor's actual speed below the theoretical speed calculated from the pump's displacement and flow

B. The engine RPM — if the engine cannot reach rated RPM under load, the pump turns slower than designed and produces less flow, directly reducing the motor speed proportionally

C. The loop flushing circuit — if the flushing valve is stuck partially open, a portion of the pump's output is diverted through the cooler instead of reaching the motor

D. The system relief valves — if both crossport reliefs have drifted low, they limit the maximum loop pressure in both directions, reducing the motor's torque and speed under load

108. A machine's hydraulic system uses an inline flow divider to split the pump's output between two circuits at a fixed ratio (60% to Circuit A and 40% to Circuit B). If Circuit A's load increases significantly while Circuit B's load remains constant, what happens to the flow split?

A. The flow divider maintains the 60/40 split regardless of the load difference — this is the fundamental purpose of a flow divider, to ensure each circuit receives its designed proportion of flow regardless of pressure variations between the circuits

B. The flow divider shifts more flow to Circuit A because it has higher pressure — the divider responds to pressure by routing more flow to the higherdemand circuit

C. The flow divider shifts more flow to Circuit B because Circuit A's higher pressure restricts the divider's orifice on the A side, diverting excess flow to the lowerresistance B side

D. The flow divider maintains the ratio but the total system pressure increases to accommodate Circuit A's higher demand, which proportionally increases the flow to both circuits

109. A hydraulic accumulator is being precharged with nitrogen. The technician connects the charging kit and begins filling. The gauge rises to the target pressure (90 bar), but when the technician closes the charging valve and disconnects the kit, the gauge on the accumulator's gas valve reads only 75 bar. What caused the pressure drop?

A. The charging kit's hose and gauge contain a volume of pressurized nitrogen that was included in the initial 90bar reading — when the hose is disconnected, that volume is lost to atmosphere, reducing the accumulator's actual charge to 75 bar

B. The nitrogen compressed the accumulator bladder, which absorbs some gas volume as the bladder material compresses under the gas pressure

C. The nitrogen gas is cooling after the rapid charging process — the compression heated the gas above ambient temperature, and as it cools to ambient, the pressure drops according to GayLussac's Law. The technician should wait for the gas to reach thermal equilibrium and recheck before adding more nitrogen

D. The accumulator's gas valve has a slow leak that will continue to deplete the charge over time

110. A machine's hydraulic pump produces a rumbling noise at all RPM. The noise does not change with load (pressure). Oil level is correct and the suction strainer is clean. The pump is a geartype pump. What is the most likely cause?

A. The pump has a damaged or worn gear tooth that produces a rumbling impact once per revolution of the damaged gear, independent of the system pressure

B. The pump's internal bearings are worn, allowing the gears to run offcentre and producing uneven tooth contact that creates the rumbling noise regardless of pressure

C. The system's relief valve is chattering at a subsonic frequency that transmits vibration through the pump housing and is perceived as a rumble

D. The pump's drive coupling has a worn elastomeric element that produces torsional vibration at the pump input shaft regardless of pump loading

111. A machine's air brake system uses a spring brake chamber for parking and emergency braking. The spring brake is released by applying air pressure to compress the spring. If the air system loses all pressure (complete system failure), what happens to the spring brakes?

A. The spring brakes apply automatically — without air pressure to hold the springs compressed, the powerful springs extend and apply the brakes mechanically. This failsafe design ensures the machine stops and remains stationary even with a total air system failure

B. The spring brakes remain in their current position (released or applied) because the spring chamber has a mechanical lock that holds the piston regardless of air pressure

C. The spring brakes release because the spring force is designed to release the brake — air pressure is used to apply the brake, not release it

D. The spring brakes apply partially — the springs do not have enough force to fully apply the brake without the air system's assistance, providing only partial braking capability

112. A technician is testing a hydraulic system's main relief valve by stalling a cylinder against its mechanical stop and reading the pressure gauge. The gauge reads 290 bar. The OEM specification is 280 bar ± 5%. Is the relief setting within specification?

A. No — 290 bar is 10 bar above the 280 bar nominal, which is 3.6% above specification. The ± 5% tolerance allows up to 294 bar (280 × 1.05), so the reading is within tolerance, but the question states the reading is 290, which is within the 5%

B. The reading is invalid because a stall test measures the working pressure, not the relief valve setting — the relief valve may not be opening at 290 bar

C. Yes — 280 bar ± 5% gives a range of 266 to 294 bar. The 290bar reading is within this range and the relief valve is correctly set

D. No — the ± 5% tolerance applies to the gauge accuracy, not the relief valve setting. The relief valve must be set at exactly 280 bar regardless of gauge tolerance

113. A machine's hydraulic system has an inline heater that warms the hydraulic oil during cold starts. The heater is thermostatically controlled to shut off at 40°C. What is the purpose of preheating the hydraulic oil before operating the machine in cold weather?

A. Cold hydraulic oil is too viscous for the pump to draw through the suction line without cavitating — the heater raises the oil temperature to the minimum viscosity where the pump can operate without inlet starvation

B. Cold hydraulic oil increases the pressure drop across the system filter, potentially collapsing the filter element or forcing the bypass valve open — the heater prevents this by reducing the oil viscosity before fullflow operation begins

C. Cold hydraulic oil has a viscosity that exceeds the pump's and motor's minimum operating specification — operating the system with oil that is too thick causes cavitation damage, excessive pressure drop across filters and orifices, sluggish actuator response, and accelerated seal wear from the highviscosity drag

D. Cold hydraulic oil cannot transmit the pilot pressure signal accurately because the thick oil dampens the pressure waves — the heater ensures the pilot circuit operates at the minimum viscosity for responsive proportional control

114. A hydraulic cylinder has a bore of 125 mm and a rod diameter of 80 mm. The system pressure is 200 bar. What is the cylinder's retract force (rodend force)?

A. 245.4 kN — calculated using the full piston area (bore area) without subtracting the rod area, which gives the extend force rather than the retract force

B. The retract force acts on the annular area (piston area minus rod area). Piston area = $\pi/4 \times 0.125^2$ = 0.01227 m². Rod area = $\pi/4 \times 0.080^2$ = 0.005027 m². Annular area = 0.01227 − 0.005027 = 0.007243 m². Force = 200 bar × 100,000 Pa/bar × 0.007243 m² = 144,860 N ≈ 144.9 kN

C. 100.5 kN — calculated using only the rod area ($\pi/4 \times 0.080^2$) rather than the annular area, which incorrectly attributes force to the rod crosssection only

D. 200 kN — calculated by multiplying the bore diameter by the pressure without applying the area formula

115. A machine's pneumatic system includes an airoperated grease pump that draws compressed air from the machine's brake air system. During heavy greasing operations, the operator notices the lowair warning buzzer sounds briefly. What is the concern?

A. The grease pump is consuming significant air volume from the brake system reservoir, temporarily dropping the brake system pressure below the warning threshold — this creates a window where the brake system has reduced stored energy for emergency stops during the greasing operation

B. The lowair warning is triggered by the grease pump's air demand cycling the compressor at a higher rate, which triggers a false warning from the pressure fluctuation

C. The grease pump's air consumption is within the brake system's designed auxiliary air allocation and the brief warning is a normal characteristic during maximum greasing demand

D. The grease pump has a leak that is consuming more air than designed — repairing the pump leak will eliminate the lowair warning during greasing operations

116. A hydraulic system's pump discharge hose has an internal wire reinforcement. Over time, the internal rubber liner can deteriorate and delaminate (separate from the wire braid). What symptom does an internally delaminated discharge hose produce?

A. The hose develops external bulges that are visible during preoperation inspections, providing advance warning before the liner fails completely

B. The delaminated liner material flaps inside the hose during oil flow, intermittently restricting flow and producing an inconsistent actuator speed or erratic DCV response that may be difficult to diagnose because the restriction is invisible from outside the hose

C. The hose immediately ruptures because the wire braid cannot contain the pressure without the liner's support

D. The delaminated liner creates turbulence that produces a distinctive whistling noise at the hose, making the fault easy to locate during a noise diagnostic

117. A hydraulic system's pilot circuit uses a dedicated pilot pump that is separate from the main pump. The pilot pump supplies 35bar pressure for DCV spool actuation, accumulator charging, and control signal generation. The technician discovers the pilot pump's case drain flow has increased from 0.5 L/min (new specification) to 2.5 L/min. What does this increased case drain indicate?

