PRACTICE EXAM 9: RED SEAL 421A SIMULATION (135 QUESTIONS)

1. A technician is assigned to perform a repair inside the engine compartment of a large mining excavator. The engine has been shut down and locked out. The technician climbs into the engine compartment and realizes the exhaust manifold and turbocharger surfaces are still radiating extreme heat. What category of hazard does this represent and what control is required?

A. Thermal contact hazard — the technician must either wait for the components to cool to a safe contact temperature or install temporary insulating barriers over the hot surfaces before positioning themselves to work in the compartment

B. Confined space atmospheric hazard — the residual heat is vaporizing oil and coolant residue on the hot surfaces, and the vapours may exceed the occupational exposure limit inside the enclosed compartment

C. Fire hazard — the hot surfaces exceed the flashpoint of the hydraulic oil present in the compartment and the technician must have a fire extinguisher staged at the entry point

D. Radiation hazard — the infrared radiation from the hot exhaust components requires the technician to wear heatreflective PPE rated for radiant heat environments

2. A heavy equipment shop is conducting a monthly emergency drill. The drill scenario involves a hydraulic oil fire in the maintenance bay. The shop is equipped with ABC dry chemical extinguishers, a foam suppression system, and an automated overhead sprinkler system. During the drill, the supervisor asks the technician: what is the correct sequence of actions when a fire is discovered?

A. Activate the overhead sprinkler system immediately, then evacuate all personnel, then call emergency services once the building is cleared

B. Attempt to fight the fire with the nearest extinguisher, continue until the extinguisher is empty regardless of whether the fire is growing, then evacuate

C. Alert other personnel, activate the fire alarm, attempt to fight the fire only if it is small and you have a clear escape path, and evacuate immediately if the fire grows beyond your ability to control it with available equipment

D. Call emergency services first, then attempt to contain the fire with available extinguishers while waiting for the fire department to arrive at the facility

3. A technician is moving a heavy hydraulic cylinder across the shop floor using an overhead crane. While the load is suspended, the technician's radio sounds and the technician steps away from the load to answer the call, leaving the cylinder suspended with no one attending the load. What safety violation has occurred?

A. The technician should have placed the radio on silent mode before beginning the crane operation to prevent distractions during the lifting task

B. The technician should have lowered the load to a temporary resting position on the floor before stepping away to take the radio call

C. No violation occurred — the load is on a crane and the crane's brake holds the load securely without requiring continuous operator attendance

D. A suspended load must never be left unattended — the technician must remain in control of the crane and maintain visual contact with the load at all times. If the technician must leave, the load must be lowered to a safe resting position first

4. A technician is performing a brake job on a machine and needs to dispose of the used brake fluid. The brake fluid container is labeled DOT 4. Under Canadian waste management regulations, how should used brake fluid be handled?

A. Used brake fluid is classified as a hazardous waste and must be collected in an approved container, stored in the designated hazardous waste area, and disposed of through a licensed hazardous waste contractor — it must not be poured down drains, mixed with other waste fluids, or placed in regular waste bins

B. Used brake fluid can be mixed with used engine oil for recycling because both are petroleumbased products that are processed together at the recycling facility

C. Used brake fluid can be poured down the shop floor drain if the drain connects to a municipal wastewater treatment system that is rated for glycolbased liquid processing

D. Used brake fluid requires no special handling — DOT 4 fluid is a nonhazardous watersoluble product that can be flushed with water into the standard shop drainage system

5. A technician is using a portable hydraulic press to remove a pin from a boom assembly in the field. The press is rated at 20 tonnes. The pin requires approximately 15 tonnes of force to press out based on previous experience. During the pressing operation, the pin does not move at 15 tonnes. The technician continues to increase pressure to 19 tonnes. What is the risk of operating at 95% of the press's rated capacity?

A. No additional risk exists — hydraulic presses are designed with a 4:1 safety factor above their rated capacity and operating at 95% is well within the design margin

B. Operating near the press's rated capacity increases the risk of catastrophic failure if the pin suddenly releases — the stored energy in the compressed hydraulic fluid can launch the pin as a projectile, and any weakness in the press frame, cylinder, or hoses is most likely to fail at nearmaximum pressure

C. The press will automatically relieve pressure at 100% of its rated capacity through a builtin safety relief valve that protects the press and the operator

D. The risk is limited to damage to the press — the hydraulic cylinder seals will extrude at 95% capacity, causing the press to lose force gradually rather than failing suddenly

6. A technician discovers that a coworker has been using a cheater pipe (extension bar) on a torque wrench to increase the leverage beyond the wrench's designed handle length. The coworker states the fastener requires more torque than the wrench can produce at its rated capacity. What are the consequences of using a cheater pipe on a torque wrench?

A. The cheater pipe increases the effective torque but also increases the wrench's accuracy by providing a longer lever arm that produces more consistent force application

B. The cheater pipe is an acceptable tool modification provided the total applied torque is calculated by multiplying the wrench reading by the ratio of the total lever arm length to the original handle length

C. The cheater pipe produces an incorrect torque reading on the wrench because the wrench was calibrated for its designed handle length — the actual torque applied to the fastener is higher than the wrench indicates, risking fastener damage, and the additional lever force can damage the wrench's internal mechanism

D. The cheater pipe only affects clicktype torque wrenches — beamtype and digital wrenches automatically compensate for changes in handle length through their flexible measuring element

7. A technician is preparing to enter a large fuel tank for internal inspection. The tank has been drained, cleaned, and gastested. The atmospheric testing shows: oxygen 20.9%, LEL 0%, hydrogen sulfide 0 ppm. The technician enters the tank wearing a suppliedair respirator and begins the inspection. After 20 minutes inside the tank, the continuous atmospheric monitor alarms for low oxygen (18.5%). What has likely occurred?

A. The suppliedair respirator is consuming oxygen from the tank atmosphere through a leak in the face seal that draws tank air into the breathing zone

B. The fuel tank's internal coating is reacting with the atmospheric oxygen inside the closed tank, slowly consuming the available oxygen through a chemical oxidation process

C. The atmospheric monitor has drifted out of calibration from the high humidity inside the tank and is producing a false lowoxygen reading

D. A displacement event is occurring — an oxygendepleting source (such as the tank's internal coating offgassing an inert gas, biological activity in residual moisture, or an adjacent connected space releasing inert gas) is displacing the oxygen inside the tank

8. A technician is servicing a machine in an underground mine. The mine's ventilation system maintains fresh air circulation throughout the working areas. The technician needs to perform a welding repair on the machine. What additional safety requirement applies to welding operations in underground mining environments compared to surface shop welding?

A. Underground welding requires specific authorization from the mine supervisor, a hot work permit, continuous atmospheric monitoring for toxic gases and oxygen levels at the work location, and may require additional ventilation to remove welding fumes from the enclosed underground space

B. Underground welding is identical to surface welding — the mine's ventilation system provides adequate air exchange to handle welding fumes without any additional precautions

C. Underground welding is prohibited in all Canadian mining jurisdictions regardless of ventilation conditions due to the explosive atmosphere risk in all underground environments

D. Underground welding requires only a fire extinguisher within 3 metres of the work area — all other hot work precautions that apply on surface are waived underground because the rock environment is noncombustible

9. A technician receives a verbal instruction from a supervisor to adjust a machine's engine speed governor to exceed the OEM maximum RPM specification. The supervisor states it is needed for increased productivity. What is the technician's professional responsibility?

A. Comply with the supervisor's instruction and document the change on the work order — the supervisor is responsible for all work instructions issued to technicians

B. Comply with the instruction but notify the joint health and safety committee of the modification at the next scheduled meeting for review

C. Decline to perform the modification — exceeding OEM specifications creates safety hazards including potential engine mechanical failure, violates the OEM's design parameters, may void warranty, and the technician has a professional obligation to not perform work that compromises machine safety

D. Perform the modification in increments of 50 RPM above specification, testing at each step to verify no adverse symptoms develop before proceeding to the next increment

10. A technician is preparing to test a highvoltage circuit on a hybrid machine. The technician reaches for a standard CAT III 600V rated DMM from the tool box. The hybrid system operates at 650 VDC. Is this meter appropriate for the measurement?

A. Yes — the CAT III 600V rating provides adequate protection because the machine's 650V system operates at DC, and the meter's AC rating does not apply to DC measurements

B. No — the meter's CAT III 600V rating is below the circuit's 650 VDC operating voltage. A meter rated at CAT III 1000V or CAT IV 600V (or higher) is required to provide adequate protection against the higher voltage and the potential transient energy present in HV systems

C. Yes — the 50V difference between the meter rating and the circuit voltage is within the standard 10% safety tolerance for DMM ratings

D. No — but the meter can be used safely if the technician wears Class 00 insulating gloves during the measurement, which extends the meter's effective voltage rating

11. A diesel engine equipped with an electronic fuel injection system produces a surging idle — the RPM oscillates rhythmically between 600 and 800 RPM with a 2second cycle time. No fault codes are stored. The throttle position sensor reads a steady idle value throughout the surging. What system should be investigated as the most likely cause?

A. The fuel supply pressure — fluctuating transfer pump output causes the highpressure pump to deliver inconsistent fuel volumes to the rail, producing the rhythmic RPM oscillation

B. The alternator — a failing voltage regulator produces cyclical voltage variations that affect the ECM's power supply and cause erratic fuel delivery commands

C. The intake manifold pressure sensor — a sticking or intermittent sensor causes the ECM to alternate between two fuel delivery calculations as the signal bounces between two values

D. The ECM's idle speed governor — the proportionalintegralderivative (PID) control loop that manages idle fuel delivery is oscillating, likely from incorrect feedback gain, a failing speed sensor, or an unstable signal from the crankshaft or camshaft position sensor

12. A technician discovers that a diesel engine's crankshaft end play (thrust clearance) measures 0.65 mm. The OEM specification maximum is 0.30 mm. What component failure causes excessive crankshaft end play, and what is the consequence?

A. The crankshaft thrust bearings (flanged main bearings) have worn — excessive end play allows the crankshaft to shift axially during clutch engagement, which can damage the rear main seal, cause the torque converter to lose its pilot engagement, and produce an audible clunking during clutch operation

B. The connecting rod bearings have worn excessively, allowing the crankshaft to move laterally in the main bore and producing the apparent end play measurement

C. The flywheel mounting bolts have stretched, allowing the flywheel to move axially on the crankshaft flange and producing the excessive end play reading

D. The crankshaft itself has stretched from overheating, increasing the distance between the thrust bearing surfaces beyond the specification

13. A diesel engine's turbocharger oil drain line is routed downward from the turbocharger bearing housing to the engine block. If this drain line becomes restricted (from carbon coke buildup or a kinked hose), what failure will develop in the turbocharger?

A. The turbocharger overspeeds because the restricted drain creates a backpressure on the turbine side that accelerates the turbine wheel beyond its design RPM

B. The engine oil pressure drops because the restricted drain forces oil to accumulate in the turbocharger housing, reducing the total oil volume circulating in the engine

C. Oil accumulates in the bearing housing because it cannot drain back to the sump — the rising oil level contacts the shaft seals from the inside, overwhelms them, and forces oil into both the compressor (intake) and turbine (exhaust) housings, producing blue smoke and oil consumption

D. The turbocharger bearing overheats because the restricted drain prevents fresh cool oil from entering the bearing housing to replace the hot oil that has been heated by the turbine shaft

14. A technician is measuring the resistance of a diesel engine's intake air heater (grid heater) element. The element should read 0.1 ohms. The DMM reads OL (open circuit). What does this confirm and what symptom will the operator experience?

A. The DMM's test leads are adding resistance that overwhelms the 0.1ohm element resistance, producing a false OL reading. The technician must use a dedicated milliohm meter for accurate lowresistance measurements

B. The heater element winding is broken (open circuit) — no current can flow through the element when the ECM commands it. The operator will experience hard starting or nostart conditions in cold weather because the intake air is not being preheated before entering the cylinders

C. The heater relay has welded contacts that are holding the element energized continuously, and the sustained current has overheated and opened the element during normal operation

D. The OL reading confirms the element is functioning correctly — grid heater elements have extremely high resistance when cold and decrease to 0.1 ohms only at operating temperature

15. A diesel engine's oil cooler uses engine coolant to cool the engine oil. The technician discovers engine oil in the coolant overflow tank — a thin oil film floats on the coolant surface. The oil level on the dipstick has not changed noticeably. What has failed?

A. The cylinder head gasket has breached between an oil gallery and a coolant passage, allowing pressurized oil to enter the cooling circuit under engine oil pressure

B. The valve cover gasket has failed at a point where it contacts the cylinder head's coolant passage, allowing oil to weep into the coolant jacket through external drainage

C. The turbocharger oil drain line has been routed too close to a coolant hose and the heat has permeated the hose wall, allowing oil vapour to migrate through the hose material into the coolant

D. The oil cooler has an internal leak — engine oil, which operates at higher pressure than the coolant, is being forced through the failed tube or gasket into the lowerpressure coolant circuit

16. A technician is troubleshooting a Tier 4 Final diesel engine that has entered a Level 2 power derate. The diagnostic software shows the derate is triggered by "aftertreatment SCR operator inducement — DEF quality." The technician tests the DEF and confirms it is the correct 32.5% urea concentration. The DEF tank temperature is 25°C. What other DEFrelated condition can trigger this derate despite correct concentration?

A. The DEF tank level is below the minimum threshold — some systems trigger a qualityrelated derate when the level drops below a programmed minimum, even if the remaining DEF is the correct concentration

B. The DEF has been contaminated with a nonurea substance that does not change the refractometer concentration reading but prevents the SCR catalyst from converting NOx at the required efficiency

C. The DEF has been contaminated with a foreign substance — such as fuel, coolant, or water — that dilutes the urea but also introduces chemicals that the DEF quality sensor detects as noncompliant, even though a refractometer measures the urea content near specification

D. The DEF has exceeded its shelf life and the urea has degraded to ammonia and CO_2, which the quality sensor detects as an expired product that can no longer produce the required ammonia for NOx conversion

17. A diesel engine has experienced a catastrophic connecting rod failure — the rod broke and punched a hole through the block wall. The postfailure analysis shows the fracture originated at the rod bolt hole on the cap side. The fracture surface shows a smooth, curved progression zone consistent with fatigue failure. What is the most probable root cause?

A. The engine was operated beyond its rated RPM for an extended period, subjecting the connecting rod to inertia forces that exceeded the material's fatigue endurance limit

B. The connecting rod bolt was not torqued to the correct specification during the last engine rebuild — undertorque allowed the rod cap to flex cyclically under combustion load, initiating a fatigue crack at the bolt hole stress concentration that propagated to failure

C. The piston in that cylinder seized momentarily from overheating, and the sudden stop subjected the connecting rod to a singleevent overload that exceeded its ultimate tensile strength

D. The connecting rod was manufactured from a defective material batch with microscopic inclusions at the bolt hole that acted as fatigue initiation sites from the first hour of operation

18. A technician performs a cooling system pressure test on a diesel engine. The system holds the rated cap pressure (103 kPa) for 15 minutes with no pressure drop. However, the operator reports the engine overheats intermittently during loaded operation. The thermostat, coolant level, fan, and radiator have all been verified correct. What intermittent condition can cause overheating that a static pressure test cannot detect?

A. A head gasket leak that only opens under the higher combustion pressures of loaded operation — the static pressure test at 103 kPa is far below the combustion pressures (3,000–5,000 kPa) that force the gasket to separate during loaded running, allowing combustion gas to enter the cooling system and displace coolant

B. The water pump impeller has a loose fit on the shaft — at idle and low RPM (during the pressure test), the impeller is held by friction, but at rated RPM under load, centrifugal force causes the impeller to slip on the shaft, reducing coolant flow

C. The radiator hose collapses under the vacuum created by the water pump at high RPM and full flow — the static pressure test pressurizes the hose from the outside, which actually holds it open rather than revealing the collapse condition

D. The fan belt tension is adequate for the static test but insufficient to prevent slipping during the highload conditions where the fan and water pump demand maximum torque simultaneously

19. A technician replaces all six fuel injectors on a common rail diesel engine. After installing the new injectors and programming the IQA trim codes, the engine starts and runs. However, the technician notices the exhaust smoke is slightly darker than expected during the first few minutes of operation. The smoke clears after approximately 5 minutes and does not return. What is the most probable explanation?

A. The replacement injectors have a slightly different nozzle spray angle than the originals, producing a permanently different combustion pattern that the ECM cannot fully compensate for through trim code adjustments

B. One or more injector trim codes were entered incorrectly and the ECM is overfuelling the affected cylinders until the adaptive learning system corrects the error over the first few minutes

C. The initial dark smoke is normal — air trapped in the fuel rail and highpressure lines during the injector installation produces a lean condition for the first few combustion cycles until the air purges, followed by a brief rich period as the ECM's adaptive system recalibrates to the new injectors

D. The replacement injectors were shipped with a preservative oil coating inside the nozzle bores that burns off during the first few minutes of operation, producing the temporary visible smoke

20. A diesel engine's DPF regeneration system uses latepost injection — a small fuel injection event after the main combustion event on the exhaust stroke — to increase exhaust temperature for active DPF regeneration. If the latepost injection strategy malfunctions and injects too much fuel, what engine damage can result?

A. The excess latepost fuel washes the cylinder wall oil film, allowing combustion gas to blow by the rings and contaminate the engine oil with soot

B. The excess fuel overloads the DOC catalyst, causing it to melt from the exothermic reaction heat that exceeds its thermal design limit

C. The excess fuel causes the DPF to regenerate too aggressively, melting the ceramic substrate from the uncontrolled exothermic soot combustion at temperatures exceeding 1,000°C

D. The excess latepost fuel passes the piston rings and enters the crankcase, diluting the engine oil with diesel fuel — the progressive fuel dilution reduces oil viscosity and loadcarrying capacity, eventually causing bearing failure if the condition persists

21. A diesel engine equipped with an electronic fan drive produces excessive fan noise during cold operation. The fan runs at maximum speed from the moment the engine starts, regardless of coolant temperature. The ECM reports no fault codes related to the fan control circuit. The technician measures the ECM's commanded fan speed signal and confirms it is at 100% duty cycle. What is the most likely cause?

A. The ECM software has been updated with a calibration that includes a coldstart maximum fan speed strategy that was not present in the previous software version

B. The fan speed command sensor input — coolant temperature, intake air temperature, or A/C pressure — has failed in a state that causes the ECM to command maximum fan speed as a protective default response, even though no fault code is generated because the sensor value is within its valid electrical range

C. The fan drive clutch has seized internally and the fan is mechanically locked at maximum speed regardless of the ECM's electrical command — the ECM is commanding low speed but the clutch cannot respond

D. The alternator's voltage output is elevated from a failing regulator, and the excess voltage is causing the fan drive solenoid to receive more current than commanded, driving the fan to maximum speed

22. A technician is diagnosing a diesel engine that runs normally at rated speed and load but produces a loud metallic knocking noise at idle that disappears when the engine speed is raised above 1,200 RPM. A cylinder cutout test does not change the noise. What is the most likely cause?

A. Piston pin (wrist pin) clearance is excessive — the loose pin produces a doubleknock at idle because the piston reverses direction twice per revolution. At higher RPM, the increased combustion force and inertia hold the pin against one side of the bore, eliminating the knock

B. The crankshaft main bearings have excessive clearance that produces an impact noise at the low oil pressure present during idle — at higher RPM, increased oil pressure fills the bearing clearance and dampens the impact

C. The timing gear train has excessive backlash that produces noise at idle when the gears unload during each firing pulse, but the noise is masked at higher RPM by the increased frequency of the gear mesh

D. The oil pump pressure relief valve is chattering at idle because the spring tension matches the idle oil pressure — at higher RPM, increased pressure holds the valve firmly closed

23. A large mining engine is equipped with a crankcase explosion relief valve — a springloaded flap on the side of the crankcase. What hazard does this valve protect against?

