

PRACTICE EXAM 5: RED SEAL WELDER SIMULATION (125 QUESTIONS)

1. A welder is performing SMAW with E308L-16 electrodes on 316L stainless steel in a fabrication shop with general dilution ventilation only. An industrial hygienist has measured hexavalent chromium [Cr(VI)] in the welder's breathing zone at 0.08 mg/m³ as an eight-hour time-weighted average. Which statement correctly identifies the hazard and the required control?

A. Hexavalent chromium at 0.08 mg/m³ is below the general welding fume OEL of 5 mg/m³ total inhalable particulate and requires no additional controls beyond the existing dilution ventilation

B. The reading confirms the base metal contains elevated chromium but the exposure is within acceptable limits — personal air monitoring is required only when Cr(VI) concentrations exceed 0.2 mg/m³ under applicable OHS regulations

C. Hexavalent chromium is classified as a known human carcinogen with OELs typically set at 0.01 to 0.05 mg/m³ — a measured concentration of 0.08 mg/m³ exceeds the limit and requires local exhaust ventilation at the source or supplied-air respiratory protection before work continues

D. The 0.08 mg/m³ reading is within acceptable range for part-time stainless steel welding tasks — the part-time exposure adjustment provision of the OHS regulation permits readings up to 0.16 mg/m³ when welding occupies less than four hours per shift

2. Under WHMIS 2015, an employer transfers a hazardous solvent from a supplier container into a smaller refillable spray bottle for use at a workstation. Which statement correctly identifies the labeling requirement that applies to the refillable spray bottle?

A. The refillable spray bottle requires at minimum the product identifier, hazard information such as a pictogram or risk phrase, and safe handling precautions appropriate for the work environment — or it must remain under the continuous direct control of the worker who filled it during the shift

B. The refillable spray bottle requires a full reproduction of the complete supplier label, including all classification elements, first aid measures, and emergency contact information, before it may leave the filling station

C. The refillable spray bottle requires only the product name label — workers are expected to consult the accessible SDS for all remaining hazard and handling information, satisfying the WHMIS communication requirement for refilled containers

D. The refillable spray bottle is exempt from all WHMIS labeling requirements if the contents are used entirely within the same shift and the container is not left unattended at any point during that shift

3. A fabricator must determine the mass of a gusset plate before rigging it for installation. The plate measures 650 mm × 450 mm × 16 mm and is cut from standard structural hot-rolled steel. Using a density of 7,850 kg/m³, what is the approximate mass of this plate?

A. 23.1 kg, calculated as volume $0.65 \times 0.45 \times 0.016 = 0.00468 \text{ m}^3$ multiplied by 7,850, then divided by 1.59 for the hot-roll density adjustment factor applied to plates under 20 mm thickness

B. 36.7 kg, calculated as volume $0.65 \text{ m} \times 0.45 \text{ m} \times 0.016 \text{ m} = 0.00468 \text{ m}^3$ multiplied by 7,850 kg/m³ = 36.7 kg

C. 73.4 kg, calculated by applying the double-plate rigging convention where the nominal plate mass is multiplied by a factor of 2.0 for all gusset plates used in structural crane applications

D. 46.8 kg, calculated using the plate surface area in square metres multiplied by the standard tabulated weight factor of 71.8 kg/m² per centimetre of thickness for structural plate

4. A worker needs to know what respiratory protection is required when using a fluoride-based brazing flux. They review the SDS and want to go directly to the most relevant section. Which SDS section contains the occupational exposure limits, required ventilation controls, and the specific respirator type and filter rating required for this operation?

A. Section 11 — Toxicological Information, which describes the acute and chronic health effects of fluoride exposure and identifies the respiratory system as the primary target organ for inhalation exposure

B. Section 7 — Handling and Storage, which specifies the ventilation requirements for the storage area and general safe handling precautions applicable during product transfer and preparation operations

C. Section 5 — Fire-Fighting Measures, which specifies the self-contained breathing apparatus required during fire emergencies involving thermal decomposition of the flux at elevated temperature

D. Section 8 — Exposure Controls and Personal Protective Equipment, which specifies the applicable occupational exposure limits, required engineering controls including ventilation type and capacity, and the specific respirator classification needed during normal use

5. A welder discovers an oxygen cylinder that has been knocked over in a storage area. The valve protection cap is missing. What is the specific hazard created by this situation, and what is the correct immediate response?

A. If the unprotected valve is sheared by the fall or subsequent contact, oxygen escapes at full cylinder pressure — approximately 20,000 kPa — through the open valve port, and the reaction force can propel the cylinder like a projectile with lethal force — clear the area immediately and notify supervision before anyone approaches

B. The missing cap indicates a slow oxygen leak is likely occurring through the Schrader valve seat — test the valve connection with soap solution and contact the oxygen supplier for emergency valve service before the cylinder is returned to the storage rack

C. The primary danger is that acetylene from adjacent cylinders may have contaminated the oxygen cylinder through the open valve — test the cylinder gas with a combustible gas detector before using the cylinder for any welding application

D. A cylinder without a protection cap should be carefully returned to the upright position in the storage rack, secured with a chain restraint, and tagged for a new cap from the supplier before the cylinder is issued for production use

6. A welder uses a CO₂ fire extinguisher to extinguish a fire involving energized electrical welding equipment. After the flames are out, the supervisor asks the welder to apply a nearby Class A water extinguisher to cool the smoldering cable insulation. Why must the electrical power be de-energized before using the water extinguisher?

A. Water extinguishers are unsuitable for smoldering cable insulation because water reacts with the thermal decomposition products of burning plastic to produce toxic gases that can overcome the person operating the extinguisher

B. Class A water extinguishers cannot effectively penetrate the charred cable jacket — the discharge pressure is insufficient to reach the still-burning conductor insulation beneath the outer char layer before evaporation occurs

C. Using a water extinguisher on energized electrical equipment creates a conductive path between the live electrical source and the operator, creating an electrocution hazard — the power must be de-energized and confirmed off before water is applied to any residual smoldering material

D. Class A water extinguishers are rated for outdoor use only — applying a water extinguisher indoors near electrical panels creates a flooding hazard that blocks emergency exit routes and must be reported to the fire authority

7. A welder returns to service a welding cable that was stored tightly coiled on a small reel for three weeks during a project shutdown. The outer insulation appears intact but the cable feels stiff and resists uncoiling. What specific safety concern does this cable condition create when the cable is returned to production current levels?

A. The tightly wound coil creates a solenoid effect in the cable that opposes current flow through the induced magnetic field, reducing the effective welding current at the arc by up to 30% at the operating amperage

B. Residual inductance stored in the coiled cable during previous service creates a voltage spike when the power source is switched on — the spike can exceed the insulation breakdown voltage and cause the power source output protection relay to trip repeatedly

C. Repeated coiling and uncoiling cycles cause work-hardening of the copper strands inside the cable, progressively reducing the conductor cross-section and increasing resistance until the cable generates sufficient heat to cause a fire during normal use

D. Tightly coiled welding cables cannot dissipate heat generated by resistance heating during operation — hot spots form where the coil prevents convective cooling of the conductor, progressively degrading the insulation at those locations and creating an electrical shock and fire risk under production current

8. A production welder performs high-frequency short-arc tack welds on structural assemblies — approximately 60 tacks per hour at 1 to 3 seconds each. The supervisor is deciding between a fixed-shade lens and an auto-darkening helmet. Which factor most directly governs the recommendation for this specific task?

A. A fixed-shade lens provides better UV protection for tack welding because tack welds produce a higher peak ultraviolet radiation intensity per arc-on second than continuous welds at the same amperage setting

B. An auto-darkening helmet allows the welder to position the electrode precisely with the lens in the clear state and have both hands free for placement — the lens darkens automatically at arc initiation, improving electrode placement accuracy and eliminating neck strain and positioning errors from repeated manual helmet flipping

C. A fixed-shade lens is required for any application where the arc duration is under five seconds — the response time of auto-darkening lenses exceeds the duration of most tack welds and the lens fails to darken before the arc extinguishes

D. The selection between fixed-shade and auto-darkening helmets for tack welding depends primarily on the ambient light level — auto-darkening lenses require a minimum shop illumination of 500 lux to activate the sensors reliably for short-arc tacking operations

9. A maintenance crew is preparing to repair a weld on a hydraulic press that has five identified energy sources: AC electric drive motor, hydraulic pressure in the accumulator, compressed air for the clutch actuator, gravitational potential energy with the press ram raised, and spring tension in the return mechanism. Under CSA Z460 lockout/tagout, what must be accomplished before any work begins?

A. All five energy sources must be individually isolated at their respective isolation devices and verified at zero energy state — each energy type requires its own documented isolation step and zero-energy verification before any component of the equipment may be contacted

B. Electrical isolation using the main disconnect is sufficient to place the equipment in a safe state — hydraulic, pneumatic, gravitational, and mechanical energy in secondary systems is automatically controlled when the primary electrical supply is locked out

C. The hydraulic accumulator and the compressed air supply are the only additional energy sources requiring formal LOTO isolation beyond the main electrical disconnect — gravitational and spring energy are classified as passive energy forms exempt from device requirements under CSA Z460

D. Isolation of the electrical main disconnect and the hydraulic pump motor is sufficient — these are the only energy sources capable of remote re-energization, and the remaining forms cannot be activated without direct physical manipulation by a worker

10. A production report shows a GMAW operator welded 87 metres of fillet weld during a 480-minute production shift at an average welding speed of 450 mm per minute. What was the operator's arc-on time percentage for the shift?

A. 40.6%, calculated as $(87 \text{ m} \div 480 \text{ min}) \times 100 = 18.1\%$, then multiplied by the GMAW arc efficiency factor of 2.24 to account for the higher deposition rate compared to SMAW

B. 29.7%, calculated as $(87,000 \text{ mm} \div 450 \text{ mm/min}) \div 480 \text{ min} \times 100$ applied with the standard GMAW 73% duty cycle correction factor for semi-automatic wire feed equipment

C. 40.2%, calculated as total arc-on time of $87,000 \text{ mm} \div 450 \text{ mm/min} = 193.3$ arc-on minutes, divided by the 480-minute shift duration = $0.402 \times 100 = 40.2\%$

D. 18.1%, calculated as 87 metres of weld produced divided by 480 metres per shift production capacity $\times 100$, using total linear metres as the operating factor denominator

11. A SMAW electrode holder slips from a workbench and the energized electrode touches a steel work table leg, briefly completing the circuit. No injury occurs and no visible damage results. Under OHS incident reporting requirements, how should this event be classified and what action is required?

A. This is a property damage incident requiring an entry in the equipment maintenance log only — near miss reporting systems apply to events involving personal injury or lost time, not brief electrical contact events with no visible damage

B. This is a near miss — an unplanned event with the potential for electric shock or fire that caused no harm — it must be reported and investigated to identify the root cause and implement corrective action before a similar event results in injury

C. This is a minor electrical event within the normal operational risk tolerance of SMAW equipment — brief accidental arc strikes from dropped electrode holders are categorized as acceptable incidental contact under production welding OHS guidelines

D. This event requires an immediate formal report to the provincial electrical safety authority — all unintended arc strikes outside the intended weld zone are classified as electrical non-conformances requiring third-party inspection of the affected area

12. A 4,500 kg pressure vessel component is being lifted using a two-legged wire rope bridle sling with equal legs, each forming a 30-degree angle above horizontal. Using $\sin(30^\circ) = 0.5$, what is the approximate tension in each sling leg, and what does this result illustrate about shallow sling angles?

A. 2,250 kg per leg — bridle sling tension equals half the total load when both legs are equal length, regardless of the sling angle from horizontal

B. 1,125 kg per leg — the shallow angle reduces load per leg to $(\text{total load} \div 2) \times \sin(30^\circ) = 2,250 \times 0.5 = 1,125$ kg, demonstrating that shallower angles reduce leg tension

C. 3,182 kg per leg — each leg carries $(\text{total load} \div 2) \div \cos(30^\circ) = 2,250 \div 0.866 = 2,598$ kg corrected by the sling angle efficiency factor for bridle configurations

D. 4,500 kg per leg — tension equals $(\text{total load} \div 2) \div \sin(30^\circ) = 2,250 \div 0.5 = 4,500$ kg, demonstrating that a 30-degree sling angle doubles the load in each leg and requires slings rated for twice the total rigging mass

13. Under the hierarchy of controls, a fabrication manager is evaluating options to control manganese fume generated during FCAW of structural carbon steel. Which sequence correctly prioritizes the control options from highest to lowest in the hierarchy?

A. Respiratory protection (N95 half-mask) is the preferred first-level control for manganese fume in welding — it is immediately deployable, cost-effective, and engineering controls such as LEV are required only when personal protection cannot achieve compliance with the OEL

B. Substitution or elimination (switching to a lower-manganese wire) ranks highest, followed by local exhaust ventilation as an engineering control, then work rotation as an administrative control, with respiratory protection as a last resort to reduce residual exposure

C. Engineering controls such as general dilution ventilation and personal protective equipment are considered equivalent levels of control for welding fume — the choice between them is an operational decision based on cost and practicality for the welding application

D. Administrative controls such as hazard awareness training and warning signs rank first in the hierarchy because they address the behavioral root causes of excessive fume exposure before any physical control measures are considered

14. Before performing a procedure qualification test (PQR) on a new alloy supplied by a customer, which step is most critical to complete before striking the first arc?

A. Verify the base metal chemical composition from the mill test report and confirm it matches the material designation specified in the qualification test plan — welding an unverified or incorrect material invalidates every test result obtained from the qualification coupon

B. Perform a Brinell hardness test on the test coupon surface to confirm the base metal is within the expected hardness range for the specified material before any welding or marking is performed on the qualification sample

C. Have a welding inspector complete and sign a pre-weld visual inspection of the test coupon surface — documented inspector sign-off before welding is a mandatory requirement under ASME Section IX before any qualification coupon welding begins

D. Submit the proposed WPS to the authorized inspection agency and receive written pre-approval before beginning any PQR qualification welding — third-party pre-approval is required whenever a new base metal is being added to the company's qualified procedure register

15. A welder is required to perform repair welding alone inside a large pressure vessel during a night shift. Under Canadian OHS working-alone legislation, which combination of safety measures best satisfies the minimum legal requirements for this specific situation?

A. Posting a "Worker Inside Vessel" sign at the entry manway and ensuring the welder carries a charged cellular phone — the combination of a posted notice and a personal communication device satisfies the working-alone requirement for confined space welding tasks

B. Designating a second worker to remain within visual line-of-sight from the vessel manway for the duration of the repair — continuous visual monitoring by a companion within sight satisfies both the working-alone and confined space requirements simultaneously

C. Completing a job safety analysis and task risk assessment before entry with a supervisor's signature, combined with radio check-ins every 90 minutes — a documented risk assessment with defined check-in intervals is sufficient for working alone in vessels under 30 minutes entry duration

D. Implementing a full confined space entry permit with a qualified standby person at the entry point, defined rescue procedures, pre-entry and periodic atmospheric testing, and a communication protocol with defined check-in intervals appropriate to the identified hazards —

the vessel entry requires both confined space controls and the working-alone communication procedure simultaneously

16. A welder receives a thermal burn to the forearm from ejected welding spatter. The injury is approximately 3 cm in diameter, the skin is red, and a fluid-filled blister has formed over the center of the burn. What is the correct classification of this burn and the appropriate first aid response?

A. Third-degree burn — blistering always indicates full-thickness skin destruction, requiring immediate transport to an emergency burn center with the burn covered in dry sterile dressing and no water application

B. Second-degree (partial thickness) burn — cool the burn immediately under cool running water for 10 to 20 minutes, do not rupture the blister as it protects the underlying tissue, cover with a clean non-adherent dressing, and seek medical evaluation for blistered burns

C. First-degree burn — blister formation from metal spatter is classified as first-degree because the heat source duration is instantaneous — treatment consists of a dry dressing and topical burn ointment, and medical referral is not required for blisters under 5 cm diameter

D. Chemical burn requiring neutralization — all burns from welding spatter are classified as chemical burns under OHS first aid protocols because molten electrode coating residue on the spatter particle must be neutralized with a buffer solution before cooling with water

17. A journeyman welder consumes 15.5 kg of E7018-1 H4R low-hydrogen electrodes during an 8-hour production shift. Using the listed deposition efficiency of 65% for iron-powder basic electrodes, what mass of weld metal was deposited?

A. 24.0 kg, calculated as $15.5 \text{ kg} \div 0.65 = 23.85 \text{ kg}$ — the deposition efficiency is applied as a divisor to convert consumed electrode mass to deposited metal mass

B. 5.4 kg, calculated as $15.5 \times (1 - 0.65) = 5.43 \text{ kg}$ — the 65% value represents the loss factor, meaning only the complement (35%) becomes deposited weld metal

C. 10.1 kg, calculated as $15.5 \text{ kg} \times 0.65 = 10.075 \text{ kg} \approx 10.1 \text{ kg}$ of deposited weld metal — the deposition efficiency means 65% of consumed electrode mass becomes weld metal and 35% is lost as stubs, spatter, and non-metallic coating

D. 6.8 kg, calculated by dividing the consumed mass by the standard arc efficiency correction factor of 2.3 applied to E7018-1 H4R electrodes at flat-position deposition rates per the electrode manufacturer's technical data sheet

18. Before welding can begin on a Canadian registered pressure vessel fabrication under applicable codes and provincial regulations, which set of documents must be available to the welder and supervisor?

A. A qualified WPS supported by a PQR approved under the applicable code, and a current welder qualification certificate confirming the welder is certified for the process, position, and base material shown on the WPS — both documents are required before any production welding begins on a registered vessel

B. A current journeyperson welding certificate is the only mandatory document — the WPS is the employer's internal production document and is not required to be reviewed by the individual welder before welding each joint on a registered pressure vessel

C. A complete NDE examination report accepted by the inspection authority from the previous inspection cycle — new welding on an in-service vessel may not proceed until prior weld NDE records are presented to the authorized inspector and formally accepted

D. An engineering change notice from the original vessel design authority confirming the new welds have been incorporated into the vessel design calculations and the vessel data report has been updated before any welding on the registered vessel begins

19. A welder discovers that the work return cable has been connected to a structural steel building column instead of directly to the workpiece being welded. The weld joint is approximately 8 metres from the work return connection. What specific hazard does this practice create?

A. The 8-metre distance between the work return and the weld joint increases circuit resistance, lowers the effective amperage at the arc, and produces incomplete fusion that cannot be detected by visual inspection of the completed weld surface

B. The building steel connection provides a lower-resistance path than a direct workpiece connection, causing the power source to increase output voltage automatically and potentially overloading the transformer during production welding

C. Welding current travels through structural connections, pipe flanges, and building ground conductors seeking the lowest-resistance return path, causing resistive heating and arc damage at metallic interfaces not designed to carry welding current levels

D. The long return path through the building column creates a strong unidirectional magnetic field along the structural steel that generates severe arc blow — the arc deflects persistently away from the joint in the direction of the work return, making consistent weld quality unachievable without repositioning the return cable

20. A steel erector is lifting two identical structural purlins simultaneously using a four-legged wire rope sling — two legs per purlin. Each purlin has a mass of 680 kg. Each sling leg makes an angle of 25 degrees from vertical. Using $\cos(25^\circ) = 0.906$, what is the approximate tension in each of the four sling legs?

A. 170 kg per leg — when four legs share the total load, the individual leg tension is reduced to one-quarter of the total load divided by the cosine of the angle from vertical

B. 375 kg per leg — each leg tension equals $(\text{total load} \div 4) \div \cos(25^\circ) = (1,360 \div 4) \div 0.906 = 340 \div 0.906 = 375$ kg per leg, accounting for the increased tension caused by the sling angle

C. 308 kg per leg — each leg tension equals $(\text{total load} \div 4) \times \cos(25^\circ) = 340 \times 0.906 = 308$ kg, since the cosine factor reduces tension at angles closer to vertical

D. 340 kg per leg — the total load divided by the number of legs $(1,360 \div 4) = 340$ kg per leg, with no angle correction since deviations under 30 degrees from vertical are within the standard rigging tolerance zone

21. A structural drawing shows a fillet weld symbol with a leg size of 8 mm and the notation "(5)×60–120" to the right of the weld symbol. What does the "(5)" specifically communicate in this intermittent fillet weld notation?

A. The "(5)" indicates a minimum of 5 total weld segments must be deposited along the joint before any portion of the joint may be released for the next assembly operation

B. The "(5)" specifies the weld must be deposited in 5 equal stages during the fabrication sequence — each stage installs one-fifth of the total weld length to balance distortion during progressive assembly

C. The "(5)" designates the total number of weld segments required — 5 individual fillet weld segments of 60 mm length are to be deposited at 120 mm centre-to-centre pitch, giving a total deposited weld length of 300 mm along the joint

D. The "(5)" identifies the allowable convexity in millimetres for each weld segment — fillet weld segments with this notation are permitted a maximum 5 mm face convexity above the theoretical throat plane

22. An inspector measures a completed structural fillet weld with a fillet gauge and finds the actual leg size is 8.5 mm against a 10 mm specified leg size on the approved drawing. Under CSA W59, what is the correct disposition of this weld?

A. The weld is acceptable — CSA W59 Table 5.5 permits actual fillet weld leg sizes to be 1.6 mm less than the specified size for statically loaded joints on members 6 mm and thicker without requiring repair or engineering disposition

B. The weld requires only supervisor documentation in the production record — deviations within 15% of the specified size are classified as minor non-conformances under CSA W59 and are resolved through the production log without corrective action

C. The weld is acceptable if the fabricator can demonstrate through calculation that the actual 8.5 mm leg size provides sufficient weld throat to carry the design load — strength-based acceptance is permitted as an alternative to dimensional compliance under CSA W59

D. The weld is non-conforming and must be built up to the specified 10 mm minimum leg size by depositing an additional weld pass, or formally accepted by engineering disposition — CSA W59 does not contain a blanket dimensional acceptance tolerance for undersize fillet welds

23. A pipe fabricator must calculate the developed arc length along the centreline of a 4-inch nominal pipe (nominal diameter = 101.6 mm) long-radius 90-degree elbow, where the centreline radius equals 1.5 times the nominal pipe diameter. Using $\pi = 3.1416$, what is the arc length?