A. The pilot pump is operating within normal parameters — pilot pumps have a wider acceptable case drain range than main pumps due to their smaller displacement and higher precision

B. The pilot pump's internal clearances have worn, allowing more fluid to bypass from the highpressure discharge to the lowpressure case. This wear will eventually reduce the pilot pump's ability to maintain 35 bar, which will affect all pilotoperated functions simultaneously

C. The increased case drain is caused by the pilot circuit relief valve leaking internally, routing pilot supply oil back through the pump housing and out the case drain

D. The case drain flow is measured incorrectly — pilot pump case drains should be measured at zero pressure, not during normal operation

118. A machine's air brake system has been sitting overnight in −25°C conditions. When the operator starts the machine, the brakes do not release after the system reaches full air pressure. What has most likely occurred?

A. The air compressor's unloader valve has frozen, preventing the compressor from building adequate pressure to release the spring brakes

B. Moisture in the air system has frozen in the brake valve, relay valve, or brake chamber air line — the ice blockage prevents the air pressure from reaching the spring brake chamber to compress the spring and release the brake

C. The brake chamber diaphragm has become stiff from the extreme cold and cannot flex to release the brake under the normal air pressure

D. The parking brake control valve handle has frozen in the applied position and must be physically freed before the brakes can be commanded to release

119. A hydraulic system's tankmounted return line filter is equipped with a differential pressure indicator. The indicator shows the filter is in bypass (filter clogged). The technician replaces the filter element and resets the indicator. After 50 operating hours, the indicator shows bypass again. What should the technician investigate?

A. The replacement filter element — the element may be the wrong micron rating (too fine) for the system, clogging prematurely from normal contamination levels

B. The oil cooler — a failed cooler may be introducing coolant into the hydraulic oil, which clogs the filter element rapidly

C. The system for an abnormal contamination source — premature filter clogging indicates the system is generating or ingressing contamination at a rate that exceeds the filter's designed dirtholding capacity. Possible sources include a wearing pump, a failed seal admitting external contamination, or a previous repair that introduced debris

D. The filter element quality — a counterfeit or substandard replacement element has lower dirtholding capacity than the genuine OEM element and clogs prematurely under normal contamination loads

120. A machine's hydraulic system uses a pilotoperated directional control valve. The pilot pressure is supplied from a dedicated pilot pump through a pressurereducing valve set at 35 bar. The technician measures the pilot pressure at 35 bar with all controls in neutral. When the operator moves a joystick, the pilot pressure drops to 20 bar. What does this pressure drop indicate?

A. The pilot pressure drop when a joystick is moved is normal — the joystick opens a metering orifice that allows pilot oil to flow to the DCV pilot piston, and the resulting flow produces a pressure drop across the pilot circuit proportional to the flow demand. If the drop to 20 bar is excessive (below the minimum needed to fully shift the DCV spool), the pilot pump may be worn or the pressurereducing valve may be malfunctioning

B. The pilot system is functioning correctly — the pressure always drops when a control is actuated because the pilot oil is being consumed by the DCV pilot piston

C. The joystick has an internal leak that is dumping pilot oil to tank whenever it is moved from neutral

D. The pressurereducing valve is failing — it cannot maintain the 35bar setting when flow demand increases from the joystick actuation

121. A hydraulic accumulator on a machine's steering circuit must provide a minimum of 3 full steering cycles after the engine shuts off (emergency steering). The technician tests the accumulator by shutting off the engine and counting the number of full steering locktolock cycles available from the stored accumulator energy. The test yields 4 cycles. Is this acceptable?

A. No — the test should yield exactly 3 cycles. Having 4 cycles suggests the accumulator is overcharged, which can damage the accumulator bladder during minimum system pressure conditions

B. Yes — 4 cycles exceeds the minimum requirement of 3, confirming the accumulator has adequate stored energy for emergency steering after engine shutdown

C. No — the test must be performed with the engine running to produce valid results because the accumulator's performance depends on the pump's standby pressure being present during the test

D. Yes — but only if the 4th cycle produces steering force equal to or greater than the minimum required by the OEM specification for emergency steering effectiveness

122. A machine's hydraulic system has been converted from mineralbased hydraulic oil to a biodegradable esterbased hydraulic fluid for environmental compliance. After 500 hours of operation on the new fluid, the technician discovers several hose assemblies are weeping at the crimp ferrule connections. The hoses are the same type that operated leakfree for thousands of hours on mineral oil. What is the most likely cause?

A. The biodegradable fluid is chemically incompatible with the hose inner liner material — the esterbased fluid can attack certain rubber compounds, causing the liner to swell, shrink, or deteriorate at the crimped ferrule connection, breaking the seal

B. The biodegradable fluid operates at higher pressures than mineral oil due to its lower compressibility, which overloads the ferrule crimp beyond its designed retention force

C. The hose assemblies have simply reached the end of their service life coincidentally with the fluid change — the ferrule leaks are agerelated, not fluidrelated

D. The biodegradable fluid has a higher viscosity at operating temperature than the mineral oil, which increases the pressure drop across the hose fittings and forces oil past the ferrule seals

123. A technician is inspecting the FOPS (Falling Object Protective Structure) on a machine operating in a forestry application. The FOPS has sustained multiple impacts from falling branches and limbs. Several dents and deformations are visible on the roof and rear panel. Can the machine continue operating in the forestry environment?

A. The FOPS must be inspected by a qualified person to determine whether the deformations have exceeded the structure's designed energy absorption capacity — if the deformations are within the OEM's damage tolerance (published in the operator's manual), the FOPS remains certified. If the damage exceeds the tolerance, the FOPS must be replaced or recertified before continued operation in the forestry environment

B. Yes — FOPS structures are designed to absorb multiple impacts and the visible dents confirm the structure is performing as designed

C. No — any visible deformation on a FOPS structure invalidates its certification and the structure must be replaced immediately

D. Yes — but only if the operator wears a hard hat inside the cab to provide secondary head protection in case the damaged FOPS fails during a subsequent impact

124. A machine's attachment quick coupler uses a hydraulic locking system with a proximity sensor that detects the lock pin position. The sensor sends a signal to the ECM that enables the implement hydraulics only when the lock is confirmed engaged. If the proximity sensor fails, what happens to the implement functions?

A. The implement hydraulics continue to operate normally — the proximity sensor is an indicator only and does not disable any hydraulic functions

B. The implement hydraulics operate at reduced pressure as a safety precaution until the sensor fault is cleared

C. The ECM disables the implement hydraulics because it cannot confirm the attachment is securely locked — the machine cannot operate the attachment until the sensor is replaced or the fault is overridden through the OEM diagnostic software

D. The ECM activates an automatic coupler lock cycle to verify the lock engagement mechanically, bypassing the failed sensor

125. A machine's operator seat has a weight adjustment that changes the seat suspension's spring rate to match the operator's body weight. If the weight adjustment is set too light for a heavy operator, what symptom will the operator experience?

A. The seat bottoms out (reaches the end of its downward travel) during normal operation because the spring rate is too soft for the operator's weight — the seat cannot adequately support the operator, producing a jarring impact each time the machine hits a bump

B. The seat bounces excessively because the light spring setting produces a resonant frequency that matches the machine's normal operating vibration — the seat amplifies the machine's vibration rather than isolating the operator

C. The seat rises too high because the light spring setting overcompensates for the operator's weight, pushing the seat above its designed midstroke position

D. The seat provides a softer ride that the operator may initially prefer, but the excessive suspension travel consumes the full stroke range and leaves no reserve for large bumps

126. A technician is replacing the windshield on a machine. The replacement windshield is polycarbonate (plastic) rather than the original laminated glass. What operational limitation does a polycarbonate windshield have compared to laminated glass?

A. Polycarbonate scratches more easily than glass from wiper blade contact, dust abrasion, and cleaning — the scratches progressively reduce visibility and may require more frequent replacement. However, polycarbonate is significantly more impactresistant than glass, which is its primary advantage in highimpact environments

B. Polycarbonate provides identical performance to laminated glass in all operating conditions and there are no operational limitations

C. Polycarbonate does not meet FOPS certification requirements and the machine cannot operate in environments where FOPS protection is required

D. Polycarbonate expands more than glass with temperature changes, which causes the windshield to bow outward in hot conditions and contract in cold conditions, potentially loosening the mounting seal

127. A mining excavator's boomtostick pivot pin must be replaced. The pin is a 200 mm diameter hardened steel pin that weighs approximately 150 kg. What is the correct method for removing and installing a pin of this size?