A. The valve releases excess engine oil pressure that develops when the oil pump's relief valve fails and the oil pressure exceeds the crankcase casting's rated strength

B. The valve releases excess blowby gas pressure that develops when the crankcase ventilation system becomes clogged and internal pressure exceeds the gasket sealing capability

C. The valve releases compressed air that enters the crankcase through a catastrophic piston failure, preventing the overpressure from rupturing the oil pan or crankcase gaskets

D. The valve relieves the pressure wave from a crankcase explosion — an ignition of the flammable mixture of oil mist and blowby gases inside the crankcase, which can occur from a hot spot such as a failing bearing or a broken piston. The valve opens to vent the pressure and prevent catastrophic crankcase rupture

24. A technician measures the fuel rail pressure on a common rail diesel engine at cranking speed. The measured pressure is 180 bar. The OEM specification for cranking rail pressure is 250–300 bar. What is the most likely cause of the low cranking rail pressure?

A. The fuel rail pressure sensor is reading 70 bar lower than actual — the rail pressure is correct but the sensor's offset error produces the low reading

B. The engine cranking speed is too slow from a weak battery, which reduces the highpressure pump's rotational speed below the minimum needed to generate rated cranking pressure

C. The highpressure pump's inlet metering valve is stuck partially closed, limiting the fuel volume entering the pump during each pumping stroke and reducing the achievable rail pressure

D. The fuel rail has a small external leak at one of the highpressure line connections that is sufficient to prevent the rail from reaching rated pressure at the low flow rate produced during cranking, but seals under the higher flow of normal running

25. A diesel engine equipped with a VGT turbocharger and EGR system produces a fault code for "boost pressure below commanded value." The turbocharger and VGT actuator are confirmed functioning correctly. What other system interaction could cause the boost pressure to read below the ECM's commanded value?

A. The engine coolant temperature sensor is reading higher than actual, causing the ECM to reduce the commanded boost target to protect the engine from perceived overheating — the lower command reduces the actual boost below the normal expected value

B. The EGR valve is stuck fully open — the excessive exhaust recirculation reduces the net exhaust energy available to drive the turbocharger turbine, limiting the turbocharger's ability to produce the commanded boost pressure despite a functional VGT

C. The intake air temperature sensor is reading colder than actual, causing the ECM to increase the commanded boost target beyond what the turbocharger can physically deliver at the current operating condition

D. The barometric pressure sensor has failed and is reading a higher altitude than actual, causing the ECM to reduce the commanded boost target for the perceived thin air conditions

26. A technician is testing an engine's crankcase ventilation system by measuring blowby flow rate using a calibrated flow meter connected to the crankcase breather outlet. The measured flow is 120 L/min. The OEM specification maximum is 80 L/min at rated RPM. All compression and leakdown tests show cylinders within specification. What could produce the elevated blowby despite normal compression readings?

A. Worn valve guide seals — while valve guide seals primarily prevent oil from entering the combustion chamber, severely worn guides also allow a small amount of combustion gas to leak past the valve stem during the compression and power strokes, contributing to blowby that compression testing does not detect

B. A failed turbocharger compressor seal that is allowing pressurized intake air to leak into the crankcase through the turbocharger oil drain line, which connects to the crankcase

C. The crankcase ventilation system's measuring port is located too close to the engine's firing order's dominant cylinder, producing an artificially high reading from the pulsating blowby discharge

D. The oil breather separator element is clogged and the restriction is producing a backpressure at the flow meter that the meter interprets as higher flow than the actual blowby volume

27. A diesel engine has been running for 500 hours since a major overhaul. The oil analysis shows a steadily increasing copper content — rising from 5 ppm at the first sample to 35 ppm at the 500hour sample. All other wear metals are normal. What is the most likely source?

A. The piston cooling jets were replaced during the overhaul and the new jets are a copper alloy that is dissolving in the oil from the chemical interaction with the oil's additive package

B. The replacement oil cooler installed during the overhaul has copperalloy internal tubes that are eroding from coolantside velocity or electrolysis in the cooling circuit, and the copper particles are entering the oil through a microleak in the cooler

C. The replacement camshaft bearings installed during the overhaul are a copperalloy material and are wearing at a rate that is normal for new bearings during the breakin period

D. The replacement connecting rod bearings installed during the overhaul have a copperlead intermediate layer that is exposed prematurely — the overlays may not have been correctly applied during remanufacturing, or the bearing clearances are incorrect, allowing the overlay to wear through early and expose the copper layer

28. A diesel engine's exhaust manifold temperature on one cylinder reads 100°C higher than the average of the remaining cylinders during loaded operation. The injector on that cylinder has been tested and delivers the correct fuel quantity. Valve lash is within specification. What other cause should be investigated?

A. The exhaust valve on that cylinder may have a receded seat — the valve sits deeper in the head, reducing the valve opening area and restricting the exhaust flow, which causes the residual exhaust gas to remain in the cylinder longer and the next combustion event to produce higher exhaust temperature from the retained heat

B. The cylinder's intake port has a restriction from a gasket tab or carbon buildup that reduces the incoming air charge — the reduced air volume produces a richer fueltoair ratio and higher combustion temperature for that cylinder

C. The piston cooling jet for that cylinder has become partially clogged, reducing the piston crown cooling and allowing higher combustion temperatures that transfer to the exhaust gas

D. The thermocouple or infrared sensor used to measure that runner has drifted out of calibration from heat exposure and is reading 100°C higher than the actual temperature

29. A technician discovers that a diesel engine's fuel tank has been filled with gasoline instead of diesel. The engine was started and run for approximately 30 seconds before the error was discovered. What immediate damage concern exists and what action is required?

A. No damage has occurred in 30 seconds — drain the fuel tank and lines, replace the fuel filters, and refill with diesel. The engine can be returned to service after the fuel system is purged

B. The engine can be run briefly on gasoline without damage — drain the tank, refill with diesel, and bleed the system normally

C. The gasoline's lower lubricity compared to diesel has begun to damage the fuel injection system's precision internal components during the 30second run — the fuel system must be completely drained and flushed, all fuel filters replaced, and the highpressure pump and injectors inspected for scoring or seizure damage before the engine is restarted

D. The gasoline has ignited at higher cylinder temperatures than diesel, causing potential piston and valve damage from detonation — a complete engine inspection including compression testing and borescope examination of all cylinders is required

30. A diesel engine's electronic unit injector system uses the camshaft to mechanically actuate each injector. The ECM controls the timing and duration of fuel injection by energizing and deenergizing a solenoid on each injector. If the solenoid fails to deenergize at the end of the commanded injection period, what happens?

A. The injector remains open and continues to inject fuel for the remainder of the camshaft actuation period — the cylinder receives significantly more fuel than commanded, producing a sharp power imbalance, excessive smoke, and potentially destructive cylinder pressures from the overfuelling event

B. The injector closes mechanically through the return spring regardless of the solenoid state — the solenoid only controls the injection start point, not the end point

C. The ECM detects the failed solenoid within one engine revolution and disables fuel delivery to that cylinder by commanding all other injectors to compensate for the lost cylinder

D. The injector delivers a normal fuel quantity because the solenoid controls only the injection timing, not the fuel volume — the camshaft lobe determines the total fuel delivery regardless of solenoid state

31. A technician is diagnosing a wheel loader that exhibits "steering wander" — the machine drifts randomly left and right during straightline travel, requiring constant steering corrections from the operator. The HMU, steering valve, and cylinders all test within specification. What mechanical cause should be investigated?

A. The front axle oscillation pivot has seized, preventing the axle from following the ground contour and transmitting every bump impulse directly to the steering geometry

B. The engine idle speed is set too low, reducing the steering pump output below the minimum flow needed for stable straightline hydraulic centering

C. Worn steering linkage components — tie rod ends, drag links, or king pins — have developed excessive play that allows the steered wheels to shift randomly in response to road surface irregularities without the steering system being able to hold a precise course

D. The steering accumulator precharge is too high, creating an overactive steering response that amplifies small road surface inputs into visible directional changes

32. A large offhighway truck experiences a complete loss of steering during loaded travel. The operator uses the emergency steering system (accumulatorassisted) to bring the truck to a controlled stop. What is the most likely cause of the sudden steering loss?

A. The steering pump has seized from internal contamination, stopping all flow to the steering circuit instantaneously

B. The steering cylinder has suffered an external hose failure, and all steering oil has been dumped to the ground in seconds

C. The steering priority valve has failed, diverting all pump flow to the implement circuit and leaving zero flow for the steering system

D. The steering pump drive has failed — a broken drive coupling, a sheared pump shaft, or a failed drive gear has disconnected the pump from the engine, stopping all steering fluid supply instantly

33. A technician is evaluating the overall condition of a crawler dozer undercarriage that has operated for 5,000 hours. The measurement results show: track links 65% worn, pins and bushings 70% worn, bottom rollers 55% worn, top rollers 50% worn, front idler 60% worn, and sprocket 45% worn. What is the key observation from this wear analysis?

A. All components are wearing at approximately the same rate (within 25% of each other), which indicates the undercarriage has been operated with correct track tension and in material conditions appropriate for its design — the components will reach endoflife at approximately the same time, minimizing wasted component life

B. The sprocket is wearing significantly slower than the chain, which indicates the sprocket is the wrong material specification and is too hard for the chain — it will accelerate chain wear

C. The bottom rollers are wearing faster than the top rollers, which indicates the track tension is set too tight and is overloading the bottom rollertochain contact zone

D. The pins and bushings are wearing faster than all other components, which indicates a pinturn should be planned before the chain reaches endoflife to maximize the investment in the remaining undercarriage components

34. A machine's hydraulic brake circuit uses a brake accumulator with an automatic pressure monitoring system. The system generates a warning if the accumulator pressure drops below the minimum required for a specified number of brake applications after the engine is shut down. The warning has activated. What does this mean for the operator?

A. The machine can continue to operate normally because the warning is an advance notice that the accumulator will need service at the next scheduled maintenance interval

B. The machine must be parked immediately and not moved until the accumulator system is diagnosed — the warning indicates the stored energy available for braking after an engine failure is below the safe minimum, and the machine may not be able to stop if the engine stalls during operation

C. The machine can continue to operate but must stay within 50 metres of the parking area so it can return to park under its own power if the brakes fail completely

D. The warning applies only to the parking brake function and does not affect the service brakes — the machine can be operated normally with the service brakes

35. A grader operator reports that the machine's circle drive (blade rotation mechanism) produces a jerky, intermittent rotation when the blade is being rotated under load during grading. The rotation is smooth when the blade is unloaded. What is the most likely cause?

A. The circle drive motor has worn pistons that leak under the high pressure of loaded rotation but seal adequately at the lower pressure of unloaded rotation

B. The circle drive relief valve is set too close to the working pressure, and the valve opens intermittently as the load pressure fluctuates during grading

C. The circle drive worm gear mesh is worn — the worn teeth cannot maintain positive engagement under the sideloading forces of grading, and the gear alternately drives and slips as the load fluctuates across each tooth, producing the jerky rotation

D. The hydraulic supply hose to the circle drive motor has a weak spot that balloons under the high pressure of loaded operation, momentarily absorbing flow and producing the intermittent rotation

36. A heavy equipment machine's parking brake is springapplied and hydraulically released. The technician tests the parking brake and finds it holds the machine on a 15% grade when applied. However, when the technician releases the parking brake and then quickly reapplies it, the brake does not hold — the machine begins to roll slowly downhill. What is the cause of this different behaviour between the first application and the reapplication?

A. The brake oil has expanded from the heat of the first application and the expanded oil prevents the springs from fully clamping the discs on the reapplication

B. The brake release circuit has a slowtoexhaust condition — the hydraulic release pressure does not fully drain from the spring chamber quickly enough, and the residual pressure partially opposes the spring force during the rapid reapplication, reducing the clamping force

C. The parking brake discs have glazed from the heat of the first application and the reduced friction coefficient prevents the springs from generating adequate holding force on the second application

D. The parking brake hydraulic release circuit has a check valve or slowreturn orifice that retains hydraulic release pressure in the brake piston chamber after the release command is removed — the trapped oil partially resists the spring force, reducing the brake's clamping force on the quick reapplication

37. A technician is inspecting a dozer track and discovers that several consecutive track shoes are cracked across the grouser base. The cracks all originate at the bolt holes where the shoes attach to the track links. What is the most likely cause?

A. The track shoe bolts were overtorqued during the last track service, and the excessive clamping force created stress risers at the bolt holes that initiated fatigue cracks during operation

B. The track shoes have been operating on frozen ground with extremely hard rocklike surfaces, and the impact loading from the hard terrain has exceeded the shoe material's fatigue endurance limit at the stress concentration of the bolt holes

C. The track shoe bolt holes were drilled offcentre during manufacturing, creating an asymmetric stress distribution that concentrated loading on one side of each hole

D. The machine was operated at excessive track speed on hard pavement, and the vibratory impact at each shoetoground contact point during highspeed travel fatigued the shoe material at the bolt hole stress risers

38. A wheel loader's rear axle differential makes a humming noise during straightline travel that gets louder with speed. The noise does not change character during turns. What does this noise pattern indicate?

A. The ring and pinion gear mesh is producing the noise — the hum during straightline travel that does not change during turns (when the differential is active) indicates the noise source is in the gear mesh, not in the differential's spider gears which only rotate during turns

B. The differential carrier bearings are worn — the carrier rotates at ring gear speed during both straight travel and turns, and worn bearings produce a consistent hum at carrier speed regardless of differential action

C. The axle shaft bearings are worn on both sides equally — both bearings produce the same noise level, which does not change during turns because both shaft speeds vary equally during turns

D. The differential oil level is low and the gears are not fully submerged — the partially submerged gear mesh produces the humming noise as the gear teeth alternately enter and exit the oil surface

39. A machine's air brake system lowair warning activates at 380 kPa (55 PSI) as designed. However, the operator reports that the warning activates briefly during heavy brake applications even though the system is fully charged before the application. What does this indicate?

A. The air reservoirs are correctly sized and the momentary pressure drop during heavy application is a normal characteristic of the system's designed capacity

B. The compressor cannot maintain system pressure during heavy brake applications because its output is insufficient to replace the air consumed by the large brake chambers

C. The check valve between the supply reservoir and the service reservoir is leaking, allowing air to flow backward from the service reservoir to the supply reservoir during heavy applications

D. The air reservoir volume is insufficient for the brake demand — the heavy application consumes enough air to momentarily drop the reservoir pressure below the 380 kPa warning threshold before the compressor can replenish the supply

40. A technician is measuring the track sag on a dozer equipped with a greasetensioned undercarriage. The measured sag is 75 mm. The OEM specification for this application (normal soil conditions) is 25–50 mm. The technician adds grease to the tensioner to tighten the track. After tensioning, the sag measures 40 mm. Is this adjustment complete?

A. No — the technician must also verify the track does not contact the undercarriage guard or belly pan when the machine traverses uneven terrain, which the 40 mm sag may not prevent

B. No — the technician must investigate why the track was so loose before simply tensioning it. Excessive sag can indicate the tensioner grease has leaked, the recoil spring has broken, or the chain has stretched beyond the tensioner's adjustment range

C. Yes — the 40 mm sag is within the 25–50 mm specification and the track is correctly adjusted. The track should be rechecked after 50 operating hours as the new tension settles

D. No — the technician must also verify the track tension by measuring it with the machine on level ground and the track suspended off the ground, because ground contact affects the sag measurement

41. A rigidframe mining truck is equipped with oilcooled multidisc service brakes on the rear axle. The operator reports the service brakes produce a shudder during moderate application that is not present during light or heavy application. What is the most likely cause?

A. The brake master cylinder has a worn piston seal that leaks at moderate pressure levels but seals at both low and high pressure extremes

B. One or more brake discs have warped from heat, and the distorted disc produces an oscillating clamping force during application — the shudder is felt at moderate pressure where the pad force alternates between contact and separation on the warped disc surface

C. The brake proportioning valve is oscillating at moderate application pressure due to a worn internal spool that cannot maintain a stable position between the lowpressure and highpressure detent positions

D. The brake cooling oil circuit has air trapped in it that compresses and releases during moderate application, producing the pulsating sensation that is masked by the high flow rate of heavy application and the low flow of light application

42. A crawler excavator operating on a steep slope develops a track derailment on the downhill side. The track rolls off the front idler and bunches up against the side of the machine. What is the most likely cause?

A. The steep slope creates a gravitational side load on the track chain that exceeds the lateral guidance capability of the idler flanges and roller flanges — the chain walks sideways off the running gear under the sustained side force

B. The drive sprocket on the downhill side has worn teeth that cannot maintain engagement with the chain under the high tension created by the slope

C. The track tension was set too tight for slope operation, and the excess tension prevented the chain from articulating around the idler during the machine's movement on the slope

D. The operator was counterrotating the tracks while on the slope, and the opposing forces between the two tracks created a lateral force that pushed the downhill chain off the running gear

43. A machine's front axle oscillation pivot uses a large steel pin with bronze bushings pressed into the frame lugs. During inspection, the technician discovers the pin is corroded and pitted where it contacts the bushings. What operational environment typically causes this type of corrosion on a pivot pin?

A. Operating in sandy desert conditions where abrasive sand particles embed in the bushing surface and scratch the pin, creating initiation points for atmospheric corrosion

B. Operating in hot, humid tropical conditions where moisture condenses on the pin surface during overnight cooling and the cyclic wetdry conditions promote surface corrosion

C. Operating in a marine or coastal saltspray environment, or in conditions where the machine is exposed to deicing salt, corrosive mine water, or chemical processing runoff that attacks the steel pin surface

D. Operating at high altitude where ultraviolet radiation degrades the pin's surface treatment and allows atmospheric oxygen to attack the base steel material

44. A machine equipped with SAHR (Spring Applied Hydraulically Released) wet disc brakes has its brake pack clearance measured at 4.2 mm. The OEM specification maximum is 3.5 mm. What must be done?

A. Add additional friction discs to the brake pack to reduce the clearance to within specification — the increased disc count compensates for the wear on the existing discs

B. Increase the hydraulic release pressure by 10% to compensate for the additional piston travel required to release the springs across the wider clearance

C. Replace the brake disc pack — the excessive clearance means the springs must travel further before clamping the discs, reducing the available clamping force and therefore the brake's holding and stopping capability

D. The brake discs have worn beyond their serviceable limit — the excessive clearance means the piston must travel further than designed before the springs clamp the discs, reducing the effective spring force at the disc contact point and compromising brake performance. The disc pack must be replaced

45. A technician is replacing the front idler on a crawler dozer. The new idler has been installed and the track reconnected. Before adjusting the track tension, the technician rotates the idler by hand and discovers it does not spin freely — it has noticeable drag resistance. Is this normal for a new idler?

A. Yes — new idler bearings have a factoryset preload that produces noticeable drag when rotated by hand. The resistance decreases after the bearing seats during the first 100 operating hours. If the idler were to spin completely freely, the bearings would have zero preload and would wear prematurely

B. No — a new idler should spin freely with zero resistance. The drag indicates the bearings were damaged during shipping or the seal is binding on the shaft, and the idler should be returned for replacement

C. Yes — but only for sealed and lubricated idlers where the grease fill creates hydraulic resistance during cold rotation that disappears once the grease warms to operating temperature

D. No — the drag indicates the idler shaft bore is undersized and the shaft is an interference fit that will seize the bearing within the first 500 hours of operation

46. A machine's brake pedal has a mechanical stop that limits the maximum pedal travel. The operator reports that the pedal reaches the mechanical stop before the brakes achieve full application force. What does this pedalatfloor condition indicate?

A. The mechanical stop has been incorrectly adjusted and needs to be repositioned to allow more pedal travel before it contacts the stop surface

B. The brake system has a condition that is consuming more pedal travel than designed — possible causes include worn brake pads requiring more piston travel, air in the hydraulic circuit absorbing pedal displacement, or a master cylinder bypass that loses fluid volume internally. The condition must be diagnosed and corrected because the brakes cannot develop full clamping force

C. The brake master cylinder bore has worn and the piston must travel further to generate the same volume of fluid displacement as a new master cylinder

D. The brake proportioning valve has restricted the rear circuit flow, causing the front brakes to absorb all of the master cylinder's displacement before the rear brakes receive any fluid, using up the available pedal travel

47. A technician is troubleshooting a machine where the starter motor engages and cranks the engine, but after release of the key from the START position to RUN, the engine dies immediately. The engine shows no driveability symptoms during the brief cranking period. What circuit should be investigated?