A. 240 mm, calculated as arc length = $2\pi \times (1.5 \times 101.6) \times (90/360) = 2 \times 3.1416 \times 152.4 \times 0.25 = 239.9 \text{ mm} \approx 240 \text{ mm}$

B. 480 mm, calculated as the full 180-degree semicircle arc at the long-radius centreline, representing twice the 90-degree arc length used as the standard developed length for butt-weld 90-degree elbows in pipe spool fabrication

C. 160 mm, calculated as $(\text{nominal pipe diameter} \times \pi) \div 2 = (101.6 \times 3.1416) \div 2 = 159.6$ mm, applying the half-circumference formula at the nominal bore diameter for arc length calculations

D. 120 mm, calculated as $\text{nominal pipe diameter} \times \pi \times (45/360) = 101.6 \times 3.1416 \times 0.125 = 39.9$ mm per segment $\times 3$ for the three-piece equivalent elbow equivalent arc length

24. A fabricator is fitting up a 12 mm thick carbon steel T-joint for structural fillet welding under a qualified WPS based on CSA W59 pre-qualified parameters. The WPS specifies minimum preheat based on the base metal carbon equivalent. When the welder measures the plate temperature, it reads 12°C. The CSA W59 minimum preheat for this material and thickness is 50°C. What must happen before welding proceeds?

A. The welder may proceed without preheat — CSA W59 minimum preheat requirements for structural carbon steel apply only when the ambient temperature is below 0°C, and a 12°C plate temperature is within the code's working temperature range without supplemental heating

B. The plate must be preheated to a minimum of 50°C throughout the joint area extending at least 75 mm on each side of the intended weld zone, and this temperature must be verified with a calibrated surface temperature measuring device before striking the first arc

C. The welder may proceed if the project weld supervisor verbally authorizes a preheat waiver for this joint — CSA W59 permits supervisory preheat waivers for single-pass fillet welds on plate under 16 mm thickness

D. The plate temperature is within the acceptable ambient range — CSA W59 preheat for 12 mm structural carbon steel at 12°C is not required and the stated 50°C requirement applies only to groove welds, not fillet welds in the T-joint configuration

25. A UT examination report describes multiple small spherical-signature reflectors distributed throughout the weld metal volume of a structural butt weld, appearing as approximately equal-amplitude signals from all scanning directions. The indications are located between 6 mm and 18 mm depth and have no consistent orientation. What discontinuity is most consistent with this UT description?

A. Transverse solidification cracks — the equal-amplitude response from all scanning directions confirms these are transverse cracks, since centreline hot cracks reflect the angle beam symmetrically from opposing probe directions in structural groove welds

B. Incomplete fusion at pass boundaries — multiple distributed reflectors throughout the weld metal cross-section with non-directional response represent unfused interfaces between individual passes that were not detected during inter-pass visual inspection

C. Porosity — multiple small, non-directional reflectors distributed randomly throughout the weld metal with equal response amplitude from all scanning directions and no consistent orientation are the characteristic UT signature of gas porosity in the weld metal

D. Lack-of-penetration at the root — distributed reflectors throughout the full weld metal cross-section indicate root-based defects that have propagated from the root into successive fill passes during the multi-pass weld deposition sequence

26. Under ASME Section IX QW-451.1, a SMAW procedure was qualified using a 50 mm thick test coupon. A production joint on the same material requires welding on 120 mm thick plate. Is the existing WPS qualified for this production application?

A. No — QW-451.1 limits the maximum qualified production thickness to two times the test coupon thickness — a 50 mm PQR coupon qualifies production welds up to a maximum of 100 mm, and the 120 mm joint falls outside the qualified range

B. No — ASME IX requires a separate PQR test for each 25 mm increment of plate thickness above 50 mm for all manual and semi-automatic welding processes regardless of the original PQR coupon thickness

C. No — the maximum qualified production thickness for SMAW under ASME IX is capped at 75 mm regardless of test coupon thickness — manual processes are excluded from the unlimited thickness provision by process type

D. Yes — under ASME IX QW-451.1, a PQR test coupon of 19 mm or greater thickness qualifies production groove welds from a minimum of 5 mm up to unlimited maximum plate thickness — the 50 mm PQR coupon covers the 120 mm production joint

27. When reading a third-angle orthographic projection drawing, a fabricator examines the right-side view and finds a series of evenly spaced dashed lines running horizontally across the full width of the part. What do these dashed lines represent in the right-side view?

A. Hidden features inside the part that are not visible from the right side but exist as internal bores, slots, or recesses that run horizontally through the full width — dashed lines in any view represent edges or surfaces hidden from that viewing direction

B. Surface finish symbols on the right face of the part — multiple evenly-spaced dashed lines on the right-side view are used in third-angle projection to indicate a ground or machined surface requiring a specific roughness measurement

C. Dimension extension lines linking the right-side view to the front view for associated dimensions — dashed horizontal lines in the right-side view indicate that these dimensions are shared between the right-side and front orthographic views

D. Center lines indicating the axis of symmetry for the part — in third-angle projection standards, dashed lines represent the part's plane of symmetry and are used to indicate that the left-side view is a mirror image of the right-side view

28. A fabrication drawing specifies that all groove welds on a structural frame are to be completed using a "balanced welding" sequence. The frame consists of 12 groove weld joints arranged symmetrically around the centreline. What specific distortion mechanism does balanced welding directly control?

A. Balanced welding controls lamellar tearing — distributing welds symmetrically around the frame centreline reduces the through-thickness stress concentration that causes lamellar tearing in heavily restrained base metal adjacent to large groove welds

B. Balanced welding does not reduce distortion in completed frames — it is a scheduling technique used to balance the workload between multiple welders and has no technical effect on the dimensional accuracy of the finished assembly

C. Balanced welding controls angular and longitudinal distortion by depositing welds on alternating sides of the frame's neutral axis — each weld's transverse and longitudinal shrinkage partially counteracts the shrinkage of the preceding weld on the opposite side, keeping the cumulative distortion near the neutral axis of the assembly

D. Balanced welding controls grain coarsening distortion — by alternating heat input on opposing sides, the thermal cycle on each side is interrupted before the HAZ reaches the grain coarsening temperature range, preserving base metal mechanical properties across the frame

29. A pipe fabricator must calculate the diagonal travel length of a 45-degree offset section that connects two horizontal pipe runs displaced 425 mm vertically. Using two 45-degree elbows, what is the length of the diagonal pipe section between the two elbows?

A. 425 mm — when 45-degree fittings are used for a vertical offset, the pipe travel equals the offset distance because the 45-degree angle and the offset dimension have an equivalent numerical relationship in the travel length formula

B. 601 mm, calculated as the offset $\div \sin(45^\circ) = 425 \div 0.707 = 601$ mm — the diagonal pipe must span the full 425 mm vertical offset at a 45-degree angle, requiring the pipe length to exceed the offset distance

C. 300 mm, calculated as the offset $\times \sin(45^\circ) = 425 \times 0.707 = 300.5$ mm — the sine factor accounts for the 45-degree inclination by converting the diagonal length to its vertical projection component

D. 850 mm, calculated as the offset $\times 2.0$, applying a factor of two to account for the diagonal travel in both vertical and horizontal components at a 45-degree angle through the fitting assembly

30. A fabricator receives a heat of structural plate with a mill test report showing the following chemistry: C=0.20%, Mn=1.40%, Si=0.30%. There are no Cr, Mo, V, Ni, or Cu additions. Using the IIW carbon equivalent formula $CE = C + Mn/6 + (Cr+Mo+V)/5 + (Ni+Cu)/15$, what is the CE, and what does it indicate for weld procedure development?

A. $CE = 0.42$, calculated as $0.20 + 1.40/6 = 0.20 + 0.233 = 0.433$ — for the applicable thickness and restraint level, this CE falls in a range where preheat and controlled welding procedures are recommended to manage cold cracking risk

B. $CE = 0.64$, calculated by including all plate chemistry elements including the silicon contribution as $CE = C + Mn/6 + Si/6 = 0.20 + 0.233 + 0.05 = 0.483$, adjusted by the mandatory silicon multiplier for structural plate applications

C. $CE = 0.29$, calculated using the simplified formula for low-carbon steels under 345 MPa yield strength that excludes the Mn/6 term — the simplified formula applies when manganese content is below 1.5%

D. $CE = 0.43$, calculated as $0.20 + 1.40/6 = 0.20 + 0.233 = 0.433 \approx 0.43$ — this CE level indicates that preheat and interpass temperature controls are likely required for joints with significant restraint, particularly on thicker sections and in cold ambient conditions

31. Under CSA W47.1, a certified company is adding a new welding process (GTAW on stainless steel) to their existing certification scope. Which actions are the minimum required to support this addition?

A. The company must qualify at minimum one WPS for the new process supported by a PQR tested under CWB surveillance or an accepted engineer, qualify welders under the new procedure, and have the CWB validate the process addition through the certification assessment process before production use begins

B. The welding supervisor may authorize production use of the new process immediately by issuing a written bulletin — under CSA W47.1, the welding supervisor's authority covers all process additions within the existing material family without CWB involvement

C. A PQR is required only if the new process will be applied to material types not already covered by existing qualifications — if the company is already certified for stainless steel SMAW, the GTAW process addition requires only a WPS revision without new PQR testing

D. The company must notify their provincial pressure vessel authority in writing 60 days before first production use of the new process — the CWB is notified automatically by the provincial authority and no separate CWB assessment is required

32. During magnetic particle testing of a fillet weld, an inspector applies particles and observes a well-defined, sharp, narrow accumulation of particles approximately 0.5 mm wide and 22 mm long running parallel to the weld toe, located 1 mm into the base metal HAZ. What characteristic of this indication is most significant?

A. The indication is a normal geometric response from the weld toe radius — sharp particle accumulations parallel to the weld toe and within 2 mm of the fusion line are classified as toe geometry indications and are automatically excluded from the rejection criteria under all structural welding codes

B. The indication is in the HAZ rather than in the weld metal — cracks and other discontinuities detected in the HAZ have lower severity than equivalent-length weld metal indications because the HAZ material is softer than the weld metal deposit

C. The indication's sharp, well-defined, narrow character and its position in the HAZ parallel to the weld toe are consistent with a toe crack or HAZ hydrogen crack — the precise linear form indicates a tight planar discontinuity rather than a geometric artifact, and the location in the HAZ makes this a high-priority indication requiring further evaluation

D. The indication is located outside the weld metal and therefore falls under base metal acceptance criteria rather than weld acceptance criteria — base metal HAZ indications are governed by different rejection thresholds that allow longer linear indications than are permitted in the weld metal deposit

33. A fabricator is cutting a 4-piece 90-degree miter bend from straight pipe using equal segments. Each piece has equal cut angles at both ends (except the end pieces which have one cut). What is the cut angle at each end of each intermediate pipe segment?

A. 22.5 degrees — a 4-piece 90-degree miter requires 4 equal-angle cuts, each contributing 22.5 degrees to the total 90-degree turn when the face angles of mating pieces are combined at each joint

B. 15 degrees — a 4-piece miter has 3 equal joints between segments, each joint deflecting $90^\circ \div 3 = 30$ degrees of the total turn, and each cut face equals half the joint deflection: $30 \div 2 = 15$ degrees per cut face

C. 11.25 degrees — the cut angle for a 4-piece 90-degree miter is calculated as the total angle divided by the number of pieces multiplied by 2: $90 \div (4 \times 2) = 11.25$ degrees applied to each cut face of each segment

D. 18 degrees — four equal pieces in a 90-degree miter each contribute 22.5 degrees of the total turn, and the cut face angle equals the segment deflection: 22.5 degrees, reduced to 18 degrees by the miter compound angle correction factor for NPS 6 pipe

34. Under ASME B31.3 Process Piping, when a welded joint is required to be post-weld heat treated (PWHT), what specific failure mechanism does the PWHT primarily address in CrMo alloy steel (P5) piping?

A. PWHT on P5 alloy steel dissolves the austenite phase that forms in the weld metal during cooling — fully austenitic weld metal is unsuitable for service in P5 piping and PWHT converts it back to the ferrite-martensite microstructure before the piping enters service

B. PWHT primarily improves corrosion resistance in P5 alloy steel — the elevated temperature restores the surface chromium concentration depleted by the welding thermal cycle and reforms the passive oxide layer that protects the pipe interior from process fluid attack

C. PWHT increases the tensile strength of the P5 weld metal to meet the minimum specified requirements — freshly deposited P5 weld metal is below the minimum strength requirement and PWHT aging treatment brings the mechanical properties to the specification minimum

D. PWHT on P5 alloy steel tempers the hard martensite formed during rapid post-weld cooling, relieves residual welding stresses, and tempers the carbides in the HAZ — these microstructural improvements reduce hardness, improve toughness, and minimize susceptibility to stress corrosion cracking and creep in elevated-temperature service

35. An angle-beam ultrasonic test of a structural CJP butt weld produces a strong signal from one scanning direction but no corresponding signal when scanned from the opposite side along the same weld centreline. What does this asymmetric detection pattern most likely indicate?

A. An indication detected from only one scanning direction is automatically classified as a geometric reflector from the weld crown profile — the one-directional response confirms the reflector is a surface geometry feature rather than a weld metal discontinuity

B. The asymmetric response pattern confirms the indication is a spherical porosity cluster — round gas pores reflect angle-beam UT signals from only one scanning direction because the spherical geometry creates a retroreflective response only when the beam approaches from the same angle as the transducer receiver orientation

C. The asymmetric detection suggests a planar reflector whose orientation is favorable to the incident beam from one side only — this behavior is characteristic of incomplete fusion or crack faces aligned parallel to the fusion line, and complementary examination with different probe angles or methods is required before a final accept/reject decision is made

D. One-directional detection automatically places the indication in the accept category under all structural welding UT codes — the absence of a signal from the opposing scanner confirms the indication does not cross the neutral axis of the weld cross-section, meeting the code's centreline penetration criterion

36. A welding inspector performing pre-weld inspection on a 304L stainless steel pressure piping joint notices the pipe end has been prepared by plasma arc cutting rather than the machined bevel preparation specified in the WPS. The plasma-cut surface appears dimensionally correct and visually smooth. What is the correct action?

A. Grind the plasma-cut bevel surface to remove at least 1-2 mm of material and produce a mechanically clean base metal surface — plasma cutting can produce a carburized and heat-affected surface layer on stainless steel that may cause sensitization or hot cracking in the root pass deposit if it is not removed before welding

B. Accept the plasma-cut bevel without any additional preparation — the surface preparation method is a non-essential variable under ASME IX and any smooth bevel meeting the dimensional tolerances in the WPS is acceptable regardless of the preparation method used

C. Document the deviation in the inspection record and submit for engineering disposition before welding proceeds — the WPS specification for machined preparation exists for a technical reason and any departure from the specified method requires authorization before the joint may proceed to welding

D. Reject the joint and require complete re-fabrication — plasma arc cutting of stainless steel pipe ends is prohibited under all applicable pressure piping codes and no surface treatment can restore the cut end to a condition acceptable for weld preparation use

37. A structural drawing specifies an unequal leg fillet weld with a horizontal leg of 10 mm and a vertical leg of 14 mm on an asymmetric joint. Using the theoretical throat formula for unequal legs (throat = $(\text{leg}_1 \times \text{leg}_2) \div \sqrt{(\text{leg}_1^2 + \text{leg}_2^2)}$), what is the effective throat?

A. 12.0 mm — the effective throat of an unequal leg fillet weld equals the average of the two leg dimensions since the mean length represents the average distance from root to theoretical face

B. 8.2 mm, calculated as $(10 \times 14) \div \sqrt{(10^2 + 14^2)} = 140 \div \sqrt{(100 + 196)} = 140 \div \sqrt{296} = 140 \div 17.2 = 8.14 \text{ mm} \approx 8.2 \text{ mm}$ — this is the altitude of the right triangle formed by the two unequal leg dimensions

C. 10.0 mm — the effective throat always equals the shorter leg dimension for unequal fillet welds since the theoretical face cannot extend beyond the shorter leg in the perpendicular direction from the root

D. 7.07 mm — the effective throat of any fillet weld is always calculated as the shorter leg $\times \sin(45^\circ) = 10 \times 0.707 = 7.07 \text{ mm}$, applying the equal-leg formula to the smaller dimension regardless of the actual leg ratio

38. On a pressure vessel assembly drawing, a welding symbol at a nozzle-to-shell connection shows a groove weld symbol on the arrow side, the letters "RT" in the tail of the reference arrow,

and the number "100" above the tail notation. What does this tail notation communicate to the fabricator?

A. "RT 100" specifies that the completed nozzle weld must have a minimum ultimate tensile strength of 100 ksi — all welds at nozzle connections are independently strength-tested to the value shown in the weld symbol tail notation

B. "RT 100" designates that 100 kJ/m of heat input per millimetre of weld length is the maximum permitted during deposition of the nozzle-to-shell weld — heat input restrictions for pressure vessel nozzle welds are communicated through the tail notation

C. "RT 100" indicates the nozzle weld has been assigned reference line number 100 in the vessel NDE plan — the fabricator must cross-reference this number against the RT examination schedule to determine the required weld radiograph coverage

D. "RT 100" specifies that 100% radiographic testing is required on the completed nozzle-to-shell weld joint — the letters in the tail identify the NDE method and the number specifies the required percentage of the joint to be examined

39. Under CSA W59, which of the following joint preparation parameters removes a single-V groove butt weld from pre-qualified status on 10 mm structural steel plate?

A. Using a root opening of 5 mm instead of the pre-qualified maximum of 6 mm — reducing the root opening below the maximum pre-qualified value requires engineering recalculation of the effective throat

B. Machining the groove angle to 65 degrees included angle instead of the pre-qualified range — minor increases in groove angle above the standard 60-degree value constitute an essential variable change requiring new qualification

C. Cutting a root face of 5 mm when the pre-qualified maximum root face for this joint type is 3 mm — exceeding the maximum pre-qualified root face dimension places the joint preparation outside the qualified parameter range, removing its pre-qualified status

D. Using an electrode two sizes smaller than the maximum recommended for the groove size — smaller electrode selection within the same classification and polarity is not a joint preparation variable and does not affect the pre-qualified joint status

40. An assembly drawing for a structural frame is marked "Issue for Construction — Revision 3." The drawing package includes a revision block table listing changes made at each revision. Revision 1 added welding symbols to two joints. Revision 2 changed two plate thicknesses. Revision 3 added a new member to the frame. What is the correct interpretation of a dimension on this drawing that has no revision triangle beside it?

A. A dimension with no revision triangle has not been changed since the original issue — it has retained the same value through all three revisions and the fabricator may use it as a stable reference dimension without checking it against earlier revision drawings

B. A dimension with no revision triangle has not yet been reviewed by the design engineer — all dimensions require a revision triangle certification before they can be used for production, and unmarked dimensions are pending review

C. A dimension with no revision triangle was established at the original issue but may have been changed multiple times — the absence of a triangle indicates the revision tracking system was not maintained and all dimensions must be verified against the prior revision

D. Dimensions without revision triangles are placeholder values only — they represent design intent rather than final fabricated dimensions and must receive a revision triangle from the engineer of record before they can be transferred to the fabrication shop order

41. Under ASME Section VIII Division 1, which NDE method is specifically required for locating and evaluating laminar defects in thick structural plate material before the plate is cut and formed into pressure vessel shell courses?

A. Radiographic testing (RT) — RT is the mandatory primary NDE method for laminar defect detection in pressure vessel plate material under ASME VIII Division 1, with 100% RT required on all plate regardless of thickness

B. Ultrasonic testing (UT) — straight-beam UT is the appropriate method for detecting laminar defects oriented parallel to the plate surface, since RT would not provide adequate sensitivity to thin laminar planar reflectors that run parallel to the radiation beam direction

C. Magnetic particle testing (MT) — MT is required for all plate surface examinations before forming and is specifically sensitive to the subsurface laminar tears that occur in plate rolled from segregated ingot material

D. Liquid penetrant testing (PT) — PT is specified in ASME VIII Division 1 for all plate surface examinations because it detects both surface and near-surface laminar defects in the outer plate skin and provides quantitative evaluation of lamellar tear depth

42. During visual inspection of completed SMAW groove welds on a structural frame, an inspector measures the cap reinforcement with a weld gauge and finds a consistent 5 mm reinforcement height on 12 mm thick plate. The applicable code is CSA W59. What is the correct disposition of these welds?

A. The 5 mm reinforcement is within the code acceptance criteria — CSA W59 permits cap reinforcement of up to 6 mm for all plate thicknesses in the structural welding scope

B. The 5 mm reinforcement must be evaluated against the design loading — convex cap reinforcement is only rejectable when the structural calculation confirms the toe notch effect reduces fatigue life below the minimum design requirement

C. The 5 mm reinforcement exceeds the CSA W59 maximum permitted cap reinforcement for 12 mm structural plate — the specification limits cap reinforcement to 3 mm maximum, and the excess must be removed by grinding before the welds are accepted

D. The 5 mm reinforcement is acceptable for statically loaded structures and is rejectable only for dynamically loaded or fatigue-classified structural connections — the inspection record must document the loading classification before a final accept or reject decision is made

43. To minimize longitudinal distortion (bowing along the length) in a 6-metre structural I-beam where both flange-to-web fillet welds must be completed, the welding engineer specifies that both flange welds are deposited simultaneously by two welders working in tandem from opposite ends toward the centre. What specific distortion mechanism does this sequence address?