A. Use a sledgehammer and a brass drift to drive the pin out and a hydraulic push cylinder to press the new pin in — the brass drift prevents damage to the hardened pin surface during removal

B. Heat the boom lugs with an oxyacetylene torch to expand the bore, then drive the pin out with a hydraulic ram. Allow the lugs to cool before installing the new pin with the same hydraulic ram

C. Use a hydraulic pin press or a purposebuilt pin removal/installation tool that provides controlled, aligned force to push the pin out and press the new pin in without cocking the pin in the bore, damaging the bushing surfaces, or creating a safety hazard from uncontrolled pin release

D. Weld a pulling eye to the end of the old pin and use a crane to extract it horizontally, then use the same crane to push the new pin in

128. A machine's ROPS has been modified by the maintenance crew — a storage box has been welded to the exterior of the ROPS top plate. What concern does this modification create?

A. The added weight of the storage box shifts the machine's centre of gravity and increases the rollover risk during slope operation

B. The welded attachment changes the ROPS tube's surface stress distribution and may introduce heataffected zone weakness at the weld points

C. The storage box creates a wind resistance increase that affects the machine's fuel consumption during travel

D. Welding to the ROPS invalidates its certification — the heat from welding changes the metallurgical properties of the ROPS material at the weld zone, potentially creating a weak point that may fail during a rollover event. Any modification to a ROPS structure must be approved by the OEM or a qualified structural engineer

129. A machine's bucket is equipped with bolton side cutters (wear plates on the side edges of the bucket). During inspection, the technician discovers one side cutter is worn to the point where the mounting bolts are nearly exposed. What is the risk of continuing to operate with the worn side cutter?

A. The mounting bolts will be exposed to the material flow and will be ground off by the abrasive material, releasing the side cutter and potentially the bolt fragments into the material stream — the worn side cutter must be replaced before the bolts are damaged

B. The worn side cutter provides adequate protection until the next scheduled maintenance interval — the remaining material is sufficient for continued operation

C. The worn side cutter reduces the bucket's digging width proportionally and the operator should compensate by overlapping passes during digging operations

D. The exposed mounting bolts will be workhardened by the material contact, making them extremely difficult to remove during the next replacement

130. A machine's cab door has a gas strut that holds the door in the open position for entry and exit. The gas strut has failed and the door drops closed under its own weight. The operator has propped the door open with a piece of wood during operation in hot weather. What safety concern does this create?

A. The wood prop may break and allow the door to slam shut on the operator during entry or exit — a fieldexpedient prop does not provide the controlled motion and holding force of the designed gas strut

B. The open door compromises the cab's ROPS integrity — the door must be closed during operation for the ROPS to provide its rated protection

C. The open door reduces the cab's pressurization, allowing dust, exhaust, and environmental contaminants to enter the operator's breathing zone during operation

D. The propped door creates a projection hazard — the open door extends beyond the machine's normal profile and can strike objects or personnel during swing, travel, or tightspace operation

131. A machine's attachment plate has four bolt holes for mounting a blade. The blade manufacturer's installation instructions specify Grade 8 bolts with a torque specification of 500 N·m. The technician discovers only Grade 5 bolts are available. Can Grade 5 bolts be substituted?

A. Yes — Grade 5 bolts can be substituted if the technician increases the torque to 600 N·m to compensate for the lower bolt strength

B. No — Grade 5 bolts have a significantly lower tensile and proof strength than Grade 8 bolts. Using Grade 5 bolts at the Grade 8 torque specification can stretch or break the bolts, and using them at a reduced torque produces insufficient clamping force. The machine must not operate with the attachment until the correct Grade 8 bolts are installed

C. Yes — Grade 5 and Grade 8 bolts of the same diameter have the same clamping force at the same torque value because torque depends on thread friction, not bolt grade

D. Yes — but only for temporary operation at reduced load until the Grade 8 bolts are obtained

132. A hybrid machine's regenerative braking system captures kinetic energy during swing deceleration and stores it in the energy storage device. The system's regenerative efficiency is rated at 70%. If the swing deceleration generates 50 kJ of kinetic energy, how much energy is stored?

A. 50 kJ — the full kinetic energy is converted to stored energy with no losses in the regenerative system

B. 35 kJ — at 70% efficiency, the system stores 70% of the 50 kJ input (50 × 0.70 = 35 kJ), and the remaining 15 kJ is lost as heat in the motorgenerator, power electronics, and energy storage device during the conversion process

C. 71.4 kJ — calculated by dividing the kinetic energy by the efficiency (50 ÷ 0.70), which incorrectly inverts the efficiency calculation

D. 15 kJ — only the loss portion (30%) of the energy is stored, and the majority (70%) is dissipated as heat during the conversion

133. A batteryelectric machine's BMS (Battery Management System) performs cell balancing during charging. What is the purpose of cell balancing?

A. Cell balancing equalizes the voltage across all cells in a series string by transferring energy from highervoltage cells to lowervoltage cells (or dissipating excess energy from high cells) — this ensures all cells reach their full charge level simultaneously and prevents overcharging strong cells or undercharging weak cells, maximizing the pack's usable capacity and service life

B. Cell balancing physically repositions the cells within the pack to distribute heat evenly and prevent hot spots from forming during highrate charging

C. Cell balancing adjusts the charging current to each individual cell based on its temperature — cells that are warmer receive less current to prevent thermal runaway

D. Cell balancing connects cells in different series/parallel configurations during charging to optimize the charging speed for the current battery temperature

134. A technician is working on a hybrid machine and accidentally contacts both HV DC bus bars simultaneously with a metal tool. The bus voltage is 650 VDC. Assuming the technician becomes the current path, what is the primary lifethreatening injury mechanism?

A. Thermal burns from the arc flash produced by the shortcircuit current flowing through the metal tool between the two bus bars

B. Blast injury from the explosive expansion of the air gap between the bus bars when the arc forms at 650 VDC

C. Muscle damage from the sustained tetanic contraction caused by the DC current passing through the technician's arms and body

D. Cardiac arrest — the electrical current passing through the body disrupts the heart's electrical rhythm (ventricular fibrillation), which stops effective blood circulation. At 650 VDC, the current through the body can far exceed the fibrillation threshold, making cardiac arrest the primary lifethreatening injury

135. A fleet operator is evaluating total cost of ownership (TCO) for a batteryelectric loader versus a diesel equivalent for a 10year service life. The batteryelectric machine has a higher purchase price but lower operating costs. What is the single largest operating cost advantage of the batteryelectric machine over its service life?

A. Tire replacement costs — electric machines produce smoother torque delivery that reduces tire wear by up to 40% compared to diesel machines with torque converterdriven wheels

B. Reduced brake maintenance — regenerative braking captures energy that would otherwise be absorbed by the service brakes, dramatically reducing brake pad and rotor wear over the machine's service life

C. Reduced energy cost per hour — electricity is significantly cheaper per kWh of work output than diesel fuel, and the electric drivetrain's higher efficiency (85–95%) compared to the diesel drivetrain (25–40%) means less total energy is consumed per unit of work performed, producing the largest single cost saving over 10 years

D. Reduced structural maintenance — the electric machine's smoother operation produces less vibration fatigue on the frame, boom, and attachment structures, extending their service life and reducing the frequency of structural repairs

Practice Exam 10: Answer Key and Explanations

1. B — With the engine shut down and locked out on a machine with no accumulator on the boom circuit, trapped pressure remains in the cylinder work ports from the last operation. Cycling the boom control lever several times with the engine off shifts the DCV spool and opens internal passages that allow the trapped oil to return to the reservoir, relieving the residual pressure safely before any fittings are disconnected.

2. D — A landfill environment presents multiple simultaneous hazards: unstable ground from compacted waste and potential subsurface voids, landfill gas (methane and hydrogen sulfide) that can accumulate in low-lying areas and machine compartments, and potentially hazardous materials in the waste stream requiring specialized PPE. All of these site-specific hazards must be assessed and controlled before repair work begins.

3. C — Petroleum products chemically degrade the synthetic fibres (nylon, polyester) used in fall protection webbing, reducing tensile strength below the rated capacity. This degradation is internal to the fibre structure and may not be visible or detectable by touch or visual inspection. The harness must be permanently removed from service and destroyed to prevent reuse.

4. A — Operating heavy equipment on a public road requires the appropriate licence endorsement for the vehicle class. Without the endorsement, the technician is operating illegally regardless of the purpose. The machine must be transported by a licensed transport driver on a lowbed, or a properly licensed operator must perform the test drive.

5. B — A new overhead crane requires a documented load test and certification by a qualified inspector before first use, all operators must be trained and certified for that specific crane type, and the crane's inspection schedule and maintenance log must be established. These steps ensure the crane, its installation, and its operators meet the regulatory and safety requirements before any lifting operations begin.