A. The fuel supply circuit — if the fuel pump relay is energized only during the START position and does not transfer to the RUN circuit, the fuel supply dies when the key moves to RUN

B. The ignition (RUN) circuit — the ECM receives power through the RUN circuit, and if the RUN position of the keyswitch or its associated relay/fuse does not deliver power to the ECM, the ECM shuts down immediately when the key leaves the START position

C. The starter solenoid holdin winding — a failed holdin winding causes the starter to disengage when the key moves from START to RUN, and the engine stalls from the sudden loss of cranking momentum

D. The glow plug circuit — the glow plugs are energized during START but deenergize in RUN, and without preheat the engine cannot sustain combustion after the cranking period ends

48. A machine's 24V charging system has two batteries in series. The technician measures 14.2V across Battery A and only 11.8V across Battery B during charging. The total system voltage is 26.0V. What is the most likely cause of the voltage imbalance?

A. Battery B has a failing cell — the weak cell cannot accept a full charge, which limits the voltage across that battery during charging. The alternator maintains total system voltage at 26.0V by overcharging Battery A to compensate for Battery B's reduced acceptance

B. The series connection cable between the two batteries has a highresistance connection that drops 2.4V under charging current, producing the apparent voltage difference between the two batteries

C. The alternator's voltage regulator has drifted and is producing a total charging voltage of only 26.0V instead of the specified 28.0–28.5V, which causes the weaker battery to receive less voltage

D. Battery A is closer to the alternator output in the circuit and receives the full charging voltage first, with Battery B receiving only the remainder

49. A machine's ECM monitors its internal operating temperature through a builtin thermistor. If the ECM's internal temperature exceeds a programmed threshold, what action does the ECM typically take?

A. The ECM increases its internal fan speed to cool the processor — all heavy equipment ECMs contain internal cooling fans that activate at the temperature threshold

B. The ECM sends a warning message to the operator display but continues to operate at full capability because electronic components are rated for temperatures well above any operating environment

C. The ECM generates a voltage spike that resets the module, similar to a computer restart, which clears the thermal condition and allows the module to resume operation from a cool state

D. The ECM enters a protective derate strategy — it reduces its processing load by disabling nonessential functions and may reduce engine power to lower the heat generated by the enginemounted ECM until the temperature drops below the threshold

50. A technician is performing a voltage drop test on a starter circuit ground path. With the engine cranking, the DMM connected between the starter motor housing and the battery negative terminal reads 1.2 volts. The OEM specification maximum is 0.5V for the ground path. What does this indicate?

A. The starter motor has an internal ground fault that is consuming 1.2V between the motor housing and the chassis ground connection

B. The battery negative terminal is corroded and the high resistance at the terminal is consuming the 1.2V before the current reaches the ground cable

C. The ground path — including the battery negative cable, battery terminal connections, ground strap to the engine block, and the enginetoframe ground — has excessive resistance that consumes 1.2V of the available battery voltage during cranking, reducing the voltage available to power the starter motor

D. The 1.2V reading is within the acceptable range for a heavy equipment starting circuit that carries several hundred amperes of cranking current through long cable runs

51. A technician is diagnosing a CAN bus fault where the diagnostic tool communicates with the engine ECM but cannot communicate with the transmission ECM. The CAN bus termination reads 60 ohms (correct). Both ECMs are powered. What type of fault could allow partial bus communication?

A. A highresistance connection on the CAN bus wiring between the engine ECM and the transmission ECM — the engine ECM side of the fault has adequate signal quality for communication, but the resistance degrades the signal on the transmission ECM side to the point where it cannot be read by the diagnostic tool

B. A CAN bus wiring fault that exists only on the segment of the bus between the engine ECM and the transmission ECM — an open wire, a corroded splice, or a damaged connector isolates the transmission ECM from the diagnostic connector while the engine ECM remains connected

C. The transmission ECM has a different CAN bus baud rate than the engine ECM, and the diagnostic tool can only communicate at one speed at a time

D. The diagnostic tool has a firmware limitation that prevents it from communicating with more than one ECM simultaneously on the same bus

52. A machine equipped with a keyless start system and an immobilizer refuses to crank. The dashboard displays "SECURITY FAULT." The technician verifies the key fob battery is not dead. What should be checked next?

A. The immobilizer antenna (transponder reader) located near the key fob receptacle — if the antenna cannot read the key fob's signal, the immobilizer will not authorize the starter circuit, even though the fob's battery is adequate for transmission

B. The starter motor relay — a security fault message combined with a nocrank condition indicates the starter relay has failed and the immobilizer has misidentified the relay failure as a security event

C. The battery voltage — if the machine's main battery voltage is below 22V on a 24V system, the immobilizer module cannot process the key fob signal and defaults to a security lockout

D. The engine ECM software — a corrupted calibration file can prevent the ECM from accepting the immobilizer's authorization signal and blocks the starter circuit as a default protection

53. A machine's electronic display module communicates with the vehicle CAN bus through a dedicated display CAN port on the gateway module. The display shows "NO DATA" for all engine parameters. The diagnostic tool communicates normally with all modules through the standard diagnostic port. What is the most likely fault?

A. The display module's internal CAN transceiver has failed and cannot receive the bus data that the gateway is transmitting correctly

B. The gateway module's display CAN port has failed — the gateway is routing data correctly on the main bus (proven by the diagnostic tool's access) but is not forwarding data to the dedicated display port

C. The display module's firmware has crashed and cannot process the incoming CAN data despite receiving it correctly from the gateway

D. The CAN bus wiring between the gateway module's display port and the display module has a fault — an open wire, a damaged connector, or a broken pin prevents the data from reaching the display even though the main bus (used by the diagnostic tool) is functioning normally

54. A technician measures the PWM duty cycle at a proportional solenoid connector. The ECM is commanding 60% duty cycle through the diagnostic software. The DMM reads 60% at the solenoid connector. However, the solenoid does not respond proportionally — it remains fully open instead of holding a 60% flow position. What is the most probable cause?

A. The solenoid's return spring has broken — without the spring opposing the electromagnetic force, any PWM command above the minimum threshold drives the spool to full open because there is no mechanical force to hold it at the proportional midposition

B. The solenoid coil has an internal short that generates more magnetic force than the 60% duty cycle should produce, overpowering the return spring at any command above 30%

C. The PWM frequency is too high for the solenoid's mechanical response time — the spool cannot follow the individual switching cycles and defaults to the fullopen position under the average force

D. The solenoid valve bore is contaminated with varnish that increases the spool's friction, preventing it from responding proportionally — the spool either sticks closed or jumps to full open when the magnetic force overcomes the friction threshold

55. A machine's electronic throttle pedal produces a stable signal at idle and at full throttle, but during the midrange transition (40–70% pedal travel), the signal drops out momentarily — reading 0V for a fraction of a second before recovering. What is the most likely cause?

A. The ECM's analogtodigital converter is saturating at the midrange voltage and producing a momentary zero reading during the conversion overflow

B. The throttle pedal connector has a loose pin that momentarily opens under the vibration that is transmitted through the pedal linkage during the midrange travel zone

C. The throttle pedal's internal potentiometer has a worn section on the resistive track in the 40–70% travel zone — the wiper loses contact with the track momentarily as it crosses the worn area, producing the brief signal dropout

D. The ECM's internal reference voltage drops momentarily when the throttle signal enters the midrange zone because the midrange voltage creates a resonant condition in the reference voltage divider circuit

56. A machine's alternator produces correct voltage at the B+ terminal during engine operation. The technician measures the AC ripple at the battery terminals and reads 1.8V AC. The OEM specification maximum is 0.5V AC. What does the elevated AC ripple confirm?

A. The battery has a failing cell that is passing AC current through the electrolyte and generating the elevated ripple reading at the battery terminals

B. The engine is running at an RPM that creates a harmonic frequency with the alternator's threephase output, producing a constructive interference pattern that amplifies the ripple beyond normal levels

C. The alternator's drive belt is slipping intermittently, causing the alternator to produce inconsistent output that the DMM registers as AC ripple

D. One or more rectifier diodes in the alternator have failed — the failed diode allows its portion of the unrectified AC waveform to pass through to the DC output, producing the elevated AC ripple that can corrupt CAN bus signals and damage sensitive electronic modules

57. A machine's ECM has been replaced. The replacement ECM is programmed with the correct machine calibration, all parameters verified, and injector trim codes entered. The engine starts but the turbocharger wastegate/VGT does not respond to ECM commands. All other engine functions operate normally. What was likely missed during the ECM setup?

A. The VGT/wastegate actuator requires a calibration or initialization procedure through the OEM diagnostic software after an ECM replacement — without this procedure, the ECM does not know the actuator's physical position endpoints and cannot command it to move

B. The VGT/wastegate actuator has a separate controller module that requires its own programming which was not performed during the ECM setup

C. The replacement ECM does not have the VGT/wastegate software option enabled — the license key for this function must be purchased separately from the OEM

D. The replacement ECM's output driver for the VGT/wastegate is a different pin assignment than the original ECM — the wiring harness connector must be modified to match the replacement module's pinout

58. A machine's battery equalization charge has been performed, and the technician measures the specific gravity of all cells in both batteries. Battery A reads 1.270 on all six cells. Battery B reads 1.270 on five cells but cell 3 reads 1.210. What does this indicate about Battery B?

A. Cell 3 on Battery B has been overcharged during the equalization and the lower gravity indicates the electrolyte has been diluted by the excessive water decomposition during the overcharge event

B. Cell 3 on Battery B has a fault — it cannot reach the same charge level as the other cells despite the equalization charge. The cell likely has a sulfated plate, a short between plates, or material shedding that permanently reduces its capacity. Battery B should be replaced

C. The 0.060 specific gravity difference between cell 3 and the other cells is within the acceptable tolerance range for a battery that has just completed an equalization charge cycle

D. Cell 3 was not adequately equalized because the equalization procedure was terminated too early — extending the equalization charge for an additional 4 hours will bring cell 3 to the same level as the other cells

59. A machine's ECMcontrolled hydraulic fan drive circuit uses a proportional solenoid to vary fan speed. The technician measures the solenoid current at idle and at rated RPM:

At idle: ECM commands 20% duty cycle → measured current = 0.4A

At rated RPM: ECM commands 80% duty cycle → measured current = 0.4A

The current does not change despite the duty cycle change. What does this indicate?

A. The solenoid is functioning correctly — proportional solenoids draw constant current regardless of duty cycle because the coil resistance determines the current, not the duty cycle

B. The DMM is not capturing the PWM signal correctly — the meter is averaging the current and displaying the same value for both duty cycles because it cannot respond fast enough to the switching frequency

C. The solenoid coil circuit has a highresistance fault (corroded connector, damaged wire, or poor crimp) that limits the maximum current to 0.4A regardless of the commanded duty cycle — the resistance bottleneck prevents the current from increasing when the duty cycle increases

D. The ECM output driver has failed in a fixedoutput state — it produces the same current regardless of the internal command, even though the diagnostic software shows different duty cycle values

60. A machine's CAN bus wiring runs through the cab floor harness. The technician notices that intermittent communication errors occur when the operator turns the cab heater to maximum. No errors occur at lower heater settings. What is the most likely connection between the heater and the CAN bus errors?

A. The heater motor draws high current at maximum speed, and the current surge on the heater circuit wire (which runs parallel to the CAN bus in the cab harness) produces electromagnetic interference that corrupts the CAN bus differential signal

B. The heater motor's brushes produce radiofrequency noise at maximum speed that radiates through the cab structure and induces false signals on the CAN bus wiring

C. The heater motor at maximum speed produces a vibration frequency that resonates with the cab floor harness, physically shaking the CAN bus connectors and producing momentary contact losses

D. The heater circuit at maximum draws enough current to cause a voltage dip on the machine's 24V power bus, which momentarily drops the CAN bus module supply voltage below the minimum operating threshold, causing the communication errors

61. A machine's implement ECM controls a proportional directional control valve through a PWMdriven pilot solenoid. The technician commands the solenoid to 50% using the diagnostic software. The solenoid produces a buzzing noise. At 0% and 100% commands, the solenoid is silent. What causes the buzzing at 50%?

A. The solenoid spool is vibrating at the PWM switching frequency — at 50% duty cycle, the spool oscillates between two positions at the switching rate because the average force is balanced at midstroke. At 0% (fully closed) and 100% (fully open), the spool is firmly held at its mechanical stop and does not vibrate

B. The solenoid coil is resonating at 50% duty cycle because the switching frequency matches the coil's natural electrical resonance, producing an audible magnetic hum

C. The solenoid has a broken return spring that allows the spool to rattle at midstroke positions where the spring would normally provide stabilizing force

D. The pilot pressure supply has a pulsation that coincides with the 50% duty cycle, creating a hydraulic resonance that vibrates the spool and produces the audible buzz

62. A technician discovers that a machine's ECM has logged over 200 occurrences of a DTC for "battery voltage low" over the past 1,000 operating hours. The battery and charging system have been tested and are currently functioning correctly. The operator has not reported any driveability symptoms. What diagnostic value do these repeated logged events provide?

A. The 200 occurrences confirm the battery has been replaced multiple times and each new battery triggered the lowvoltage DTC during the first start cycle

B. The repeated events suggest there is an intermittent electrical fault — such as a loose battery connection, a corroded terminal, or a failing battery disconnect switch — that briefly drops the ECM supply voltage during specific operating conditions (vibration, high electrical load, or temperature extremes) and may eventually cause a permanent failure

C. The repeated DTCs are a software artifact caused by the ECM's selftest routine that runs at each key cycle — each test generates a lowvoltage event when the ECM samples voltage during the microsecond before the power stabilizes

D. The 200 occurrences over 1,000 hours are within the acceptable range for normal battery voltage fluctuations during starter engagement and do not require investigation

63. A machine's electronic throttle is equipped with an idle validation switch (IVS) that signals the ECM when the throttle pedal is in the fully released (idle) position. If the IVS fails in the open (notatidle) state while the throttle pedal is at idle, what symptom will the operator experience?

A. The engine revs to maximum governed speed because the ECM interprets the open IVS as a fullthrottle command from the operator

B. The engine will not reach maximum power under load because the ECM limits fuel delivery whenever the IVS disagrees with the APPS (accelerator pedal position sensor) reading

C. No symptom — the IVS is a redundant signal that the ECM uses only during selfdiagnostic routines and has no effect on normal engine operation

D. The ECM cannot confirm the throttle is at idle — it may prevent the engine from entering idle mode, cause elevated idle speed, disable autoidle features, or generate a fault code that triggers a derate, depending on the OEM's programmed response to an IVS disagreement

64. A technician is testing a pressure switch that should close at 350 kPa and open at 280 kPa (a 70 kPa hysteresis). The technician applies increasing pressure from a hand pump and the switch closes at 360 kPa. During decreasing pressure, the switch opens at 330 kPa. What is the measured hysteresis and is the switch within specification?

A. The hysteresis is 30 kPa (360 − 330), and the specification calls for 70 kPa — the reduced hysteresis means the switch will cycle more frequently than designed, potentially causing the controlled component to rapidcycle and wear prematurely

B. The hysteresis is 70 kPa (360 − 290 extrapolated), and the switch is within specification despite the slightly elevated closing pressure

C. The switch is within specification — the closing point of 360 kPa is within the ±10 kPa tolerance of the 350 kPa specification, and the 30 kPa hysteresis is acceptable for heavy equipment pressure switch applications

D. The closing pressure is 10 kPa above specification (360 vs. 350), the opening pressure is 50 kPa above specification (330 vs. 280), and the hysteresis is only 30 kPa instead of the designed 70 kPa — the switch is out of specification on all parameters and must be replaced

65. A machine has a datalink connector with three separate diagnostic ports: one for the engine J1939 bus, one for the implement bus, and one for the body/chassis bus. The technician connects the diagnostic tool to the engine port and reads all engine DTCs. The technician then needs to check the transmission for DTCs. The transmission ECM is on the implement bus. What must the technician do?

A. Move the diagnostic tool connection from the engine port to the implement bus port — the transmission ECM can only be accessed through the bus segment it is connected to

B. The diagnostic tool can access all modules on all bus segments through the engine port because the gateway module routes all data between the three bus segments

C. The technician must use a different diagnostic tool — each bus segment requires a busspecific tool that communicates at that segment's data rate and protocol

D. The technician must power down the machine and restart it before switching diagnostic ports — the diagnostic tool cannot connect to a different port while the machine is running

66. A machine equipped with a telematics system generates a remote fault alert for "engine derate — aftertreatment." The dealer service department receives the alert and contacts the machine owner. The machine is 300 km from the nearest dealer location. What advantage does the telematics system provide in this scenario?

A. The telematics system provides no advantage beyond the alert notification — the technician must still travel to the machine to diagnose and repair the fault

B. The telematics system allows the dealer to remotely read the specific DTCs, view freeze frame data, check current engine operating parameters, and determine whether the machine can safely travel to the dealer or requires field service — reducing unnecessary dispatch trips and ensuring the correct parts and tools are sent on the first trip

C. The telematics system allows the dealer to remotely clear the derate and restore full engine power until the machine can be brought to the shop for repair

D. The telematics system can remotely reprogram the ECM to bypass the aftertreatment derate, allowing the machine to continue operating at full power until a scheduled service can be arranged

67. A machine's ECM uses a 5V reference that is shared between a coolant temperature sensor, an oil pressure sensor, and a fuel pressure sensor. The technician reads the 5V reference at the ECM connector with all sensors disconnected and measures 5.02V. The technician then reconnects the coolant temperature sensor only and the reference drops to 4.1V. What does this confirm?

A. The coolant temperature sensor has failed and is drawing excessive current from the 5V reference — the sensor's internal fault creates a lowresistance path that pulls the shared reference voltage down, affecting all three sensor readings when all are connected

B. The coolant temperature sensor is a lowresistance type at the current operating temperature and the 0.92V drop is the normal loading effect of the sensor on the reference supply

C. The 5V reference regulator inside the ECM is failing and cannot maintain the reference voltage when even a single sensor load is applied

D. The reference wire between the ECM and the coolant temperature sensor has a highresistance connection that creates a voltage divider, dropping the reference from 5.02V to 4.1V before it reaches the sensor

68. A machine's CAN bus J1939 network has been experiencing intermittent communication faults that occur primarily during the afternoon on hot days. In the morning and evening, the bus operates normally. What thermalrelated fault mechanism is the most likely cause?

A. The CAN bus termination resistors change value with temperature, shifting from their designed 120 ohms to a higher or lower value that degrades bus impedance matching during peak heat

B. The hot afternoon ambient temperature heats the machine's cab and engine compartment, causing thermal expansion of a harness connector that creates an intermittent open or highresistance connection on one of the CAN bus wires — the connector cools in the evening and the contact is restored

C. A CAN bus connector or splice with a marginal contact — possibly a corroded pin, a cold solder joint, or a loose crimp — expands at elevated temperature, opening the contact enough to disrupt communication. As the temperature drops, the metal contracts and restores the connection

D. The ECM modules' internal processors slow down at elevated temperatures, reducing their CAN bus data processing speed and causing missed or delayed message transmissions

69. A technician is measuring the voltage output of a Halleffect wheel speed sensor used for an ABS system. The sensor produces a constantamplitude digital square wave signal. During testing at 30 km/h, the sensor output shows clean square waves. During testing at 60 km/h, the square wave edges become rounded and the amplitude drops from 5V to 3.2V. What is the most likely cause?

A. The sensor is exceeding its maximum frequency rating — at 60 km/h, the reluctor teeth pass the sensor at a rate above the sensor's designed switching speed, and the internal electronics cannot transition fast enough to produce clean square waves

B. The sensor air gap has increased from bearing play at the higher speed, reducing the magnetic field strength that the Hall element detects and causing the signal degradation

C. The ABS module is applying a signal dampening filter at higher speeds to reduce electrical noise, which rounds the square wave edges and reduces the apparent amplitude

D. The wiring between the sensor and the ABS module has excessive capacitance from being routed alongside other highcurrent wiring — the capacitance loads the highfrequency signal at 60 km/h more than the lower frequency at 30 km/h, rounding the edges and reducing the amplitude

70. A technician needs to test a fuel shutoff solenoid that is directly controlled by the keyswitch — there is no ECM in the circuit. The solenoid has two windings: a pullin winding that generates high force to open the solenoid (draws 30A briefly) and a holdin winding that maintains the solenoid open (draws 3A continuously). When the key is turned to RUN, the solenoid should pull in and hold. The technician turns the key to RUN and the solenoid pulls in with an audible click but immediately releases. What is the most likely cause?