A. The simultaneous opposing sequence eliminates the risk of angular distortion by ensuring both flanges receive equal heat simultaneously — heating both flanges at equal rates prevents one flange from cooling and contracting before the other is welded

B. Simultaneous tandem welding from both ends reduces the required preheat temperature by creating a symmetrical heat distribution that self-preheats the beam center, eliminating the need for external supplemental heat during cold ambient welding

C. Welding from both ends toward the centre prevents the last-to-solidify weld metal at the centreline from being in a high-restraint state — relieving centreline restraint reduces longitudinal residual stress in the web and minimizes hot cracking at the central weld stop locations

D. Welding simultaneously from opposite ends toward the centre balances the longitudinal shrinkage forces so that the progressive contraction from each end acts in opposition — the shrinkage from the south-end welder is progressively counteracted by the shrinkage from the north-end welder, keeping the beam's neutral axis straight

44. A fabricator must develop the flat pattern for a right circular cone frustum with a top diameter of 400 mm, a bottom diameter of 800 mm, and a slant height of 500 mm. Using radial line development, what is the outer arc radius in the flat pattern?

A. 1,000 mm — the outer arc radius equals the slant height from the apex to the large base circle:
 $R = \text{slant height} \times (D_{\text{large}} \div (D_{\text{large}} - D_{\text{small}})) = 500 \times (800 \div 400) = 500 \times 2 = 1,000 \text{ mm}$

B. 707 mm — the outer arc radius equals the hypotenuse of the right triangle formed by the slant height and the radius difference: $R = \sqrt{(500^2 + 200^2)} = \sqrt{(250,000 + 40,000)} = \sqrt{290,000} = 538 \text{ mm}$

C. 500 mm — the outer arc radius of any frustum flat pattern equals the slant height regardless of the diameter ratio, since the slant height is the measured distance from the large base to the small base along the cone surface

D. 600 mm — the outer arc radius equals the arithmetic mean of the slant height and the outer base radius: $R = (500 + 400)/2 + 100 = 600 \text{ mm}$ for frustum developments where the diameter ratio is 2:1

45. A welding quality inspector is reviewing radiographic film of a structural groove weld and finds a dark indication at the weld root described as approximately 10 mm long with well-defined, nearly parallel edges running along the weld axis. The welder reported a pause at this location due to an electrode change. What is the most probable discontinuity?

A. A burn-through — the dark, parallel-edged indication at the root at the electrode change location represents a point where the root pass melted completely through during the brief arc hold before the electrode was changed, with the edges defined by the solidified metal at the margins of the through-hole

B. A lack-of-penetration indication — the well-defined parallel-edged dark zone along the weld axis at the electrode change location indicates incomplete filling of the root gap during the restart, creating an unfused zone at the root centreline between the end of the first electrode's pass and the restart of the next electrode

C. A crater crack — electrode change locations consistently produce crater cracks from the rapid solidification of the final weld pool, which appear as dark, elongated indications with parallel-edged character at the root of groove welds

D. A tungsten inclusion — electrode changes in SMAW produce occasional tungsten transfer events that appear as high-density bright indications rather than the dark, parallel-edged character described, requiring the interpreter to reconsider the indication classification

46. Under ASME Section IX, a WPS qualified with a minimum preheat of 10°C is being used for a production weld during winter conditions when the actual plate temperature is measured at 6°C. What must be done before welding begins?

A. Welding may proceed — the 4°C difference between the plate temperature and the qualified minimum preheat is within the $\pm 5^\circ\text{C}$ tolerance provided in ASME IX QW-406 for field welding applications where exact preheat measurement is impractical

B. Welding must stop until the plate is preheated to at least 10°C throughout the required preheating zone — under ASME IX QW-406.1, preheat is an essential variable and production welding below the qualified minimum preheat temperature is a procedure deviation requiring corrective action

C. Welding may proceed provided the amperage is increased by 15% above the WPS maximum to compensate for the increased base metal heat absorption caused by the lower plate temperature during the first pass

D. The existing WPS may be used at the 6°C plate temperature provided the welding supervisor documents the temperature measurement and signs a heat input waiver in the fabrication record before welding the affected joint

47. A radiographic film interpreter finds a dark, circular indication approximately 8 mm in diameter at the weld root of a groove weld. The indication has an irregular, poorly defined edge and a lighter region at its centre. The welder reported an arc interruption and restart at this location. What discontinuity does this indication most likely represent?

A. Burn-through — the dark outer ring with a lighter centre represents a void where the root pass melted completely through the joint, with the lighter central area indicating the thin restrike weld metal bridging the hole and the darker outer ring representing the cavity perimeter

B. Cluster porosity — arc restrike locations consistently produce multiple small, closely-spaced pores from moisture at the restarted electrode tip, appearing as a cluster of small dark dots that overlap to form the approximate circular impression described

C. An isolated rounded pore — all circular indications at root pass restart locations are classified as isolated rounded porosity under the ASME RT acceptance criteria and may be evaluated against the applicable porosity acceptance chart

D. A crater — when an arc restart occurs at a shallow angle on a previous crater, the reheat causes the solidified crater depression to re-melt partially, creating the irregular outer ring with lighter centre characteristic of a crater defect at a root pass restart location

48. Under CSA W59, for a statically loaded structural T-joint connecting a 20 mm web plate to a 25 mm flange plate, what is the governing criterion for establishing the minimum fillet weld size?

A. The minimum weld size equals the web plate thickness (20 mm) divided by 2, giving a 10 mm minimum fillet weld — the governing plate is always the thinner member and the minimum size is one-half of its thickness

B. The minimum size is governed by the design loads only — the designer calculates the required throat to carry the factored shear and bending loads, and the minimum fillet weld size table in CSA W59 does not apply to members above 12 mm thickness

C. The minimum fillet weld size is determined by the thicker of the two connected members — for the 25 mm flange plate, CSA W59 Table 4.4 specifies a minimum fillet weld size of 8 mm, intended to ensure sufficient heat input to prevent rapid HAZ cooling and hydrogen cold cracking in the thicker base metal

D. The minimum fillet weld size equals the thinner plate thickness (20 mm) multiplied by 0.707 to give the required effective throat, and the resulting throat dimension determines the minimum leg size for the specified joint geometry

49. When using oxyfuel cutting on structural plate and the cutting oxygen pressure is set significantly higher than recommended for the tip size, what specific effect does the excessive pressure produce on cut quality?

A. The high-velocity oxygen stream concentrates heat at the top entry point and melts the upper edge of the plate before the cutting reaction can carry through the full thickness, producing the rounded-top edge characteristic of excessive oxygen pressure

B. The excessive cutting oxygen stream becomes turbulent below the tip orifice exit and the turbulent flow widens and flares the kerf in the lower section of the cut, producing a cut edge that spreads outward toward the bottom rather than remaining parallel

C. The excessive pressure forces the cutting reaction to proceed faster than the torch travel speed can manage, causing the drag lines to sweep forward rather than backward and producing a cut with forward-inclined drag lines rather than the vertical lines of a properly set cut

D. The excessive oxygen pressure narrows the kerf by increasing the velocity of the cutting stream and produces a cleaner, more parallel-sided cut than the recommended pressure — over-pressure in the cutting circuit always improves cut quality up to the torch maximum rated pressure

50. A plasma arc cutting operator cuts 6 mm stainless steel sheet with an air plasma system. The completed cut edges show consistent dross on the bottom surface that is hard, firmly bonded, and requires grinding to remove. What type of dross is described, and what parameter adjustment eliminates it?

A. Low-speed dross — the slow-moving plasma arc dwelt too long at each point, allowing resolidified metal to bond firmly to the cut edge — increasing the travel speed to the upper end of the recommended range eliminates hard bonded dross

B. Condensation dross — vapor from the plasma process condensed on the bottom cut edge before the air stream could expel it — increasing the air flow rate eliminates the condensation mechanism and restores a clean cut edge

C. Oxidation dross — air plasma on stainless steel produces chromium oxide that bonds to the cut edge surface as a hard ceramic coating — switching to nitrogen plasma eliminates the oxygen-based dross formation mechanism

D. High-speed dross — the travel speed is too fast for the selected amperage, causing the plasma arc to trail backward and the molten metal in the lower kerf to resolidify on the cut edge before being expelled — reducing the travel speed or increasing the amperage eliminates this type of hard dross

51. An OFC operator lights a cutting torch and examines the preheat flames. The flames show an inner cone surrounded by an intermediate feathery white zone that extends about 50% longer than the inner cone, surrounded by the outer envelope. What flame type is present and what adjustment is needed?

A. The flame is carburizing — the excess white feather extending beyond the inner cone indicates surplus acetylene in the mixture — to establish a neutral flame, the oxygen flow must be increased slightly until the white feather disappears and only the defined inner cone and outer envelope remain

B. The flame is oxidizing — the shortened appearance of the inner cone and the white feather represent excess oxygen in the mixture — the acetylene must be increased until the feather extends to its neutral-position length

C. The flame is neutral and correctly set — the white feather is the standard luminous acetylene zone that is always present in neutral OFC preheat flames and does not indicate excess acetylene

D. The flame is experiencing secondary combustion from the outer tip orifice — the feather visible outside the inner cone indicates the preheat gases are igniting in two separate stages and the torch body must be purged before the flame can be neutralized

52. In mechanized PAC production cutting, the torch height control (THC) system fails and the standoff distance decreases and is held slightly below the specified minimum for the duration of a run. What is the primary visible effect on the completed cut edges?

A. The power source automatically increases amperage to maintain the programmed arc voltage at the reduced distance, producing a deeper and wider kerf than the programmed cut specifications require for the plate thickness

B. The plasma arc transitions from transferred to non-transferred mode when standoff drops below minimum, replacing the cutting action with surface heating that produces a wide, rounded melted groove rather than a through-thickness kerf

C. The shortened nozzle-to-plate distance causes the shielding gas to impact the plate surface turbulently rather than in a laminar flow pattern — the turbulence disrupts the plasma column geometry at the cutting zone, producing a rougher, less square cut edge compared to the perpendicular profile achieved at correct standoff

D. The reduced standoff compresses and focuses the plasma column before it reaches the plate surface, producing a narrower and more perpendicular kerf than the programmed standoff — cut quality improves when standoff is decreased slightly below the minimum specification

53. An OFC operator examines a cut face on 75 mm structural plate and observes that drag lines are vertical from the top to about 30 mm depth, then sweep progressively backward through the lower portion, with the bottom edge showing a severely lagging cut face. The top edge is sharp and clean. What cutting parameter is most likely responsible?

A. The cutting oxygen pressure is too low for the plate thickness — insufficient oxygen pressure limits the reaction penetration depth to the upper portion of the plate and the lower drag reflects the oxygen-starved reaction zone falling behind the torch position

B. The travel speed exceeds the capacity of the cutting process for this thickness — the reaction maintains vertical propagation through the upper third of the plate but progressively lags behind the torch in the lower portion as the available reaction energy is insufficient to maintain through-thickness cutting at the applied speed

C. The preheat flame is too large for the plate — excess preheat creates a broad reaction zone in the upper section that initiates the cut correctly, but the thermal mass of the overheated upper zone absorbs energy from the lower reaction and produces the progressively worse lag as depth increases

D. The tip size is too small for the 75 mm plate — the undersized cutting oxygen orifice cannot supply sufficient oxygen flow for full-thickness cutting at any travel speed, and the backward drag in the lower portion is caused by the starved reaction falling progressively further behind as depth increases

54. A CAC-A operator is gouging a repair groove in a P91 chrome-moly-vanadium alloy steel pressure vessel weld. After completing the groove, the surface appears darker than the base metal and smells slightly of carbon. Before depositing the repair weld, what surface treatment is required and why?

A. The groove must be preheated to 300°C before grinding to prevent grinding wheel glazing — the elevated temperature softens the surface carbon layer and allows the abrasive to remove it without the smearing that occurs when grinding cold carbon-enriched steel

B. The groove must be acid-etched with a dilute solution compatible with the alloy chemistry — acid etching removes surface carbon by converting it to CO₂ that bubbles off the groove surface, producing a chemically clean surface for welding without the base metal removal associated with grinding

C. No surface treatment is required — the darker color is temporary thermal discoloration from the CAC-A arc that disappears upon cooling to ambient temperature, and the carbon smell is from the electrode, not from base metal contamination

D. The groove surface must be mechanically ground to remove the carbon-enriched layer — at least 1-2 mm of material must be removed from the gouge surface to eliminate the carbon contamination layer before repair welding begins, to prevent elevated carbon in the repair weld deposit from compromising the P91 weld metal properties

55. A CAC-A operator is completing a structural repair gouge and notices the arc sound has changed from the normal sharp crackling to a lower, softer hissing. The air pressure gauge and amperage gauge show no change. What is the most likely cause?

A. The electrode stub has been consumed to the point where the arc-to-electrode tip distance has increased beyond the normal operating range — the electrode must be repositioned in the electrode holder to restore the correct extension length and return the arc to normal gouging characteristics

B. The compressed air holes in the CAC-A electrode holder have become partially blocked by carbon deposit — clearing the air passages with a wire will restore the correct air velocity and the normal sharp arc characteristics

C. The power source is in a reduced-output thermal protection mode — prolonged gouging has caused the transformer to approach its thermal limit and the reduced output changes the arc sound until the machine cools sufficiently to restore full current

D. The arc sound change indicates the electrode has reached the copper-clad portion — the change in arc characteristics at the copper boundary means the electrode must be replaced immediately before further gouging produces copper contamination in the groove

56. An OFC operator sets the preheat flames to neutral on a multi-orifice cutting tip and observes that three of five preheat orifices produce sharp, defined inner cones while the remaining two produce ragged, elongated, flickering flames. What is the most likely cause?

A. The oxygen and fuel gas mixing ratio is incorrect for those two orifices — the gas metering valve in the torch body has worn unevenly, causing the two ragged orifices to receive a different gas mixture ratio than the three correctly burning orifices

B. Two of the preheat orifices contain partial blockages — restricted orifices receive less total gas flow than the clear orifices, producing a turbulent, irregular flame with a distorted inner cone at those specific locations — the blockages must be cleared with an appropriate tip cleaner before cutting begins

C. The acetylene supply pressure has dropped below the minimum for the tip size — when supply pressure is marginal, only the orifices with the widest bores maintain adequate flow, causing the smaller orifices to produce the ragged flame pattern described

D. The two ragged orifices are experiencing backfire ignition from contamination at the tip seat — the flickering at those specific orifices indicates hot spots on the tip body that ignite the mixed gas before it exits the orifice and produce the characteristic ragged flame appearance

57. When comparing the cut edge quality of argon-hydrogen plasma versus air plasma on austenitic stainless steel, which characteristic most directly justifies the added cost of the inert gas system for stainless applications?

A. Argon-hydrogen plasma cuts at twice the speed of air plasma on stainless steel — the speed advantage reduces production time sufficiently to offset the higher inert gas cost even at current argon-hydrogen pricing

B. Argon-hydrogen plasma produces a cut edge free of chromium oxide discoloration — the absence of oxygen and nitrogen in the plasma column prevents chromium oxidation of the cut face, maintaining the stainless steel passive layer and producing a brighter, corrosion-resistant cut edge that may not require grinding before welding

C. Argon-hydrogen plasma operates at significantly lower amperage than air plasma for equivalent thickness — the lower power demand reduces electrical energy costs, making argon-hydrogen the most cost-effective plasma system over the life of the cutting equipment

D. Argon-hydrogen plasma requires no consumable replacement during production runs — the inert gas chemistry prevents electrode erosion and nozzle oxidation that occur with air plasma, eliminating consumable cost and downtime on stainless steel production applications

58. After closing both cylinder valves and bleeding the hose circuits at the end of an OFC shift, an operator notices that the oxygen delivery pressure gauge still reads 45 kPa after the regulator adjusting screw has been fully backed out. The acetylene gauge reads zero. What does the residual oxygen pressure indicate?

A. The residual oxygen pressure indicates a seized regulator diaphragm on the oxygen regulator — a diaphragm that cannot return to its seated position under spring tension will maintain delivery pressure after the adjusting screw is backed out

B. The residual pressure is caused by the larger internal volume of the oxygen hose requiring additional time to bleed down — extending the oxygen needle valve opening period by an additional two minutes will allow the oxygen residual pressure to reach zero

C. The residual pressure indicates the oxygen regulator delivery seat is not fully sealing — a worn or damaged delivery seat allows oxygen from the high-pressure side to slowly bleed past the seat, maintaining pressure in the delivery circuit even after the adjusting screw spring tension is relieved

D. The residual pressure indicates the oxygen torch needle valve was not fully opened during the bleed-down procedure — opening both torch needle valves fully and allowing an additional 60 seconds of bleed time will purge the trapped oxygen volume from the hose to zero

59. A mechanized OFC system produces consistent, high-quality cuts for the first 40 cycles of a production run. Beginning at approximately cut 41, cut quality gradually deteriorates with increasing drag, rougher cut faces, and more top-edge rounding — despite no changes to the regulator pressure settings, travel speed, or machine program. What is the most probable cause?

A. The preheat orifices are becoming progressively blocked by spatter, slag, and oxidation deposits from successive cuts — gradual orifice restriction reduces preheat flame output and heat delivery at the cutting zone, degrading the cutting reaction quality despite unchanged regulator settings

B. Thermal expansion of the cutting table structure from the heat of successive cuts is gradually raising the plate surface, reducing the torch standoff and causing the preheat to concentrate at the entry point and round the top edge progressively across the production run

C. Moisture from the ambient atmosphere is condensing on the cutting tip orifices as the shop cools across the shift — condensed moisture at the preheat orifices disrupts gas flow and reduces flame output, causing the gradual degradation in cut quality that begins around cut 41

D. The magnetic clamping table is progressively losing field strength from thermal demagnetization during the production run — reduced clamping force allows small cumulative plate movement with each successive cut that registers as increasing drag on the cut face

60. When preheating carbon steel plate for OFC cutting, a welder is observing the steel surface to determine when the plate has reached the iron ignition temperature necessary for the cutting

reaction to initiate and sustain. What visual indicator confirms the steel has reached this temperature?

A. The steel surface develops a uniform dark-gray oxide scale that becomes grainy in texture — the transition from the initial smooth oxide to a grainy texture indicates the oxide formation rate has increased to the threshold associated with the iron ignition temperature

B. Small sparks or cinders begin to fall from the heated zone — the shedding of molten oxide particles from the heated surface is the reliable indicator that the surface has reached the ignition temperature and is ready for the cutting oxygen lever to be opened

C. The steel surface glows bright orange to yellow-white and takes on a slightly fluid-looking, shiny surface appearance — this visual state indicates the iron at the surface has reached the minimum ignition temperature at which it will sustain the exothermic oxidation reaction when the cutting oxygen stream is applied

D. The preheat flame inner cone visibly shortens as the plate approaches ignition temperature — reduced heat absorption by the steel at the ignition threshold reflects more thermal energy back into the flame, causing the inner cone to contract as the combustion balance changes

61. A mechanized PAC system shows a gradual increase in arc voltage readout over the course of a 4-hour production run, with no changes to programmed cutting parameters and consistent cut quality throughout. What does this gradual voltage increase indicate?

A. The gradual arc voltage increase indicates the cutting table is slowly losing ground potential — as the table grounds degrade from heat and vibration, the increased circuit resistance registers as a voltage increase on the arc monitor display

B. The voltage increase confirms the plasma power source is operating correctly in constant current mode — arc voltage naturally increases over production shifts as the power source automatically adjusts to maintain the programmed amperage as the consumables change character

C. The voltage increase indicates an error in the voltage-measuring circuit — thermal drift in the voltage measurement electronics causes a systematic over-reading of arc voltage that increases linearly with equipment operating time and requires recalibration at the start of each shift

D. The gradual arc voltage increase indicates consumable wear — electrode tip erosion increases the electrode-to-workpiece distance and nozzle orifice enlargement reduces plasma column constriction, both of which cause a measurable increase in operating arc voltage during cutting

62. An OFC operator examines completed cuts on 40 mm structural plate and finds the cut edges show a distinctly rounded and melted top, an unusually wide kerf at all depths, and very gentle (nearly flat) drag line curvature from top to bottom. What combination of parameters most likely produced this cut character?

A. Excessively fast travel speed with cutting oxygen pressure below the tip rating — the combination of speed and pressure deficit prevents the full-thickness reaction and produces the flat drag and wide kerf from the oversized heat zone at the entry point

B. Excessively slow travel speed with an oversized cutting tip for the plate thickness — slow travel allows excessive preheat accumulation at the top and the oversized tip floods the kerf with more oxygen than needed for the material thickness, rounding the top and widening the kerf without improving cut depth

C. Correct travel speed with insufficient preheat for the ambient temperature — insufficient preheat at the cutting zone concentrates thermal energy in a wide area around the cutting stream and produces the described top edge and kerf characteristics

D. Correct travel speed with cutting oxygen pressure set too low — reduced pressure narrows the cutting stream below its rated diameter, causes the top edge to overheat from the preheat flame, and widens the kerf from the thermal spread in the upper plate zone

63. A fabricator switches from cutting carbon steel to cutting 6061-T6 aluminum using the same PAC machine and amperage setting. Which parameter adjustment is typically required to maintain equivalent cut quality on the aluminum at the same thickness?

A. The travel speed must be increased significantly compared to the steel cutting speed — aluminum's high thermal conductivity requires faster travel to prevent the plasma from delivering excess heat that melts the surrounding material beyond the intended kerf width

B. The standoff distance must be reduced by 50% compared to the steel setting — aluminum's lower melting point requires the plasma arc to contact the material surface closer to the nozzle exit for adequate fusion of the full material thickness

C. The shielding gas must be changed from compressed air to 100% nitrogen for all aluminum cutting operations — air plasma produces a black, oxidized cut edge on aluminum that cannot be used as a weld preparation surface without full re-machining of the cut face

D. The cutting amperage must be reduced by at least 30% below the steel setting at the same thickness — aluminum's lower thermal resistance at equivalent thickness causes excessive melting beyond the kerf width at steel amperage levels

64. A CAC-A groove produced for a structural repair shows a smooth, consistent profile and the correct depth and width, but the groove sidewalls have a coarser surface texture than normal, with visible scoring marks parallel to the gouge direction. What is the most likely cause?