6. D — The technician must stop cutting immediately and shut off the torch to eliminate the ignition source. The hose fire must then be extinguished using the fire extinguisher that should be staged at every hot-work location. After extinguishing, the hose must be inspected for damage — any heat or flame compromise to the outer cover requires hose replacement because the internal reinforcement may have been weakened.

7. A — The belt guard is a safety device that prevents contact with the rotating belt and pulleys — a contact that can cause severe injury or death. Elongated mounting holes allow the guard to shift or detach during operation from vibration. The guard must be repaired (holes welded and re-drilled) or replaced before the machine returns to service. Operating without a functional guard is not acceptable.

8. C — The WPS requires E7018 electrodes to be stored at 120°C in a rod oven. While factory-sealed cans protect the electrodes during storage, once the can is opened the electrodes are exposed to atmospheric moisture. For structural welding, the WPS is the governing document — all electrodes must be placed in the rod oven at the specified temperature before use to maintain the low-hydrogen condition that prevents hydrogen cracking in the weld.

9. B — A sling that meets or exceeds any single rejection criterion is condemned and must be removed from service immediately. There is no tolerance, no temporary exception, and no "one-time use" allowance for condemned rigging. Six broken wires in one lay length exceeds the five-wire maximum — the sling is unsafe and an alternative sling rated for the load must be obtained before the lift proceeds.

10. D — A machine parked on a slope is subject to gravitational forces that can cause it to roll or slide. The parking brake alone is not a sufficient single-point restraint — wheel chocks, blocked frame rails, or other positive mechanical restraints must be placed before the technician positions themselves near or under the machine. A brake failure without secondary restraint can be fatal.

11. C — Silicon in oil analysis is the primary indicator of dirt ingestion. A sudden spike from 8 ppm to 52 ppm in one interval confirms an acute contamination event. Silicon originates from sand, soil, and dust that enters the engine through a compromised air filtration system — a torn air filter element, a loose clamp on the intake duct, or an improperly sealed filter housing allows abrasive particles to enter and damage internal components.

12. A — At 82°C coolant temperature, the engine is fully warmed and the glow plug circuit is disabled by the ECM — glow plugs are only energized during cold starts (typically below 40°C). The three non-functional glow plugs are unrelated to the current white smoke complaint. The white smoke at operating

temperature must have a different cause: coolant entering the combustion chamber, low compression, or incorrect injection timing.

13. B — The micrometer reads 89.952 mm. The standard journal is 90.000 mm and the wear limit is 89.960 mm. At 89.952 mm, the journal is 0.008 mm below the 89.960 mm wear limit — it has worn beyond the serviceable threshold. The crankshaft must be reground to the next available undersize dimension and fitted with the corresponding undersize bearing shells.

14. D — Active DPF regeneration raises exhaust temperature to 600°C or higher. In a mine staging area, the ground surface may contain combustible materials — dry vegetation, spilled fuel, rubber mats, or paper debris. The high-temperature exhaust directed at or near these materials during the automatic regeneration can start a fire. The machine must be positioned to ensure the exhaust outlet is clear of all combustible materials during regeneration.

15. A — Prolonged coolant contamination in engine oil produces a thick sludge (coolant-oil emulsion) that deposits throughout the oil system — in galleries, passages, cooler tubes, and bearing clearances. A standard oil change cannot remove these deposits. The oil system must be flushed with a suitable flushing oil to dissolve and remove the emulsion before fresh oil and filters are installed.

16. B — A new turbocharger's bearing housing arrives dry from manufacturing and shipping. The engine-driven oil pump requires several seconds of cranking to build pressure and fill the turbocharger's oil supply passage, bearing housing, and drain. During those first seconds, the exhaust gas immediately begins spinning the turbine shaft at high speed on dry bearings. Pre-lubrication fills the bearing housing before the first start, preventing immediate scoring damage.

17. D — The VGT actuator moves freely during the diagnostic test at a cooler temperature, ruling out a mechanical failure. Carbon accumulation on the vane ring and unison ring bonds the vanes in place at full operating temperature but breaks free under the diagnostic tool's commanded force at a lower temperature. The fault will return during normal operation when the carbon re-accumulates at operating temperature.

18. C — A thin oil mist film in the intake manifold is normal when a CCV system is installed — the separator cannot capture 100% of the oil vapour in the blowby gas. However, a heavy oil coating, pooled liquid oil, or visible oil dripping indicates a problem: excessive blowby, a failed CCV separator element, or a turbocharger compressor seal failure that is passing oil into the intake stream at an abnormal rate.

19. A — Each fuel injector has slight manufacturing variations in nozzle flow rate, opening pressure, and internal clearances. The IQA trim codes encode these individual characteristics so the ECM can adjust each injector's pulse width to deliver the exact fuel quantity commanded, compensating for manufacturing tolerances. Without correct trim codes, cylinder-to-cylinder fuel delivery variations cause rough running, smoke, and power imbalance.

20. D — A puff of blue smoke only at startup after an overnight sit — with clean running for the rest of the day — is the classic symptom of hardened valve guide seals. When the engine is cold and shut down, the hardened seals cannot flex to maintain their seal on the valve stems. Oil seeps past the stiff seals and pools on the valve tops overnight. At startup, this accumulated oil burns as a brief puff of blue smoke.

21. B — Exhaust valves and their components operate at significantly higher temperatures than intake components because they are exposed to hot exhaust gases. The wider cold lash specification for exhaust valves compensates for this greater thermal expansion — as the engine reaches operating temperature, the exhaust valve train grows more than the intake, consuming the larger cold-set clearance and arriving at the correct running clearance.

22. C — New piston rings must seat against the cylinder wall's honed surface by progressively wearing the microscopic surface peaks into a gas-tight seal. The varied load during break-in provides alternating compression pressures that promote even ring seating across the entire cylinder bore without overloading the unmated ring-to-wall interface. Sustained full-load before the rings have seated can glaze the cylinder walls and prevent proper seating.

23. A — The fuel-water separator is functioning as designed — it has collected water from the fuel and stored it in the bowl. The water must be drained using the drain valve before the water level rises high enough to overflow into the secondary fuel filter and reach the high-pressure injection system, where water causes corrosion, erosion, and potential injector failure.

24. B — A green tint in the flush water after the first cycle confirms residual contaminated coolant remains in passages, heater circuits, heat exchangers, and low points that did not drain completely during the initial drain. Additional flush cycles are required until the drain water runs completely clear, confirming all contaminated coolant has been removed from the system.

25. D — In hot ambient conditions (above 35°C), the fuel in the low-pressure supply lines absorbs ambient heat. If the fuel temperature exceeds its vapour pressure threshold, vapour bubbles form in the low-pressure circuit (vapor lock). The vapour displaces liquid fuel from the supply lines, preventing the

high-pressure pump from receiving adequate liquid fuel during cranking and causing the hard-start condition.

26. C — The DOC converts carbon monoxide (CO) to carbon dioxide (CO_2) and hydrocarbons (HC) to CO_2 and water (H_2O) through catalyzed oxidation. The platinum and palladium catalyst surfaces lower the activation energy required for these exothermic oxidation reactions to occur at normal exhaust temperatures, converting toxic CO and unburned HC into less harmful CO_2 and water vapour.

27. B — The audible click during a buzz test only confirms the injector's solenoid valve operates electrically — the coil generates magnetic force and the armature moves. It does not confirm the nozzle is atomizing correctly, the delivery quantity is accurate, the injector is not leaking internally, or the return flow is within specification. Further testing (flow testing, back-leak testing) is required to evaluate full injector function.

28. D — Coolant leaking from the EGR cooler enters the exhaust stream and passes through the DOC and into the DPF. The glycol and silicate compounds in the coolant poison the catalytic coating on the DPF substrate and clog the ceramic wall-flow channels. This contamination reduces the DPF's filtration efficiency and prevents successful regeneration, potentially requiring DPF replacement.

29. A — Before condemning a mechanically sound turbocharger for low boost, the entire intake and exhaust system must be checked for restrictions and leaks. A clogged air filter, collapsed intake hose, charge air cooler leak, or exhaust restriction (DPF loading, kinked exhaust pipe) reduces the effective airflow through the turbocharger and limits achievable boost pressure — even with a perfectly functioning turbo.

30. C — Sodium and potassium are the primary metallic components of the corrosion inhibitor additives in engine coolant formulations. A gradual increase over four consecutive oil samples (without corresponding increases in other wear metals) indicates a small, slow coolant leak into the oil system. The leak rate is too low to produce visible contamination on the dipstick but is detectable through oil analysis trending.