A. The battery voltage has dropped below the minimum threshold for the holdin winding, which requires a higher minimum voltage than the pullin winding to maintain its magnetic field

B. The holdin winding has failed (open circuit) — the pullin winding generates enough force to open the solenoid, but when the solenoid reaches the fullopen position and the main contacts short out the pullin winding (as designed), only the failed holdin winding remains and it cannot sustain the magnetic field. The solenoid releases immediately

C. The solenoid return spring has weakened from age and cannot provide adequate force to hold the solenoid in the open position against the residual magnetic force of the deenergized coil

D. The keyswitch contact for the RUN position is bouncing (opening and closing rapidly) and the solenoid is following the intermittent power supply by pulling in and releasing repeatedly

71. A technician is diagnosing a machine where the engine starts normally but the electronic instrument cluster remains dark (no display, no indicator lights, no gauge operation). All other machine systems function correctly. The cluster fuse is intact. What should be checked first?

A. The cluster's CAN bus data supply — if the cluster requires CAN data to initialize its display, a bus fault on the cluster's data input may prevent the cluster from powering up its display

B. The instrument cluster's serial number — a mismatch between the cluster and the machine's vehicle identification module (VIM) may trigger a security lockout that disables the cluster display

C. The instrument cluster's power and ground connections — the fuse supplies power, but the ground path and the ignitionswitched power input must also be verified at the cluster connector. A failed ground or a missing switchedpower supply prevents the cluster from operating despite an intact fuse

D. The alternator output — if the alternator is not producing charging voltage, some instrument clusters will not initialize to protect their internal components from the lower batteryonly voltage

72. A machine equipped with a torque converter and powershift transmission exhibits a condition where the engine reaches its governed speed but the machine does not accelerate — the transmission appears to be in neutral despite the operator selecting a gear range. What is the unique torque converter condition that could cause this?

A. The torque converter has been installed backward on the flywheel, reversing the direction of fluid flow through the converter and producing zero net torque transfer to the turbine

B. The torque converter lockup clutch has engaged prematurely and is holding the turbine stationary while the pump rotates, preventing any torque transfer to the transmission

C. The stator oneway clutch has failed and is freewheeling in both directions, preventing the converter from multiplying torque during the stall phase

D. The torque converter turbine hub spline has stripped — the turbine rotates freely inside the converter without transferring any torque to the transmission input shaft, despite the converter pump spinning at engine speed

73. A technician discovers that a machine's automatic transmission produces correct shift timing in manual mode (operatorselected gear) but shifts erratically in automatic mode. In manual mode, the operator commands each gear change through the shift lever. In automatic mode, the TCM determines shift timing based on speed and load sensors. What does the difference between manual and automatic mode indicate?

A. The transmission's clutch packs and valve body are functioning correctly (proven by correct manual shifts) — the fault is in the automatic control system's input signals (speed sensors, throttle position, or load signals) or the TCM's shift logic that processes those signals to determine automatic shift timing

B. The manual mode bypasses the TCM entirely, and the erratic automatic shifts confirm the TCM hardware has failed and must be replaced

C. The transmission oil temperature is affecting only the automatic shift quality because the temperature sensor is used only in automatic mode — manual mode ignores the temperature input

D. The manual valve in the valve body has a wear groove that produces correct pressure in the manually positioned detent positions but allows pressure leakage during the automatic valve body's continuously variable positioning

74. A heavy equipment machine has a rigid rear axle with a single reduction spiral bevel gear set. The ring gear has 43 teeth and the pinion has 11 teeth. What is the gear ratio?

A. 3.91:1 — calculated as 43 ÷ 11 = 3.909:1. The pinion rotates 3.91 times for each single revolution of the ring gear and wheel assembly

B. 0.256:1 — calculated as 11 ÷ 43 = 0.256:1, which represents the reverse ratio (ring gear speed relative to pinion speed) rather than the standard inputtooutput ratio

C. 4.91:1 — calculated by adding the two tooth counts and dividing by the pinion count ((43 + 11) ÷ 11), which is the incorrect formula for a simple gear reduction

D. 32:1 — calculated by subtracting the pinion tooth count from the ring gear count (43 − 11 = 32), which is the tooth count difference, not the gear ratio

75. A technician is rebuilding a differential and discovers that the carrier housing bore (where the carrier bearings seat) has been distorted from a previous bearing failure. The bore is 0.05 mm outofround. What effect does this distortion have on the differential assembly?

A. The distorted bore causes the ring gear to orbit offcentre once per carrier revolution, which produces a cyclical noise and vibration at carrier speed and accelerates ring and pinion gear wear from the oscillating mesh position

B. The distorted bore causes the ring gear to run at a constant offcentre position that shifts the gear mesh to one side of the tooth face, concentrating wear on the heel or toe of the ring gear teeth

C. The distorted bore prevents the carrier bearings from seating squarely, which changes the contact angle of the bearing rollers and reduces their loadcarrying capacity — the bearings will fail prematurely from the uneven loading

D. The 0.05 mm outofround condition is within the normal manufacturing tolerance for differential carrier housing bores and does not require correction

76. A machine's hydrostatic drive system includes an electronically controlled pump, two independent drive motors (left and right), and an ECM that manages both motor displacements for speed and steering

control. If the ECM loses the signal from the left motor speed sensor, what is the typical system response?

A. The ECM continues to operate both motors normally using only the right motor speed sensor and calculates the left motor speed from the known pump displacement and left motor displacement

B. The ECM reduces both motors to minimum displacement and limits the machine to slow travel in a straight line only — the lost sensor prevents the ECM from safely controlling the left motor's speed and steering input

C. The ECM disables the left motor entirely and operates only the right motor at reduced displacement, causing the machine to turn continuously to the left until the operator countersteers

D. The ECM enters a reducedcapability mode — it may limit maximum speed, disable steering functions that require precise leftmotor speed feedback, and alert the operator through a warning indicator, while still providing basic forward and reverse travel capability

77. A technician inspects a clutch disc that has been removed from a machine during a clutch replacement. The friction facing on one side shows heavy glazing and heat discoloration (blue/brown), while the opposite side appears normal. What does this asymmetric wear pattern indicate?

A. The clutch was installed with the wrong side facing the flywheel, exposing the wrong friction material to the higher heat of the flywheel contact surface

B. The clutch disc was manufactured with different friction materials on each side — one material has a higher temperature rating than the other, and the side with the lower rating glazed from the normal operating temperature

C. The pressure plate or flywheel has uneven clamping — a warped pressure plate, a worn diaphragm spring, or uneven flywheel surface concentrates the clamping force on one side of the disc, overheating that face while the opposite face carries less load and runs cooler

D. The clutch slave cylinder is not retracting fully, maintaining a slight clamping force on one side of the disc after the clutch is fully released, causing that side to drag and overheat during each disengagement event

78. A machine's final drive planetary reduction produces a gear whine that was not present before a scheduled oil change. The oil level is correct and the correct viscosity grade was used. What oilrelated factor could cause the new noise?

A. The replacement oil does not contain the EP (extreme pressure) additive package required for the hypoidtype gears in the planetary set — the reduced film strength under load produces the gear whine

B. The replacement oil was poured directly from a cold container and the temperaturerelated viscosity difference is causing cavitation at the gear mesh that produces the whining noise until the oil warms to operating temperature

C. The replacement oil has a different base stock (synthetic vs. mineral) that produces different acoustic properties inside the gear housing, amplifying gear mesh noise that was previously dampened by the original oil

D. The replacement oil may not contain the correct gear oil specification for this final drive — even if the viscosity grade is the same, the API or OEMspecific gear oil classification may differ, affecting the oil film behaviour under the loaded gear mesh

79. A wheel loader's torque converter is equipped with a lockup clutch that the TCM disengages during directional shifts (forward to reverse). The technician discovers the lockup clutch remains engaged during the directional shift. What symptom does this produce?

A. The directional shift is extremely harsh because the locked converter mechanically transmits the full engine inertia through the drivetrain during the gear change, producing a severe shock load on the transmission clutch packs, driveshaft, and axles

B. The directional shift produces no noticeable difference because the converter lockup disengagement is a comfort feature only and does not affect the mechanical load during the shift

C. The engine stalls during the directional shift because the locked converter cannot absorb the torque reversal and the engine is mechanically connected to the suddenly reversing drivetrain

D. The directional shift is slower than normal because the locked converter must slow to zero before the reverse clutch can engage, adding the converter deceleration time to the shift duration

80. A technician is measuring backlash on a ring and pinion gear set using a dial indicator mounted on the ring gear tooth face with the pinion locked. The measured backlash varies between 0.15 mm at one position and 0.35 mm 180 degrees later. The OEM specification is 0.20–0.25 mm. What does this variation indicate?

A. The ring gear is running eccentrically — either the ring gear is not seated squarely on the differential case, the carrier bearings are worn allowing the carrier to shift, or the ring gear itself is warped. The variable backlash produces cyclical noise, vibration, and uneven tooth loading that accelerates wear

B. The pinion has a damaged tooth that creates the wider backlash measurement at the specific rotational position where the damaged tooth faces the ring gear

C. The backlash variation is within the normal manufacturing tolerance for heavy equipment ring and pinion gear sets and does not require correction

D. The differential side bearing preload is insufficient, allowing the entire carrier to shift under the dial indicator force — the true backlash is constant but appears to vary as the carrier moves

81. A technician discovers that a machine's powershift transmission's modulation pressure is adjusted by a screwtype adjustment on the modulation valve. A previous technician has adjusted the modulation pressure above the OEM specification. What symptom does this elevated modulation pressure produce?

A. Faster, harsher shifts — the elevated pressure fills and engages the clutch pack faster than designed, reducing the controlled slip period and producing abrupt engagement that transmits shock loads through the drivetrain

B. Slower, smoother shifts — the elevated pressure fills the clutch accumulator faster, which extends the modulation period and produces a more gradual engagement

C. No change in shift quality — the modulation pressure only affects the hold pressure after engagement, not the engagement pressure ramp rate

D. Intermittent slipping in all gears — the elevated modulation pressure pushes the clutch apply piston past its designed stroke limit, preventing the piston from fully clamping the disc pack

82. A machine has a fullfloating rear axle. The technician discovers oil leaking from the wheel hub area. What are the possible oil leak sources at this location?

A. The hub seal (which seals between the rotating hub and the stationary spindle), the axle shaft flange gasket or Oring (which seals between the axle shaft flange and the hub), or the hub bearing cap gasket — all are potential oil leak points at the wheel hub area on a fullfloating axle

B. Only the axle shaft seal can leak at the hub — the hub bearings are sealed and do not contain oil in a fullfloating design

C. Only the hub bearing cap gasket can leak — the hub seal and axle shaft flange are metaltometal pressfit connections that do not use seals or gaskets

D. Oil at the hub area must be from the brake circuit, not the axle — fullfloating axle hubs are greaselubricated and do not contain oil

83. A technician is performing a stall test on a machine with a torque converter and powershift transmission. During the stall test in 1st gear forward, the engine reaches the OEM stall speed of 2,050 RPM. During the stall test in 3rd gear forward, the engine reaches only 1,850 RPM. What does the lower stall speed in 3rd gear indicate?

A. The 3rd gear clutch pack is applying with more force than the 1st gear clutch pack, creating higher resistance that the converter must overcome and preventing the engine from reaching the same stall speed as in 1st gear

B. The stall speed in each gear should be identical because the torque converter's resistance is independent of which transmission gear is engaged — the lower stall speed in 3rd gear indicates the 3rd gear has a mechanical binding or excessive clutch drag that adds resistance to the converter

C. The 3rd gear planetary configuration has a different gear ratio than 1st gear, which changes the effective load on the converter and produces a naturally different stall speed — this is a normal characteristic of multispeed transmissions

D. The engine governor reduces the maximum fuel delivery in higher gears to protect the transmission, which limits the engine RPM during a stall test in 3rd gear compared to 1st gear

84. A machine's differential oil analysis shows elevated levels of both iron and aluminum. All other wear metals are at normal trending levels. What components in the differential contain these two metals?

A. Iron originates from the ring gear, pinion, and bearing races; aluminum originates from the differential case casting — the combined wear suggests the gear mesh is wearing the case by splashing debris against the aluminum housing walls

B. Iron originates from the gear teeth, shafts, and bearing components (all hardened steel); aluminum originates from bearing cages (retainers), thrust washers, or the differential case itself — the simultaneous increase suggests a bearing cage failure that is releasing both aluminum cage fragments and steel bearing elements

C. Iron comes from the lubricant additive package breakdown and aluminum comes from the drain plug washer — neither represents actual component wear

D. Iron originates from the axle housing material and aluminum from the ring gear bolt washers — both are external contamination rather than internal wear

85. A hydrostatic drive machine experiences a sudden loss of drive in one direction only. Forward operates normally. Reverse produces no drive output — the engine RPM increases but the machine does not move. Charge pressure is correct. What is the most likely cause?

A. The pump's servo has broken a spring that returns the swashplate from the reverse stroke, trapping the swashplate at zero displacement for the reverse command

B. The reverse crossport relief valve is stuck fully open, dumping all reverse loop pressure to the charge circuit immediately upon command

C. The pump EDC solenoid for the reverse command has failed — the solenoid cannot stroke the pump swashplate in the reverse direction, so the pump remains at zero displacement when reverse is commanded

D. The reverse crossport relief valve is stuck open — all pump output pressure intended for the reverse motor port is bypassed back to the lowpressure return side of the loop, leaving zero pressure to drive the motor in reverse while forward operation (using the other crossport relief) functions normally

86. A machine's transmission produces a rumbling/grinding noise in all forward gears but is quiet in reverse and neutral. The noise increases with speed and is present regardless of engine load. What does this noise pattern indicate?

A. The forward clutch pack bearing is failing — this bearing is loaded only when a forward gear is engaged and rotates at a speed proportional to the output shaft, producing noise in all forward gears but not in reverse or neutral

B. The torque converter pump hub bearing is worn — this bearing is loaded differently in forward and reverse modes due to the directional change of the fluid reaction forces

C. The input shaft bearing is failing — but this bearing rotates in all modes (forward, reverse, and neutral when the engine is running), which contradicts the noise pattern described

D. The transmission output shaft bearing is the source — but this bearing rotates whenever the machine moves, including reverse, which contradicts the noise pattern described

87. A machine's clutch hydraulic release system uses a master cylinder operated by the clutch pedal and a slave cylinder at the clutch release bearing. The technician bleeds the system until no air bubbles are visible in the bleed fluid. However, the clutch pedal still feels spongy and the clutch does not fully disengage. What could cause this persistent sponginess despite airfree bleed fluid?

A. The slave cylinder internal bore has a surface pit or scratch that allows microleakage past the piston seal during application — the fluid loss absorbs pedal travel without producing visible air bubbles

B. The master cylinder is failing internally — a worn or damaged piston cup seal allows fluid to bypass past the piston during application, consuming pedal travel without releasing adequate fluid volume to the slave cylinder

C. The flexible hydraulic hose between the master and slave cylinders is expanding under pressure — the old, weakened hose balloons outward during application, absorbing a portion of the master cylinder's fluid displacement before it reaches the slave cylinder

D. The release bearing has excessive clearance on the input shaft retainer, and the bearing must travel through this clearance before contacting the pressure plate fingers — the additional travel is consumed by pedal stroke that feels spongy because no resistance is encountered until the bearing contacts the fingers

88. A machine has a transfer case with a front axle disconnect. The disconnect is vacuumoperated — vacuum from a solenoidcontrolled valve actuates a shift fork inside the transfer case. The operator reports the front axle does not engage when the switch is activated. The technician hears the solenoid click when the switch is pressed. What should be checked?

A. The shift fork inside the transfer case — a worn or broken fork cannot engage the disconnect collar even when the vacuum actuator is functioning correctly

B. The vacuum supply to the actuator — the solenoid clicks (confirming the electrical circuit is functional), but if the vacuum source is insufficient (leaking hose, weak engine vacuum, or a failed vacuum reservoir), the actuator does not develop enough force to shift the fork against the return spring and the collar does not engage

C. The solenoid's electrical circuit — the click does not confirm the solenoid is opening its internal valve; some solenoids click audibly even when the internal valve mechanism is seized

D. The front axle differential — a seized differential prevents the axle shafts from equalizing speed, which blocks the shift fork collar from engaging the splines

89. A machine's A/C compressor clutch engages and the system produces some cooling, but the vent temperature cannot drop below 18°C despite the ambient temperature being 28°C. The manifold gauges show lowside pressure slightly above normal and highside pressure slightly below normal. What is the most likely cause?

A. The compressor is worn internally — it produces some compression (enough for partial cooling) but cannot develop the full pressure differential between the high and low sides needed for maximum cooling capacity. The low side cannot be pulled down to its design pressure and the high side cannot be pushed up to its design pressure

B. The condenser fan has failed and the condenser cannot reject adequate heat, causing the highside pressure to remain low and limiting the total system cooling capacity

C. The expansion valve is stuck partially open, allowing more refrigerant flow than designed and preventing the evaporator from reaching its optimal temperature

D. The system has a minor overcharge that is flooding the evaporator with excess liquid, which raises the lowside pressure above its optimal operating point

90. A machine operating in a tropical climate has its A/C system serviced. The technician evacuates the system and achieves 300 microns on the vacuum gauge. The technician then charges the system with the OEMspecified refrigerant weight. After charging, the system cools adequately but the technician notices ice formation on the liquid line near the receiverdrier. What does this indicate?

A. The system is functioning correctly — ice formation on the liquid line in tropical conditions indicates the condenser is subcooling the refrigerant very effectively due to the high ambient temperature differential

B. The system has been undercharged — insufficient refrigerant causes the liquid line pressure to drop below the saturation point, which cools the remaining liquid refrigerant to a temperature that freezes moisture on the line surface

C. The receiverdrier has a restriction that creates a pressure drop across it — the pressure reduction causes the refrigerant temperature to drop below the dew point on the line surface downstream of the restriction, forming ice

D. The receiverdrier has an internal restriction — the pressure drop across the clogged drier causes the downstream liquid refrigerant temperature to drop below freezing, forming ice on the line surface. The restriction also reduces the refrigerant flow to the expansion device, which will progressively reduce cooling capacity

91. A machine's cab fresh air intake is equipped with a rain and debris separator (a precleaner stage before the cabin air filter). The separator uses a cyclone effect to remove large particles and water droplets before the air reaches the paper filter element. If the separator's drain is blocked, what symptom will develop?

A. The cab pressurization pressure will increase because the blocked drain reduces the separator's internal volume, increasing the air velocity through the remaining passage

B. No operational symptom will develop — the separator's cyclone function does not require an open drain to separate particles from the airstream

C. Water and debris accumulate in the separator housing and eventually overflow into the cabin air filter, saturating it with water and severely restricting airflow to the cab — cab pressurization drops and the filter clogs prematurely

D. The separator becomes a restriction that increases the fan motor current draw, eventually burning out the blower motor from the sustained overload

92. A technician discovers that a machine's A/C system receiverdrier has a sight glass. During normal operation with the engine at rated RPM and the A/C at maximum cooling, the sight glass shows clear liquid with no bubbles. The technician then moves the engine to idle speed. At idle, bubbles appear in the sight glass. Is this a fault?

A. Yes — a properly charged system should show clear liquid at all engine speeds, and bubbles at idle indicate the charge is slightly low and the system needs a small amount of additional refrigerant

B. No — at idle, the compressor runs at reduced speed and produces less flow, which can cause momentary flash gas (bubbles) in the liquid line that disappears when engine speed increases. If the sight glass is clear at rated RPM, the charge is correct

C. Yes — the compressor clutch is slipping at idle speed and cannot maintain adequate compression to keep the liquid line fully liquid at the lower RPM

D. No — the sight glass should always show bubbles at idle because the expansion valve opens wider at reduced condenser pressure, allowing vapour to reach the liquid line temporarily

93. A dieselfired coolant heater is equipped with a flame detection system that monitors whether the combustion flame is established during the start sequence. If the flame sensor detects no flame after the preglow and fuel delivery period, what does the heater control module do?