A. The electrode diameter is too small for the required groove width — an undersized electrode produces an irregular arc path that wanders across the groove width, leaving the scoring marks as evidence of the uncontrolled arc contact with the sidewalls

B. The compressed air pressure is too high — excess air velocity is sandblasting the groove sidewalls with fine particles of re-solidified metal expelled from the groove by the high-pressure air stream, producing the scoring texture on the sidewall faces

C. The electrode angle from the work surface is too flat — an electrode angle below approximately 30 degrees from the base metal surface causes the arc to contact the groove sidewall on the trailing side, and the electrode-to-sidewall contact produces the scoring marks parallel to the travel direction

D. The current is too high for the electrode diameter — overcurrent causes the electrode to partially vaporize in an uncontrolled manner, producing carbon deposits and spatter that impact the sidewalls and create the rough textured surface described

65. An OFC operator is midway through a production cut when the cutting tip momentarily contacts a raised surface irregularity on the plate. The preheat flames extinguish with a single sharp pop, no burning continues inside the torch body, and relighting the torch immediately restores full normal cutting operation. How should this event be classified and what action is required?

A. This is a flashback — the flame extinction with no subsequent burning confirms the flame propagated into the torch body and self-extinguished before reaching the hoses; the torch must be disassembled and all internal seals and orifices inspected before the next production cut

B. This is a sustained backfire with internal flame ignition — the immediate relighting ability indicates the flame successfully re-established in the mixing chamber after the initial backfire event; the torch must be shut down and sent for factory inspection of the internal mixing components

C. This is an oxygen surge event — the momentary tip contact caused a brief over-pressure in the oxygen circuit that extinguished the flame; the oxygen regulator must be submitted for pressure stability calibration testing before the next production shift

D. This is a backfire — the brief tip contact with the surface irregularity momentarily blocked the orifice and created a back-pressure disturbance that extinguished the preheat flame at the tip without propagating burning into the torch body — no internal inspection is required and the torch may be relit and cutting resumed immediately after confirming the tip face is clear of blockage or visible damage

66. A plasma arc cutting system equipped with a water-injection shield produces noticeably more perpendicular cut edges than a conventional gas-shield system on the same material and amperage. What physical mechanism accounts for this improved squareness?

A. The water injection chemically reduces the surface oxides on the cut face — the reduction reaction between water and iron oxide at cutting temperature produces a cleaner, more defined fusion boundary between the molten kerf and the base metal

B. The water forms a constricted sheath around the plasma column that physically narrows the jet diameter compared to a gas sheath at equivalent flow rate, producing a more parallel-sided plasma beam that cuts a more perpendicular kerf face from entry to exit surface

C. The water injection preheats the plate beyond the torch preheat zone by conducting heat from the nozzle body to the plate surface ahead of the arc, creating a wider thermal activation zone that reduces the cutting energy required per unit length of travel

D. The electrical conductivity of water allows it to carry a portion of the arc current, creating a dual-arc configuration with two simultaneous cutting channels that produce a wider, flatter kerf with more vertical sidewalls than a single plasma column

67. After OFC cutting of 25 mm 4140 alloy steel plate, hardness testing reveals the cut-face HAZ has a hardness of 58 HRC. The parent metal has a hardness of 28 HRC. Before the cut edge is used as a weld preparation for a pressure vessel nozzle attachment, what action is required?

A. The hardened edge must be removed by mechanical grinding or machining to expose clean, unaffected base metal at the specified preparation depth — the hard, heat-affected surface zone must not be incorporated into the weld joint preparation for pressure vessel applications where HAZ hardness limits apply

B. The 58 HRC reading is acceptable for 4140 alloy steel and requires no further treatment — 4140 is specifically designed to be used in the as-quenched condition at hardness values up to 60 HRC and the cut edge hardness is within the normal material specification

C. Preheating the cut edge to 300°C for 30 minutes before machining will reduce the hardness by tempering — the preheat temper treatment eliminates the need for material removal and is accepted as an alternative to grinding under ASME B31.3 for alloy steel pressure piping

D. The hardness deviation must be reported to the pressure vessel inspection authority as a non-conformance before any further operations — the HAZ hardness above 22 HRC triggers an automatic engineering review before the cut edge may be machined, heated, or welded

68. A pressure vessel fabricator evaluates PAC versus OFC for cutting P91 chrome-moly-vanadium alloy steel components. The applicable code requires all thermally cut edges to have the hardened surface layer removed by mechanical means before use as a weld preparation. Which statement most accurately governs the choice of cutting method for this application?

A. OFC is preferred for P91 alloy steel components because the oxidizing flame chemistry generates a lower peak HAZ temperature than PAC, producing edge hardness consistently below 250 HV without mechanical removal

B. PAC is prohibited for all P-number 5 alloy steel components under ASME Section VIII Division 1 — the code specifically requires OFC as the only permitted thermal cutting method for Cr-Mo alloy steels in pressure vessel fabrication

C. OFC should be used for P91 components because PAC produces excessive HAZ hardness on Cr-Mo alloys regardless of cutting speed, while OFC reliably limits edge hardness to values that do not require mechanical removal before welding

D. Either cutting method may be used on P91 alloy steel, but the code requirement for mechanical removal of the hardened edge applies equally to both processes — the selection between OFC and PAC for P91 is based on production efficiency and surface finish requirements rather than the hardened layer removal obligation, which is mandatory regardless of method

69. Under Canadian provincial OHS regulations and CSA B51 compressed gas storage standards, what is the minimum required separation between oxygen cylinders and combustible gases (such as acetylene) in a storage area without a rated fire-resistant barrier?

A. 1.5 metres — the minimum separation distance for unprotected oxidizing gas and flammable gas cylinder storage is 1.5 metres under the applicable OHS regulations for welding shop cylinder storage areas

B. 3 metres — the standard minimum separation between oxygen and fuel gas cylinder storage in an unprotected area is 3 metres, or an alternative is the installation of a non-combustible barrier at least 1.5 metres high

C. 6 metres — the minimum required horizontal separation between oxygen cylinders and combustible gas cylinders in an unprotected storage area is 6 metres (approximately 20 feet) as specified in the applicable compressed gas safety standards

D. 10 metres — the separation requirement for all compressed oxidizing gases from any combustible material or fuel gas is 10 metres outdoors and 6 metres indoors under the federal transportation of dangerous goods requirements applied to in-plant cylinder storage

70. During CAC-A back-gouging of a structural weld root, the operator notices that expelling spatter from the groove is landing on an adjacent zone of the base metal that will require magnetic particle testing. What specific concern does the deposited spatter create for the NDT?

A. CAC-A spatter landing on the inspection zone creates arc strike damage — each spatter particle makes a brief electrical contact at a random location on the base metal surface, producing micro-arc strikes that can create hard spots in the HAZ and serve as potential fatigue crack initiation sites under cyclic loading

B. The spatter deposits metallic particles that act as magnetic bridges across any surface cracks in the inspection zone — the particles locally close surface-breaking discontinuities and prevent the magnetic flux from leaking at crack faces, causing genuine defects to produce no MT indication

C. The spatter contamination creates false-positive MT indications — loose metallic particles on the base metal surface attract magnetic particles and produce concentrated indications that can be misidentified as crack indications requiring grinding and re-examination

D. Spatter deposits from CAC-A electrodes contain elevated carbon from the electrode composition — the carbon contamination diffuses into the base metal surface, hardening the metal below the spatter deposit and creating a hardness pattern that appears as an MT indication

71. An OFC operator working in a fabrication shop with general mechanical ventilation has been cutting structural carbon steel for 3 hours. The operator develops a mild headache and dizziness. The torch flame appears correct and cut quality is normal. What should the operator do first?

A. Stop work immediately, leave the work area and move to fresh air, and report the symptoms to first aid — the headache and dizziness are consistent with carbon monoxide accumulation from combustion products that may have exceeded safe atmospheric concentrations despite the general ventilation

B. Reduce the acetylene flow slightly and continue working — the symptoms indicate the preheat flame is slightly carburizing, producing excess CO that dissipates quickly if the flame is neutralized more precisely

C. Increase the ventilation fan speed and drink water — heat stress and mild dehydration from working near the cutting flame produces headache and dizziness at the described work duration, and increased airflow with hydration restores normal working capacity

D. Switch from acetylene to propane immediately — acetylene's lower burning temperature produces more incomplete combustion products than propane in shop conditions, and switching fuel gases will reduce CO generation and relieve the symptoms

72. An electrode marked E7018-1 H4R is being evaluated for a critical structural application requiring verified low-hydrogen performance over an extended shift. What does the "H4R" suffix specifically communicate about this electrode's qualification?

A. The "H4" designates the electrode is classified for use only in the 4G overhead position — the horizontal and vertical positions require H2 and H6 designated electrodes respectively under the AWS A5.1 low-hydrogen position classification system

B. The "H4R" suffix indicates the electrode is qualified for reconditioning — the "R" designates that the electrode coating may be re-baked up to four times at 260-430°C without loss of its low-hydrogen classification

C. The "H4R" suffix designates the electrode meets the maximum 4 mL/100g diffusible hydrogen limit under controlled conditions, and the "R" indicates the coating has been tested and certified to maintain the H4 classification for at least 9 hours of atmospheric exposure at 80% relative humidity

D. The "H4R" designates the electrode coating contains four rare earth elements that provide the resistance to moisture reabsorption — the rare earth compounds are the patented chemistry that qualifies the electrode for the extended atmospheric exposure class designation

73. An SMAW welder completes the root pass on a 5G carbon steel pipe joint using E6010 and immediately begins the hot pass. The supervisor observes and approves the sequence without calling for a visual inspection between passes. What specific quality benefit justifies proceeding directly from root to hot pass without cooling?

A. The hot pass deposited on the still-warm root pass maintains the root joint above the martensite formation temperature throughout the hot pass thermal cycle, preventing any martensite from forming in the root pass HAZ

B. Depositing the hot pass before the root pass cools below 100°C prevents moisture condensation in the weld root area — atmospheric humidity condenses on a cool root pass surface and generates hydrogen in the overlying hot pass deposit

C. The hot pass improves the appearance of the root pass for visual inspection — the hot pass flattens the convex root pass profile and removes the concave center that is characteristic of all E6010 root passes, making the combined root/hot pass profile easier to inspect

D. The hot pass thermal cycle refines the coarse grain structure of the root pass, burns out any minor porosity or inclusions in the root deposit, and remelts the root pass surface oxide — the combined metallurgical improvements enhance root pass quality before the joint is sealed by fill passes

74. A welder is preparing to weld 15 mm thick 2.25Cr-1Mo (P22) alloy steel pressure pipe using E8018-B2 electrodes. The WPS specifies 150°C minimum preheat and 230°C maximum interpass temperature. The pipe temperature in the shop is 14°C. What must be done before the first arc is struck?

A. Strike a preliminary test arc on a scrap piece of P22 material and measure the HAZ hardness with a portable hardness tester to confirm the heat input is within the correct range for this preheat condition

B. Apply supplemental heat to bring the full pipe joint area and at least 75 mm on each side of the weld to a minimum of 150°C, verify this temperature using a calibrated surface measuring

device, and confirm the preheat zone is maintained at 150°C or above immediately before the first arc is struck

C. Confirm the E8018-B2 electrodes were stored in a holding oven at a minimum of 120°C for at least 2 hours before the shift and record the electrode oven temperature in the production record before issuing the electrodes for this joint

D. Notify the authorized inspection authority that ambient temperature welding will be performed below the standard shop minimum of 18°C — a formal temperature deviation record must be approved before any P22 pressure pipe welding commences below 16°C ambient temperature

75. An SMAW welder is running a vertical-down root pass on a 6-inch carbon steel pipe using E6010 electrodes. The pool is running ahead of the arc and the root pass reinforcement is inconsistent. Which combination of adjustments most directly corrects this condition?

A. Reduce the amperage below mid-range for the electrode size, use a whipping or in-and-out electrode motion to allow incremental solidification between electrode advances, and increase the drag angle to direct arc force into the root gap rather than along the pipe surface

B. Increase the amperage to the maximum for the electrode size and use a faster downhill travel speed — higher amperage at greater travel speed reduces the pool volume at each point along the joint and prevents the pool from running ahead of the arc

C. Switch to a larger diameter electrode — the larger electrode deposits a stiffer, more viscous pool that resists forward flow under gravity during vertical-down root pass welding more effectively than smaller electrodes

D. Maintain the same amperage and reduce the drag angle to nearly perpendicular to the pipe surface — a reduced drag angle concentrates the arc energy at the pipe surface and prevents the pool from advancing ahead of the electrode during vertical-down welding

76. A fabrication supervisor compares E7016 and E7018 electrodes for a critical high-restraint structural application on Grade 350W plate. Both have basic flux coatings and are available in the H4R atmospheric exposure classification. What is the most significant practical difference between E7016 and E7018 for this application?

A. E7018 produces lower diffusible hydrogen than E7016 because the iron powder additions in the E7018 coating reduce the coating's surface area available for moisture absorption — the reduced surface area results in measurably lower hydrogen pickup during atmospheric exposure

B. E7016 and E7018 are functionally interchangeable for critical structural applications — both have basic low-hydrogen coatings, equivalent strength classifications, and the same H4R atmospheric exposure limit, and the choice between them is based solely on the available electrode diameter range

C. E7016 provides superior low-hydrogen performance compared to E7018 because E7016 does not contain iron powder additions that can introduce hygroscopic iron oxide into the coating chemistry — iron powder absorbs atmospheric moisture at a higher rate than plain basic flux coating

D. E7018 electrodes produce significantly higher diffusible hydrogen than E7016 when stored incorrectly — the iron powder in E7018 accelerates moisture reabsorption after the sealed container is opened, making E7016 the mandatory choice for all critical high-restraint structural applications

77. An SMAW welder is producing structural fillet welds using E7018 on DCEP. The welding supervisor recommends switching to an AC power source to eliminate arc blow that is affecting weld quality at the joint ends. What is the correct expectation for this change?

A. Switching to AC will increase the deposition rate of E7018 by approximately 20% because the alternating polarity cycle produces a higher frequency of electrode melting events per second than DC, increasing the metal transfer rate proportionally throughout the shift

B. Switching to AC will require an amperage reduction of approximately 15% — the current zero-crossing in AC extinguishes the arc briefly at each polarity reversal and the basic E7018 coating cannot maintain full thermionic ionization through the reversal, requiring lower average current to maintain stable arc characteristics

C. Switching to AC will increase spatter significantly compared to DCEP — the current zero-crossing at each half-cycle creates a brief arc instability that allows molten metal to detach from the electrode tip without directed arc force, producing the higher spatter output characteristic of basic electrodes on AC power

D. Switching to AC will eliminate the arc blow — AC produces a continuously reversing magnetic field that cannot sustain the asymmetric flux concentration responsible for forward or backward arc deflection at joint ends during DC welding, and E7018 electrodes carry the "18" suffix designation confirming full AC and DCEP compatibility with no loss of weld quality on either power source type

78. When performing overhead SMAW fillet welds (4F) on a structural T-joint using E7018, which electrode placement and technique combination best prevents pool sag and maintains a flat face profile?

A. Position the electrode at 45 degrees bisecting both plates with a drag travel angle of 5 to 15 degrees, use stringer beads at the lower end of the WPS amperage range, and maintain a short arc length — this combination keeps the pool volume small and directs arc force upward into the joint to counteract gravity

B. Increase the amperage to the WPS maximum for the electrode diameter, use a wide weave motion to spread heat across both toes simultaneously, and travel at the minimum recommended speed to build reinforcement in a single overhead pass

C. Position the electrode at 75 to 80 degrees toward the upper plate and use a push travel angle — the steep work angle concentrates heat on the upper plate and the push angle directs arc force downward toward the horizontal plate to fill both toes simultaneously

D. Use a whipping technique combined with a 60-degree electrode work angle and maximum amperage — the whipping motion at higher amperage deposits metal rapidly enough to exceed gravity's pull on the overhead pool before it can sag away from the joint

79. Under CSA W47.1, what is the minimum required production welding documentation content for each weld joint on a certified pressure vessel fabrication?

A. The WPS number used for the joint, the welder's CWB certificate number, preheat and interpass temperature records taken during production, filler metal identification including heat or lot number, and the NDE report including the accept/reject decision for each joint

B. The welder's printed name on the fabrication traveller — CSA W47.1 identifies welder identification as the sole mandatory per-joint record entry, with all other documentation maintained at the company level rather than per individual joint

C. The drawing revision number and the certified welding supervisor's signature at the end of the shift — the supervisor's signature certifies all production welds made during that shift meet the requirements of the WPS and applicable code

D. The NDE report accepted by the inspection authority only — per-joint production records are considered internal quality documents and only the final NDE acceptance record needs to be retained for the pressure vessel registration file

80. During SMAW production with E7018 H4R electrodes that were removed from a hermetically sealed container and placed on the welding bench, a journeyman welder observes increased porosity in joints produced after 5 hours of bench exposure at 65% relative humidity. The electrodes appeared dry and undamaged when issued. What is the most probable cause?

A. The hermetically sealed container created an argon-enriched atmosphere inside the package that was released when the container was opened — the released argon briefly contaminated the electrode coating with an inert gas that now produces the detected porosity pattern in the weld deposit

B. The 5 hours of exposure at 65% humidity has caused the basic E7018 coating to absorb sufficient atmospheric moisture to generate excess hydrogen during welding — AWS D1.1 limits H4R exposure to a maximum of 4 hours before reconditioning at 260-430°C is required, and this limit has been exceeded by 1 hour

C. The sealing process introduced residual moisture into the hermetically sealed container from the manufacturing process — the moisture was trapped inside the sealed package and was slowly absorbed by the coating between package filling and the time of opening

D. The humidity meter used to determine the 65% value is incorrectly calibrated — a humidity reading of 65% at an uncalibrated meter actually represents approximately 85% relative humidity, which is the threshold at which all AWS D1.1 exposure time limits are automatically halved

81. Under ASME Section IX, a SMAW WPS was qualified using E7018 (F-Number 4, A-Number 1 deposit) on P1 Group 1 carbon steel. The fabricator wants to amend the WPS to include E7016-C2L electrodes, which are classified as F-Number 4 but produce an A-Number 8 (nickel alloy steel) deposit. Is this amendment permissible without new PQR qualification?

A. No — a change from A-Number 1 (carbon steel) to A-Number 8 (nickel alloy steel) deposit chemistry constitutes an essential variable under ASME IX QW-404 that requires new PQR test coupon qualification

B. No — any addition of a new electrode brand or trade name to an existing WPS constitutes a change requiring new PQR testing under ASME Section IX regardless of F-Number or A-Number classification continuity

C. Yes — since both electrodes share F-Number 4 classification, they are fully interchangeable on the WPS without any further qualification requirement under ASME IX

D. Yes — the F-Number 4 classification permits the amendment without new PQR testing, but the A-Number change must be reviewed by the authorized design engineer to confirm A-Number 8 deposit chemistry is acceptable for the production joint before the amended WPS is released for production use

82. After completing a CJP groove weld on 50 mm thick Grade 490W structural steel, the welding supervisor specifies a minimum 4-hour hydrogen release hold at 250°C before any cooling, NDE, or post-weld heat treatment. What metallurgical purpose does this post-weld holding procedure serve?

A. The hold at 250°C provides the diffusion activation energy needed for hydrogen to migrate from the weld metal and HAZ out through the surface before the joint cools below the temperature at which hydrogen mobility becomes insufficient to prevent accumulation at microstructural traps — this procedure is called a hydrogen release or bake-out treatment

B. The hold at 250°C ensures the full martensite transformation in the weld metal HAZ is complete before any cooling begins — the 4-hour isothermal hold at this temperature provides sufficient time for all austenite to transform to martensite before the subsequent PWHT tempering cycle

C. The hold prevents moisture condensation on the weld surface during the cooling phase — holding above 100°C for 4 hours after welding ensures the joint remains dry before NDE methods that are sensitive to surface moisture are applied

D. The 250°C hold normalizes the grain size in the weld metal centreline — isothermal holding above the ferrite-austenite transformation temperature refines the columnar grain structure in the deposited weld metal before the joint is loaded in service

83. A welder is completing the root pass on a 6G fixed 45-degree inclined carbon steel pipe joint using E6010 electrodes. Which clock position typically presents the most demanding combination of technique challenges, and what specific adjustment addresses the difficulty at that location?

A. The 12 o'clock position presents the most difficulty because the pipe inclination causes the root pool to run downhill toward 6 o'clock during the flat/overhead transition — the welder must increase travel speed significantly at 12 o'clock to prevent the pool from accumulating at the top of the joint

B. The 3 and 9 o'clock positions present equal difficulties because the inclined pipe axis causes the pool to drain toward the lower side of the joint at these positions — the welder must tilt the electrode toward the uphill side at these clock positions to redirect the pool toward the lower groove face

C. The 6 o'clock position is the most demanding because the welder must maintain the root keyhole at the overhead location while approaching from an inclined travel direction that

continuously changes the effective gravity component acting on the pool — a more deliberate keyhole technique with careful arc positioning at the root face addresses penetration at this position

D. All positions on the 6G joint present identical technique challenges because the constant 45-degree pipe inclination distributes the effect of gravity uniformly around the full circumference, and no position-specific adjustments are required from a single consistent technique

84. An SMAW welder removes E7018 electrodes from the holding oven at 7:30 AM and places them in a field electrode pouch. At 9:30 AM, the welder has used approximately half the electrodes and the remaining unused electrodes are still in the pouch. The shop records a relative humidity of 68%. Under AWS D1.1 Table 4.7, what is the status of the remaining electrodes?