31. D — Excessive vertical play at the articulation joint (1.5 mm vs. 0.5 mm maximum) allows the front and rear frames to shift vertically relative to each other during loaded operation. This misalignment produces uneven loading on the articulation pivot pins and bearings, accelerates wear at the joint, stresses the frame structures, and reduces the steering precision because the geometric relationship between the frames is unstable.

32. B — The left strut at 685 mm is at the extreme lower limit of the 700 ± 15 mm specification (685 = 700 − 15), and the right strut at 720 mm exceeds the upper limit (715 = 700 + 15). The left strut may be low on nitrogen or oil, and the right strut is above the allowable upper limit, indicating it may be overcharged or have a mechanical issue preventing normal compression.

33. C — The track chain's pins and bushings wear on one contact surface during normal operation. At approximately 50% wear, the pin turn (re-bushing) rotates the pins 180 degrees, exposing the unworn contact surface. Turning at 50% maximizes both wear lives — the first 50% on the original surface and the second period on the turned surface. Turning too late (at 80%) wastes potential second-life service.

34. A — Solid rubber tires have no pneumatic cushion — they cannot absorb and dampen road impacts through air compression like pneumatic tires. Every road impact transmits directly through the rigid tire to the machine's frame and any suspension components. Without the damping effect of air-filled tires, the machine oscillates longer after each bump because there is no energy-absorbing mechanism to dampen the motion.

35. D — The 4-minute build-up time (vs. 3-minute maximum) means the system is not accumulating air fast enough. The causes include: reduced compressor output (worn valves/cylinders), system air leaks consuming air during build-up, or increased system volume (additional components). All three conditions reduce the net air stored per unit time. The technician must determine which specific cause is responsible.

36. A — Rotating the hub during bearing preload adjustment seats the tapered rollers against the cup surfaces and distributes the lubricant evenly across all roller contact points. This ensures the measured preload reflects the actual running condition of the bearing — not a partially seated or dry condition that would produce an artificially high or inconsistent torque reading.

37. C — The steering valve centering and hydraulic system are confirmed functional. A steering wheel that does not return to centre after a turn points to insufficient mechanical self-centering force. Insufficient caster angle reduces the self-centering effect generated by the tire contact patch trailing behind the steering axis — without adequate caster, the wheels lack the geometric force needed to return to straight-ahead naturally.

38. B — Static friction (holding a stationary load) produces a higher friction coefficient than kinetic friction (decelerating a moving load). The brake generates sufficient static friction to hold the machine on a grade but the lower kinetic friction coefficient cannot generate enough decelerating force to stop the

machine from 10 km/h within the specified distance. The brake's actuating force or friction material is marginal.

39. A — The idler bearings have failed, allowing the idler to run eccentrically. The eccentric rotation causes the idler's tread to orbit rather than rotate concentrically, wearing a concave (cupped) profile into the tread as the high and low points of the eccentric path wear different zones at different rates. The cupped profile is a definitive indicator of bearing failure.

40. D — Brake-based traction control works by braking the spinning wheel, which converts the spinning wheel's kinetic energy to heat in the brake rather than redirecting it through the differential to the non-spinning wheel. The system wastes energy during every activation, the total available tractive effort is less than a mechanical lock provides, and the brake heat generation limits the duration the TCS can operate before thermal protection deactivates it.

41. B — The replacement cylinder has the correct stroke but the rod end attachment point on the steering arm determines the effective lever arm and maximum angular displacement. If the rod end was connected to a different hole on the steering arm than the original, the cylinder's stroke produces a different maximum steering angle, directly affecting the turning radius.

42. C — In wet disc brake assemblies, copper typically originates from bronze friction disc material. A sudden spike from 15 to 85 ppm indicates accelerated brake disc wear — the friction material is being consumed at a rate significantly above normal. The brake pack should be inspected for excessive disc wear, contamination (oil or water), inadequate cooling, or incorrect disc specifications.

43. D — A segmented sprocket design allows the sprocket to be replaced without removing the track chain. Individual worn segments can be unbolted from the hub and replaced while the chain remains on the machine, significantly reducing the service downtime compared to a solid one-piece sprocket that requires full track disassembly for replacement.

44. A — A firm pedal confirms the hydraulic circuit is bled of air and the master cylinder is functioning. A caliper that produces no braking force despite correct system pressure points to a blockage between the system and the caliper bore. A manufacturing plug, shipping cap, or internal passage obstruction in the replacement caliper prevents hydraulic pressure from reaching the caliper pistons.

45. B — The recoil spring and grease-filled adjuster cylinder allow the front idler to move rearward when the track encounters an obstruction. The relief valve opens when the obstruction force exceeds the

valve's cracking pressure, allowing grease to escape and the spring to compress — absorbing the shock load. Without this relief, the sudden track tightening would transfer the full shock force to the chain, sprocket, final drive, and frame.

46. C — The bearing cup must have an interference fit in the axle bore — the bore must be slightly smaller than the cup's outer diameter. If the cup was cocked during installation (from incorrect tooling), the effective press-fit contact area is reduced. The reduced contact area cannot resist the cyclical steering loads, and the cup gradually works loose and begins to rotate in the bore.

47. A — Many fuel injection systems use a fuel prime strategy that delays injector firing for the first several engine revolutions during cranking. This delay allows the high-pressure pump to build adequate rail pressure before the ECM commands fuel delivery. The 0V reading at the injector connector during this initial prime period is normal — the ECM has not yet commanded the injectors to fire.

48. D — A fusible link melts when the current flowing through it exceeds its rated capacity for a sustained period. The most common cause is a short circuit in the protected wiring that creates a direct low-resistance path to ground, drawing current far above the circuit's normal operating range. A shorted charging wire or internally shorted alternator rectifier diodes can produce this condition.

49. C — The injector coil tests within specification at the injector connector (0.6 ohms), confirming the injector is electrically functional. The persistent "circuit open" DTC with a good injector points to the wiring between the ECM and the injector — an open wire, a corroded splice, or a damaged connector pin interrupts the circuit somewhere between the two endpoints that individually test as functional.

50. B — A yellow oil pressure indicator at idle that clears above 1,200 RPM confirms the oil pressure at idle is below the yellow warning threshold. The pressure rises with RPM as the oil pump increases output, clearing the warning above 1,200. This pattern indicates a worn oil pump, worn bearings, low oil level, or incorrect oil viscosity that produces inadequate pressure at the low pump speed of idle.

51. D — A CAN bus splice made by twisting wires without proper shielding, strain relief, or environmental protection is vulnerable to moisture ingress, corrosion, vibration-induced fatigue, and electromagnetic interference. Any of these conditions can produce intermittent communication faults that are difficult to diagnose because the bare-wire splice may test as functional during controlled bench conditions but fail under the machine's operating environment.

52. A — Dual-track APPS sensors with different voltage ranges provide redundancy and cross-checking. The ECM continuously compares Track 1 and Track 2 — if one fails, the ECM uses the other. The different voltage ranges allow the ECM to immediately detect if one track's signal is accidentally connected to the other track's circuit, because the wrong signal would produce values outside that track's expected range.

53. B — A fully charged 24V battery bank reads 25.2–25.4V OCV after a 48-hour rest. A 50% charge reading is approximately 24.0V. The 24.8V reading falls between these benchmarks at approximately 85% state of charge. The batteries should be charged and load tested to verify they can deliver rated cranking current.

54. C — Ohm's Law: $R = V \div I = 0.8V \div 150A = 0.00533$ ohms (approximately 0.0053 ohms). This is the resistance of the charge wire that produces the 0.8V voltage drop when carrying 150A of charging current. The power dissipated as heat in this wire is $P = V \times I = 0.8 \times 150 = 120$ watts.

55. A — Each watchdog reset forces the ECM through its initialization sequence. During this brief reset cycle (typically milliseconds to seconds), the ECM's outputs — including fuel injection commands — are interrupted. The engine briefly cuts out until the ECM completes its startup checks and resumes fuel delivery. If the watchdog resets repeatedly, the operator experiences cyclical engine cutouts.

56. D — The engine-to-frame ground strap is the primary designed current path for all engine-mounted electrical devices to reach the frame ground. Without it, all ground current from the alternator, sensors, solenoids, ECM, and starter must find alternate paths — through throttle cables, hydraulic lines, control linkages, and drivetrain components. These unintended paths produce arcing, bearing damage from electrical erosion, and signal interference.

57. B — When the main contacts close, both ends of the pull-in winding are at battery voltage — one end from the solenoid terminal and the other from the closed main contacts. With equal voltage on both ends, no current flows through the pull-in winding (no potential difference). Only the hold-in winding (connected between the solenoid terminal and ground) maintains current flow and the magnetic field that keeps the solenoid engaged.