A. The module increases the fuel delivery rate to overcome the ignition threshold and establish the flame at the higher fuel flow rate

B. The module extends the glow period indefinitely until the flame is detected or the operator manually cancels the start sequence

C. The module commands continuous fuel delivery without a flame, filling the combustion chamber with unburned fuel that will ignite when the glow plug eventually reaches sufficient temperature

D. The module initiates a lockout — it stops fuel delivery, purges the combustion chamber with the air blower, and prevents further start attempts until the fault is diagnosed and the lockout is manually reset. This prevents unburned fuel from accumulating in the combustion chamber and igniting in an uncontrolled manner

94. A machine's A/C compressor is a variabledisplacement piston type controlled by an electronic displacement valve. The ECM controls the valve to vary the compressor's pumping capacity based on the evaporator pressure and temperature targets. If the displacement valve's control solenoid wire is disconnected, what happens to the compressor's displacement?

A. The compressor defaults to zero displacement and produces no cooling — the solenoid must be energized to command any displacement above zero

B. The compressor defaults to maximum displacement and runs at full capacity continuously — the solenoid normally controls a valve that reduces displacement, and without the signal, the valve allows full displacement as the mechanical default

C. The compressor's displacement remains at whatever position it was in when the wire was disconnected and does not change until the wire is reconnected

D. The compressor stops running entirely because the displacement valve also controls the clutch engagement signal

95. A technician is testing a machine's cab pressurization and measures 75 pascals positive pressure. The OEM specification is 50–100 pascals. The operator complains the cab door is difficult to open. Is the highend pressurization related to the door difficulty?

A. No — 75 pascals of pressure creates an insignificant force on the door surface area and cannot produce noticeable resistance to door opening

B. No — door difficulty is always caused by a mechanical latch, hinge, or seal problem and is never related to internal cab pressure regardless of the pressurization level

C. Yes — positive cab pressure acts on the entire interior surface area of the door. At 75 pascals, the total force on a large cab door can be significant (pressure × area = force), creating noticeable resistance when the operator pushes the door open against the internal pressure

D. Yes — but only if the door's pressure equalization valve has failed. All heavy equipment cab doors have a builtin pressure equalization valve that prevents internal pressure from creating door resistance

96. A machine's exhaust brake (VGTbased) produces a noticeable roaring noise during operation on a downhill grade. The noise is not present during normal driving. Is this noise expected?

A. Yes — the VGT exhaust brake closes the turbine vanes to create high exhaust backpressure for retarding. The pressurized exhaust gas forced through the narrowed vane openings produces the characteristic roaring noise that is a normal byproduct of the exhaust brake's operation

B. No — the VGT exhaust brake should operate silently because the backpressure is created upstream of the turbocharger and no noise should escape downstream

C. No — the roaring noise indicates the VGT vanes are physically contacting the turbine housing due to a calibration error that closes them beyond their designed minimum position

D. Yes — but the noise is from the turbocharger overspeeding as the compressed exhaust energy drives the turbine faster than its designed operating range during the retarding event

97. A technician is diagnosing a cab HVAC system where the recirculation door actuator has failed in the recirculation position. The cab pressurization system is off (no fresh air is entering the cab). What immediate operational concern does this create beyond reduced cab pressurization?

A. The cab windows will fog from the moisture in the recirculated air because the recirculation mode bypasses the evaporator that normally dehumidifies the incoming air

B. The operator will experience progressive drowsiness from elevated CO_2 levels as the recirculated air is depleted of oxygen and enriched with the operator's exhaled CO_2 — this is a safety hazard that requires immediate correction

C. The cab heater will overheat because the recirculation mode continuously heats the same air, raising the cab temperature beyond the thermostat's control range

D. The A/C system will freeze the evaporator because the recirculated air has already been cooled by the previous pass through the evaporator, and the precooled air entering the evaporator drops the coil temperature below freezing

98. A hydraulic system uses a variabledisplacement axial piston pump with a loadsensing controller. During operation, the technician notices the pump produces a rhythmic surging — the system pressure cycles between 180 bar and 230 bar approximately once per second during a steadystate loaded operation. The joystick is held steady. What is the most likely cause of this pressure oscillation?

A. The pump's compensator spool is chattering between its open and closed positions due to a worn spool, a contaminated orifice, or a weak compensator spring that cannot maintain a stable position under the fluctuating loadsensing signal

B. The load on the actuator is fluctuating cyclically at a 1second period, and the pump is correctly responding to the changing demand by adjusting its displacement to match

C. The pump's swashplate servo piston seal is leaking, causing the swashplate to destroke and restroke as the servo alternately loses and regains control of the swashplate position

D. The pump's compensator spring has weakened and the pump oscillates between the compensated (destroked) and decompensated (full stroke) states as the system pressure fluctuates around the weakened spring's unstable set point

99. A technician is testing a hydraulic motor's performance by measuring its inlet pressure, outlet pressure, flow rate, and output shaft speed. The inlet pressure is 250 bar, the outlet back-pressure is 15 bar, the flow rate is 100 L/min, and the motor speed is 320 RPM. The motor displacement is 280 cm^3/rev. What is the motor's volumetric efficiency?

A. 111.6% — calculated as theoretical speed divided by actual speed, which exceeds 100% and confirms the motor is performing above its rated specification

B. 89.6% — the theoretical speed is (100,000 cm^3/min ÷ 280 cm^3/rev) = 357 RPM; the actual speed is 320 RPM; volumetric efficiency = (320 ÷ 357) × 100 = 89.6%, meaning 10.4% of the delivered flow is bypassing internally through the motor's clearances

C. 78.1% — calculated as (250 bar − 15 bar) ÷ 250 bar × 100, which is the pressure efficiency rather than the volumetric efficiency

D. 35.7% — calculated by dividing the motor displacement by the flow rate without converting units, producing a ratio that does not represent volumetric efficiency

100. A hydraulic system uses a pilotoperated relief valve as the main system relief. The valve has a remotecontrol port that accepts an external pilot signal to lower the relief setting below the main spring's setting. If a small orifice in the pilot circuit becomes blocked, how does this affect the relief valve's operation?

A. The relief valve opens at a lower pressure than its set point because the blocked orifice traps pressure on the pilot piston and assists the main spring in opening the valve

B. The relief valve opens erratically — the blocked orifice prevents the pilot from sensing the actual system pressure accurately, causing delayed and inconsistent relief valve response

C. The relief valve operates normally at its main spring setting — the blocked orifice only affects the remotecontrol function, which lowers the setting. Without the remote signal, the valve defaults to its maximum (main spring) setting

D. The relief valve cannot open at all because the blocked orifice traps pressure behind the main poppet that opposes the system pressure, hydraulically locking the valve closed

101. A wheel loader's hydraulic system has a bucket cylinder that drifts down slowly under a loaded bucket. The technician performs a cylinder bypass test (full extension against the stop with DCV in extend, then disconnects the rodend hose to check for flow from the rod port). No oil flows from the disconnected rod port. What does this result tell the technician?

A. The cylinder's internal piston seals are intact — the drift is NOT caused by piston seal bypass. The fault is external to the cylinder, likely in the DCV spool, a pilotoperated check valve, or the supply circuit that is allowing oil to leak from the capend circuit back to tank

B. The test is inconclusive because the cylinder was at full extension against its mechanical stop — the test must be repeated with the cylinder at midstroke under load to produce meaningful results

C. The cylinder must be removed and disassembled for further internal inspection because the bench test is the only definitive method to confirm piston seal condition

D. The lack of flow confirms the rodend hose is blocked and the drift is caused by external restriction preventing the rodend chamber from filling as the cylinder extends under load

102. A hydrostatic drive system's left track motor has been rebuilt with new internal components. After installation, the left track operates normally in forward but produces a grinding noise in reverse at high displacement. The right track operates normally in both directions. What is the most probable cause?

A. The rebuilt motor's internal timing is incorrect — the valve plate or port plate was installed at the wrong angular position during assembly, causing the pistons to transition between suction and pressure at the wrong point in reverse direction only

B. The rebuilt motor has a bearing that was pressed to the wrong depth, creating interference with the motor housing only when the internal components are loaded in the reverse direction

C. The left track's reverse crossport relief valve was disturbed during the motor installation and is now set too low, causing flowinduced noise as oil bypasses through the relief at high displacement in reverse

D. The rebuilt motor was assembled with the correct parts but the cylinder barrel was installed backward (180 degrees rotated), producing correct operation in one direction but mechanical interference in the reverse direction

103. A machine's hydraulic accumulator is charged with nitrogen to a precharge pressure of 70 bar. The system operating pressure cycles between 100 bar and 200 bar during normal operation. The technician notices the accumulator's bladder is failing prematurely — lasting only 6 months instead of the expected 5 years. What is the most likely cause of the premature bladder failure?

A. The system's operating pressure range is too narrow for the precharge setting — the 70bar precharge is too close to the 100bar minimum operating pressure, and the bladder fully expands against the shell at low system pressure, stressing the rubber beyond its design capacity

B. The nitrogen precharge is too low relative to the system operating range — at the 200bar maximum, the 70bar gas compresses to approximately onethird of its original volume, which may fully compress the bladder against the gas valve end of the housing, extruding bladder material into the valve opening and causing accelerated fatigue from the extreme compression

C. The hydraulic oil temperature exceeds the bladder material's rated temperature, causing thermal degradation of the rubber compound over 6 months that would not occur at normal operating temperatures

D. The system pressure cycling frequency is too high — the bladder is rated for a specific number of cycles, and the machine's operating pattern exceeds this cycle count within the 6month period

104. A hydraulic cylinder on a crane must hold a suspended load for 30 minutes with the engine shut off. The circuit uses a pilotoperated check valve (POCV) to lock the capend oil. After 30 minutes, the load has drifted down by 50 mm. The POCV has been tested and confirmed leakfree. What other component could allow the drift?

A. The cylinder rod seal is leaking externally — oil weeping past the rod seal reduces the capend volume and allows the piston to retract under the load's weight

B. The capend supply hose has expanded from the sustained pressure, absorbing oil volume and allowing the piston to retract by the volume of the hose expansion

C. The cylinder's piston seals are allowing internal bypass from the pressurized cap end to the rod end — even with the POCV holding the capend circuit, oil crossing the piston reduces the capend pressure and allows drift. The POCV only blocks the line between the valve and the cylinder — it cannot prevent leakage across the piston inside the cylinder

D. The DCV spool is leaking internally, allowing oil to bleed from the capend work port to the tank port through the spooltobore clearance — but the POCV should block this path. If drift occurs with a leakfree POCV, the leak must be between the POCV and the cylinder

105. An air brake system on a heavy equipment machine has been converted from a singlecircuit to a dualcircuit design during a rebuild. The dualcircuit design uses separate primary and secondary reservoirs with independent check valves from the supply tank. What safety advantage does the dualcircuit design provide?

A. The dual circuit provides redundant braking capability on different axles — if one circuit develops a leak or failure, the other circuit continues to provide braking on its assigned axle, ensuring the machine can still be stopped safely

B. The dual circuit doubles the total air volume available for braking, providing more brake applications per compressor charge cycle

C. The dual circuit allows the front and rear brakes to be applied at different pressures without a proportioning valve

D. The dual circuit provides faster brake response because two smaller circuits fill faster than one large circuit with the same compressor output

106. A hydraulic system's tankmounted return line filter has a differential pressure gauge that reads in bar. The gauge currently reads 2.8 bar. The filter element specification states the bypass valve opens at 3.5 bar. What does the 2.8 bar reading indicate about the filter element condition?

A. The filter element is approaching its clogging limit — 2.8 bar is 80% of the 3.5bar bypass threshold. The element should be replaced soon because it is consuming significant restriction and is nearing the point where the bypass valve will open and allow unfiltered oil to pass through the system

B. The 2.8 bar reading is within the normal cleanfilter range and no action is required until the gauge reading reaches the bypass threshold

C. The gauge is misread — differential pressure gauges on return line filters should read in kPa, not bar, and the 2.8 reading represents kPa rather than bar

D. The 2.8 bar reading indicates the filter housing has an internal leak that is reducing the differential pressure below what it would be if the housing were sealed correctly

107. A hydrostatic drive machine is being tested for straightline tracking. On a level, smooth surface, the machine drifts to the right despite the operator holding the controls centred. Both track motors and pumps test within specification for pressure and flow. What should be investigated?

A. The right track's rolling resistance — a mechanical binding in the rightside undercarriage (dragging brake, tight track tension, or seized roller) creates more resistance on the right side, causing the machine to pull right as the left track overdrives

B. The left and right track motor displacements may not be exactly matched — even a small displacement difference (within the motors' individual specifications but different from each other) produces a speed differential that causes the machine to veer toward the slower side at a consistent rate

C. The right track's sprocket has more tooth wear than the left, producing a smaller effective drive circumference on the right side and causing the right track to travel less distance per motor revolution

D. The hydrostatic system's charge pressure is slightly different between the left and right loops due to a partially restricted charge filter that affects one loop more than the other

108. A machine's hydraulic oil cooler uses a thermostatically controlled bypass valve that diverts oil around the cooler when the oil temperature is below 60°C. Above 60°C, the valve progressively directs more oil through the cooler. The technician notices the hydraulic oil temperature is consistently 15°C above normal despite the cooler being clean and the fan operating correctly. What should be checked?

A. The oil cooler air filter — if equipped, a plugged air filter restricts the cooling air flow through the cooler, reducing heat rejection despite the cooler tubes being clean inside

B. The hydraulic system's total heat generation — a worn pump, leaking valve, or incorrect relief valve setting may be generating more heat than the cooling system was designed to reject

C. The thermostat bypass valve — if the valve is stuck partially in the bypass position, a portion of the oil always bypasses the cooler even at high temperatures, reducing the effective cooling capacity and causing the elevated temperature

D. The system's total oil volume — if the reservoir level is low, the reduced oil volume circulates through the system faster, absorbing heat faster than the cooler can reject it, producing the elevated temperature

109. A hydraulic cylinder's capend port has a factoryinstalled restrictor (fixed orifice) in the supply line fitting. The restrictor limits the maximum extend speed of the cylinder to prevent uncontrolled rapid extension. If a technician replaces the capend hose fitting and omits the restrictor, what operational change will occur?

A. The cylinder will extend at the same speed because the DCV metering edge controls the extend speed, not the port restrictor

B. The cylinder will retract faster because the unrestricted cap end allows oil to exhaust more freely during the retract stroke

C. The cylinder retract force will increase because the unrestricted capend port reduces the backpressure that opposes the rodend during retraction

D. The cylinder will extend faster than designed because the full pump flow reaches the cap end without the restriction — the unrestricted speed may create a safety hazard from rapid, uncontrolled boom or implement extension

110. A machine's pilotoperated hydraulic system uses a 35bar pilot pressure circuit supplied by a dedicated pilot pump. If the pilot pump fails, what happens to the main hydraulic system?

A. The main DCV spools cannot be shifted because the pilot pressure that moves them is absent — all implement functions stop responding to operator commands even though the main pump continues to produce flow and pressure

B. The main system operates normally at reduced speed because the main pump's compensator senses the lost pilot pressure and reduces its output to compensate

C. The main DCV spools shift to their fully open positions when pilot pressure is lost, causing all actuators to receive maximum flow simultaneously

D. The main system relief valve opens because the lost pilot pressure removes the pilot assist that normally keeps the relief valve closed, dumping all main pump flow to tank

111. A machine's air brake system has a relay valve that controls the rear axle service brakes. The relay valve delivers stored air from the rear reservoir to the brake chambers in proportion to the brake pedal application pressure. If the relay valve sticks in the applied position, what symptom does the operator experience?

A. The rear brakes do not release when the pedal is released — the stuck relay valve continues to supply application pressure to the rear brake chambers even though the foot valve has exhausted its control signal

B. The rear brakes do not apply when the pedal is pressed — a stuck relay valve blocks the stored air from reaching the brake chambers

C. The rear brakes apply and release normally but produce a delayed response compared to the front brakes because the stuck relay requires higher pilot pressure to shift than its design threshold

D. The rear brakes apply only at maximum force regardless of pedal position — the stuck relay delivers full reservoir pressure to the brake chambers instead of proportional pressure

112. A hydraulic system has two parallel circuits — Circuit A (boom) and Circuit B (bucket). Both are supplied by the same pump through separate DCV sections. When Circuit A is operated alone, its speed is normal. When both circuits are operated simultaneously, Circuit A's speed drops by 50%. What causes this speed reduction during simultaneous operation?

A. The pump has a pressure compensator that reduces total output when the combined demand exceeds the pump's rated flow — the reduced output is divided between the two circuits

B. Circuit B has a lower working pressure than Circuit A, and the pump's loadsensing controller adjusts to Circuit B's lower pressure, limiting the flow available to Circuit A

C. The DCV's internal passages create a restriction when both sections are actuated simultaneously that does not exist when only one section is operated

D. The pump has a fixed flow output that must be shared between both circuits during simultaneous operation — Circuit B is consuming approximately half the pump's output, leaving only half for Circuit A. The total available flow is divided between the two active circuits in proportion to their individual resistance

113. A hydraulic motor is installed on a conveyor drive and the motor shaft seal begins leaking within 200 hours. The replacement motor's shaft seal leaks again within 300 hours. Both motors are correct for the application. What should the technician investigate as the root cause?

A. The conveyor's shaft alignment — if the motor shaft is misaligned with the conveyor drive shaft, the coupling transmits radial loads to the motor's shaft seal that it was not designed to carry, causing premature seal failure

B. The motor's case drain line — if the case drain has a restriction or is routed higher than the motor, backpressure builds inside the motor housing and forces oil past the shaft seal

C. The hydraulic oil temperature — elevated oil temperature degrades the seal material faster than normal and produces premature failure regardless of the seal's mechanical loading condition

D. The motor mounting bolt torque — undertorqued mounting bolts allow the motor to vibrate on its mount, which transmits the vibration through the shaft and seal contact zone, wearing the seal prematurely

114. A hydraulic cylinder on a machine extends to full stroke but does not fully retract — it stops approximately 25 mm short of full retraction. The DCV and pump are confirmed functioning correctly. What is the most likely cause?

A. The rodend supply hose has an internal restriction (a collapsed liner or a pinched section) that limits flow at the end of the retraction stroke when the cylinder rod is fully retracted and the hose routing is at its tightest bend angle

B. The cylinder's internal cushion plunger (if equipped) is misaligned and is physically preventing the piston from reaching the fully retracted position

C. Air trapped in the cap end of the cylinder creates a compressible gas pocket that the rodend hydraulic pressure cannot fully compress, leaving the piston 25 mm short of full retraction

D. The cylinder rod has bent slightly and the bent section creates interference with the rod seal gland at the fully retracted position, preventing the last 25 mm of travel

115. An air brake system's air dryer has a desiccant cartridge that must be replaced periodically. The OEM replacement interval is 24 months or 4,000 operating hours. A technician discovers the cartridge was last replaced 36 months and 6,000 hours ago. What consequence has the overdue replacement likely caused?

A. The saturated desiccant has been passing moistureladen air into the brake system for the extended period, allowing moisture to accumulate in the reservoirs, valves, and brake chambers — the contaminated system is at high risk of valve malfunction, seal degradation, and freezerelated brake failure in cold weather

B. The overdue cartridge has been regenerating normally through the purge cycle and no moisture contamination has occurred because the purge cycle removes moisture regardless of the desiccant condition

C. The desiccant has dissolved from the moisture saturation and the dissolved desiccant material has contaminated the air system downstream, clogging valve passages

D. The overdue cartridge has collapsed internally and is restricting the air supply to the brake reservoirs, increasing the compressor buildup time by approximately 50%

116. A machine's hydraulic system includes a heat exchanger that uses a separate electric fan for cooling (not driven by the engine). The fan is controlled by a thermostat that turns the fan on at 65°C oil temperature and off at 55°C. The technician measures the oil temperature at a steady 80°C during loaded operation. The fan is running. What should be investigated?