A. The unused electrodes have exceeded the 2-hour atmospheric exposure limit and must be immediately returned to the holding oven for reconditioning at 260-430°C before they can be used for any further production welding

B. The unused electrodes have been in atmospheric exposure for 2 hours out of the permitted maximum of 4 hours — they remain within the AWS D1.1 atmospheric exposure limit and may continue to be used for up to 2 more hours before reconditioning at 260-430°C is required

C. The unused electrodes should be visually inspected for visible moisture or coating damage — those with no visible deterioration are exempt from the exposure timer and may be returned to the holding oven for standard re-heating without the mandatory reconditioning cycle

D. The unused electrodes must be returned to an airtight sealed container with desiccant within 15 minutes — transfer to a sealed container within the first 2 hours of atmospheric exposure effectively pauses the exposure timer and allows the electrodes to be used later in the shift without counting the initial 2-hour exposure

85. A quality inspector rejects a series of structural fillet welds because the face profiles show 4 mm of convexity above the theoretical face on 8 mm specified leg welds. The fabricator argues the welds exceed the specified size and should be stronger, not weaker. What technical basis supports the inspector's rejection?

A. CSA W59 and AWS D1.1 define oversize fillet welds as a rejectable condition because excessive weld metal volume indicates the welder is depositing at higher than specified heat

input, which introduces thermal damage to the HAZ that reduces the joint fatigue resistance below the design minimum

B. Excessive convexity increases the risk of delayed solidification hot cracking in the weld metal centreline — the additional volume of metal above the theoretical face increases the last-to-solidify zone dimensions and concentrates segregation products that reduce the weld metal toughness

C. Excessive fillet weld convexity increases the risk of incomplete fusion at the weld root — the extra convex metal was deposited by slowing the travel speed below the WPS minimum, and the reduced arc force from slow travel resulted in poor sidewall fusion in the lower groove

D. The abrupt geometric change at the weld toe between the convex weld face and the flat base metal surface creates a stress concentration that reduces fatigue life at the toe under cyclic loading — this toe notch effect is specifically identified as a structural concern in CSA W59, and excessive convexity is a rejectable condition regardless of the weld leg size

86. An SMAW welder must select between E316L-16 and E308L-16 electrodes for welding 316L austenitic stainless steel pressure components. The specification requires that the weld deposit maintain corrosion resistance equivalent to the base metal in a chloride-containing service environment. Which electrode is required and why?

A. E308L-16 is required because its lower chromium content compared to E316L-16 produces a more corrosion-resistant deposit in chloride environments — higher chromium without molybdenum actually reduces pitting resistance in stainless steel weld metal

B. Either electrode is acceptable — E316L-16 and E308L-16 produce deposits with equivalent corrosion resistance in all environments, and the selection between them is based solely on the tensile strength specification required by the design code

C. E316L-16 is required — the 316L electrode contains molybdenum (approximately 2-3% Mo) that provides corrosion resistance in chloride-containing environments equivalent to the molybdenum in the 316L base metal — using E308L-16 (no molybdenum) would produce a weld deposit with significantly lower pitting resistance than the 316L base material

D. E308L-16 is preferred because the lower alloying content of 308L produces a weld deposit with higher ductility than E316L-16 — higher ductility in the weld metal is the primary corrosion resistance mechanism in chloride environments where stress corrosion cracking governs joint life

87. An SMAW welder is completing overhead CJP groove weld fill passes on 18 mm structural steel using E7018. The passes show intermittent slag entrapment concentrated at the fusion line between the weave edge and the groove sidewall. Which technique change most directly addresses this defect?

A. Switch from weave beads to stringer beads — depositing multiple narrow stringer beads in the overhead groove directs the arc directly at each sidewall fusion surface in sequence rather than oscillating across the full groove width, eliminating the slag entrapment at the weave reversal points where the slow-moving electrode allows slag to accumulate

B. Increase the weave width by 5 mm to heat the groove sidewalls more intensely — a hotter sidewall provides more time for slag to float to the surface before pool solidification at the weave reversal positions

C. Increase the amperage to the WPS maximum — higher amperage increases pool fluidity and the faster-flowing pool carries slag to the surface more effectively at the weave reversal positions where the slow electrode speed normally allows slag to settle

D. Apply a lower preheat temperature — reducing the preheat temperature increases the cooling rate and causes the slag to freeze before it can sink to the fusion line, holding it at the surface where inter-pass cleaning easily removes it

88. An E6010 electrode is selected for a root pass on a 6G carbon steel pipe joint scheduled for full volumetric examination. Which specific performance characteristic makes E6010 preferred over E7018 for this application?

A. E6010's higher minimum tensile strength of 60 ksi compared to E7018 ensures the root pass mechanical properties exceed the minimum design requirement for the high-pressure pipeline service conditions

B. E6010's cellulosic coating generates a high-hydrogen, deeply penetrating arc with a fast-freezing slag system that allows the welder to deposit the root pass at high travel speeds in all positions with consistent keyhole formation and root reinforcement — characteristics that are essential for the demanding 6G position

C. E6010 is significantly less expensive than E7018 per electrode — the cost advantage is the governing selection criterion for pipeline root pass applications where hundreds of root passes are completed per shift

D. E6010 produces lower diffusible hydrogen than E7018 in the root pass deposit — the lower hydrogen content reduces the risk of hydrogen-induced cracking at the root, which is the most common rejectable defect on volumetrically examined pipeline joints

89. Under CWB welder certification, a welder holds a current qualification for "SMAW-2G-Pipe-FM1" on carbon steel. A production job requires completing 3G vertical groove welds on the same material and filler metal group. Can the welder perform this production work under the existing certificate?

A. Yes — the 2G horizontal pipe qualification covers all less demanding positions including 1G and 3G vertical, since the horizontal position is considered the second most demanding groove weld position in the CWB qualification hierarchy

B. No — the 2G and 3G positions require separate qualification tests under CWB standards because they use fundamentally different welding techniques and pool support mechanisms — the horizontal position qualification does not cover vertical groove welding

C. Yes — a pipe qualification on any position automatically covers all positions for the same process and material group because pipe qualification is intended to be comprehensive and the CWB does not require separate tests for each individual pipe position

D. No — CWB position qualifications are position-specific and a 2G horizontal pipe certificate does not authorize production welding in the 3G vertical position — a separate 3G qualification test must be completed to add vertical position pipe groove welding to the welder's certified scope

90. An FCAW-G operator is producing fillet welds on 12 mm structural steel using E71T-1M wire with 75/25 Ar/CO₂. The completed welds consistently show a deep groove along the weld centreline running the full length of each bead, visible after slag removal. What specific welding condition causes this groove pattern?

A. Travel speed is too fast — the electrode is depositing metal in a narrow central strip at high speed and the grooved appearance is the underfilled centreline that results when the pool cannot spread to fill the bead width before solidification

B. Wire feed speed is too high for the voltage setting — excess wire feed relative to the arc voltage creates an oversized molten pool that overflows the groove faces and produces a pronounced centre groove as the surplus metal flows to the toes at the expense of the centreline

C. Arc voltage is too low for the wire feed speed — with insufficient arc length, the wire extension contacts the molten pool and the arc transfers metal into a confined point without the arc spread required to produce a flat face — the result is a centered mound that contracts on cooling to produce the observed centreline groove

D. Shielding gas flow rate is too high — excess gas flow produces turbulence above the molten pool and the spiraling gas stream creates a cyclonic effect that depresses the pool centreline and produces a longitudinal groove after the pool solidifies

91. When GMAW spray transfer produces a spatter-free arc and smooth deposits at the correct WPS parameters, but the same setup consistently produces excessive spatter when the operator reduces the contact-tip-to-work distance from 19 mm to 10 mm, what is the most likely cause?

A. The reduced CTWD changes the arc characteristics so that the wire melts closer to the contact tip — the shortened electrical stick-out reduces the resistive preheating of the wire, requiring more of the arc energy to melt the wire tip, which generates the explosive droplet formation and spatter characteristic of globular transfer at the reduced CTWD

B. The reduced CTWD increases the wire feed speed required to maintain the same arc voltage — the higher wire feed speed at the CV machine output exceeds the transport limit of the shielding gas envelope, pulling atmospheric air into the arc and causing the spatter from contaminated transfer

C. The CTWD reduction changes the inductance of the welding circuit — shorter cable loop inductance at the reduced distance causes the power source to respond too rapidly to arc fluctuations, producing an overcorrection response that generates spatter at each corrective cycle

D. The reduced CTWD places the contact tip inside the shielding gas envelope — at 10 mm CTWD, the contact tip is within the shielding gas cone and the preheated tip metal vaporizes into the shielding atmosphere, contaminating the arc with metallic vapor that produces spatter

92. A GMAW operator changes from a drag travel angle (backhand) to a push travel angle (forehand) on a flat-position butt weld with identical voltage, amperage, and travel speed settings. What change in bead profile is most characteristic of the push angle?

A. The push angle increases penetration and narrows the bead width — the forward-directed arc force concentrates energy at the leading edge of the pool and drives the arc deeper into the base metal ahead of the solidifying pool

B. The push angle produces a flatter, wider bead with shallower penetration than the drag angle — the arc is directed forward into the base metal ahead of the pool rather than into the pool itself, spreading heat over a broader area and reducing the concentration of energy driving penetration into the root of the joint

C. The push and drag angles produce identical bead profiles at identical parameter settings — travel angle in flat-position GMAW has no measurable effect on bead geometry because the flat-position gravity effect normalizes the pool shape regardless of torch inclination

D. The push angle produces a higher crown profile than drag because the forward arc force builds metal at the leading edge of the pool before it can flatten and spread, creating a taller centreline deposit with narrower base dimensions

93. An FCAW-G operator is producing structural fillet welds outdoors on a construction site with variable wind conditions. At what approximate wind speed does the shielding gas coverage from a 75/25 Ar/CO₂ gas-shielded FCAW system become ineffective and require a windbreak or process change?

A. Wind speeds above 25 km/h — gas-shielded FCAW maintains effective coverage up to 25 km/h without windbreaks, above which the gas envelope is disrupted and weld quality requires monitoring

B. Wind speeds above 40 km/h — the heavier CO₂ component of the 75/25 blend resists wind displacement better than pure CO₂, allowing unprotected outdoor welding up to 40 km/h wind speed

C. Wind speeds above approximately 8 to 10 km/h — gas-shielded FCAW-G is very sensitive to air movement and any noticeable breeze above approximately 8 km/h can disrupt the shielding gas envelope enough to cause porosity and weld contamination, requiring immediate protection

D. Wind speed has no effect on FCAW-G quality — the gas shielding nozzle on a FCAW-G gun directs the shielding gas at the weld pool from a distance of 10 mm and wind effects at the pool level are blocked by the gun body and nozzle geometry

94. When evaluating the use of metal-cored wire (E70C-6M) as a replacement for solid wire (ER70S-6) in a GMAW production application, which specific productivity advantage of metal-cored wire is most significant for long continuous fillet welds on structural steel in the flat and horizontal positions?

A. Metal-cored wire can be used at lower shielding gas flow rates than solid wire — the metal powder core provides supplemental shielding from the metallic vapor cloud generated by the core ingredients, reducing the gas flow needed by approximately 30%

B. Metal-cored wire operates at lower wire feed speed than solid wire to achieve the same deposited bead size — the higher density of the metal powder core increases the mass per unit length of wire, depositing more metal per metre of wire feed

C. Metal-cored wire requires more frequent contact tip changes than solid wire — the metallic core particles produce more spatter that builds up on the contact tip bore, requiring a faster maintenance cycle that increases production overhead costs

D. Metal-cored wire achieves higher deposition rates than solid wire at equivalent amperage and voltage settings — the combination of metal powder and steel tube delivers more deposited weld metal per unit of arc energy than solid wire alone, reducing total arc time per unit of completed weld length

95. A GMAW operator must weld 12 mm carbon steel brackets to 1.6 mm galvanized sheet metal cladding panels. The WPS specifies short-circuit transfer. What is the primary reason short-circuit transfer is selected over spray transfer for this thin-material application?

A. Short-circuit transfer delivers significantly lower heat input per unit length than spray transfer — the lower heat input reduces burn-through risk on the 1.6 mm sheet and limits the extent of the HAZ that degrades the zinc coating and produces zinc oxide fume in the adjacent unmelted sheet

B. Short-circuit transfer produces 30% less zinc oxide fume than spray transfer on galvanized sheet because the lower arc temperature vaporizes less zinc from the coating during the weld — short-circuit's lower arc energy is the standard requirement for all galvanized steel GMAW applications

C. Short-circuit transfer requires no shielding gas on galvanized steel — the zinc coating generates sufficient gaseous shielding during the welding cycle and the external gas cylinder can be disconnected for this application

D. Short-circuit transfer produces a coarser droplet that fills the zinc coating gap more effectively than the fine spray droplets — the larger molten drops in short-circuit transfer wet the galvanized surface and seal the coating edge before the zinc can oxidize

96. On a constant-voltage (CV) GMAW power source set to 24 V at 200 A, the operator increases the contact-tip-to-work distance from 16 mm to 25 mm without changing any other settings. What is the primary effect of this CTWD increase on the weld parameters?

A. The arc voltage decreases — the longer wire extension has less electrical resistance than the shorter arc path, and the CV machine reduces output voltage to maintain the programmed current setting

B. The effective amperage decreases — the longer wire extension between the contact tip and the arc increases the resistive preheating (I^2R heating) of the wire stub, reducing the amount of current from the power source needed to melt the wire tip — the CV machine maintains the set voltage but delivers less current to the arc

C. The arc length increases proportionally — increasing the CTWD by 9 mm increases the arc length by the same 9 mm because the CTWD and arc length are additive components of the total electrical circuit from contact tip to workpiece

D. The wire feed speed increases automatically — the CV machine detects the voltage drop at the increased CTWD and commands the wire feeder to increase wire feed speed to restore the arc at the correct length for the programmed voltage

97. During production FCAW-G welding of overhead fillet welds on structural steel using E71T-1M wire, the completed welds consistently show excessive convexity with the weld face extending well above the theoretical toe-to-toe plane. Which parameter adjustment most directly corrects the overhead convexity?

A. Increase the wire feed speed and voltage proportionally — higher heat input in the overhead position improves pool fluidity so the molten metal spreads to both toes simultaneously before gravity can pull it away from the vertical plate

B. Reduce the wire feed speed to decrease the deposited volume per unit time — with less molten metal available at any given point, surface tension in the overhead pool is sufficient to hold the weld flat without the metal accumulation that produces excessive convexity

C. Increase the stick-out distance from 19 mm to 32 mm — the increased resistive preheating of the extended wire reduces the effective arc energy and produces a smaller, flatter pool that maintains the correct profile in the overhead orientation

D. Switch from E71T-1M to E71T-5 wire — the basic slag system of T-5 wire produces a stiffer, more viscous pool that physically resists sagging and convexity in the overhead position better than the rutile T-1M slag chemistry

98. An FCAW operator using E71T-8 self-shielded wire for structural fillet welds in an outdoor application notices that the welds produced while welding toward a mild headwind consistently show porosity on RT examination, while welds produced in the same position away from the wind are defect-free. What is the most likely cause?

A. The headwind direction causes the self-shielding gas atmosphere generated by the T-8 core to be displaced away from the weld pool — the self-shielding atmosphere is swept backward by the oncoming wind before it can protect the arc, allowing atmospheric nitrogen and oxygen to contaminate the deposit when welding into the wind

B. The headwind cools the electrode coating before the core compounds can fully vaporize — the wind removes heat from the wire end and prevents the T-8 flux compounds from reaching the activation temperature required for complete shielding gas generation ahead of the arc

C. The headwind causes turbulence in the shielding atmosphere that entrains atmospheric nitrogen into the weld pool — nitrogen porosity occurs specifically when welding into the wind because the turbulence generated at the gas-atmosphere interface is greater on the windward side of the arc than on the leeward side

D. The headwind changes the contact-tip-to-work distance by causing the gun cable to vibrate — the CTWD variation on the windward pass reduces the shielding gas volume flowing from the core compounds in proportion to the vibration frequency, producing intermittent porosity that correlates with the wind gusts

99. A production manager reviews the parameters for a GMAW application and finds the wire feed speed is set to 8 m/min on 1.2 mm ER70S-6 solid wire, producing 225 A. The power source output is set to 26 V. What is the calculated heat input per millimetre at a travel speed of 400 mm/min?

A. 0.88 kJ/mm, calculated as $(26 \text{ V} \times 225 \text{ A} \times 60) \div (400 \text{ mm/min} \times 1,000) = 351,000 \div 400,000 = 0.878 \text{ kJ/mm} \approx 0.88 \text{ kJ/mm}$

B. 1.46 kJ/mm, calculated as $(26 \text{ V} \times 225 \text{ A}) \div (400 \times 60) = 5,850 \div 24,000 = 0.244 \text{ kJ/mm}$, then multiplied by the GMAW process efficiency factor of 6.0 for spray transfer mode applications

C. 0.35 kJ/mm, calculated as $(26 \text{ V} + 225 \text{ A}) \div (400 \text{ mm/min}) = 251 \div 400 = 0.628 \text{ kJ/mm}$, then divided by the thermal efficiency factor of 1.8 for gas metal arc welding applications

D. 1.76 kJ/mm, calculated as $(26 \text{ V} \times 225 \text{ A} \times 60) \div (200 \text{ mm/min} \times 1,000)$, applying a 50% efficiency reduction factor for the GMAW process thermal heat transfer to the base metal at spray transfer conditions

100. An FCAW-G operator consistently produces structural fillet welds where the slag is extremely difficult to remove, requiring multiple chisel strikes and heavy grinding even after the bead has fully cooled. The arc voltage is within the manufacturer's recommended range. What is the most likely cause, and what adjustment eliminates the problem?

A. The slag is sticking because the contact tip is worn and producing an inconsistent arc — contact tip wear changes the electrical characteristics and prevents the slag from reaching the correct thermodynamic state for self-release — replacing the contact tip will restore normal slag release

B. The gas shielding flow rate is too high and is creating turbulence that rapidly cools the slag before it can assume the correct fluid state for proper release from the bead surface — reducing the flow rate to the lower limit of the specification will restore normal slag release behavior

C. The slag system is not reaching the required fluid state for proper self-release — this typically occurs when the voltage is at the lower end of the range for the current wire feed speed, and increasing the voltage slightly to the upper end of the recommended range raises the slag temperature enough to restore the differential cooling contraction that produces clean self-release

D. The slag is bonding to the base metal toes because the electrode angle is producing an overlap condition at the toes — the weld metal flowing past the toes is trapping slag at the interface — correcting the work angle to bisect the joint at 45 degrees will eliminate the toe-bonded slag deposits

101. A GTAW welder is setting up to weld carbon steel pipe and selects a power source. The WPS specifies DCEN (direct current electrode negative). Which power source type is required for GTAW on carbon steel, and why is DCEN specified rather than DCEP?

A. An AC power source is required for all GTAW applications — AC current is specified because it provides the high-frequency arc stabilization that prevents arc extinction during the

current zero-crossing, and the alternating polarity prevents electrode overheating on carbon steel pipe joints

B. A constant-voltage (CV) power source is required for GTAW on carbon steel pipe — the CV characteristic maintains a stable voltage at the arc regardless of the arc length changes that occur during manual torch manipulation in all pipe welding positions

C. Either AC or DC power may be used for GTAW on carbon steel pipe — the WPS specification for DCEN is a manufacturer recommendation rather than a technical requirement since the carbon steel base metal chemistry is not sensitive to polarity selection for the GTAW process

D. A constant-current (CC) DC power source set to DCEN is required — DCEN directs approximately 70% of the arc energy to the workpiece for efficient fusion while protecting the tungsten electrode from the excessive heat that would ball the tip under DCEP, and the CC characteristic maintains stable amperage despite arc length variations during manual pipe welding

102. A GTAW welder is back-purging a large-diameter stainless steel pressure pipe spool before welding a circumferential joint. The spool measures 300 mm internal diameter and 1,200 mm in length. The welder is using 100% argon at 6 L/min with the purge dampers sealed. Approximately how long must the spool be purged before the oxygen level can be expected to reach below 1,000 ppm?

A. Approximately 5 to 6 volume changes of the pipe interior — at the 300 mm ID and 1,200 mm length, the internal volume is approximately $\pi \times 0.15^2 \times 1.2 = 0.0848 \text{ m}^3 = 84.8 \text{ litres}$. At 6 L/min, one volume change takes $84.8 \div 6 = 14.1 \text{ minutes}$ — 5 to 6 changes requires approximately 70 to 85 minutes of purge time before welding begins

B. Approximately 10 to 12 minutes — the 300 mm internal diameter spool purges rapidly because the argon's greater density than air causes it to displace the lighter air from the bottom of the horizontal pipe, requiring only 2 volume changes to achieve sub-1,000 ppm oxygen

C. Approximately 2 to 3 minutes — modern argon purge systems using high-flow rates above 5 L/min achieve below 1,000 ppm oxygen in less than 3 minutes for all pipe spools under 2 metres length regardless of diameter

D. There is no specified minimum purge time — the only reliable indication that the spool has reached below 1,000 ppm oxygen is a reading from a calibrated oxygen analyzer inserted into the purge exhaust vent — time-based purge calculations should never be used as the sole acceptance criterion for critical stainless steel pressure pipe joints

103. During GTAW of stainless steel with a 2.4 mm EWCe-2 tungsten electrode on DCEN, the electrode tip accidentally contacts the molten pool. After the arc is re-established, the arc is visibly unstable and wanders. What must the welder do before continuing production welding?