58. C — The ECM measures the time interval between successive CKP signal edges (reluctor teeth). A normally firing cylinder accelerates the crankshaft during its power stroke, producing shorter intervals between teeth. A misfiring cylinder does not accelerate the crankshaft, producing longer intervals. The ECM detects this interval variation and attributes the misfire to the specific cylinder based on the crankshaft position.

59. D — An increasing CAN bus error frame rate without any individual module logging a fault indicates a developing hardware issue on the bus itself. A degrading connection, a failing CAN transceiver in one module, or increasing electromagnetic interference is producing signal integrity problems that will escalate to communication loss if not diagnosed and corrected before the error rate exceeds the bus's error tolerance threshold.

60. A — The transmission ECM uses the engine load data to determine shift timing. If the engine ECM sends an artificially low load value, the TCM believes the engine is lightly loaded and commands an upshift earlier than appropriate. After the premature upshift, the engine encounters the actual (higher) load in the higher gear and lugs — the RPM drops and the engine struggles until the TCM commands a corrective downshift.

61. A — The replacement ECM was programmed with the correct calibration file, but the machine's individual parameter settings were not transferred. Parameters such as idle speed, fan control map, tire size, implement calibrations, and security codes are machine-specific settings that are stored separately from the base calibration. Without these settings, the ECM operates on default values that differ from the machine's optimized configuration.

62. C — The hour meter requires an input signal to recognize the engine is running. If the signal source (oil pressure switch, alternator R-terminal, or ECM data) has failed or been interrupted, the meter does not receive the "engine running" indication and stops incrementing. All other cluster functions operate correctly because they use different input signals.

63. B — The GPS antenna cable, connector, or antenna mount is the most likely cause of degraded positioning accuracy. A damaged cable, loose connector, or corroded antenna mount attenuates the satellite signals below the receiver's threshold for high-accuracy RTK or differential correction, forcing the receiver into a lower-accuracy autonomous positioning mode.

64. B — Four glow plugs rated at 6A each should draw a total of $4 \times 6 = 24$A. The measured total of 24A confirms all four glow plugs are drawing their rated current and the glow plug circuit is functioning correctly. If any plug were non-functional, the total would be lower (e.g., 18A for three working plugs).

65. A — The freeze frame shows intake air temperature at −5°C in 25°C ambient conditions. The charge air cooler can cool the compressed intake air below ambient, but −5°C is unrealistically low for a 25°C ambient. The IAT sensor has likely failed and is reading a fixed incorrect value. This false reading causes the ECM to calculate an incorrect boost target, which is the probable cause of the "boost pressure low" DTC.

66. B — The engine percent load PID reflects fuel consumption relative to the engine's maximum fuel delivery at the current RPM. Any condition that increases fuel usage — a malfunctioning injector, incorrect timing, excessive parasitic loads from a seized accessory, a failing hydraulic pump, or a dragging brake — increases the percent load reading even when the external work demand on the machine is low.

67. B — All BCM-controlled functions are inoperative simultaneously, but the engine and transmission (which communicate through the gateway) work normally. The gateway functions correctly for non-BCM data. The most likely cause is a failure in the CAN bus connection between the gateway's BCM port and the BCM itself — the module cannot receive commands or send status data through the broken communication path.

68. A — The fuse blows consistently when the key reaches the RUN position, confirming a fault in one of the circuits energized by the RUN position. Systematically disconnecting each circuit on the RUN bus one at a time and testing with a new fuse after each disconnection isolates the specific circuit. When the fuse stops blowing, the last disconnected circuit contains the fault (short to ground or excessive current draw).

69. D — The 0.5V baseline at zero pressure allows the ECM to distinguish between a valid zero-pressure reading (sensor outputting 0.5V) and a faulted condition where the signal wire is shorted to ground (0V). Without this offset, the ECM cannot determine whether a 0V reading means zero pressure or a wiring fault, eliminating the system's ability to detect and flag a grounded signal wire.

70. B — The fuel pump runs continuously regardless of the ECM's command. The relay is the component that directly switches the pump's power supply on the ECM's command. If the relay contacts have welded (fused) together from arcing, the relay maintains the circuit regardless of whether the ECM energizes the coil. The pump receives continuous battery power through the welded contacts.

71. C — The joystick reads exactly 2.50V (confirmed centred), and the ECM shows no fault codes. The drift must originate downstream of the ECM's command — in the pilot solenoid or the main DCV spool. A pilot solenoid with a small internal leak allows a trickle of pilot pressure to reach the main spool even when commanded off, shifting the spool slightly off neutral and producing the slow actuator drift.

72. A — The lockup clutch initially held (engine and turbine RPM matched) but after 5 minutes the turbine RPM begins to drop below engine RPM. The lockup clutch has begun to slip — the friction material has either overheated from the sustained lock, become contaminated with oil from a seal

failure, or worn to the point where it cannot maintain the mechanical connection under the current torque load.

73. C — The ring and pinion teeth have two distinct contact surfaces — the drive side (convex face) loaded during acceleration and the coast side (concave face) loaded during deceleration. The change in noise character between drive and coast indicates the gear mesh contact pattern is not correctly centred on both faces. A correctly adjusted gear set produces minimal noise change during the drive-to-coast transition.

74. B — The oil's friction modifier content controls the engagement characteristics of the transmission's wet clutch packs. Different oil manufacturers use different friction modifier formulations, and even oils that meet the same viscosity and API specification may produce different clutch engagement profiles. The replacement oil's friction characteristics may not match the clutch material's designed engagement profile.

75. D — Full pump displacement in both directions (confirmed by swashplate angle) with correct charge pressure rules out the pump and charge system. The motor's cross-port relief in the reduced-speed direction may be stuck partially open, diverting a portion of the pump's output before it drives the motor. This directional relief fault affects only one direction while the other direction's relief functions normally.

76. A — The governor pressure commands upshifts by pushing the shift valve against the opposing throttle pressure. Low governor pressure at a given speed means the shift valve does not receive enough force to overcome the throttle pressure and command the upshift. The machine must reach a higher speed — where the governor finally produces sufficient pressure — before the upshift occurs. All upshifts are delayed.

77. C — The limited slip clutch pack requires a specific friction modifier additive to control its engagement characteristics. Without the modifier, the clutch plates alternate between grabbing (static friction exceeds the operator's input) and slipping (kinetic friction drops below the holding point) during the speed differential required for tight turns. This cyclical grab-and-release produces the characteristic chatter.

78. D — A welded driveshaft repair permanently changes the metallurgical properties of the shaft material at and near the weld. The heat-affected zone (HAZ) is annealed — the steel is softened from the welding heat, reducing its torsional strength and fatigue endurance. A driveshaft failure at the weld

during high-speed operation can cause catastrophic damage including cab penetration and personnel injury.

79. B — Series-connected gear reductions multiply: total ratio = Stage 1 ratio × Stage 2 ratio = 4.5 × 6.2 = 27.9:1. The input shaft rotates 27.9 times for each single revolution of the output shaft. This is the correct calculation for series planetary reductions where the output of Stage 1 becomes the input of Stage 2.

80. A — At 130°C (20°C above the 110°C maximum), the oil's oxidation rate increases exponentially. The antioxidant additives are consumed at a dramatically accelerated rate, and once depleted, the base oil oxidizes rapidly — producing acids that corrode seals and metal surfaces, and varnish that clogs passages and deposits on valve spools. Extended operation at this temperature degrades the oil's lubricating and hydraulic properties.

81. D — The charge pressure is within specification and the hydrostatic system is not designed to hold a stationary machine on a grade through hydraulic lock alone. Internal leakage through the pump and motor clearances always allows slow drift under gravity loading when the pump is at zero displacement. The parking brake — not the hydrostatic system — is the designed restraint for holding the machine stationary on a grade.

82. C — The pump produces 35 L/min vs. the 38 L/min new specification — a 7.9% reduction. However, the typical minimum acceptable threshold for a serviceable transmission pump is 95% of new output. At 92.1% (35 ÷ 38), the pump has fallen below the 95% threshold and should be scheduled for rebuild. While it may still support basic transmission operation, it is at the margin.

83. A — A vibration from the torque converter area that changes frequency with engine RPM and is present in all gear ranges and both directions points to a converter internal failure. Broken lockup clutch disc fragments circulating inside the housing create mass imbalances and intermittent impacts with the pump, turbine, and stator that produce RPM-proportional vibration regardless of transmission gear selection.

84. B — The two-zone fracture surface is the classic signature of fatigue failure. The smooth curved zone is the fatigue crack that propagated slowly over thousands of load cycles — the smooth surface results from the repeated crack-face contact during each loading cycle. The rough granular zone is the final sudden fracture when the remaining cross-section could no longer carry the applied load.