A. The fan may be running but producing inadequate airflow — a failed motor that runs at reduced speed, damaged fan blades, or an obstruction in the cooling air path can prevent the fan from moving enough air to reduce the oil temperature below 80°C despite running continuously

B. The fan motor is running in reverse, blowing air away from the cooler rather than through it — the motor leads may have been connected backward during a previous repair

C. The thermostat's off setting (55°C) is too low and the fan cycles off before the oil has cooled adequately, allowing the temperature to climb back to 80°C before the fan reengages at 65°C

D. The hydraulic oil has oxidized and its specific heat has decreased, reducing its ability to absorb and transport heat effectively from the system components to the cooler

117. A hydrostatic drive machine's charge pressure gauge shows a slow oscillation — the pressure rises and falls by approximately 5 bar over a 10second cycle during steadystate operation. All other system parameters are stable. What could cause this charge pressure oscillation?

A. The charge relief valve is hunting between its open and closed positions because the valve spring has weakened and cannot maintain a stable pressure threshold — the weakened spring allows the valve to oscillate around its unstable set point

B. The charge pump is producing pulsating output from a worn gear or gerotor element that has developed a clearance allowing variable displacement per revolution

C. The flushing valve is cycling open and closed at a low frequency, alternately diverting charge flow to the cooling circuit and then restoring it to the main loop

D. The main pump's swashplate is oscillating slightly due to a servo control instability, and the cyclical displacement change creates a corresponding charge pressure fluctuation as the loop demand varies with the swashplate angle

118. A machine's hydraulic system includes a suction line with a shutoff valve that was installed during a previous pump replacement. The valve is partially closed — the technician can see the handle is only 70% open. What effect does this partial restriction have on pump performance?

A. The partially closed valve restricts the oil flow to the pump inlet, creating a suctionside vacuum that can cause pump cavitation, accelerated wear, noise, and aerated oil. The valve must be fully opened to provide unrestricted suction flow to the pump

B. The partially closed valve has no measurable effect because the pump creates its own suction and can draw oil through a partially restricted inlet without performance loss

C. The partially closed valve provides a beneficial flow dampening effect that reduces pump pulsation and extends the pump's service life by smoothing the inlet flow

D. The partially closed valve reduces the pump's maximum flow output proportionally to the valve opening percentage, providing a simple flow control function that limits the maximum system speed

119. A hydraulic accumulator on a machine's brake circuit is tested by depressurizing the hydraulic oil side and checking the nitrogen precharge pressure. The precharge reads 95 bar. The OEM specification is 100 bar. Should the accumulator be recharged to exactly 100 bar?

A. No — the 5 bar difference is within the normal measurement tolerance and the accumulator is functioning within its designed performance range

B. No — the precharge should be checked at the OEMspecified ambient temperature using the OEM's temperature correction chart before making any adjustment. The 95 bar reading may already equal 100 bar at the reference temperature if the current ambient is lower than the reference

C. Yes — a 5% low precharge reduces the accumulator's stored energy by more than 10%, which may not provide enough brake applications in an emergency

D. Yes — but only after verifying the accumulator bladder is intact by performing a full charge/discharge test that confirms the bladder can hold the precharge without decay over a 24hour period

120. A machine's hydraulic system has a closedcentre DCV with electricoverhydraulic pilot actuation. The pilot circuit uses dedicated proportional solenoid valves for each DCV spool. The technician discovers that one solenoid valve has been leaking pilot oil externally. What is the consequence of this external pilot leak?

A. The affected DCV spool may not shift fully because the leaking pilot circuit cannot build adequate pressure on the pilot piston — the actuator speed is reduced proportionally to the pilot pressure loss

B. The affected DCV spool receives full pilot pressure because the pump compensates for the leak — but the constant leak drains the pilot circuit oil into the main circuit, contaminating the pilot oil with particles from the main circuit

C. The main pump compensates for the pilot leak by increasing its output, which raises the system temperature because the additional pump output is not performing useful work

D. The external pilot leak has no effect on the main DCV operation because the pilot circuit is a separate lowpressure system with its own pump that can easily overcome a small leak

121. A machine's hydraulic system is designed to operate at 250 bar working pressure with a 350 bar relief valve setting. The technician notices the system has been operating consistently at 300 bar during normal loaded operation — 50 bar above the designed working pressure. No changes have been made to the machine. What could cause the elevated working pressure?

A. The operator is consistently overloading the machine beyond its rated capacity, requiring more hydraulic force (and therefore more pressure) to perform each work cycle than the machine was designed for

B. The pump's loadsensing margin has drifted upward, adding more pressure above the load signal than designed — increasing the total supply pressure by the amount of the margin increase

C. The relief valve has drifted upward from its 350 bar setting, which would not explain the 300 bar working pressure since the relief is a maximum limiter, not a working pressure controller

D. The hydraulic oil temperature is consistently below normal, and the thick cold oil produces higher pressure drop through the circuit restrictions, requiring the pump to generate higher supply pressure to deliver the same flow to the actuators

122. A technician is installing a new hydraulic hose assembly on a highpressure circuit. The hose has the correct length, pressure rating, and fitting specification. Before tightening the fittings, the technician verifies the hose is not twisted by checking the layline (identification stripe printed along the hose length). The layline spirals along the hose rather than running straight. What should the technician do?

A. Do not install the hose in its current state — hold one end fitting stationary and rotate the opposite end until the layline runs straight along the entire hose length, then tighten both fittings. A twisted hose has dramatically reduced fatigue life and may fail prematurely from the torsional stress on the reinforcement

B. Install the hose asis — the layline is a cosmetic feature and does not indicate the actual torsional state of the hose reinforcement

C. Cut the hose shorter to remove the twisted section and install a shorter hose with the correct layline alignment

D. Return the hose to the supplier — a twisted layline indicates the hose was manufactured incorrectly and the reinforcement spiral angle is not aligned with the rubber outer cover

123. A technician discovers a crack in a hydraulic excavator's boom that runs transversely across the top plate between two weld joints. The crack is approximately 100 mm long. The machine has 22,000 operating hours. What is the most critical piece of information the technician must document before any repair is attempted?

A. The crack length, orientation, and location must be documented, but the repair can proceed using standard welding procedures for structural steel

B. The exact location, length, orientation, depth (surface or throughthickness), and whether the crack terminates in a weld zone or extends into parent metal must be documented — this information determines whether the repair requires simple weld overlay, full excavation and rewelding, or structural engineering assessment before any welding is performed

C. The crack should be photographed and reported to the OEM, but no documentation of the physical characteristics is needed because the OEM will determine the repair procedure remotely from the photographs

D. The machine's total operating hours and the date of the last structural inspection must be documented — the crack characteristics are less important than establishing whether the failure occurred within the OEM's expected service life

124. A machine's operator seat has an integrated seatbelt with a pretensioner — a pyrotechnic device that instantly tightens the belt during a rollover event. The pretensioner has been deployed (fired) during a minor rollover incident. The machine was recovered and appears structurally sound. Can the seat be returned to service?

A. Yes — the pretensioner is a supplemental safety device and the seatbelt functions normally without it. The deployed pretensioner does not affect the basic belt restraint function

B. Yes — but only if a visual inspection confirms the pretensioner cartridge is intact and the belt webbing shows no damage from the deployment event

C. No — but only the pretensioner cartridge needs replacement, which is a fieldreplaceable component. The rest of the seat and belt assembly can be returned to service after the cartridge is replaced

D. No — a deployed pretensioner cannot be reset or replaced independently. The entire seat assembly including the belt, retractor, and pretensioner must be replaced because the deployment may have stressed the belt webbing, retractor mechanism, and anchor points beyond their designed singleevent capacity

125. A machine's quick coupler has successfully engaged an attachment and the operator has performed the required weighted test lift. During the first digging cycle, the attachment tilts forward in the coupler — one pin appears to be partially disengaged. What is the most likely cause?

A. The coupler's front hook or cradle has worn to a point where it no longer captures the front pin securely — the pin slides forward under the digging load and the attachment tilts as it partially disengages

B. The attachment's rear pin is worn to a smaller diameter and the coupler's rear lock cannot maintain a secure grip on the undersized pin during the dynamic loading of digging

C. The coupler's secondary lock mechanism was not verified after the test lift and the hydraulic lock gradually released during the first operating cycles

D. The operator performed the test lift at too low a height and the brief lift duration was insufficient to verify that the coupler could sustain the full digging load under dynamic conditions

126. A mining excavator's bucket has been operating in extremely abrasive material (hard rock quarry). The bucket floor liner plates are replaced at the correct interval, but the bucket sidewall plates are wearing faster than expected. What modification could extend the sidewall plate life?

A. Install thicker sidewall plates with a higher hardness rating — the increased thickness provides more wear material and the harder surface resists abrasion more effectively in the highimpact rock environment

B. Install a rubber lining on the inside of the sidewall plates — the rubber absorbs the impact of the rock and reduces the direct abrasion on the steel plate surface

C. Install additional wear strips (chocky bars or wear buttons) on the sidewall interior at the highwear zones — these sacrificial wear elements protect the base plate by taking the abrasion and impact contact and are individually replaceable when worn

D. Reduce the bucket's fill factor to 80% to prevent material from contacting the upper sidewall areas during loading — the reduced fill prevents the highestimpact zone from being loaded

127. A machine's ROPS frame has been repainted by the maintenance crew. During the repainting, the crew used an angle grinder to remove rust and old paint from the ROPS surface. Some grinding marks are 2–3 mm deep in the ROPS tube wall. What concern does this grinding introduce?

A. The grinding marks create stress risers on the ROPS surface that can initiate fatigue cracks during a rollover or during normal vibration loading — the marks must be blended smooth to remove the sharp profile and the remaining wall thickness must be verified against the ROPS tube's minimum wall specification

B. The grinding marks are cosmetic only and do not affect the ROPS structural performance because the marks are on the outer surface and do not penetrate the tube's structural core

C. The grinding marks improve the paint adhesion and the roughened surface provides a better mechanical bond for the new paint coating than the original smooth surface

D. The grinding marks must be welded over with a structural electrode to restore the full tube wall thickness before the ROPS can be returned to service

128. A machine's hydraulic thumb on an excavator has gradually developed a slow response compared to when it was new. The hydraulic supply and return circuits test within specification. The thumb's pivot pins and bushings are tight. What should be investigated?

A. The thumb cylinder's piston seals — progressive internal bypass allows fluid to leak across the piston rather than pushing it, slowing the response as the seals deteriorate. A cylinder bypass test confirms the diagnosis

B. The pilot solenoid that controls the thumb circuit's DCV has weakened magnetically over time and cannot shift the DCV spool as quickly as a new solenoid

C. The thumb's hydraulic hose assemblies have ballooned from fatigue and age, absorbing a portion of the pump's flow as the hoses expand under pressure rather than delivering it to the cylinder

D. The DCV spool metering edge has worn wider from repeated use, which changes the flow characteristic and reduces the maximum flow delivered to the thumb cylinder

129. A technician is inspecting the cab structure of a compact excavator after a tipover incident. The machine was recovered and returned to the upright position. The cab shows no visible deformation from the outside. The ROPS certification plate is intact. Can the machine be returned to service?

A. Yes — if no visible deformation is present, the ROPS has not exceeded its designed energy absorption and the machine can be returned to service after verifying the operator seat and belt are undamaged

B. Yes — but only after a qualified structural engineer performs an NDE inspection of all ROPS weld joints and mounting points to confirm no hidden damage occurred during the tipover that may have exceeded the ROPS structure's elastic limit

C. No — any ROPS that has been involved in a tipover event must be replaced regardless of visible condition because the structure may have absorbed energy through elastic deformation that weakened it below its certified rating

D. No — the ROPS must be assessed by the OEM or a qualified structural engineer — even without visible deformation, the tipover may have loaded the structure to a level that created internal stress, microcracking, or fastener deformation that is not visible externally but compromises the ROPS rating for a subsequent event

130. A wheel loader's cutting edge bolt pattern uses alternating long and short bolts. The long bolts pass through the cutting edge, the blade, and a backing plate. The short bolts pass through the cutting edge and blade only (no backing plate). The technician replaces the cutting edge and installs all bolts as the same (short) length. What problem does this create?

A. The blade has no structural consequence from the uniform bolt length because both bolt lengths provide the same clamping force when torqued to the same specification

B. The mixed bolt pattern is designed so that the long bolts provide clamping for the backing plate, while the short bolts clamp only the cutting edge to the blade — using all short bolts means the backing plate is not secured, and it will loosen and fall off during operation

C. The uniform short bolts do not engage the backing plate, which is a structural reinforcement that distributes the cutting loads across the full blade width — without the backing plate properly bolted, the blade may bend or crack from concentrated stress at the unsupported sections

D. The short bolts do not have sufficient thread engagement in the blade's tapped holes and will strip out under the dynamic loading of dozing operations

131. A mining shovel's dipper (bucket) teeth are available in two retention systems: a horizontal pin with a rubber retainer, and a vertical pin with a mechanical lock. The machine operates in hard rock where dipper teeth frequently break under impact. Which retention system makes field tooth changes faster?

A. The horizontal pin with rubber retainer — the pin is tapped out horizontally and the rubber retainer stretches to release without tools, allowing the tooth to drop free for immediate replacement

B. The vertical pin with mechanical lock is faster in the field because the pin can be tapped upward out of the tooth with gravity assisting the removal, and the mechanical lock provides positive engagement feedback that confirms the replacement tooth is fully seated

C. Both systems require identical time for field replacement because the pin removal and insertion steps are functionally equivalent regardless of pin orientation

D. Neither system is suitable for field replacement in hard rock — both require the dipper to be transported to the shop for tooth changes because the impact damage deforms the adapters beyond the fieldreplaceable threshold

132. A hybrid machine's energy management system decides whether to use the diesel engine, the electric motor, or both based on the instantaneous power demand and the battery's state of charge. During a loading cycle, the system switches between dieselonly and dieselpluselectric modes multiple times per minute. What determines the switching threshold?

A. The switching is based on a fixed engine RPM threshold — above the threshold, the electric motor assists; below it, the diesel operates alone

B. The switching is random — the energy management system alternates between modes at a fixed frequency to distribute wear equally between the diesel and electric power sources

C. The switching is based on a fixed battery SOC threshold only — above the threshold, the motor assists; below it, the diesel operates alone to allow the battery to recharge

D. The switching is determined by the realtime comparison of the current power demand against the optimal operating point of the diesel engine — when demand exceeds the engine's most efficient output, the electric motor supplements the deficit; when demand drops below the optimal point, the engine drives the generator to recharge the battery while providing the reduced mechanical output

133. A technician is servicing a batteryelectric machine and notices the HV battery pack's state of health (SOH) is displayed as 85%. The machine is 3 years old. The OEM projects the battery should reach 80% SOH at 8 years. Is this degradation rate concerning?

A. Yes — the battery has degraded faster than projected. At 85% SOH in 3 years, the degradation rate suggests the battery will reach the 80% endoflife threshold in approximately 4–5 years rather than the projected 8 years. The operating conditions (charging rate, depth of discharge, temperature exposure) should be reviewed to identify the accelerating factor

B. No — 85% SOH at 3 years is well within the OEM's projected degradation curve and the battery is on track to reach the 80% threshold at or near the 8year projection

C. Yes — but only if the machine operates in a hot climate where thermal degradation accelerates the chemical aging process beyond the OEM's baseline projection

D. No — SOH measurements are only accurate when performed by the OEM's diagnostic tool under controlled conditions, and the onboard display reading is an estimate that should not be used for degradation tracking

134. A batteryelectric machine's drive controller converts DC battery power to variablefrequency AC power to drive the traction motors. The controller uses highpower semiconductor switches (IGBTs) that

switch at frequencies of 5–20 kHz. What is a potential side effect of these highfrequency switching events on the machine's other electronic systems?

A. The highfrequency switching produces vibrations in the traction motor windings that generate audible noise (known as inverter whine) but has no effect on other electronic systems

B. The highfrequency switching draws large current pulses from the battery that reduce the battery's cycle life faster than DC loads of the same average power level

C. The highfrequency switching generates electromagnetic interference (EMI) that can couple into nearby CAN bus wiring, sensor circuits, and communication systems — producing signal noise that causes erratic readings or communication faults if proper shielding and filtering are not maintained

D. The highfrequency switching creates harmonic currents in the HV DC bus that heat the battery cables and connectors, requiring larger cable sizes than DC systems of the same power rating

135. A fleet operator is evaluating a hydrogen fuel cell powered mining truck against a batteryelectric equivalent. Both are zeroemission at the point of use. What is the primary operational advantage of the fuel cell machine over the batteryelectric machine for a large mining haul truck application?

A. The fuel cell machine produces higher peak power than the batteryelectric machine because the fuel cell's electrochemical reaction generates more instantaneous current than a battery can discharge

B. The fuel cell machine can be refuelled with hydrogen in approximately the same time as a diesel machine, providing nearcontinuous operation without the multihour charging time required for a batteryelectric machine — this refuelling speed advantage is critical for maximizing the machine's productive utilization in a 24hour mining operation

C. The fuel cell machine is lighter than the batteryelectric machine because hydrogen has a higher energy density than lithiumion batteries, allowing the fuel cell truck to carry more payload for the same gross vehicle weight

D. The fuel cell machine produces water as its only emission, which can be collected and used for dust suppression on the haul roads, providing a secondary operational benefit that offsets the higher fuel cost

Practice Exam 9: Answer Key and Explanations

1. A — Exhaust manifold and turbocharger surfaces retain extreme heat for an extended period after shutdown. Contact with these surfaces causes severe burns. The technician must either wait for the components to cool to a safe contact temperature or install temporary insulating barriers (heat blankets, shields) over the hot surfaces before positioning themselves to work in the confined engine compartment.

2. C — The correct fire response sequence is: alert other personnel, activate the fire alarm to initiate building evacuation, attempt to fight the fire only if it is small and contained and you have a clear escape route, and evacuate immediately if the fire grows beyond your ability to control it. Never continue fighting a growing fire — life safety always takes priority over property protection.

3. D — A suspended load must never be left unattended. Crane brakes can fail, rigging can shift, and environmental conditions (wind) can cause the load to swing. The technician must remain in control of the crane and maintain visual contact with the load at all times. If the technician must step away for any reason, the load must first be lowered to a safe resting position on the ground.

4. A — Used DOT 4 brake fluid is classified as hazardous waste under Canadian environmental regulations. It must be collected in approved containers, stored in the designated hazardous waste area, and disposed of through a licensed hazardous waste contractor. It must not be mixed with other waste oils, poured down drains, or placed in regular waste containers.

5. B — Operating a hydraulic press at 95% of its rated capacity provides almost no safety margin. If the pin suddenly releases, the stored energy in the compressed hydraulic fluid can launch the pin as a projectile. Any weakness in the press frame, cylinder, hoses, or fittings is most likely to manifest at near-maximum pressure. The technician should use a higher-capacity press or investigate why the pin requires more force than expected.

6. C — A torque wrench is calibrated for its specific handle length. Adding a cheater pipe increases the actual torque applied to the fastener beyond the wrench's indicated reading because the longer lever produces more torque per unit of force. The operator over-torques the fastener while the wrench reads within specification. Additionally, the excessive lever force can permanently damage the wrench's internal calibration mechanism.

7. D — The initial gas test was clean, but the oxygen level has dropped from 20.9% to 18.5% during the 20-minute entry. A displacement event is occurring — an oxygen-depleting source inside the tank is consuming or displacing the available oxygen. Possible sources include the tank's internal coating off-gassing an inert gas, biological activity in residual moisture, or an adjacent connected space releasing inert gas into the tank.

8. A — Underground welding requires additional controls beyond surface shop welding: specific authorization from the mine supervisor, a hot work permit, continuous atmospheric monitoring for toxic gases (carbon monoxide, nitrogen dioxide) and oxygen levels at the work location, and potentially additional local exhaust ventilation to remove welding fumes from the enclosed underground space where natural dispersion is limited.

9. C — A technician has a professional obligation to decline work that compromises machine safety. Exceeding the OEM maximum RPM creates risks including engine mechanical failure (connecting rod, valve train, turbocharger overspeed), voided warranty, and potential injury if a catastrophic failure occurs. The technician should explain the safety risks and document the refusal.

10. B — The meter's CAT III 600V rating is below the circuit's 650 VDC operating voltage. Using an underrated meter on a high-voltage circuit risks meter failure, arc flash, and potentially fatal electrical shock. A meter rated at CAT III 1000V (or higher) must be used to provide adequate protection against the voltage level and the transient energy present in HV battery systems.