A. Increase the argon shielding gas flow rate to 20 L/min for 30 seconds — the increased gas flow removes the metallic vapor from the contaminated electrode surface by sandblasting action and restores a clean, stable tip chemistry before normal welding resumes

B. No action is required if the arc stabilizes within 3 to 5 seconds of re-establishment — minor electrode tip contamination from pool contact self-resolves as the arc temperature burns the contamination layer from the tip during normal welding

C. Stop welding, remove the contaminated tungsten, and re-prepare or replace the electrode — a tungsten tip contaminated by pool contact will continue to produce arc wander and may deposit tungsten inclusions in the weld metal; the electrode must be cleaned by re-grinding to the correct taper geometry before welding resumes

D. Increase the amperage by 20% above the WPS maximum — the elevated amperage burns the contamination from the tip through the increased electron emission energy, restoring a clean stable tip within 3 to 5 seconds before the amperage is returned to the specified range

104. When adding filler wire during GTAW pipe welding in the vertical (2G) position, what specific technique prevents the hot end of the filler rod from becoming contaminated between additions?

A. After each addition, withdraw the filler rod completely from the shielding gas zone and quench the hot end in a water-soaked sponge mounted on the welding table — this removes the oxidized tip layer before the rod is reinserted into the arc zone for the next addition

B. Keep the hot end of the filler rod inside the trailing edge of the shielding gas envelope during the pause between additions — by maintaining the glowing rod tip within the argon coverage zone, the tip is protected from atmospheric oxidation until it is advanced for the next weld pool addition

C. Grind the hot end of the filler rod after every 5 to 6 additions to remove the accumulated surface oxide — the oxidized layer that builds on the rod tip between additions creates a black contamination stripe in the deposited weld metal that appears as porosity on the RT film

D. Replace the filler wire with a new rod after every electrode change — filler wire exposed to the welding environment for more than 30 minutes accumulates sufficient surface oxide to

contaminate all subsequent weld additions, and fresh wire is required each time the tungsten is replaced

105. A GTAW welder is qualifying a procedure for 316L stainless steel pressure piping. The WPS specifies argon shielding gas. A production engineer proposes substituting an argon/2% nitrogen blend to slightly increase fusion at the root. Under ASME Section IX, how is this gas composition change classified?

A. Non-essential variable — argon and argon/nitrogen blends are both inert shielding gases and are interchangeable within the ASME IX shielding gas category without requiring new PQR qualification

B. Supplementary essential variable — the shielding gas composition change becomes essential only when the procedure includes Charpy impact testing at temperatures below -29°C and nitrogen additions could affect toughness

C. Minor administrative change — shielding gas composition adjustments within the same gas family (inert gas blends) require only a WPS revision with supervisor authorization, not PQR requalification under ASME IX

D. Essential variable — under ASME IX QW-408, shielding gas composition is an essential variable for GTAW; adding nitrogen to the shielding gas changes the arc characteristics, pool chemistry, and potentially the mechanical properties of the deposit, requiring new PQR test coupon qualification

106. An automated orbital GTAW machine is programmed to weld 25 mm OD stainless steel tubing circumferential joints at constant amperage throughout the circuit. Completed welds show excessive crown height at the 12 o'clock position and intermittent undercut at the 6 o'clock position. Which program modification addresses both conditions simultaneously?

A. Increase the programmed amperage by 10% for the full circuit — higher amperage improves pool fluidity at all positions and allows the metal to flow to the toes at 6 o'clock and flatten the crown at 12 o'clock simultaneously

B. Add a filler wire subroutine at the 6 o'clock position only — the additional filler metal at the overhead position fills the undercut without affecting the crown at 12 o'clock since the two positions have different correction requirements

C. Reduce the programmed amperage at the 12 o'clock flat position to reduce the crown height and reduce the programmed amperage at the 6 o'clock overhead position to tighten the pool

against gravity and prevent it from dripping away from the toes — both defects are addressed by position-specific amperage reduction

D. Increase the shielding gas flow rate at both 12 and 6 o'clock by 25% — the increased gas pressure above the pool at 12 o'clock physically depresses the crown and provides a pneumatic support force against pool dripping at 6 o'clock

107. A GTAW welder is welding Grade 1 commercially pure titanium sheet in a fabrication shop. The completed welds show consistent blue and purple discoloration on the weld face and in the HAZ adjacent to the weld bead. What does this discoloration indicate and what control is required?

A. The blue-purple discoloration is the normal coloration of titanium oxide (TiO_2) that forms on all titanium welds and is an expected appearance confirming the correct post-weld oxidation treatment has been applied to the weld surface for corrosion protection

B. Blue-purple discoloration on titanium is the expected color for the weld deposit during the first 24 hours after welding — the discoloration is a temporary appearance from retained welding heat that fades to the normal metallic silver over the following day

C. Blue-purple discoloration on titanium indicates elevated oxygen and nitrogen contamination from inadequate shielding coverage of the hot weld metal and HAZ during and after welding — titanium is highly reactive above approximately 400°C , and the contaminated surface exhibits reduced ductility and requires investigation of the shielding system before welding continues

D. The discoloration confirms the shielding gas is contaminated with a small percentage of CO_2 from the gas supply system — CO_2 contamination of the argon shielding stream produces the characteristic blue-purple titanium oxide coloration and requires purging the gas lines before welding resumes

108. A GTAW welder setting up for the first time on a 6G pipe joint using 3.2 mm ER70S-2 filler wire asks about the correct filler wire addition angle. What guidance correctly describes the filler addition angle and its effect on root pass quality?

A. Filler wire should be added at 90 degrees to the weld pool surface — a perpendicular addition creates the deepest weld pool penetration by directing the filler wire into the keyhole and using the filler wire's impact to mechanically open the root gap

B. Filler wire should be held at a shallow angle of 10 to 20 degrees from the pipe surface and fed into the leading edge of the pool — the shallow angle allows the wire to be melted smoothly by the arc without plunging into the pool and allows the welder to control the volume added with each increment

C. Filler wire should be added at exactly 45 degrees to the pipe surface at all positions throughout the circuit — the 45-degree angle provides the optimal geometric balance between pool penetration depth and lateral distribution that produces consistent root pass profiles in all clock positions

D. Filler wire angle is not a significant technique variable in 6G GTAW pipe welding — the root pass quality is governed entirely by amperage and travel speed, and filler wire angle has no measurable effect on root bead profile or root reinforcement consistency

109. A GTAW procedure is qualified on 304L austenitic stainless steel using ER308L filler and 100% argon shielding gas. A production job requires welding 304L components using an argon/2% hydrogen blend for improved fusion on thicker sections. Under ASME Section IX, which statement correctly identifies the qualification status?

A. The argon/2% hydrogen blend is within the acceptable variation range for argon shielding gas — hydrogen additions up to 5% are considered minor chemistry variations that are permitted without new PQR qualification under the ASME IX shielding gas tolerance provision

B. The change from 100% argon to argon/hydrogen is a supplementary essential variable that becomes essential only when the procedure requires impact testing — the change may be incorporated into the WPS without PQR testing provided no Charpy testing was specified in the original qualification

C. The change from 100% argon to argon/hydrogen is an administrative amendment requiring only WPS revision and engineering sign-off — shielding gas additions of non-reactive gases such as hydrogen are considered process enhancements rather than essential variables

D. The change from 100% argon to an argon/hydrogen blend is an essential variable under ASME IX QW-408 — shielding gas composition changes affect arc characteristics, heat transfer, and weld metal properties, requiring new PQR qualification testing to support the amended WPS

110. When welding aluminum alloys using AC GTAW, the machine's AC balance control adjusts the ratio of electrode-positive to electrode-negative time within each AC cycle. If the AC balance is shifted so that electrode-negative comprises more than 80% of each cycle, what is the primary observable effect on the completed weld?

A. The cathodic cleaning band visible beside the weld bead becomes noticeably narrower — increasing the EN ratio reduces the electrode-positive portion of each cycle, providing less cathodic bombardment time and therefore removing aluminum oxide from a smaller surface area adjacent to the bead compared to a more balanced AC setting

B. The weld pool becomes significantly more fluid and the bead width increases — the elevated EN ratio concentrates more arc energy at the workpiece surface per cycle, melting the aluminum over a broader lateral area and producing a wide, fluid pool with substantially greater bead width than balanced AC operation

C. The tungsten electrode develops a large ball at the tip from overheating — the extended EN portion of each cycle concentrates arc energy at the electrode tip progressively over successive passes, overheating and balling even ceriated or thoriated tungsten grades not specifically designed for AC operation

D. The weld penetration decreases significantly and the bead profile becomes very flat and shallow — the EN-biased balance reduces the electrical potential at the workpiece and produces shallower fusion per ampere than balanced AC or DCEN welding achieves at the same current setting

111. A GTAW welder is welding thin-wall 304L stainless steel tube for dairy process equipment. The WPS specifies ER308L filler wire and maximum heat input of 0.5 kJ/mm. During welding, the heat input is confirmed at 0.48 kJ/mm, but the HAZ beside the completed welds shows a distinctive straw-yellow to golden discoloration. What does this HAZ color indicate?

A. The straw-to-gold discoloration confirms the heat input is correctly controlled — these colors indicate the HAZ temperature did not exceed the sensitization threshold and the passive layer remains intact on 304L stainless

B. The discoloration confirms the back purge was inadequate — the root side of the weld was exposed to oxygen during welding and the HAZ gold color on the outside of the tube is the same reaction occurring on the back side where the purge failed to maintain below 1,000 ppm oxygen

C. The straw-to-gold discoloration indicates the HAZ reached temperatures in the sensitization range (approximately 425-870°C) for a sufficient duration to begin chromium carbide precipitation at the grain boundaries — while lighter than blue or black oxidation, this appearance requires evaluation of whether sensitization has occurred and whether the passive layer has been compromised

D. The straw-yellow color confirms the shielding gas was contaminated with approximately 2% oxygen — pure argon shielding produces a completely clear, unstained HAZ on 304L at any heat input, and any coloration confirms a gas purity problem that must be investigated

112. A GTAW welder completing the root pass on an inconel 625 (nickel alloy) pipe joint notices the puddle appears excessively fluid and difficult to control, with the pool running ahead of the arc. The WPS specifies 75 A DCEN, ER625 filler, and argon shielding. The welder is welding at approximately 80 A. What is the most likely contributing cause of the excessive pool fluidity?

A. The ER625 filler wire is oversize for the joint root gap — filler wire larger than the root gap diameter deposits too much metal per addition, overloading the pool beyond the root gap capacity and causing the pool to run ahead

B. The 5 A excess above the WPS amperage (80 A vs 75 A specified) is producing more heat input than the root pass pool can manage — reducing to 75 A and confirming the WPS parameters reduces the pool temperature and restores manageable pool characteristics

C. Nickel alloys have very low thermal conductivity compared to carbon steel or stainless steel — the low thermal conductivity prevents heat from dissipating laterally from the weld pool into the base metal, concentrating heat in a smaller zone and producing a smaller but extremely fluid pool that loses viscosity rapidly at welding temperatures

D. The DCEN polarity is incorrect for nickel alloy welding — nickel alloys require DCEP for proper arc stability and heat distribution, and the incorrect DCEN polarity is distributing heat to the tungsten rather than the base metal, causing the base metal to overheat locally

113. A GTAW welder is completing multi-pass welds on UNS S31803 duplex stainless steel pipe. The WPS specifies a minimum heat input of 0.5 kJ/mm per pass and a maximum interpass temperature of 150°C. Why is the minimum heat input requirement especially critical for duplex stainless steel compared to standard austenitic stainless?

A. Duplex stainless steel solidifies as 100% ferrite, and austenite must re-form during solid-state cooling from the ferrite phase — if heat input per pass is too low, the HAZ and weld metal cool too rapidly for sufficient austenite re-formation to occur, leaving an excessively ferritic microstructure with reduced Charpy impact toughness and pitting corrosion resistance below the design minimum

B. Duplex stainless steel has higher thermal conductivity than austenitic grades and dissipates weld heat from the pool more rapidly — without meeting the minimum heat input threshold, the pool cools too quickly to establish adequate fusion with the groove sidewall surfaces, producing lack-of-fusion defects regardless of the amperage or voltage settings used

C. Minimum heat input prevents hydrogen-induced cold cracking in the ferritic phase of duplex stainless steel — the ferritic microstructure component is significantly more susceptible to hydrogen embrittlement than the austenite phase, and sufficient heat input per pass drives

diffusible hydrogen from the ferritic grains before the pass cools to the critical cracking temperature range

D. Minimum heat input prevents nitrogen porosity formation in the duplex weld deposit — at very low heat input, nitrogen dissolved in the weld pool does not have sufficient time to diffuse back into the shielding gas atmosphere before the pool solidifies, trapping nitrogen bubbles as porosity in the rapidly solidified duplex weld metal deposit

114. A SAW operator is reviewing the flux-wire classification F7A4-EH14 on the flux package. What does the "EH14" portion of this designation communicate about the wire used during the classification test?

A. "EH14" identifies the electrode wire classification used in the qualification test — "E" indicates an electrode wire, "H" indicates high manganese content, and "14" indicates the wire contains 0.14% carbon, which directly affects the deposit chemistry and mechanical properties produced by this flux-wire combination

B. "EH14" is the shielding flux composition designation — E=eutectic, H=high basicity, and 14=14% manganese oxide content in the flux granules, defining the flux active component that governs the deposit chemistry

C. "EH14" identifies the flux lot number and heat treatment code — E indicates the flux was tested in an electric arc furnace, H indicates it was heat-treated before classification testing, and 14 is the calendar week of the qualification test

D. "EH14" is the AWS classification of the SAW electrode wire used during the deposit composition and mechanical property qualification test — this classification must be referenced when selecting production wire to ensure the flux-wire combination in production matches the combination used during the classification test

115. In a single-wire SAW welding procedure, the welding engineer changes the electrode polarity from DCEP to DCEN to evaluate the effect on bead characteristics. How does this polarity change affect the weld bead profile and deposition rate?

A. Changing to DCEN increases penetration and reduces the deposition rate — the electrode-negative polarity concentrates the majority of arc energy at the workpiece as the anode, driving the arc deeper into the base metal while reducing the arc energy available for melting the electrode wire

B. Changing from DCEP to DCEN on SAW has no measurable effect on bead geometry or deposition rate — the submerged flux layer creates an electrically symmetric arc confinement

that equalizes the energy distribution between electrode and workpiece regardless of which DC polarity is applied to the circuit

C. Changing to DCEN increases the deposition rate and reduces penetration — with the electrode as cathode, a greater fraction of the arc energy is directed toward melting the electrode wire rather than the base metal, increasing the electrode melt-off rate and depositing more metal per unit time while reducing the thermal energy driving fusion into the base metal fusion zone

D. Changing to DCEN from DCEP causes arc instability and erratic bead profiles in SAW — the submerged arc process requires DCEP polarity to maintain the arc ionization required for stable operation through the flux layer, and DCEN operation causes the arc to wander intermittently and extinguish unpredictably during production welding

116. After a SAW production run, the recovered granular flux is found to contain fine black particles and a higher proportion of smaller particle sizes than the fresh flux used at the start of the run. Before the recovered flux can be recycled into the flux hopper for the next production run, what processing step is required?

A. Mix the recovered flux with 15% fresh flux to dilute the fine particle concentration — blending the degraded recovered flux with fresh material improves the particle size distribution without requiring the full screening and drying procedure

B. Screen the recovered flux through a sieve of appropriate mesh size to remove fines, slag chips, and oversize particles, and dry the flux to the manufacturer's specified temperature and duration before returning it to the hopper for production use

C. The recovered flux may be returned directly to the hopper without processing — the fine particles in recovered SAW flux are the result of thermal cycling during welding and have the same chemistry as the original flux, with no change in welding characteristics from the particle size reduction

D. Recovered SAW flux must be discarded entirely — once flux has been subjected to the arc environment, its chemistry is permanently altered by the arc reactions and it can no longer produce deposits meeting the original classification mechanical properties

117. A SAW procedure uses wire oscillation to achieve the full required bead width on a wide-groove pressure vessel seam. The completed weld surface shows an uneven ripple pattern with peaks and valleys at regular intervals equal to the oscillation cycle wavelength. Which parameter adjustment most directly smooths the surface ripple pattern and improves the surface finish appearance?

A. Reduce the oscillation frequency — a slower oscillation frequency increases the distance between successive ripple peaks, producing wider, flatter ripple transitions that blend more smoothly and give the bead a more consistent surface finish appearance compared to high-frequency oscillation

B. Increase the oscillation amplitude — a wider oscillation path deposits metal over a larger area per cycle, reducing the height differential between ripple peaks and valleys by spreading each deposit increment over a greater width

C. Increase the wire feed speed — more metal deposited per unit of arc movement fills the valleys between ripple peaks and raises the average bead face height to the same level as the ripple peaks, producing a flatter surface finish

D. Reduce the flux depth — shallower flux coverage above the arc allows more radiant heat to escape from the arc zone upward, reducing the temperature gradient between ripple peaks and valleys and producing a more uniform surface temperature for smoother solidification

118. Under ASME Section IX, a SAW welding procedure is qualified using a fused flux. The production department proposes switching to a bonded flux of different composition for improved weld pool fluidity. Which classification correctly identifies this change under ASME IX QW-408?

A. Non-essential variable — ASME IX considers all SAW flux types within the same basicity classification range as equivalent for procedure qualification purposes, and switching flux types within the same composition group requires only a WPS revision

B. Supplementary essential variable — the flux type change becomes essential only when the procedure requires impact testing, because flux type affects the deposit toughness but not the fusion or strength properties of the joint

C. Administrative amendment — SAW flux selection is a production decision managed by the welding supervisor and does not require any WPS documentation change since the flux performance is governed by the combined F-number of the flux-wire system

D. Essential variable — under ASME IX QW-408, a change in SAW flux type or composition is an essential variable because different flux types and compositions produce different deposit chemistries and mechanical properties that may not satisfy the qualification test requirements of the original PQR

119. A SAW operator is welding 50 mm pressure vessel plate at a travel speed of 400 mm/min, 31 V, and 600 A. The maximum heat input allowed by the impact-tested procedure is 3.0 kJ/mm. Using $HI = (V \times A \times 60) \div (\text{speed} \times 1,000)$, what is the actual heat input and what does the comparison indicate?

A. $HI = 2.79$ kJ/mm, exceeding the procedure maximum — $(31 \times 600 \times 60) \div (400 \times 1,000) = 1,116,000 \div 400,000 = 2.79$ kJ/mm, which is below the 3.0 kJ/mm maximum, confirming the parameters are within the qualified procedure range

B. $HI = 3.41$ kJ/mm, within the procedure range — the heat input formula applied to the given parameters produces a value that falls exactly within the qualified procedure range and no adjustment is required

C. $HI = 2.79$ kJ/mm, within the procedure maximum — $(31 \times 600 \times 60) \div (400 \times 1,000) = 1,116,000 \div 400,000 = 2.79$ kJ/mm is below the 3.0 kJ/mm maximum, confirming the production parameters are qualified and welding may continue

D. $HI = 4.65$ kJ/mm, exceeding the procedure maximum — the heat input calculated from the given parameters significantly exceeds 3.0 kJ/mm and the parameters must be adjusted before production welding continues

120. A SAW procedure uses an active flux for single-pass fillet welds on carbon steel structural applications. After a production run, the flux supervisor proposes doubling the recycled flux ratio from 30% to 60% recycled flux in the hopper to reduce consumable costs. What quality concern must be evaluated before implementing this change?

A. Doubling the recycled flux percentage increases the total fume generation rate by concentrating arc reaction byproducts in the recycled material — increasing recycled ratio beyond 50% requires a new fume exposure assessment before production use

B. Doubling the recycled flux ratio may increase manganese and silicon in the weld deposit — active flux adds Mn and Si to the deposit with each arc pass, and recycled flux that has already been through the arc carries elevated concentrations of these elements — the higher recycled ratio may push the deposit chemistry beyond the specified maximum, reducing toughness and requiring chemistry verification

C. Increasing the recycled flux ratio reduces the flux particle size distribution below the minimum for effective arc shielding — fine particles in recovered flux make up the majority of the recycled fraction and fine particles reduce flux coverage effectiveness at high recycled ratios

D. The recycled flux ratio change requires a new procedure qualification test because ASME Section IX classifies the flux recycling percentage as an essential variable that limits the maximum permissible recycled fraction to 30% for all impact-tested SAW procedures

121. A SAW operator is depositing the first layer of a SAW cladding overlay on carbon steel using Type 309L stainless steel composite wire and neutral flux. The dilution calculation from the PQR shows that the first layer deposit has a 25% dilution from the carbon steel base metal. Why is this dilution level a critical quality concern for the cladding application?

A. At 25% dilution from the carbon steel base metal, the deposited overlay chemistry has been significantly diluted with iron and carbon from the base metal — the 309L deposit composition may be shifted away from the required chemistry needed to provide corrosion resistance or serve as a buffer layer for subsequent stainless overlay passes

B. A 25% dilution level in SAW cladding is unacceptable because dilution must be maintained below 5% for all stainless steel overlay applications — above 5% dilution, the carbon steel elements are present at concentrations that cause immediate hot cracking in the 309L overlay deposit

C. At 25% dilution, the overlay has consumed 25% of the total required cladding thickness — the additional dilution from the base metal means that the total number of overlay layers must be increased by 25% to achieve the specified minimum thickness of undiluted stainless composition

D. A 25% dilution level indicates the SAW heat input was 25% higher than the qualified maximum for this cladding application — dilution percentage and heat input are directly proportional and the measured dilution confirms the parameters must be reduced before additional overlay layers are deposited

122. Under ASME Section IX, a SAW procedure was qualified using fused flux and EL8 wire (low manganese, low silicon). If a production operator proposes substituting a high-manganese EH14 wire to improve deposit toughness, which statement correctly describes the qualification requirement?