85. C — A noise only during deceleration (coast) that disappears during acceleration (drive) points to a component whose loading changes between these two modes. The gear teeth's coast-side surfaces (concave faces) are loaded during deceleration, while the drive-side surfaces carry the load during acceleration. Worn coast-side tooth surfaces produce the rattle exclusively during coast loading.

86. D — The measured pinion rotating torque of 1.5 N·m falls within the OEM specification of 1.0–2.0 N·m for used bearings. The preload is correct for reinstallation. Note: the specification states "used bearings," which accounts for the reduced preload that occurs as bearing rollers polish the races during initial service.

87. A — Increasing the pump's maximum displacement increases the maximum flow delivered to the fixed-displacement motor, which directly increases the motor speed and the machine's travel speed. However, the increased flow demand requires more engine power (power = pressure × flow). If the engine cannot supply the additional power, it will lug or stall under load. Additionally, the higher motor speed may exceed the motor's and drivetrain's design limits.

88. B — An isolated engine flare during only the 3-4 shift with all other shifts smooth points to the 4th gear clutch pack's apply circuit. A hydraulic leak in the 4th gear apply circuit (leaking piston seal, scored clutch housing bore, or cracked piston) causes the clutch to fill and clamp more slowly than designed. The engine flares during the delay between 3rd gear releasing and 4th gear fully engaging.

89. C — R-1234yf operates at slightly different pressures than R-134a as a characteristic of its thermodynamic properties. The 15% lower high-side pressure is a normal expected result of using R-1234yf in a system designed for its properties. If the system produces adequate cooling at the OEM-specified charge weight, the lower gauge readings are the normal operating pressures for this refrigerant.

90. A — A hot-water valve stuck in the fully open position allows maximum coolant flow through the heater core regardless of the operator's temperature lever position. The heater core receives maximum heat input at all times, producing constant maximum cab temperature that the temperature control cannot reduce. The valve must be repaired or replaced to restore temperature regulation.

91. D — Both low-side and high-side pressures significantly below normal with the system running indicates insufficient refrigerant mass in the system. There is not enough refrigerant volume to develop normal operating pressures at any point in the circuit. The system requires leak testing to locate the refrigerant loss, followed by repair and recharging to the correct weight.

92. C — The internal heat exchanger subcools the high-pressure liquid by transferring heat to the low-pressure suction gas. Subcooling ensures only liquid enters the expansion device (improving efficiency and preventing flash gas). Simultaneously, superheating the suction gas ensures only vapour enters the compressor inlet, protecting the compressor from liquid slugging that can cause mechanical damage.

93. B — The combustion air blower supplies the primary air for the diesel-fired heater's combustion. An inconsistent airflow — from a worn blower motor bearing, a dirty blower wheel, or a restricted air intake — produces a fluctuating air-to-fuel ratio. The combustion alternates between fuel-rich (excess fuel, incomplete combustion, smoke) and fuel-lean (flame instability, potential flameout) cycles, producing the pulsing flame.

94. A — When ambient temperature equals the set point, the ATC system is near thermal equilibrium. However, the A/C compressor provides dehumidification in addition to cooling — the evaporator removes moisture from the cab air, which adds a small amount of heat. The ATC cycles the compressor to manage humidity while maintaining the temperature set point. Small variations in solar load or occupant heat produce the frequent cycling.

95. D — The HEPA filter is the most expensive and finest filter in the series. The cyclonic pre-cleaner and primary filter protect the HEPA by removing the bulk of the contamination before it reaches the HEPA element. The pre-cleaner is serviced most frequently (every service interval), the primary filter at the manufacturer's interval, and the HEPA filter only when the cab pressurization drops below specification — indicating it has loaded to its service limit.

96. B — A new compressor shipped without oil (or with insufficient oil) runs with metal-to-metal contact between the pistons and cylinder walls, the swash plate and shoe surfaces, and the shaft and bearing surfaces. The metallic knocking is the sound of these unlubricated components impacting during each compression cycle. The compressor requires the correct oil type and quantity before operation.

97. C — DEF freezes at −11°C. At −20°C ambient without the line heater, the DEF freezes solid in the supply line. No DEF can be delivered to the dosing module, and the SCR system cannot reduce NOx emissions. The ECM detects the failed DEF delivery and initiates a progressive power derate per the emission compliance strategy (EPA/Environment Canada requirements) until the heater is repaired and the DEF thaws.

98. D — The 30-bar standby pressure is the pump's designed idle condition. The pressure compensator has destroked the pump to minimum displacement — the pump produces only enough flow to overcome

internal leakage and maintain the system in a "ready" state. This standby pressure minimizes heat generation and parasitic power consumption when no hydraulic function is being commanded.

99. A — The pump flow is within specification and the relief valve is correct, so the system can deliver full flow at the correct pressure. The slow extension must be caused by a restriction in the cap-end supply path that limits the flow reaching the cylinder. A partially blocked hose, contaminated check valve, restricted fitting, or a flow control valve set too low can reduce the effective flow to the cylinder despite correct pump output.

100. C — The pressure line filter (6-micron) provides finer filtration because it protects the high-precision control valves and actuators downstream — these components have tight internal clearances that are vulnerable to particles above 6 microns. The return line filter (10-micron) catches the bulk contamination at a coarser rating that provides lower flow restriction and longer element life, since it filters the full system return flow volume.

101. B — The counterbalance valve requires a positive pilot signal to remain open during lowering. If the DCV spool has a worn metering edge, or the pilot circuit pressure fluctuates from a loose connection or erratic supply, the counterbalance valve receives an inconsistent pilot signal. The valve alternately opens (load accelerates) and partially closes (load catches) as the pilot signal fluctuates.

102. D — A compressor duty cycle above the OEM maximum (65% vs. 50%) means the system is consuming air faster than the compressor can replenish during 50% loaded time. The most common cause is an air leak somewhere in the system that continuously bleeds stored air, requiring the compressor to run loaded for a greater percentage of time. Higher-than-designed air demand from additional or larger brake chambers also produces elevated duty cycle.

103. A — A proportional pressure-reducing valve produces downstream pressure proportional to its electrical command signal. If the ECM sends a higher command than intended — from an incorrect input signal, a calibration error, or a wiring fault — the valve opens further and produces higher downstream pressure. The valve hardware is functioning correctly but is receiving an incorrect command.

104. B — A sheared flange bolt at 280 bar working pressure is a critical failure indicator. The remaining three bolts are carrying the load that was designed for four — each bolt is overloaded by approximately 33%. Operating the machine risks a cascading bolt failure as the overloaded bolts fatigue rapidly, potentially producing a catastrophic high-pressure hydraulic release. The machine must be shut down immediately.

105. C — Each ISO cleanliness code number represents a doubling of particle count. A 4-code-number difference between the actual (22/20/17) and the specification (18/16/13) means the actual contamination is approximately 16 times higher ($2^4 = 16$) than the specification at each particle size range. The system requires contamination source identification and aggressive filtration to bring the cleanliness to the specified level.

106. D — The POCV has been replaced and the drift persists — ruling out the POCV as the cause. The drift source must be between the POCV and the cylinder or inside the cylinder. The most likely remaining cause is the cylinder's piston seal bypassing internally — oil crosses the piston from the pressurized cap end to the rod end inside the cylinder, reducing the holding pressure and allowing the boom to drift down.

107. A — The pump produces full displacement (confirmed by swashplate angle measurement) and charge pressure is correct. With full displacement and correct charge, the pump should deliver its rated flow. If the motor has excessive internal leakage, it converts a portion of the pump's output to heat rather than shaft rotation. The motor's reduced volumetric efficiency produces the 75% speed in both directions.

108. B — A flow divider's fundamental purpose is to maintain the designed flow ratio between two circuits regardless of pressure differences. If Circuit A's load increases, the flow divider compensates by maintaining the 60/40 split — it resists the pressure imbalance and continues to deliver the programmed proportion to each circuit. This is the core function that distinguishes a flow divider from a simple tee connection.

109. C — During rapid nitrogen charging, the compression process heats the gas above ambient temperature (adiabatic heating). The initial 90-bar gauge reading includes the thermally elevated pressure. As the gas cools to ambient temperature over several minutes, the pressure drops according to Gay-Lussac's Law. The technician should wait for thermal equilibrium and recheck the pressure before adding more nitrogen.

110. D — An internally delaminated hose has a rubber liner that has separated from the wire reinforcement. The loose liner material flaps inside the hose during oil flow, intermittently restricting the flow path. This produces inconsistent actuator speed or erratic DCV response that is extremely difficult to diagnose because the restriction is invisible from outside the hose — the hose appears normal externally.