11. D — A rhythmic idle surge with no DTCs and a steady throttle position sensor suggests the ECM's idle speed PID control loop is oscillating. The PID controller adjusts fuel delivery based on feedback from the crankshaft or camshaft speed sensor. If the feedback gain is incorrect, the sensor signal is unstable, or the ECM's idle calibration is corrupted, the controller overcompensates in alternating directions, producing the rhythmic surge.

12. A — The crankshaft thrust bearings (flanged main bearing set) control the crankshaft's axial position. At 0.65 mm — more than double the 0.30 mm maximum — the crankshaft can shift excessively during clutch engagement or torque converter loading. This movement damages the rear main seal, can cause the torque converter to lose pilot engagement, and produces audible clunking during directional changes.

13. C — The turbocharger oil drain relies on gravity flow. If the drain is restricted by carbon coke or a kinked hose, oil accumulates in the bearing housing because it cannot drain back to the sump at the rate it is supplied. The rising oil level contacts the turbine-side and compressor-side shaft seals from the

inside, overwhelms them, and forces oil into both housings — producing blue/white exhaust smoke and progressive oil consumption.

14. B — An OL (open circuit) reading on a component that should read 0.1 ohms confirms the heater element winding is broken — the circuit is interrupted and no current can flow. The intake air heater cannot preheat the intake charge. The operator will experience hard starting or complete failure to start in cold ambient conditions because the intake air temperature remains too low for reliable diesel autoignition.

15. D — Engine oil operates at higher pressure than the coolant in most operating conditions. An internal oil cooler failure (cracked tube, failed gasket, or corroded passage) allows the higher-pressure oil to be forced into the lower-pressure coolant circuit. The oil floats on top of the coolant and appears as a film in the overflow tank. The small volume may not produce a noticeable drop on the oil dipstick.

16. C — A refractometer confirms the urea concentration is correct, but DEF contamination with a foreign substance (fuel, coolant, water, or non-urea chemicals) can introduce compounds that the ECM's DEF quality sensor detects as non-compliant. Some contaminants do not significantly change the urea concentration reading on a refractometer but poison the SCR catalyst or trigger the quality sensor, producing the derate.

17. B — A fatigue fracture originating at a bolt hole stress concentration on the rod cap side is characteristic of a bolt that was not maintaining adequate clamping force. Undertorque allows the rod cap joint to flex cyclically under each combustion load — the alternating tension and compression at the bolt hole initiate a fatigue crack that propagates slowly until the remaining cross-section fails catastrophically.

18. A — A static pressure test at 103 kPa cannot detect a head gasket leak that only opens under the much higher combustion pressures (3,000–5,000 kPa) generated during loaded operation. Under load, the combustion pressure forces the gasket to separate at the weak point, allowing combustion gas to enter the cooling circuit and displace coolant. The intermittent nature correlates with load — the leak seals when the engine is unloaded.

19. C — New injectors shipped from the manufacturer may contain a preservative oil coating inside the nozzle bores that protects the precision surfaces during storage and shipping. This oil burns off during the first few minutes of engine operation, producing temporary visible exhaust smoke. Once the preservative is consumed, the smoke clears and does not return. This is a known and expected behaviour.

20. D — Late-post injection occurs during the exhaust stroke when the piston rings have minimal sealing contact with the cylinder wall. Excessive late-post fuel passes the rings and drains into the crankcase, progressively diluting the engine oil with diesel fuel. The fuel dilution reduces oil viscosity and load-carrying capacity. If uncorrected, the thinned oil causes bearing failure.

21. B — The ECM commands maximum fan speed as a protective default when a critical input sensor fails in a value that appears valid but indicates a condition requiring maximum cooling. No fault code is generated because the sensor's electrical output is within its valid range — the value is simply incorrect. A coolant temperature sensor failed at a high resistance (cold reading) that requires maximum cooling is a common cause.

22. A — A metallic knock at idle that disappears above 1,200 RPM and is not affected by cylinder cut-out testing points to piston pin (wrist pin) clearance. At idle, the low gas loading and low piston inertia allow the loose pin to rattle as the piston changes direction at TDC and BDC. At higher RPM, increased combustion force and piston inertia hold the pin against one side of the bore, eliminating the knock.

23. D — Large diesel engines can develop a flammable atmosphere inside the crankcase from the mixture of oil mist and blowby gases. A hot spot — such as a failing bearing, a broken piston, or an overheated component — can ignite this mixture, producing a crankcase explosion. The relief valve opens instantly to vent the pressure wave, preventing catastrophic rupture of the crankcase, oil pan, or block.

24. C — Cranking speed is typically low enough that the HP pump's output per stroke is adequate if all components are functioning correctly. A rail pressure of 180 bar (vs. 250–300 bar specification) at cranking suggests the HP pump is not receiving enough fuel per pumping stroke. The inlet metering valve — which controls the volume of fuel entering the pump — stuck partially closed limits the fuel supply and therefore the achievable rail pressure.

25. B — A fully open EGR valve recirculates a large volume of exhaust gas back to the intake, displacing fresh air. The exhaust gas that is recirculated has already expanded through the turbine and carries less energy than fresh exhaust. The recirculated gas also bypasses the turbine, reducing the total exhaust energy available to drive the turbocharger. The turbocharger cannot produce commanded boost with insufficient exhaust energy.

26. A — Valve guide seals primarily prevent oil from entering the combustion chamber, but severely worn valve guides also allow a small amount of combustion gas to leak past the valve stem during the compression and power strokes. This blowby pathway bypasses the piston rings entirely and is not

detected by compression or leak-down tests, which measure only the cylinder-to-crankcase seal at the piston ring level.

27. D — Steadily increasing copper in oil analysis following an overhaul points to a component installed during that overhaul. Connecting rod bearings with a copper-lead intermediate layer are the most common high-copper source. If the overlays were incorrectly applied during remanufacturing or the bearing clearances are too loose, the soft overlay wears through early, exposing the copper layer to the oil.

28. B — One cylinder running significantly hotter with a confirmed-correct fuel delivery and valve lash isolates the cause to a cylinder-specific airflow issue. A restricted intake port — from a gasket tab, carbon buildup, or casting flash — reduces the incoming air charge for that cylinder only. The reduced air volume creates a locally rich fuel-to-air ratio that burns hotter and produces the elevated exhaust temperature.

29. C — Gasoline has significantly lower lubricity than diesel fuel. The fuel injection system's precision internal components — the high-pressure pump plungers, the delivery valves, and the injector needle seats — rely on diesel fuel's lubricating properties for their protection. Even 30 seconds of operation on gasoline can score or seize these precision surfaces. The entire fuel system must be drained, flushed, and inspected.

30. A — In an electronic unit injector system, the solenoid controls both the start and end of injection. When the solenoid fails to de-energize, the injector remains open for the full remaining camshaft actuation period — delivering significantly more fuel than the ECM commanded. The over-fuelled cylinder produces excessive cylinder pressure, smoke, and a power imbalance that can be destructive if sustained.

31. C — The HMU, steering valve, and cylinders all test within specification, ruling out the hydraulic circuit. Steering wander during straight-line travel points to mechanical play in the steering linkage. Worn tie rod ends, drag links, ball joints, or king pins allow the steered wheels to shift randomly in response to road surface irregularities faster than the hydraulic centering system can correct.

32. D — A sudden complete loss of steering indicates total failure of the hydraulic fluid supply to the steering circuit. The most immediate cause is a pump drive failure — a broken coupling, sheared shaft, or failed drive gear physically disconnects the pump from the engine. A seized pump would also stop flow but would typically produce warning noise before complete failure.

33. A — All components wearing within approximately 25% of each other at the 5,000-hour inspection indicates balanced undercarriage wear. The machine has been operated with correct track tension and in material conditions appropriate for its design. The components will reach their end-of-life at approximately the same time, which maximizes the return on the undercarriage investment by minimizing wasted component life.

34. B — The brake accumulator low-pressure warning means the stored hydraulic energy available for emergency braking is below the certified minimum. If the engine stalls or the pump fails during operation, the machine may not have sufficient stored energy to stop safely. The machine must be parked immediately and not operated until the accumulator system is diagnosed and restored to full capacity.

35. C — The circle drive worm gear mesh has worn, reducing the positive tooth engagement needed to hold the blade position under load. During grading, the side-loading forces on the blade fluctuate as material passes under the cutting edge. The worn gear teeth cannot maintain positive engagement under these varying loads — the gear alternately grips and slips at each tooth, producing the jerky, intermittent rotation.

36. D — The parking brake hydraulic release circuit contains a check valve or slow-return orifice that is designed to allow controlled release timing. However, this feature retains hydraulic oil in the brake piston chamber after the release command is removed. During a rapid reapplication, the trapped oil partially resists the spring force, reducing the net clamping force below the level needed to hold the machine on the grade.

37. B — Multiple consecutive track shoe cracks originating at bolt holes indicate fatigue failure from impact loading. Operating on frozen ground (which is as hard as rock) subjects each shoe to extreme impact forces at the bolt hole stress concentrations during every ground contact. The cyclic impact loading exceeds the shoe material's fatigue endurance limit and initiates cracks that propagate to failure.

38. A — A humming noise during straight-line travel that does not change during turns isolates the source to a component whose operating conditions are identical in both modes. The ring and pinion gear mesh rotates at the same speed and carries the same load whether the differential is locked (straight travel) or differentiating (turning). The spider gears only rotate during turns — since the noise does not change, the spider gears are not the source.

39. D — The system charges to full pressure and the warning activates only during heavy brake applications. This indicates the reservoir volume is insufficient to maintain pressure above the 380 kPa

warning threshold during the air volume consumed by a heavy application. The reservoirs may be undersized for the brake chamber configuration, or the heavy application is consuming more air than the system was designed to deliver.

40. C — The 40 mm sag is within the OEM specification of 25–50 mm and the track is correctly adjusted. However, the technician should investigate why the track was so loose (was the tensioner leaking grease? had the recoil spring failed?). The adjustment should be rechecked after 50 hours of operation as the new tension settles. The question asks only whether the adjustment itself is complete — at 40 mm within spec, it is.

41. B — A brake shudder during moderate application that is absent during light and heavy application is the classic symptom of a warped brake disc. At light pressure, the pad force is insufficient to follow the disc distortion. At heavy pressure, the clamping force overcomes the warp and maintains contact. At moderate pressure, the pad alternately contacts and separates from the warped surface, producing the pulsating shudder.

42. A — A steep slope creates a sustained gravitational side-load on the downhill track chain that acts perpendicular to the chain's travel direction. This side force pushes the chain laterally against the roller and idler flanges. If the force exceeds the lateral guidance capability of the worn flanges, the chain walks sideways off the running gear on the downhill side.

43. C — Marine or coastal salt spray, de-icing salt, corrosive mine water, and chemical processing runoff attack unprotected steel surfaces aggressively. The pivot pin, partially shielded by the bushings, retains moisture and corrosive agents in the pin-to-bushing interface where it cannot dry. The sustained wet-chemical contact corrodes and pits the pin surface, destroying the bearing surface.

44. D — SAHR brake disc pack clearance exceeding the maximum specification means the spring-applied piston must travel further than designed before clamping the discs. The springs lose mechanical advantage over the additional travel distance, reducing the effective clamping force at the disc contact point. The weakened clamping force compromises both the parking brake holding capacity and the emergency brake stopping capability.

45. A — New idler bearings have a factory-set preload that produces noticeable drag when the idler is rotated by hand. This preload is intentional — it ensures the bearing rollers maintain contact with the races during the varying loads of track operation. A new idler that spins completely freely has zero preload and will experience roller skidding, accelerated race wear, and premature failure.

46. B — When the brake pedal reaches its mechanical stop before full braking force is developed, the hydraulic circuit is consuming more pedal travel than designed. The root cause is within the brake system — worn pads (more piston travel needed), air in the circuit (compressible), or master cylinder bypass (internal fluid loss) are the primary causes. The condition must be diagnosed because the brakes cannot develop full clamping force.

47. B — The engine starts during cranking (proving fuel, compression, and injection are functional) but dies immediately when the key moves to RUN. This isolates the fault to a circuit that is active in the START position but inactive in the RUN position. The ECM's power supply through the RUN circuit is the critical path — if the keyswitch, relay, or fuse serving the RUN-position power does not deliver voltage to the ECM, the ECM shuts down.

48. A — In a series battery configuration, the alternator maintains total system voltage. If Battery B has a weak cell that limits its voltage acceptance, Battery A absorbs the excess charging voltage to maintain the system total. The 14.2V/11.8V split confirms Battery B cannot accept a full charge — likely from a sulfated plate, internal short, or material shedding in one cell. Battery B should be replaced.

49. D — When the ECM's internal temperature exceeds its programmed threshold, the module enters a protective strategy to prevent permanent damage to its electronic components. The ECM typically reduces its processing load, disables non-essential functions, and may reduce engine power to lower the heat produced by the engine-mounted module. This protects the module until the temperature drops below the safe operating limit.

50. C — A voltage drop of 1.2V on the ground path between the starter housing and the battery negative terminal — with a maximum specification of 0.5V — confirms excessive resistance in the ground circuit. This resistance consumes 1.2V of the available battery voltage, reducing the voltage powering the starter motor. The high-resistance point must be located and corrected (typically a corroded connection, loose ground strap, or damaged cable).

51. B — Partial bus communication (engine ECM responds but transmission ECM does not) with correct termination and power to both modules suggests the CAN bus wiring is intact at both ends but interrupted in between. An open wire, corroded splice, or damaged connector on the bus segment between the two ECMs isolates the transmission ECM from the diagnostic connector while the engine ECM (on its side of the break) communicates normally.

52. A — The key fob battery is confirmed adequate, and the security fault message confirms the immobilizer system has detected a problem. The immobilizer antenna — the transponder reader near the

key receptacle — is the next component to check. If the antenna cannot read the key fob's encrypted signal, the immobilizer cannot verify the key's authorization and blocks the starter circuit.

53. D — The diagnostic tool accesses all modules through the standard diagnostic port (proving the main CAN bus and gateway are functional). The display shows "NO DATA" (proving the display cannot receive data). The fault is in the dedicated CAN bus segment between the gateway's display port and the display module — an open wire, damaged connector, or broken pin on this specific wiring path.

54. B — The DMM confirms 60% duty cycle is reaching the solenoid connector, and the solenoid coil is receiving the correct electrical command. The solenoid's failure to respond proportionally despite a correct signal points to a mechanical failure. A broken return spring eliminates the opposing force that determines the proportional position — without it, any command above the minimum threshold drives the spool to full open.

55. C — A stable signal at idle and full throttle with momentary dropouts in the 40–70% travel zone indicates the potentiometer's resistive track has a worn or damaged section in that specific area. The wiper loses contact with the track as it crosses the worn zone, producing the brief 0V signal dropout. The stable readings at idle and full throttle confirm the track is intact at those positions.

56. D — Elevated AC ripple (1.8V vs. 0.5V maximum) on the DC output of a three-phase alternator confirms one or more rectifier diodes have failed. The failed diode allows its unrectified AC waveform component to pass through to the DC output. This AC ripple can corrupt CAN bus signals, damage ECMs, cause erratic gauge readings, and reduce battery life from the pulsating charge current.

57. A — Many VGT and wastegate actuators require a calibration or initialization procedure through the OEM diagnostic software after an ECM replacement. The new ECM must learn the actuator's physical position endpoints (fully open and fully closed) to correctly command intermediate positions. Without this calibration, the ECM cannot determine the actuator's current position and will not command movement.

58. B — After a full equalization charge, all cells in a healthy battery should reach approximately the same specific gravity. Cell 3 at 1.210 (while all others read 1.270) after equalization confirms that cell cannot reach the same charge level. The cell has a permanent deficiency — sulfated plates, internal short, or material shedding — that limits its capacity. Battery B must be replaced.

59. C — At 20% duty cycle and 80% duty cycle, the solenoid current should differ proportionally — a higher duty cycle produces higher average current through the coil. A constant 0.4A reading at both duty

cycles confirms a resistance bottleneck in the circuit that limits the maximum current regardless of the duty cycle command. A corroded connector, damaged wire, or poor crimp is capping the current at 0.4A.

60. D — The communication errors correlate directly with the heater at maximum setting. At maximum, the heater motor draws its highest current. The resulting current draw can cause a voltage dip on the machine's power bus that momentarily drops the CAN bus module supply voltages below their minimum operating threshold, causing the modules to drop off the bus briefly and produce the communication errors.

61. A — At 50% duty cycle, the solenoid spool is commanded to a mid-stroke position where the electromagnetic force and the return spring force are balanced. The PWM switching alternately applies and removes the magnetic force at the switching frequency, causing the spool to vibrate at that frequency — producing the audible buzz. At 0% and 100%, the spool is firmly held at its mechanical stop and does not vibrate.

62. C — Over 200 occurrences of "battery voltage low" over 1,000 hours with a currently functional battery and charging system suggests an intermittent connection. A loose terminal, corroded cable end, or failing disconnect switch can briefly drop the ECM's supply voltage during specific conditions such as vibration, thermal expansion, or high electrical load. The intermittent connection must be found before it becomes permanent.

63. B — The IVS provides confirmation to the ECM that the throttle pedal is at idle. If the IVS fails in the open (not-at-idle) state while the pedal is at idle, the ECM receives conflicting signals — the APPS says idle but the IVS says not-at-idle. The ECM may limit fuel delivery to protect against an unintended acceleration condition, producing a derate or elevated idle.

64. D — The switch closes at 360 kPa (specification 350, deviation +10), opens at 330 kPa (specification 280, deviation +50), and the measured hysteresis is 30 kPa (specification 70 kPa). The closing point is slightly above specification, the opening point is significantly above specification, and the hysteresis is less than half the designed value. All parameters are out of specification and the switch must be replaced.

65. A — The transmission ECM is physically connected to the implement bus, not the engine bus. The diagnostic tool connected to the engine port can only access modules on that bus segment (and any modules the gateway routes through that port). To access the transmission ECM, the diagnostic tool must be connected to the implement bus port where the transmission ECM resides.

66. B — Telematics provides the dealer remote access to the machine's diagnostic data — specific DTCs, freeze frame data, current operating parameters, and fault history. This allows the service department to diagnose the derate remotely, determine whether the machine can safely travel or requires field service, and dispatch the correct parts and tools on the first trip — potentially saving a 600 km round trip.

67. D — The 5V reference drops to 4.1V when only the coolant temperature sensor is connected, confirming that sensor is loading the reference excessively. A sensor with a short to ground or an internal low-resistance fault creates a low-resistance path that draws excessive current from the shared 5V reference, pulling the voltage down. This affects all three sensor readings when all are connected.

68. C — Intermittent CAN bus faults that correlate with afternoon heat point to a temperature-sensitive connection. A marginal contact — a corroded pin, cold solder joint, or loose crimp — expands at elevated temperature, opening the contact enough to disrupt communication. As the temperature drops in the evening, the metal contracts, the contact is restored, and communication resumes normally.

69. A — A Hall-effect sensor produces a constant-amplitude digital square wave. If the signal degrades (rounded edges, reduced amplitude) at higher speed, the reluctor teeth are passing the sensor faster than the sensor's internal electronics can switch between high and low states. The sensor is being driven beyond its maximum frequency rating, and either the sensor specification is incorrect for the application or the reluctor tooth count is too high.

70. B — The fuel shutoff solenoid has a pull-in winding (high force, high current) and a hold-in winding (low force, low current). When the solenoid reaches full open, the main contacts short out the pull-in winding (as designed), and only the hold-in winding maintains the magnetic field. If the hold-in winding is open-circuit, no current flows through it, the magnetic field collapses, and the return spring closes the solenoid immediately.

71. C — The instrument cluster fuse is intact, but the cluster needs both a power supply and a ground return to operate. The fuse confirms the fuse-protected supply wire is intact, but the ground path and the ignition-switched power input must be verified at the cluster connector. A failed ground or a missing switched-power signal prevents the cluster from initializing its display.

72. D — The engine reaches governed speed but the machine does not move despite a gear being selected. The torque converter turbine hub spline has stripped — the turbine rotates freely inside the converter housing without transferring any torque to the transmission input shaft. The converter pump

spins at engine speed and the fluid circulates, but the stripped spline prevents the turbine from driving the transmission.