A. No requalification is required — EL8 and EH14 are both AWS A5.17 classified SAW wires and ASME IX permits unrestricted wire substitution within the same SFA specification without new PQR qualification

B. Requalification is only required if the production joint is impact-tested — changing from EL8 to EH14 is a supplementary essential variable that becomes mandatory only when the WPS includes a Charpy impact test requirement

C. Requalification may not be required if the change is within the same F-number and A-number classification — however, the significantly different Mn and Si content of EH14 compared to EL8 will change the deposit chemistry and may alter the A-number classification of the deposit, requiring re-evaluation and potentially new PQR testing

D. Requalification is required — the change from EL8 (low manganese, low silicon) to EH14 (high manganese, high silicon) changes the filler metal composition and the resulting deposit A-number classification, constituting an essential variable change under ASME IX QW-404 that requires new PQR qualification testing

123. SAW welding produces a condition known as "flux bridging" in which the flux solidifies in a connected mass over the completed bead before the molten weld metal has fully solidified. What specific weld defect is most likely to result from flux bridging?

A. Slag inclusions — when the flux bridges over the weld pool before full solidification, slag particles trapped beneath the bridge cannot float to the surface and are incorporated into the upper portion of the weld metal as the deposit solidifies

B. Excess reinforcement — flux bridging traps heat beneath the solidified flux layer, maintaining the pool in the molten state longer and allowing more metal to pile up at the bead centre before the pool finally freezes

C. Cracking — when flux bridges over the pool before complete solidification, the rigid flux shell constrains the shrinking weld metal — the solidifying weld metal cannot contract freely, generating tensile stress in the cooling deposit that can cause longitudinal cracking in the upper portion of the bead

D. Porosity — gas evolved during weld metal solidification cannot escape through the solidified flux bridge, and the trapped gas becomes entrapped in the last-to-solidify weld metal beneath the flux, producing porosity concentrated in the upper bead cross-section

124. During a tandem SAW production run using DC lead and AC trail, the welding supervisor notices that the trail arc is producing erratic arc extinction and re-ignition visible in the flux surface behavior. The lead arc appears stable. What is the most likely cause of the trail arc instability in tandem SAW?

A. The AC trail arc is operating at the correct frequency but the arc gap is too wide — the trail arc requires a closer electrode-to-work distance than the lead arc to maintain stable re-ignition on every AC half-cycle

B. The arc-to-arc spacing between the lead and trail electrodes is too close — the magnetic field from the DC lead arc is interacting with the AC trail arc and deflecting it erratically on each half-cycle, producing the observed extinction and re-ignition behavior

C. The trail flux hopper is empty — the arc is operating with insufficient flux coverage above the trail arc, causing the arc to break through the flux layer and extinguish on each upward oscillation cycle

D. The trail power source is set to the wrong AC frequency — a mismatch between the power source output frequency and the plant supply frequency causes the AC trail arc to extinguish at the frequency mismatch nodes

125. A SAW completed weld is submitted for radiographic examination and the interpreter identifies "a bright linear indication parallel to the weld axis, 30 mm long, located at one-third depth from the weld face, with a well-defined upper edge and diffuse lower edge." What is the most consistent interpretation of this indication?

A. An incomplete fusion zone at a pass boundary — the bright upper edge of the indication represents the fusion boundary where the arc melted the previous pass cleanly, and the diffuse lower edge represents the less distinct thermal boundary on the unmelted side of the partially fused pass interface

B. A slag inclusion — elongated slag particles at pass fusion boundaries appear as dark, irregular indications on RT film due to lower density than weld metal — this description of a bright, well-defined upper edge is not consistent with slag inclusion RT appearance

C. A crack — linear indications parallel to the weld axis with defined edges and consistent depth are characteristic of longitudinal solidification cracks in SAW weld metal — the bright appearance confirms the crack faces have not oxidized and the crack is tight and relatively recent

D. A copper inclusion from backing bar contamination — copper is denser than steel and appears as a bright, high-density indication on RT film — a bright linear indication at consistent depth with well-defined upper edge is characteristic of copper that entered the weld pool from the backing bar surface during initial passes

Practice Exam 5: Answer Key and Explanations

1. C — Hexavalent chromium is a classified human carcinogen with OELs typically set at 0.01–0.05 mg/m³. A breathing-zone reading of 0.08 mg/m³ exceeds these limits, meaning dilution ventilation is inadequate and local exhaust ventilation at the source or supplied-air respiratory protection is required before welding continues.
2. A — WHMIS 2015 workplace labels require at minimum the product identifier, hazard information sufficient to convey the risk (such as a pictogram or risk phrase), and safe handling precautions appropriate for the work environment. These three elements allow workers to recognize the product's hazards immediately at the point of use without locating the full SDS.
3. B — Volume = $0.65 \times 0.45 \times 0.016 = 0.00468 \text{ m}^3$. Mass = $0.00468 \times 7,850 = 36.7 \text{ kg}$. This calculation applies the standard structural carbon steel density directly to the plate dimensions without any correction factors.
4. D — SDS Section 8 (Exposure Controls and Personal Protective Equipment) is the designated location for occupational exposure limits, required engineering controls including ventilation type, and the specific respirator classification and filter rating required for worker protection during normal product use. This is the section consulted first when PPE selection is the immediate priority.
5. A — An unprotected oxygen cylinder valve, if sheared during a fall, releases gas at approximately 20,000 kPa through the open valve port. The escaping gas propels the cylinder with lethal projectile force. The area must be cleared immediately and supervision notified before anyone approaches — attempting inspection while the hazard exists risks fatal injury.
6. C — Water is electrically conductive. Applying a water extinguisher to energized equipment creates a conductive path from the live source through the water stream to the operator, creating an immediate electrocution hazard. The electrical power must be confirmed de-energized before any water-based agent is applied to smoldering residual material near electrical equipment.
7. D — Tightly coiled welding cables cannot dissipate resistive heating during operation because the coiled geometry prevents convective cooling at coil-to-coil contact points. Hot spots form progressively at these locations, degrading insulation integrity and creating an electrical shock and fire hazard under production current loads.

8. B — An auto-darkening helmet allows the welder to position the electrode precisely with the lens clear and both hands available for placement. The lens darkens automatically upon arc initiation, eliminating the repositioning errors and cumulative neck strain that occur during repetitive manual helmet-flipping in a high-frequency tacking application.

9. A — CSA Z460 requires every identified energy source to be individually isolated at its specific device and independently verified at zero-energy state before any equipment contact is permitted. Electrical isolation alone does not control hydraulic accumulator pressure, compressed air, gravitational potential, or spring tension — all five sources must be isolated and verified.

10. C — Arc-on time = $87,000 \text{ mm} \div 450 \text{ mm/min} = 193.3$ minutes. Operating factor = $193.3 \div 480 = 40.2\%$. This value represents the fraction of total shift time spent with the arc established, which is typical for efficient GMAW production.

11. B — A near miss is an unplanned event with harm potential that caused no actual injury or damage. Its root causes are identical to injury-producing incidents, so reporting and investigation identify and eliminate the underlying hazard before a similar event causes harm — this is the entire purpose of the near miss reporting requirement.

12. D — Each sling leg tension = $(\text{total load} \div 2) \div \sin(30^\circ) = 2,250 \div 0.5 = 4,500$ kg per leg. A 30-degree sling angle from horizontal doubles the load in each leg compared to the half-load value at vertical, demonstrating why shallow sling angles require slings rated far beyond the apparent rigging load.

13. C — The hierarchy ranks elimination/substitution highest, followed by engineering controls, administrative controls, and PPE as the last resort. Switching to a lower-manganese wire addresses the hazard at the source (substitution), which ranks above local exhaust ventilation, work rotation, and respiratory protection in the hierarchy.

14. A — The mill test report provides the actual chemical composition of the specific plate being tested. Confirming the MTR chemistry matches the specified material designation before any arc is struck ensures the PQR test results are valid for the intended production application — welding an incorrect material invalidates all coupon mechanical test results.

15. D — Working alone inside a confined vessel requires both the full confined space entry permit framework (standby person, rescue procedures, atmospheric testing, communication

protocol) and the working-alone check-in system appropriate to the identified hazards. Both regulatory frameworks apply simultaneously and neither can substitute for the other.

16. B — Blistering indicates a second-degree (partial thickness) burn involving the dermis. Cooling with running water for 10–20 minutes removes retained heat from the tissue and reduces injury depth. The blister dome must not be ruptured as it protects the underlying tissue from infection and further trauma.

17. C — Deposition efficiency of 65% means 65% of consumed electrode mass becomes weld metal: $15.5 \times 0.65 = 10.075 \approx 10.1$ kg deposited. The remaining 5.4 kg represents stubs, spatter, and non-metallic coating components that are not incorporated into the deposited weld.

18. A — Welding on a registered pressure vessel requires both a qualified WPS supported by an approved PQR and a current CWB welder qualification certificate confirming the welder is certified for the specific process, position, and base material. Both documents are mandatory before production welding begins on any registered vessel joint.

19. D — A long work return path through structural steel creates a strong, unidirectional magnetic field along the current path. This sustained field generates persistent arc blow that deflects the arc away from the joint toward the remote work return connection, making consistent fusion unachievable without repositioning the return cable adjacent to the weld zone.

20. B — Each sling leg tension = $(\text{total load} \div 4) \div \cos(25^\circ) = 340 \div 0.906 = 375$ kg. Dividing by the cosine of the angle from vertical accounts for the increased tension from the inclined leg — even at 25° from vertical, leg tension is meaningfully higher than the simple load-per-leg value.

21. C — The "(5)" in intermittent fillet weld notation specifies the total number of weld segments required. Combined with the 60 mm segment length at 120 mm centre-to-centre pitch, this notation calls for 5 individual 60 mm fillet weld segments, providing 300 mm of total deposited weld length along the joint.

22. D — CSA W59 contains no blanket dimensional acceptance tolerance for undersize fillet welds. An actual leg of 8.5 mm against a specified 10 mm is a non-conformance that must be corrected by depositing an additional pass to achieve the minimum 10 mm leg, or formally accepted through engineering disposition with documented structural justification.

23. A — Arc length = $2\pi \times (1.5 \times 101.6) \times (90/360) = 2 \times 3.1416 \times 152.4 \times 0.25 = 239.9 \approx 240$ mm. The centreline radius for a long-radius elbow equals 1.5 times the nominal pipe diameter, and the 90-degree arc is one-quarter of the full circumference at that radius.

24. B — With the plate at 12°C, the CSA W59 minimum preheat of 50°C has not been satisfied. The full preheat zone extending at least 75 mm on each side must be brought to and verified at 50°C using a calibrated surface temperature device immediately before the first arc is struck — welding below the code minimum preheat risks hydrogen-induced cold cracking in the HAZ.

25. C — Multiple small reflectors distributed throughout the weld metal volume with equal amplitude from all scanning directions and no consistent orientation are the UT signature of gas porosity. Each spherical pore reflects the angle beam similarly regardless of probe direction, producing the non-directional, equal-amplitude response pattern described.

26. D — Under ASME IX QW-451.1, a test coupon of 19 mm or greater thickness qualifies production groove welds from a 5 mm minimum to unlimited maximum plate thickness. A 50 mm PQR coupon therefore covers the 120 mm production joint without any additional qualification.

27. A — Dashed lines in standard orthographic projection represent edges and surfaces hidden from the viewing direction. Evenly spaced horizontal dashed lines in the right-side view indicate a hidden internal feature — a slot, bore, or recessed profile — running horizontally through the full width of the part.

28. C — Balanced welding alternates successive welds on opposing sides of the frame's neutral axis. Each weld's transverse and longitudinal shrinkage partially counteracts the shrinkage of the preceding weld on the opposite side, keeping cumulative distortion near the neutral axis and preventing progressive angular and longitudinal bowing from accumulating to one side.

29. B — A 4-piece 90-degree miter has 3 miter joints, each deflecting the pipe $90^\circ \div 3 = 30^\circ$. Each cut face equals half the joint deflection: $30^\circ \div 2 = 15$ degrees from perpendicular to the pipe axis. This angle is applied to both ends of each intermediate segment and one end of each end piece.

30. D — $CE = C + Mn/6 = 0.20 + 1.40/6 = 0.20 + 0.233 = 0.433 \approx 0.43$. This CE level falls above the common 0.40 threshold above which preheat and controlled procedure parameters are

recommended for restrained joints, particularly on thicker sections at risk of hydrogen-induced cold cracking.

31. A — CSA W47.1 requires that any new process addition be supported by a WPS backed by a qualified PQR tested under CWB surveillance or an accepted engineer, that welders be qualified under the new WPS, and that the CWB assess and formally approve the scope addition before the new process is used on certified work.

32. C — A sharp, narrow, well-defined linear MT accumulation parallel to the weld toe in the HAZ is the classic signature of a toe crack or HAZ hydrogen crack. The precise linear form distinguishes it from a broad geometric artifact, and its position in the high-stress HAZ adjacent to the fusion line makes it a high-priority indication requiring immediate further evaluation.

33. B — A 4-piece 90-degree miter has 3 joints, each deflecting the pipe $90^\circ \div 3 = 30^\circ$. The cut angle at each mating face = $30^\circ \div 2 = 15$ degrees. This cut angle is applied to both ends of each intermediate segment and one end of each end piece to produce the correct geometry at every weld joint in the assembled bend.

34. D — PWHT on P5 CrMo alloy steel tempers the martensite formed during rapid post-weld cooling, relieves the residual tensile stresses locked in during the welding cycle, and tempers the carbide structure in the HAZ. These combined effects reduce hardness, improve toughness, and minimize susceptibility to stress corrosion cracking and creep under the elevated-temperature and pressure service conditions for which P5 is specified.

35. C — A reflector detected from one scanning direction but not the opposing direction suggests a planar surface whose geometry is favorable to the probe beam angle from that side only. Incomplete fusion faces and crack planes aligned parallel to the fusion line commonly exhibit this asymmetric response. Complementary examination with additional probe angles or methods is required before a final accept/reject decision.

36. A — Plasma arc cutting can produce a carburized surface layer and HAZ on 304L stainless steel cut edges through thermal interaction between the plasma and the base metal chemistry. This layer must be removed by grinding at least 1–2 mm below the cut surface before the preparation is used as a weld joint surface, preventing carbon incorporation into the root pass deposit.

37. B — Effective throat of an unequal leg fillet = $(10 \times 14) \div \sqrt{(10^2 + 14^2)} = 140 \div \sqrt{296} = 140 \div 17.2 = 8.14 \approx 8.2$ mm. This formula calculates the altitude of the right triangle formed by the two leg dimensions, representing the shortest distance from root to theoretical face.

38. D — The tail of the weld symbol reference arrow communicates supplementary requirements not conveyed by the symbol geometry. "RT 100" in the tail specifies that 100% radiographic testing is required on this joint — the letters identify the NDE method and the number designates the required coverage percentage of the completed joint.

39. C — A root face of 5 mm exceeds the pre-qualified maximum root face of 3 mm for this joint type under CSA W59. Exceeding the pre-qualified dimensional tolerance places the joint preparation outside the qualified parameter range, removing its pre-qualified status and requiring PQR qualification testing to validate weld quality at the actual geometry.

40. A — A dimension on an engineering drawing with no revision triangle carries the same value it had at the original drawing issue. It has not been changed through any subsequent revision cycle and represents a dimensionally stable reference that does not require comparison against earlier revision drawings before use in fabrication.

41. B — Straight-beam UT detects planar discontinuities oriented parallel to the plate surface by sending the beam perpendicularly through the plate thickness and measuring reflections from internal interfaces. Radiography has very poor sensitivity to planar reflectors aligned parallel to the radiation beam direction — laminar defects running parallel to the plate surface are essentially invisible on RT film.

42. C — CSA W59 specifies a maximum cap reinforcement height of 3 mm for structural groove welds in the 12 mm plate thickness range. A 5 mm reinforcement exceeds this limit, creating an abrupt toe geometry that concentrates stress and reduces fatigue life — the excess reinforcement must be removed by grinding to bring the cap within the 3 mm maximum.

43. D — Welding simultaneously from opposite ends toward the centre means the longitudinal shrinkage force from each welder's arc progressively counteracts the shrinkage from the opposite end. This bilateral cancellation of progressive longitudinal contraction keeps the beam's neutral axis straight and prevents cumulative bowing from developing along the beam length.

44. A — For radial line development of a frustum, the outer arc radius = slant height $\times (D_{\text{large}} \div (D_{\text{large}} - D_{\text{small}})) = 500 \times (800 \div 400) = 500 \times 2 = 1,000$ mm. This locates the

development apex and establishes the outer radius for drawing the large base circle arc on the flat pattern.

45. B — Lack-of-penetration at the root creates two planar surfaces meeting at approximately 90 degrees — the unfused root face and the groove base — which retroreflect the angle-beam UT signal back to the transducer as a strong corner reflector response. This geometry efficiently returns the beam from that specific orientation, producing the characteristically strong signal associated with root-area LP.

46. D — The minimum preheat of 10°C established by the PQR is a production requirement that must be satisfied before welding. The WPS remains technically valid — the plate must be brought to at least 10°C by supplemental heating and verified immediately before the first arc is struck. The WPS specifies a minimum condition for production, not an ambient temperature exemption.

47. A — A dark, circular, irregular-edged RT indication with a lighter central zone at the weld root at the location of an arc interruption indicates burn-through. The dark outer ring represents the void cavity perimeter and the lighter centre is the thin metal bridge where the root partially resolidified after melting through — consistent with the arc-interruption history at that location.

48. C — CSA W59 Table 4.4 specifies minimum fillet weld sizes as a function of the thicker connected member to ensure the heat input is sufficient to prevent rapid HAZ quench cooling and hydrogen-induced cold cracking. For a 25 mm flange plate, the minimum is approximately 8 mm — this heat-input-based rationale governs the minimum size independently of the strength calculation.

49. B — Excessive cutting oxygen pressure creates turbulent flow below the tip orifice exit rather than the laminar stream required for a parallel-sided cut. The turbulent cutting stream spreads and flares outward in the lower section of the kerf, widening the cut toward the bottom and producing a cut edge that diverges outward rather than remaining parallel from top to bottom.

50. D — Hard, firmly bonded dross on the bottom cut edge is classified as high-speed dross, caused by travel speed that exceeds the capacity of the amperage setting. The plasma arc trails behind the torch and molten metal in the lower kerf resolidifies against the cut edge before the plasma jet can expel it — reducing travel speed or increasing amperage eliminates this dross type.

51. A — A bright white acetylene feather extending beyond the inner cone indicates excess acetylene in the preheat mixture — the defining characteristic of a carburizing flame. To establish a neutral flame, oxygen flow must be increased slightly until the white feather disappears and only the well-defined inner cone and outer envelope remain visible.

52. C — Running the PAC torch below the specified minimum standoff causes the shielding gas exiting the nozzle to impact the plate surface at reduced distance, creating turbulent rather than laminar gas flow around the plasma column. This turbulence disrupts the consistent plasma jet geometry and produces a rougher, less square cut edge compared to the perpendicular profile achieved at correct standoff.

53. B — Vertical drag lines in the upper portion with progressive backward sweep through the lower section indicate the oxidation reaction maintains vertical propagation at shallow depth but falls progressively further behind the torch in the lower plate as the available arc energy is exhausted. This is the defining signature of travel speed exceeding the cutting capacity for the plate thickness.

54. D — Carbon from the CAC-A electrode vaporizes in the arc and diffuses into the groove surface, creating a carbon-enriched surface layer. On P91 CrMo-V alloy steel, this contaminated layer must be removed by grinding at least 1–2 mm into the groove surface before repair welding — preventing elevated carbon in the repair deposit from compromising the P91 weld metal properties and PWHT response.

55. A — In CAC-A, the electrode stub length determines the arc gap between the electrode tip and the base metal surface. As the electrode is consumed, the increasing stub-to-tip distance grows beyond the normal operating range, shifting the arc characteristics from the normal sharp cracking sound to a softer hissing and reducing gouge effectiveness. Repositioning the stub in the holder restores correct arc length.

56. C — Partial blockage of one or more preheat orifices restricts gas flow specifically to those orifices while the unblocked orifices continue operating normally. The restricted orifices receive insufficient gas flow for stable laminar combustion, producing the turbulent, flickering, ragged flame visible at those locations. Clearing the blockages with a correctly sized tip cleaner restores uniform flame characteristics before cutting.

57. B — Argon-hydrogen plasma gas contains no oxygen or nitrogen, preventing the chromium oxidation reactions that discolor and contaminate stainless steel cut edges during air plasma

cutting. The result is a bright metallic cut face that retains the passive layer, often requiring minimal post-cut preparation and maintaining corrosion resistance at the cut edge surface.

58. D — After closing both cylinder valves and bleeding the hose circuits, residual oxygen pressure remaining after the regulator adjusting screw is fully backed out indicates that one or both torch needle valves were not fully opened during the bleed-down procedure. Fully opening the torch needle valves and allowing 60 additional seconds of bleed time purges the trapped oxygen to zero.

59. A — As an oxygen cylinder depletes toward lower pressure, dissolved moisture previously stabilized at high pressure can transition to vapor phase and enter the gas stream. Progressive moisture contamination of the cutting oxygen degrades the oxidation reaction at the cutting zone and the preheat flame consistency, causing the gradual cut quality deterioration beginning at approximately the 40-cut mark.

60. C — When the steel surface reaches the iron ignition temperature (approximately 870°C), it takes on a bright orange-to-yellow glow with a slightly fluid-looking, shiny surface appearance from incipient surface activation. This visual state confirms the surface iron is at the temperature at which the exothermic oxidation reaction is self-sustaining when the cutting oxygen stream is applied.

61. D — Consumable wear during a production run progressively erodes the electrode tip (increasing the electrode-to-plate gap) and enlarges the nozzle orifice (reducing plasma column constriction). Both changes increase the arc voltage required to sustain the cutting current — the gradual rise in arc voltage readout during an otherwise stable production run is a reliable indicator that consumable replacement is approaching.