111. A — Spring brake chambers are fail-safe devices. The powerful springs are held compressed by air pressure during normal operation (brakes released). If the air system loses all pressure — from a leak, a line failure, or system damage — the springs extend automatically and apply the brakes mechanically. This ensures the machine stops and remains stationary even with a complete air system failure.

112. C — The OEM specification is 280 bar ± 5%. The acceptable range is 280 × 0.95 = 266 bar to 280 × 1.05 = 294 bar. The measured 290 bar falls within this 266–294 bar range. The relief valve is correctly set and no adjustment is needed.

113. D — Cold hydraulic oil has a viscosity that exceeds the pump's and motor's minimum operating specifications. Operating the system with excessively viscous oil causes pump inlet cavitation (the thick oil cannot flow fast enough to fill the pump chambers), excessive pressure drop across filters and orifices, sluggish actuator response, and accelerated seal wear from the high-viscosity drag on moving seal surfaces.

114. B — The retract force acts on the annular area (piston area minus rod area). Piston area = $\pi/4 \times 0.125^2 = 0.01227$ m². Rod area = $\pi/4 \times 0.080^2 = 0.005027$ m². Annular area = $0.01227 - 0.005027 = 0.007243$ m². Force = 200×10^5 Pa × 0.007243 m² = 144,860 N ≈ 144.9 kN.

115. A — The air-operated grease pump draws from the brake system reservoir. During heavy greasing, the pump's air consumption temporarily drops the reservoir pressure below the 380 kPa low-air warning threshold. During this window, the brake system has reduced stored energy for emergency stops. This is a system design concern — the grease pump should ideally be supplied from a separate auxiliary reservoir.

116. D — An internally delaminated discharge hose produces the most challenging diagnostic symptom. The loose liner flaps intermittently in the flow stream, partially blocking flow during some strokes and allowing full flow during others. The erratic restriction produces inconsistent actuator speed that cannot be reproduced consistently because the liner's position changes randomly with each flow event.

117. C — The pilot pump's case drain has increased from 0.5 to 2.5 L/min — a fivefold increase. The increased drain confirms the pump's internal clearances have worn, allowing more fluid to bypass internally. As the wear progresses, the pilot pump will eventually be unable to maintain the 35-bar specification, which will affect all pilot-operated functions simultaneously — DCV actuation, accumulator charging, and control signals.

118. B — Moisture that entered the air system (from inadequate air drying or desiccant depletion) has frozen inside the brake valves, relay valves, or brake chamber air lines at −25°C. The ice blockage prevents the air pressure from reaching the spring brake chambers to compress the springs and release the brakes. The system has adequate pressure (confirmed by the gauge) but the ice prevents delivery.

119. D — Premature filter clogging (50 hours vs. normal service interval) indicates the system is generating or ingressing contamination at an abnormal rate. The contamination source must be identified — a wearing pump generating metal particles, a failed seal admitting external dirt, a previous repair that introduced debris, or a failed cooler introducing coolant. Repeatedly replacing filters without finding the source wastes filters and risks component damage.

120. A — A pilot pressure drop from 35 bar to 20 bar when a joystick is actuated indicates the pilot system cannot maintain pressure under demand. The drop occurs because the joystick opens a flow path and the pilot pump cannot maintain 35 bar against the combined leakage and demand. If 20 bar is below the minimum needed to fully shift the DCV spool, the system response will be sluggish and the pilot pump or pressure-reducing valve should be tested.

121. B — The emergency steering requirement is a minimum of 3 full lock-to-lock cycles after engine shutdown. The test yields 4 cycles — which exceeds the minimum requirement. The accumulator has adequate stored energy for emergency steering. There is no upper limit concern from having one extra cycle, as long as the pre-charge and system pressures are within their individual specifications.

122. C — Ester-based biodegradable hydraulic fluids can be chemically incompatible with certain rubber compounds used in standard hydraulic hose inner liners. The ester fluid can cause the liner to swell, shrink, harden, or soften, breaking the seal between the liner and the crimped ferrule. The hose assemblies must be verified as compatible with the specific biodegradable fluid or replaced with compatible hoses.

123. A — The FOPS must be inspected by a qualified person against the OEM's published damage tolerance criteria. If the dents and deformations fall within the acceptable damage tolerance, the FOPS remains certified. If any deformation exceeds the tolerance, the structure has absorbed a significant portion of its designed energy capacity and must be replaced or re-certified before the machine continues in the forestry environment.

124. C — The proximity sensor provides the ECM with lock-pin position confirmation. If the sensor fails, the ECM cannot verify the attachment is securely locked. As a safety measure, the ECM disables

the implement hydraulics — the machine cannot operate the attachment until the sensor is replaced and confirms lock engagement, or the fault is overridden through the OEM diagnostic procedure.

125. B — A weight adjustment set too light for a heavy operator produces a seat suspension natural frequency that coincides with the machine's operating vibration range. The soft spring allows the seat to oscillate in resonance with the machine's vibration, amplifying the motion rather than isolating the operator. The result is excessive bouncing that the operator perceives as a rough, uncomfortable ride.

126. A — Polycarbonate windshields scratch more easily than glass from wiper blade contact, dust abrasion, and cleaning agents. The scratches progressively reduce visibility, requiring more frequent replacement than laminated glass. However, polycarbonate is significantly more impact-resistant than glass — its primary advantage in forestry, demolition, and other high-impact environments where object strikes are common.

127. C — A 200 mm, 150 kg pivot pin requires controlled, aligned force for removal and installation. A hydraulic pin press or purpose-built removal tool provides the controlled force needed to push the pin straight through the bore without cocking it, damaging the bushing surfaces, or creating a safety hazard from uncontrolled pin ejection. Hammering or heating risks bore damage, bushing distortion, and personal injury.

128. D — Welding to a ROPS structure invalidates its certification. The welding heat changes the metallurgical properties of the ROPS tube material in the heat-affected zone (HAZ), potentially creating a weak point that could fail during a rollover event. Any modification to a ROPS — including welding attachments, drilling holes, or adding brackets — must be approved by the OEM or a qualified structural engineer.

129. A — The mounting bolts will be exposed to the abrasive material flow once the protective side cutter material is worn away. The material will grind off the bolt heads, releasing the side cutter and potentially introducing hardened bolt fragments into the material stream. The worn side cutter must be replaced before the bolts are damaged to prevent uncontrolled side cutter loss.

130. C — The gas strut is designed to hold the door open in a controlled manner. A wood prop is not a positive restraint — it can break, slip, or dislodge during machine operation or while the operator is entering/exiting. An open door also reduces the cab's positive pressurization, allowing dust, exhaust, and environmental contaminants to enter the operator's breathing zone during operation in dusty or hazardous environments.

131. B — Grade 5 and Grade 8 bolts have significantly different mechanical properties. Grade 8 bolts have approximately 50% higher tensile strength and 40% higher proof strength than Grade 5. Applying the Grade 8 torque specification to a Grade 5 bolt will stretch or fracture it. Using a reduced torque produces insufficient clamping force for the application. The correct Grade 8 bolts must be obtained.

132. B — At 70% regenerative efficiency, the system stores 70% of the captured kinetic energy and loses 30% as heat during the conversion process. Stored energy = 50 kJ × 0.70 = 35 kJ. The remaining 15 kJ is dissipated as heat in the motor-generator windings, power electronics switching losses, and internal resistance of the energy storage device.

133. A — Cell balancing equalizes the voltage across all cells in a series string during charging. Manufacturing variations cause individual cells to charge at slightly different rates. Without balancing, the strongest cell reaches full voltage first (risking overcharge) while the weakest cell remains partially charged (wasting capacity). Balancing ensures all cells reach their optimal charge level simultaneously, maximizing usable pack capacity and extending service life.

134. D — At 650 VDC, the electrical current passing through the body far exceeds the ventricular fibrillation threshold (approximately 100 mA). Cardiac arrest from ventricular fibrillation — the disruption of the heart's electrical rhythm that stops effective blood circulation — is the primary life-threatening injury mechanism. Even brief contact at this voltage can deliver lethal current through the body's relatively low resistance path.

135. C — The single largest operating cost advantage is reduced energy cost. Electricity is significantly cheaper per kWh of delivered work output than diesel fuel. Combined with the electric drivetrain's dramatically higher efficiency (85–95% from battery to wheel vs. 25–40% from fuel tank to wheel for diesel), the battery-electric machine consumes far less total energy per unit of work — producing the largest single cost saving over the 10-year service life.