73. C — Correct manual shifts prove the clutch packs, valve body, and hydraulic circuits are functional. The erratic automatic shifts must originate in the automatic control system — the input signals that tell the TCM when to shift (speed sensors, throttle position, load sensors) or the TCM's shift logic that processes those inputs. Manual mode bypasses these inputs, which is why manual shifts are correct.

74. A — Gear ratio = driven gear teeth ÷ driving gear teeth = 43 ÷ 11 = 3.909:1, rounded to 3.91:1. The pinion (driving gear with 11 teeth) must rotate 3.91 times for each single revolution of the ring gear (driven gear with 43 teeth). This ratio multiplies the driveshaft torque by 3.91 while reducing the output speed by the same factor.

75. B — A 0.05 mm out-of-round carrier housing bore prevents the carrier bearings from seating concentrically. The ring gear — bolted to the carrier — runs at a fixed off-centre position determined by the oval bore. This shifts the gear mesh to one side of the tooth face, concentrating the contact pattern on the heel or toe and accelerating wear from the uneven loading.

76. D — Loss of a motor speed sensor reduces the ECM's ability to precisely control that motor's speed. The typical response is a reduced-capability mode — the ECM limits maximum speed to prevent uncontrolled acceleration on the sensorless side, may disable steering functions that require precise left-motor speed feedback, and alerts the operator. Basic forward and reverse travel remains available.

77. C — Asymmetric wear — one side glazed and discoloured while the opposite appears normal — indicates uneven clamping across the disc. A warped pressure plate, a worn diaphragm spring with uneven finger heights, or uneven flywheel surface finish concentrates the clamping force on one face of the disc. That face overheats from the concentrated friction while the opposite face carries insufficient load.

78. B — A new gear whine that appeared immediately after an oil change with correct viscosity suggests the replacement oil does not contain the EP additive package specification required for the gear set. The viscosity may match, but the EP additive level, type, or the API gear oil classification may differ. The insufficient EP additive reduces the lubricant film strength under the loaded gear mesh, producing the noise.

79. A — With the lockup clutch engaged, the engine is mechanically connected to the transmission input shaft. During a directional shift, the transmission must reverse the driveline rotation. The locked

converter cannot absorb the torque reversal — the full engine inertia and driveline momentum transmit directly through the drivetrain as a severe shock load that can damage clutch packs, driveshafts, and axle components.

80. C — Backlash that varies between 0.15 mm and 0.35 mm over one ring gear revolution confirms the ring gear is running eccentrically. The cause is either the ring gear not seated squarely on the differential case (loose bolts, contamination under the gear), worn carrier bearings allowing the carrier to shift, or a warped ring gear. The variable backlash produces cyclical noise, vibration, and uneven tooth loading.

81. D — Elevated modulation pressure increases the rate at which the clutch apply piston fills and engages the clutch pack. The faster pressure rise reduces the controlled-slip period that the modulation is designed to provide. The clutch engages abruptly rather than progressively, transmitting a harsh shock through the drivetrain that the operator feels as a hard, jerky shift.

82. A — On a full-floating rear axle, several components at the hub area contain oil and have seal interfaces. The hub seal (between the rotating hub and the stationary spindle), the axle shaft flange gasket or O-ring (between the flange and the hub), and the hub bearing cap gasket are all potential oil leak sources. Each must be inspected to determine the specific leak point.

83. B — Stall speed should be identical in all gear ranges because the torque converter's resistance to the engine is determined by the converter's internal characteristics — not by which downstream gear is engaged. At stall, the turbine is stationary regardless of the engaged gear. A lower stall speed in 3rd gear indicates an additional resistance source specific to 3rd — such as clutch drag or mechanical binding in the 3rd gear power path.

84. C — Iron originates from the hardened steel components — gears, shafts, and bearing races. Aluminum originates from bearing cages (retainers), thrust washers, or the case casting. A simultaneous increase in both metals suggests a bearing cage failure — the aluminum cage disintegrates, releasing both aluminum fragments and steel needle rollers or roller elements into the oil.

85. D — Full forward drive with zero reverse drive and correct charge pressure isolates the fault to a component specific to the reverse direction. The reverse cross-port relief valve stuck open dumps all pump output pressure intended for the reverse motor port back to the low-pressure return side of the loop. No pressure reaches the motor in reverse, but forward operation uses a separate cross-port relief and functions normally.

86. A — Noise in all forward gears that is absent in reverse and neutral points to a component that is loaded only when a forward gear is engaged. The forward clutch pack bearing (which carries the load whenever any forward gear is active) meets this criterion — it is loaded in 1st, 2nd, 3rd, and 4th forward but not in reverse or neutral. The speed-proportional rumble confirms it is a rotating component.

87. C — Air-free bleed fluid with persistent sponginess points to a component that absorbs pedal travel without releasing air. A deteriorated flexible hydraulic hose expands outward under application pressure, absorbing a portion of the master cylinder's fluid displacement. The aged hose balloons with each application, consuming pedal travel that should be moving the slave cylinder piston, producing the spongy feel.

88. B — The solenoid clicks (confirming the electrical command is reaching the solenoid and the solenoid armature is moving), but the front axle does not engage. The click proves the solenoid's electrical circuit is functional. The next component in the chain is the vacuum supply — if the vacuum source is insufficient (leaking hose, weak engine vacuum, or failed vacuum reservoir), the actuator cannot develop enough force to physically shift the fork against the return spring.

89. A — A worn compressor that cannot develop the full pressure differential between high and low sides produces the characteristic pattern of slightly-above-normal low-side and slightly-below-normal high-side. The compressor generates some compression (enough for partial cooling at 18°C) but lacks the capacity to pull the low side down to its design pressure or push the high side up to its design pressure for full cooling.

90. D — Ice forming on the liquid line near the receiver-drier indicates a restriction at or inside the drier. The pressure drop across the clogged drier drops the refrigerant temperature below the dew point (and potentially below freezing) on the downstream side. The restriction also limits refrigerant flow to the expansion device, which will progressively reduce cooling capacity as the restriction worsens.

91. C — The rain/debris separator's drain allows accumulated water and large particles to exit the separator housing before reaching the paper cabin air filter. A blocked drain traps water and debris inside the separator — as the level rises, the accumulated water and debris overflow into the paper filter element, saturating it with water. The wet filter severely restricts airflow, reducing cab pressurization and clogging the element prematurely.

92. A — A properly charged system should show clear liquid in the sight glass at the rated engine speed where the compressor produces its designed flow. At idle, the reduced compressor speed and flow can

cause momentary flash gas (bubbles) in the liquid line — this is a normal condition that does not indicate undercharge. The charge should be verified by weight, not by the sight glass at idle.

93. D — A no-flame lockout is a critical safety response. If flame is not established within the designed start sequence, the module stops fuel delivery, purges the combustion chamber with the air blower to remove any unburned fuel vapour, and locks out further start attempts. This prevents the dangerous accumulation of unburned fuel that could ignite in an uncontrolled manner during a subsequent start attempt.

94. B — Variable-displacement compressor control solenoids typically energize to reduce (destroke) the compressor displacement from its maximum mechanical default. Without the control signal, the compressor's internal spring returns the swashplate or wobble plate to its maximum displacement position. The compressor runs at full capacity continuously until the solenoid wire is reconnected.

95. C — Positive cab pressure acts on the entire interior surface area of the cab door. Even at 75 pascals (a seemingly small pressure), the total force on a large cab door can be significant. Force = pressure × area: a door measuring 0.8 m × 1.5 m = 1.2 m^2 at 75 Pa = 90 newtons (approximately 20 lbs) of force resisting the door opening.

96. A — The VGT exhaust brake closes the variable geometry vanes to restrict the exhaust flow, creating high back-pressure in the exhaust manifold that resists the engine's rotation. The pressurized exhaust gas forced through the narrowed vane openings produces the characteristic roaring noise — this is a normal byproduct of the exhaust brake's designed function and is not indicative of a fault.

97. B — With the recirculation door stuck in the recirculation position and no fresh air entering the cab, the operator's exhaled CO_2 progressively accumulates while oxygen is consumed. Elevated CO_2 causes drowsiness, reduced alertness, headaches, and impaired cognitive function. This is a direct safety hazard — the operator may become impaired while operating the machine. The actuator must be repaired immediately.

98. D — A load-sensing pump's compensator adjusts the swashplate based on the LS signal. If the compensator spring has weakened, the pump oscillates between the compensated (destroked) and full-stroke states because the weakened spring cannot maintain a stable equilibrium. The pump's swashplate surges back and forth at the compensator's response frequency, producing the rhythmic pressure oscillation.

99. B — The theoretical motor speed at 100 L/min with 280 cm^3/rev displacement is (100 × 1,000) ÷ 280 = 357 RPM. The actual measured speed of 320 RPM is lower because internal leakage allows 10.4% of the supplied flow to bypass through the motor's clearances without producing shaft rotation. Volumetric efficiency = (320 ÷ 357) × 100 = 89.6%, which is below the typical 92–95% minimum for a healthy motor and indicates the motor is approaching the rebuild threshold.

100. C — The pilot-operated relief valve uses the pilot circuit to modulate the main poppet. The blocked orifice in the remote-control pilot circuit only affects the remote-control function that lowers the relief setting below the main spring's maximum. Without the remote signal, the valve simply operates at its main spring's full setting — which is the designed maximum system pressure.

101. A — The cylinder bypass test at full extension with no flow from the disconnected rod port confirms the piston seals are not allowing oil to cross from the cap end to the rod end internally. The cylinder is leak-free. The drift must originate external to the cylinder — the DCV spool, a pilot-operated check valve, or any circuit component between the DCV and the cylinder that allows cap-end oil to leak back to tank.

102. D — A rebuilt motor that grinds in reverse only at high displacement points to an internal assembly error that produces mechanical interference in one direction. Installing the cylinder barrel backward (180 degrees rotated) is a common assembly error that produces correct operation in one direction (where the port timing aligns) but mechanical interference or incorrect timing in reverse, generating the grinding noise.

103. B — With a 70-bar pre-charge and a 200-bar maximum operating pressure, the gas compresses from its pre-charge volume to approximately one-third (70/200) at maximum pressure. This extreme compression may fully compress the bladder against the gas valve end of the housing, extruding rubber into the valve opening. The repeated extrusion and retraction at each pressure cycle fatigue the bladder material rapidly.

104. C — The POCV has been tested and confirmed leak-free — it is blocking the line between the DCV and the cylinder. However, the POCV cannot prevent leakage across the piston inside the cylinder. Internal piston seal bypass allows oil to cross from the pressurized cap end to the unpressurized rod end, reducing cap-end volume and allowing the load to drift down despite the external circuit being locked.

105. D — A dual-circuit brake system provides redundant braking on separate axles. If one circuit develops a leak, rupture, or component failure, the other circuit continues to provide full braking on its

assigned axle. The machine can still be stopped safely — with reduced total braking force but with at least one axle fully functional — rather than experiencing complete brake failure.

106. A — The differential pressure gauge reads 2.8 bar of the 3.5-bar bypass threshold — 80% of the clogging limit. The element has captured significant contamination and is approaching the point where the bypass valve will open. The element should be replaced at the next convenient service opportunity to prevent the bypass from opening during operation, which would allow unfiltered oil to circulate through the system.

107. B — Both pumps and motors test within their individual specifications, but even a small displacement difference between the left and right motors (each within its own tolerance but different from each other) produces a consistent speed differential. The motor with the larger displacement turns slower per litre of flow, and the machine drifts toward the slower side.

108. C — The thermostat bypass valve controls the proportion of oil that flows through the cooler versus the bypass. If the valve is stuck partially in the bypass position, a portion of the hot oil always bypasses the cooler — even at high temperatures when all oil should flow through the cooler. The reduced effective cooling capacity produces the consistently elevated temperature.

109. D — The cap-end restrictor limits the maximum flow entering the cylinder during extension, controlling the maximum extend speed. Without the restrictor, the full pump flow reaches the cap end unrestricted, and the cylinder extends faster than designed. The unrestricted speed may exceed the safe operating speed for the boom or implement, creating a safety hazard.

110. A — In a pilot-operated hydraulic system, the pilot pressure physically shifts the main DCV spools. Without pilot pressure (pilot pump failure), the DCV spool centering springs hold all spools in neutral — no spool can be shifted regardless of the operator's joystick input. All implement functions become unresponsive even though the main pump continues to produce flow and pressure.

111. C — A relay valve stuck in the applied position continues to deliver stored air from the rear reservoir to the brake chambers after the foot valve has exhausted its control signal. The rear brakes remain applied even when the operator releases the pedal. The front brakes (on a separate circuit) release normally, creating a dangerous imbalance that drags the rear axle.

112. D — The pump has a fixed total flow output. During simultaneous operation of two parallel circuits, the total flow is divided between them based on their individual resistances. Circuit B consumes

approximately half the pump's output, leaving only half for Circuit A. This flow-sharing is the fundamental limitation of parallel circuits supplied by a single fixed-displacement pump.

113. B — Two consecutive motor shaft seal failures on correctly specified motors point to a common external cause. The most common root cause is a restricted case drain line. If the case drain cannot flow freely (from a restriction, a kinked hose, or a line routed higher than the motor), back-pressure builds inside the motor housing and forces oil past the shaft seal — the weakest seal in the motor housing.

114. A — A cylinder that extends fully but stops 25 mm short of full retraction points to a restriction that worsens at the extreme retract position. The rod-end supply hose routing changes as the cylinder retracts — the hose bends to its tightest angle at full retraction. A hose with an internal liner collapse or a pinched section restricts flow at this extreme bend angle, preventing the last 25 mm of travel.

115. D — The air dryer desiccant cartridge has been in service 50% beyond its replacement interval. The saturated desiccant has been passing moisture into the brake system for the extended period. Moisture accumulation in reservoirs, valves, and chambers produces valve malfunction from corrosion and seal degradation, and creates a high risk of freeze-related brake failure when the machine operates in cold weather.

116. C — The cooler is clean, the fan is running, and the fan airflow appears adequate — yet the temperature is 15°C above normal. A thermostatic bypass valve stuck partially in the bypass position diverts a portion of the oil around the cooler even at temperatures that should command full cooler flow. The reduced effective cooling capacity produces the consistently elevated temperature.

117. B — A slow charge pressure oscillation during steady-state operation with all other parameters stable points to the charge pump. A worn gear or gerotor element with a developing clearance produces slightly variable output per revolution. The variable output creates the slow pressure oscillation as the worn area of the pumping element cycles through the discharge zone.

118. A — A suction line valve partially closed restricts the oil flow to the pump inlet. The pump must draw oil through the restriction, creating a vacuum at the inlet. If the vacuum exceeds the oil's vapour pressure, cavitation occurs — producing noise, aerated oil, accelerated pump wear, and reduced output flow. The valve must be fully opened to provide unrestricted suction flow.

119. D — Before adjusting the pre-charge, the technician must verify the ambient temperature relative to the OEM's reference temperature. Nitrogen gas pressure changes with temperature — the 95-bar

reading at the current ambient may already equal 100 bar at the OEM's reference temperature if the current temperature is cooler than the reference. The OEM's temperature correction chart must be consulted before any adjustment is made.

120. B — An external pilot oil leak reduces the pilot pressure available to shift the affected DCV spool. The leaking pilot circuit cannot build full pressure on the pilot piston, which limits how far the spool shifts and therefore how much flow reaches the actuator. The actuator speed is reduced proportionally to the pilot pressure loss at that specific DCV section.

121. C — The system working pressure has increased from 250 to 300 bar without any changes to the machine. The most common explanation for elevated working pressure in a load-sensing system is that the LS margin (the pressure differential the pump maintains above the load signal) has drifted upward. A stuck or contaminated LS compensator spool adds more margin than designed, increasing the total supply pressure.

122. A — A spiraling layline indicates the hose is twisted. The technician must hold one end fitting stationary and rotate the opposite end until the layline runs straight along the entire hose length before tightening the fittings. A twisted hose has dramatically reduced fatigue life because the torsional stress on the reinforcement layers was not part of the hose's pressure rating design.

123. B — Before any repair is attempted, the crack must be fully documented: exact location on the boom structure, length, orientation (transverse, longitudinal, or diagonal), depth (surface or through-thickness), and whether the crack terminates in a weld zone or extends into parent metal. This information determines the repair method — simple overlay, full excavation and re-weld, or engineering assessment. Incomplete documentation may lead to an inadequate repair.

124. D — A deployed pyrotechnic pretensioner cannot be reset or reused. The deployment event subjects the belt webbing, retractor mechanism, and anchor points to forces that may have exceeded their designed single-event capacity. The entire seat assembly — including belt, retractor, and pretensioner — must be replaced as a complete unit to ensure the restraint system meets its certified protection level for a subsequent event.

125. A — A weighted test lift was performed successfully, but the attachment tilts during the first digging cycle. The front hook or cradle of the coupler has worn to a point where it captures the front pin under static (vertical) load but cannot maintain a secure grip under the dynamic multi-directional loads of digging. The worn front hook allows the front pin to slide forward and the attachment tilts as it partially disengages.

126. C — Additional wear strips (chocky bars, wear buttons, or weld-on wear elements) installed at the high-wear zones on the sidewall interior provide sacrificial protection for the base plate. These elements are individually replaceable when worn — far less expensive and time-consuming than replacing the entire sidewall plate. They protect the base structure by absorbing the abrasion and impact contact.

127. B — Grinding marks 2–3 mm deep on the ROPS tube surface create stress risers — sharp notches in the tube wall that concentrate stress during loading. Under a rollover event or even normal vibration, these stress risers can initiate fatigue cracks. The marks must be blended smooth to eliminate the sharp profile, and the remaining wall thickness must be verified against the ROPS tube's minimum specification.

128. A — A hydraulic thumb that has gradually slowed with no changes to the supply circuit points to progressive internal wear. The thumb cylinder's piston seals deteriorate over time, allowing increasing internal bypass — fluid crosses the piston rather than pushing it. A cylinder bypass test (pressurizing one port and checking for flow at the other) confirms the diagnosis.

129. D — A ROPS that has been involved in a tip-over must be assessed by the OEM or a qualified structural engineer before the machine returns to service. Even without visible deformation, the tip-over may have loaded the structure to a level that created internal stress, micro-cracking at weld joints, or fastener deformation that is not visible externally but compromises the ROPS certification for a subsequent event.

130. C — The mixed bolt pattern secures both the cutting edge and the backing plate. The long bolts clamp through the cutting edge, blade, and backing plate — securing the plate as a structural reinforcement that distributes cutting loads across the blade width. Using all short bolts leaves the backing plate unsecured, and the blade loses the load distribution that prevents bending or cracking at the unsupported sections.

131. B — The vertical pin with mechanical lock offers faster field replacement in the mining environment. The pin can be tapped upward with gravity assisting removal (or downward for installation), and the mechanical lock provides positive engagement feedback — an audible or tactile click that confirms the replacement tooth is fully seated. This positive confirmation is critical in a high-production environment where incomplete installation risks catastrophic tooth loss.

132. D — The energy management system compares instantaneous power demand against the diesel engine's optimal efficiency point in real time. When demand exceeds the engine's most efficient output,

the electric motor supplements the deficit. When demand drops, the engine operates at its efficient point while the excess mechanical output drives the generator to recharge the battery.

133. A — At 85% SOH in 3 years, the battery is degrading at approximately 5% per year — significantly faster than the OEM's projected 2.5% per year (reaching 80% at 8 years). At this rate, the battery will reach the 80% end-of-life threshold in approximately 4–5 years. The operating conditions should be reviewed to identify the accelerating factor — charging rates, depth of discharge, and temperature exposure.

134. C — High-power IGBT switches operating at 5–20 kHz generate significant electromagnetic interference from the rapid current switching transitions. This EMI can couple into nearby CAN bus wiring, sensor circuits, and communication systems through radiated and conducted pathways. Proper EMI shielding, filtering, and cable routing are essential to prevent erratic readings or communication faults.

135. B — In a 24-hour mining operation, machine utilization is critical. A hydrogen fuel cell machine can be refuelled in approximately the same time as a diesel machine (minutes), providing near-continuous operation. A battery-electric machine requires multi-hour charging sessions that remove the machine from production. The refuelling speed advantage of hydrogen is the primary operational benefit for maximizing utilization in continuous mining operations.