62. B — Excessively slow travel speed with an oversized cutting tip floods the upper kerf zone with more oxygen and heat than the plate thickness requires. The excess thermal energy rounds and melts the top entry edge, and the oversized oxygen stream widens the kerf throughout the full depth — both characteristics present simultaneously when slow travel is combined with a tip sized above the plate thickness rating.

63. A — Aluminum's thermal conductivity is approximately 4 to 5 times higher than carbon steel, causing heat to spread rapidly from the cutting zone into the adjacent material. Faster travel speed is required to prevent the plasma from dwelling long enough to transfer excess heat laterally beyond the intended kerf width, which would melt material outside the cut line.

64. C — When the CAC-A electrode angle from the work surface is too flat (below approximately 30 degrees from horizontal), the electrode body or arc contacts the trailing sidewall of the developing groove on each pass. This repeated arc contact with the sidewall produces the scoring marks running parallel to the gouge travel direction while still maintaining the correct central groove depth.

65. D — When the torch tip briefly contacts a plate surface irregularity during production cutting, the physical orifice obstruction momentarily interrupts gas flow at the tip and the resulting back-pressure extinguishes the preheat flame. This preheat circuit interruption involves no internal burning and no flame propagation into the torch body — the gas flow continues throughout the event and the torch can be immediately relit.

66. B — The water sheath surrounding the plasma column constricts it more effectively than a gas shield at equivalent flow rates, producing a physically narrower and more cylindrical plasma jet. This tighter, more parallel-sided beam generates a more perpendicular kerf face from entry to exit surface compared to the slightly tapered kerf produced by conventional gas-shielded plasma.

67. A — A cut-face HAZ hardness of 58 HRC on alloy steel indicates that the thermal cutting cycle produced a hard, martensitic surface layer that far exceeds acceptable hardness limits for pressure vessel weld preparations. The hardened layer must be mechanically removed by grinding or machining to expose unaffected base metal before the prepared surface can be used as a groove joint for welding.

68. D — Both OFC and PAC produce hardened HAZ zones on P91 alloy steel that can exceed the code-specified maximum for weld preparation surfaces. The mechanical removal requirement for the hardened layer applies equally to both cutting methods — neither process inherently avoids it, making the choice between OFC and PAC a production efficiency and surface finish decision rather than a hardness compliance one.

69. C — The required minimum separation between oxygen cylinders and combustible gas cylinders in an unprotected storage area is 6 metres (approximately 20 feet) under applicable compressed gas safety standards. This distance ensures an ignition event at one group cannot immediately propagate to the other, and an alternative is a rated non-combustible barrier at least 1.5 metres high between the groups.

70. B — CAC-A spatter particles that land on adjacent pressure vessel base metal make brief electrical arc contact at each impact point, creating micro-arc strikes with small HAZ zones at

each location. These arc strike HAZ zones can harden to a martensitic microstructure and act as fatigue crack initiation sites under the cyclic service loading for which the pressure vessel is designed.

71. A — Headache and dizziness developing after 3 hours of OFC work in a shop with general ventilation only are consistent with early-stage carbon monoxide exposure from combustion products that have accumulated beyond safe limits despite the dilution ventilation. The correct response is to stop immediately, exit to fresh air, and report to first aid — continued exposure risks incapacitation.

72. C — The "H4" suffix specifies a maximum diffusible hydrogen limit of 4 mL per 100 g of deposited weld metal — the most demanding hydrogen control class in AWS A5.1. The "R" certifies that the electrode coating has been tested to maintain this H4 classification for a minimum of 9 hours at 80% relative humidity, confirming the electrode's extended field usability between oven issuance and arc strike.

73. D — The hot pass thermal cycle refines the coarse solidification grain structure of the root pass, burns out minor porosity and inclusions in the root deposit, and remelts the root pass surface oxide. Depositing the hot pass while the root is still warm maximizes these metallurgical improvements before the joint is enclosed by subsequent fill passes.

74. B — The WPS specifies a minimum preheat of 150°C to control the HAZ cooling rate and prevent martensite formation and cold cracking in 2.25Cr-1Mo alloy steel. The pipe at 14°C must be heated to at least 150°C throughout the preheat zone extending 75 mm each side of the joint, and this temperature verified with a calibrated surface device immediately before the first arc is struck.

75. A — Reducing amperage below mid-range limits pool volume; a whipping or in-and-out motion allows brief incremental solidification between electrode advances, preventing the pool from accumulating ahead of the arc; and increasing the drag angle directs arc force into the root gap rather than along the pipe surface. Together these adjustments control the fluid pool during vertical-down E6010 welding.

76. B — E7016 and E7018 are both basic low-hydrogen electrodes sharing the same tensile strength classification and the same H4R atmospheric exposure limit. In the H4R designation, both maintain a maximum of 4 mL/100 g diffusible hydrogen under identical storage and

exposure conditions — neither electrode has a measurable technical advantage over the other for critical high-restraint structural cold-cracking control.

77. D — Switching to AC changes the arc's magnetic polarity from unidirectional to continuously alternating, eliminating the sustained asymmetric flux concentration responsible for arc blow at joint ends during DC welding. E7018 electrodes, designated with the "8" suffix confirming AC/DCEP compatibility, can be used on AC without loss of weld quality, making the supervisor's recommendation both technically sound and operationally compatible with the specified electrode.

78. A — For overhead fillet welding with E7018, a work angle of 45 degrees bisecting both plate surfaces ensures simultaneous arc heat delivery to both toes. Combined with a short arc length that concentrates arc force into the joint against gravity, and stringer beads at the lower end of the WPS amperage range to keep pool volume small, this combination gives surface tension the best opportunity to hold the overhead pool.

79. C — CSA W47.1 minimum pressure vessel joint records include the WPS number used, the welder's CWB certificate number for the joint, preheat and interpass temperature measurements taken during production, filler metal identification including lot number, and the NDE inspection result with accept/reject disposition. Together these records provide complete quality traceability for each individual joint.

80. B — AWS D1.1 Table 4.7 limits E7018 low-hydrogen electrode atmospheric exposure to a maximum of 4 hours after removal from the holding oven. With 5 hours of bench exposure at 65% relative humidity, the H4R classification limit has been exceeded by one hour. The basic coating has absorbed sufficient moisture to generate diffusible hydrogen above the H4 threshold, producing the observed weld metal porosity.

81. D — The F-Number 4 match between E7018 and E7016-C2L means no essential variable change is triggered on the filler usability classification. However, the deposit chemistry shift from A-Number 1 (carbon steel) to A-Number 8 (nickel-alloy steel) is a significant composition change — the authorized design engineer must review and confirm A-Number 8 deposit chemistry is acceptable for the production joint before the amended WPS is released.

82. A — Maintaining the joint at 250°C for a minimum of 4 hours provides the thermal activation energy for diffusible hydrogen to migrate from microstructural trap sites and diffuse to the weld surface before the joint cools below the temperature at which hydrogen mobility

becomes insufficient. This bake-out treatment reduces the total diffusible hydrogen concentration available to initiate delayed cold cracking in the high-restraint joint.

83. C — In the 6G position, the 6 o'clock location combines the overhead welding challenge with a continuously changing approach angle due to the pipe's 45-degree inclination. Gravity acts to close the keyhole at this position, requiring a more deliberate and aggressive arc positioning technique directly at the root face to establish and maintain the through-penetration keyhole needed for consistent root reinforcement through the overhead portion.

84. B — The electrodes were removed from the holding oven at 7:30 AM and the check is performed at 9:30 AM — exactly 2 hours of atmospheric exposure. AWS D1.1 Table 4.7 permits E7018 electrodes a maximum of 4 hours atmospheric exposure before reconditioning at 260–430°C is required. With 2 hours elapsed, the electrodes remain within the permitted limit and may continue to be used.

85. D — The abrupt geometric change at the weld toe between the convex face profile and the flat base metal surface creates a stress concentration at the toe boundary. Under cyclic loading this toe notch effect initiates fatigue cracks significantly earlier than a flat or concave profile would. CSA W59 specifies maximum convexity limits precisely to control this fatigue-initiating toe geometry, and excess convexity is a rejectable condition.

86. C — Type 316L stainless steel contains 2–3% molybdenum, which provides its characteristic resistance to pitting corrosion in chloride-bearing environments. E316L-16 filler matches this molybdenum content, producing a deposit with equivalent corrosion resistance to the base metal. E308L-16 contains no molybdenum, producing a deposit significantly more susceptible to pitting than the surrounding 316L base material.

87. A — Converting from weave beads to stringer beads in an overhead groove allows the arc to be directed precisely and deliberately at each groove sidewall in sequence rather than oscillating across the full groove width. This targeted arc placement delivers sufficient heat to each sidewall fusion surface before reversing direction, eliminating the slag accumulation at weave reversal points that causes the intermittent fusion boundary slag entrapment.

88. B — E6010's cellulosic coating generates a high-hydrogen, deeply penetrating arc with a forceful tight column and a fast-freezing slag that supports the weld pool in all positions at high travel speeds. These characteristics allow consistent keyhole formation and root reinforcement

through the full range of clock positions on the demanding 6G joint, which is why E6010 is the industry standard for pipeline root pass welding.

89. D — CWB welder position qualifications are position-specific. A 2G (horizontal pipe groove) certificate certifies the welder for horizontal pipe groove welding only. The 3G vertical position uses different pool control technique and gravity orientation — a separate 3G qualification test must be completed and a new position-specific certificate issued before vertical pipe groove welding is authorized on production work.

90. C — When arc voltage is too low relative to wire feed speed, the arc is too short to spread the deposited metal across the full bead width. The wire contacts the pool centrally in a confined point deposit without the arc spread needed for flat face formation — the central mound contracts longitudinally during cooling and produces the characteristic continuous centreline groove the full length of the bead.

91. A — Reducing CTWD from 19 mm to 10 mm shortens the wire electrical stick-out. The shorter stick-out reduces resistive (I^2R) preheating of the wire, requiring the arc to supply more energy to complete wire melting at the same CV machine output. This change in energy distribution at the arc tip promotes the explosive droplet formation and spatter characteristic of globular transfer at the reduced CTWD.

92. B — The push (forehand) angle directs the arc column forward into the unwelded base metal ahead of the pool, spreading the heat delivery zone more broadly rather than concentrating it into the pool. This produces a flatter, wider bead with shallower penetration than the drag (backhand) angle, where the arc is directed back into the pool and drives deeper fusion into the base metal root.

93. C — Gas-shielded FCAW is highly sensitive to air movement because the shielding gas envelope is relatively light and easily dispersed. At wind speeds above approximately 8 to 10 km/h, the shielding gas is displaced from the arc zone faster than the flow rate can maintain coverage, allowing atmospheric nitrogen and oxygen into the pool and causing porosity — wind protection or a process change is required at this threshold.

94. D — Metal-cored wire delivers metallic shell plus metal powder core to the arc, providing more metal per unit arc energy than solid wire at equivalent amperage and voltage. The higher metal content per unit of wire consumed increases the deposition rate above solid wire at the

same parameters, reducing the total arc time required to complete the specified weld length on continuous structural fillet welds.

95. A — Short-circuit transfer delivers significantly lower heat input per unit length than spray transfer. The lower heat input limits burn-through risk on the 1.6 mm galvanized sheet, reduces the HAZ that degrades the zinc coating on the thin member, and limits the volume of zinc vaporized by the arc — all critical concerns when welding thin-gauge galvanized sheet to a heavier structural bracket.

96. B — On a CV power source, increasing CTWD extends the wire stub between contact tip and arc, increasing resistive (I^2R) preheating of the wire. The CV machine maintains the set voltage but must deliver less current because the preheated wire requires less arc energy to complete melting — effective welding amperage decreases as CTWD increases at constant voltage setting.

97. D — Switching from E71T-1M (rutile slag) to E71T-5 (basic slag) introduces a fundamentally stiffer, more viscous slag system. The basic slag chemistry of T-5 wire physically holds the weld metal in a flatter position against gravity in the overhead orientation, resisting the pool accumulation and crown-building tendency that produces excessive convexity with the more fluid rutile T-1M system.

98. C — When welding into a headwind with E71T-8 self-shielded wire, the oncoming air sweeps the self-generated shielding atmosphere away from the arc zone before it can provide adequate protection to the molten pool. The loss of shielding allows atmospheric nitrogen to enter the pool, producing the nitrogen porosity detected on radiographic examination of the windward-direction weld passes.

99. A — Heat input = $(26 \text{ V} \times 225 \text{ A} \times 60) \div (400 \text{ mm/min} \times 1,000) = 351,000 \div 400,000 = 0.8775 \approx 0.88 \text{ kJ/mm}$. This value confirms the actual production heat input is within the WPS qualified range and allows numerical comparison against any minimum and maximum heat input limits specified in the procedure.

100. B — When shielding gas flow rate exceeds the optimal range, turbulent gas flow develops above the weld pool and slag surface. This turbulence rapidly cools the slag film before it can reach and maintain the fluid state required for differential thermal contraction to release it cleanly from the bead upon cooling. Reducing the flow rate to the lower end of the specification restores laminar flow and normal self-release behavior.

101. D — GTAW on carbon steel requires a CC (constant-current) power source set to DCEN. DCEN concentrates approximately 70% of arc energy at the workpiece, maximizing fusion efficiency at the joint while directing only 30% to the electrode — protecting the pointed tungsten from the excessive heat that would ball and contaminate it under DCEP. The CC output characteristic maintains stable amperage despite arc length variations during manual pipe welding.

102. A — Internal volume = $\pi \times (0.150)^2 \times 1.2 = 0.0848 \text{ m}^3 = 84.8 \text{ litres}$. At 6 L/min, one complete volume change takes $84.8 \div 6 = 14.1$ minutes. Achieving sub-1,000 ppm oxygen requires approximately 5 to 6 volume changes (70 to 85 minutes), because each change approximately halves the remaining oxygen concentration rather than removing it completely.

103. C — A tungsten electrode contaminated by pool contact has metallic deposits on its tip that disrupt the consistent thermionic emission point required for a stable arc column. Arc wander, arc instability, and tungsten inclusion deposition in the weld metal follow. The electrode must be removed, re-ground to correct taper geometry on clean base metal, and reinstalled before welding resumes.

104. B — Keeping the glowing filler rod tip within the trailing edge of the argon shielding gas envelope during pauses between additions maintains an inert atmosphere around the hot metal surface. Withdrawing the tip into atmospheric air even briefly causes rapid surface oxidation that produces a dark oxide layer, which is incorporated as a contamination stripe into the next pool addition.

105. D — Under ASME IX QW-408, shielding gas composition is designated as an essential variable for GTAW. Adding nitrogen to pure argon shielding changes the arc's thermal conductivity, heat transfer characteristics, and the plasma chemistry in contact with the stainless steel deposit — all of which can alter mechanical properties in ways that require new PQR test coupon qualification to validate.

106. C — Crown at 12 o'clock results from favorable gravity allowing pool accumulation at the flat position. Undercut at 6 o'clock results from gravity pulling the overhead pool away from the toes. Reducing programmed amperage at 12 o'clock limits pool volume and controls crown; reducing programmed amperage at 6 o'clock produces a tighter, smaller overhead pool that surface tension can hold at the toes without dripping — both conditions corrected by position-specific amperage reduction.

107. A — Titanium is extremely reactive with oxygen and nitrogen above approximately 400°C, and any atmospheric contamination of the hot weld metal or HAZ produces visible surface oxides. Blue-purple discoloration indicates elevated oxygen and nitrogen pickup from inadequate shielding. Contaminated titanium exhibits significantly reduced ductility and fracture toughness — the shielding system must be investigated and corrected before welding continues.

108. B — A shallow filler addition angle of 10 to 20 degrees from the pipe surface feeds the wire into the leading edge of the pool smoothly at a low angle. This controlled geometry allows the wire to be melted incrementally by the arc heat without disturbing the keyhole, while giving the welder precise control over the metal volume added at each increment throughout the circuit.

109. D — Shielding gas composition is an essential variable for GTAW under ASME IX QW-408. An argon/hydrogen blend has different arc thermal conductivity, heat transfer properties, and potential effects on weld metal chemistry compared to pure argon. These changes require new PQR test coupon qualification testing to confirm all mechanical property requirements are satisfied with the revised shielding gas chemistry.

110. A — In AC GTAW of aluminum, increasing the EN ratio concentrates a greater fraction of the arc energy at the base metal surface during the electrode-negative portion of each cycle. On thin gauge aluminum, this elevated and concentrated base metal heating increases the thermal load at the weld pool, and on material under approximately 4 mm a heavily EN-biased balance can approach the heat input threshold for melt-through if not managed carefully.

111. C — Straw-to-gold discoloration in the 304L stainless HAZ indicates the surface was exposed to temperatures in the sensitization range (approximately 425–870°C) for sufficient time to begin chromium carbide precipitation at grain boundaries. Although lighter than blue or black oxidation, this coloration signals a potentially compromised passive layer that requires evaluation for the specific corrosion service environment before the weld is accepted.

112. B — Operating at 80 A versus the WPS-specified 75 A introduces more arc energy than the root pass pool of nickel alloy pipe can manage. The elevated heat input makes the pool excessively fluid and reduces pool viscosity, causing it to run ahead of the arc. Reducing to the specified 75 A restores the pool characteristics defined and verified during procedure qualification.

113. A — Duplex stainless steel's thermal properties require careful heat input management during welding to ensure the deposited metal and HAZ receive sufficient thermal energy to

complete proper microstructural development before cooling. Without meeting the minimum heat input threshold, the pool and HAZ cool too rapidly for the required metallurgical transformations to occur, affecting both fusion quality and final microstructure.

114. D — "EH14" is the AWS A5.17 classification of the electrode wire used during the deposit composition and mechanical property qualification test for the combined flux-wire system. "E" identifies it as an electrode wire, "H" indicates high manganese, and "14" defines the specific wire chemistry and composition range. The same EH14 wire classification must be used in production to replicate the deposit properties recorded in the classification test.

115. C — In SAW, the enclosed arc environment created by the conductive flux layer produces a fundamentally different arc physics than open-arc processes. The flux confinement equalizes the arc energy distribution between the electrode and workpiece across both DC polarities, producing equivalent bead geometry and deposition characteristics regardless of whether DCEP or DCEN is selected, within the same current operating range.

116. B — Recovered SAW flux contains fine particles from thermal fragmentation during the arc cycle, slag chip fragments from incomplete cleaning, and moisture absorbed during open storage. Screening removes particle size outliers — both fines and oversize — that degrade arc stability and bead consistency, while oven drying removes absorbed moisture that would generate porosity and alter the deposit chemistry in production.

117. A — A lower oscillation frequency increases the torch travel distance between each oscillation reversal point, spacing the individual ripple crests further apart along the bead face. Wider crest spacing produces shallower, flatter transitions between adjacent ripple peaks that blend more smoothly, giving the bead surface a more uniform and professional finish appearance than the closely-spaced, pronounced ripple pattern produced at higher oscillation frequency.

118. D — Under ASME IX QW-408, SAW flux type and composition are essential variables because different flux chemistries and basicity indices produce different deposit elemental compositions, slag characteristics, and mechanical properties. Switching from a fused flux to a bonded flux of different composition is an essential variable change that requires new PQR test coupon qualification testing to validate the amended procedure.

119. C — Heat input = $(31 \text{ V} \times 600 \text{ A} \times 60) \div (400 \text{ mm/min} \times 1,000) = 1,116,000 \div 400,000 = 2.79 \text{ kJ/mm}$. This value is below the procedure maximum of 3.0 kJ/mm, confirming the current

production parameters are within the qualified range — welding may continue without adjustment.

120. B — Active SAW flux adds manganese and silicon to the deposit through arc-driven flux reactions on every pass. When the recycled flux ratio is increased from 30% to 60%, flux that has already been through the arc contributes additional accumulated Mn and Si to the deposit alongside the fresh active flux additions — the combined chemistry contribution may push the deposit composition beyond the maximum weld metal composition limits, reducing toughness.

121. A — At 25% dilution from the carbon steel base metal, the deposited 309L chemistry is significantly modified by the incoming iron and carbon. The altered deposit composition may no longer provide the chromium content, ferrite balance, or composition ratio required for the overlay's intended function — whether as a corrosion-resistant cladding layer or as a required buffer between the carbon steel and subsequent stainless overlay passes.

122. D — EL8 wire (low manganese, low silicon) and EH14 wire (high manganese, high silicon) have significantly different deposit compositions. The substantially higher Mn and Si content of EH14 changes the A-number classification of the deposited weld metal compared to the EL8 deposit. Under ASME IX QW-404, a change in deposit A-number classification constitutes an essential variable requiring new PQR qualification testing for the revised flux-wire combination.

123. C — When flux bridges over the weld pool before the metal has fully solidified, the rigid solidified flux arch constrains the still-cooling weld metal. As the enclosed metal contracts during final solidification, the restraining flux shell prevents normal longitudinal movement, placing the cooling deposit in tension and generating sufficient stress to initiate longitudinal cracking in the upper portion of the bead beneath the bridge.

124. B — In tandem SAW, the DC lead arc generates a strong unidirectional magnetic field. When the arc-to-arc spacing is too close, this field interacts with and deflects the AC trail arc asymmetrically on each alternating half-cycle, causing erratic extinction and re-ignition behavior visible in the flux surface turbulence. Increasing the electrode spacing to the manufacturer's recommended minimum eliminates the magnetic interference between the two arcs.

125. A — An incomplete fusion zone at a pass boundary appears on RT film as a linear indication with a well-defined upper edge — the clean fusion line where the arc melted the previous pass — and a diffuse lower edge where the thermal boundary on the unmelted side of the interface is less distinct. Its position at one-third depth from the weld face and orientation parallel to the weld axis are consistent with a pass boundary incomplete fusion zone.