

# PRACTICE EXAM 9: PE CONTROL SYSTEMS SIMULATION

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**Recommended Time: 9.5 hours | Questions: 85 | References: NCEES PE Control Systems Reference Handbook, ANSI/ISA-5.1 (2009), ISA/IEC 61511 (2018)**

## **DOMAIN 1: MEASUREMENT (Questions 1–22)**

1. A DP flow transmitter with square root extraction disabled is calibrated for a maximum flow of 500 gpm at 100 in H<sub>2</sub>O full-scale DP. The transmitter outputs 12 mA. What is the actual flow rate?

- A. 250 gpm
- B. 354 gpm
- C. 435 gpm
- D. 177 gpm

2. Using the linear RTD approximation  $R(T) = 100 \times (1 + 0.00385 \times T)$ , what is the resistance of a Pt100 RTD at 175°C?

- A. 174.9  $\Omega$
- B. 162.4  $\Omega$
- C. 171.0  $\Omega$
- D. 167.4  $\Omega$

3. According to ANSI/ISA-5.1, which tag designates a primary flow measurement element with no signal transmission in loop 118?

- A. FE-118
- B. FT-118
- C. FI-118
- D. FR-118

4. A process line carries a non-conductive hydrocarbon liquid at 15,000 barrels per day requiring mass flow custody transfer accuracy. Which technology is most appropriate?

- A. Magnetic flowmeter with ceramic electrodes
- B. Ultrasonic transit-time flowmeter
- C. Coriolis mass flowmeter
- D. Vortex flowmeter with temperature compensation

5. A Type J thermocouple is operated at 700°C. What is the primary concern limiting its service life at this temperature?

- A. Constantan conductor melts above 650°C
- B. Iron conductor oxidizes progressively, causing calibration drift
- C. Reverse polarity occurs above the Curie temperature
- D. Type J EMF output becomes nonlinear above 500°C

6. A closed-vessel DP level transmitter has: process liquid SG = 0.82, span = 137.8 inches, wet leg (SG = 1.00) height = 177.2 inches above the lower tap. What is the transmitter LRV in inches H<sub>2</sub>O?

- A. -118.0 in H<sub>2</sub>O

- B. -142.5 in H<sub>2</sub>O
- C. -153.6 in H<sub>2</sub>O
- D. -177.2 in H<sub>2</sub>O

7. An IR CO<sub>2</sub> analyzer using 4.26 μm absorption is installed in a wet gas application without moisture removal. What measurement error results?

- A. Systematically low CO<sub>2</sub> readings from water vapor dilution
- B. Random errors from water droplets intermittently blocking the optical path
- C. Artificially high CO<sub>2</sub> readings from water vapor absorption near 4.26 μm
- D. Complete analyzer failure from liquid water contacting the optical cell

8. A differential pressure transmitter with a 0–500 in H<sub>2</sub>O span is specified with ±0.1% of span accuracy. What is the maximum absolute error at any reading?

- A. ±0.10 in H<sub>2</sub>O
- B. ±0.20 in H<sub>2</sub>O
- C. ±0.25 in H<sub>2</sub>O
- D. ±0.50 in H<sub>2</sub>O

9. A turbine flowmeter has a K-factor of 54.8 pulses per liter. A batch totalizer counts 219,200 pulses at the end of a loading operation. What volume was transferred?

- A. 2,500 liters
- B. 4,000 liters
- C. 6,000 liters
- D. 1,200 liters

10. An opacity transmitter uses a retroreflector mounted on the opposite side of the stack from the source-detector unit. What is the effective optical path length if the stack diameter is 2.5 meters?

- A. 5.0 meters
- B. 2.5 meters
- C. 1.25 meters
- D. 3.54 meters

11. An eddy current proximity probe is calibrated on carbon steel and then used on a stainless steel shaft without recalibration. What is the primary source of measurement error?

- A. Surface hardness difference between the two materials
- B. Shaft diameter tolerance difference affecting gap sensitivity
- C. Differences in magnetic permeability and electrical conductivity between the two materials
- D. Surface finish roughness difference scattering the electromagnetic field

12. A pressure transmitter calibration certificate shows errors of: 0% span = +0.2%, 25% = +0.1%, 50% = 0%, 75% = -0.1%, 100% = -0.2%. What type of calibration error is present?

- A. Zero error
- B. Span error
- C. Nonlinearity error
- D. Combined zero and span error

13. A portable combustible gas detector reads 45% LEL near a natural gas source. The LEL of methane is 5% by volume in air. What is the actual methane concentration?

- A. 45.0% v/v

- B. 22.5% v/v
- C. 9.0% v/v
- D. 2.25% v/v

14. A plant must measure pH in ultrapure water with conductivity less than  $0.1 \mu\text{S}/\text{cm}$  where standard glass electrodes give unstable readings. What solution is most appropriate?

- A. Flow-through pH cell with low-impedance electrode design rated for low-conductivity service
- B. Colorimetric pH indicator with optical absorbance detection
- C. Standard combination glass pH electrode with PTFE reference junction
- D. ISFET (ion-sensitive field-effect transistor) pH sensor

15. In ANSI/ISA-5.1, what function does the succeeding letter "S" designate in an instrument tag?

- A. Signal converter or transducer function
- B. Scanner for multipoint sequential measurement
- C. Switch — output changes state based on the measured variable
- D. Safety-rated instrument classification marker

16. A displacer level instrument has a displacer volume of  $0.025 \text{ ft}^3$ . The process fluid is  $\text{SG} = 0.72$ . What is the buoyant force on the fully submerged displacer?

- A. 1.33 lbf
- B. 1.12 lbf
- C. 1.56 lbf
- D. 0.94 lbf

17. A sample conditioning system transports a hot process gas at 320°C through a 30-meter unheated sample line to an ambient-temperature analyzer. What is the most critical parameter to maintain?

- A. Sample pressure above 5 psig to prevent air ingress
- B. Volumetric sample flow within the analyzer manufacturer specification
- C. Filter differential pressure below the scheduled maintenance threshold
- D. Sample temperature above the hydrocarbon dew point throughout the entire sample line

18. A magnetic flowmeter reads 110 gpm. An independent diverter test collects 52 gallons in exactly 30 seconds. What is the meter error?

- A. Reference = 104 gpm; meter reads 5.8% high
- B. Reference = 110 gpm; meter reads accurately
- C. Reference = 96 gpm; meter reads 14.6% high
- D. Reference = 104 gpm; meter reads 5.8% low

19. A fiber optic temperature measurement system uses fluorescence decay time in a rare-earth doped fiber tip. What is its primary advantage over thermocouples in high-voltage electrical equipment?

- A. Higher maximum rated temperature range
- B. Faster response time from reduced thermal mass
- C. Complete electrical isolation with no current path and no EMI coupling
- D. Lower long-term calibration drift compared to thermocouple alloys

20. A Coriolis meter measures a slurry at 18,500 kg/hr with a slurry density of 1,180 kg/m<sup>3</sup>. What is the volumetric flow rate?

- A. 22.0 m<sup>3</sup>/hr

- B. 18.5 m<sup>3</sup>/hr
- C. 12.4 m<sup>3</sup>/hr
- D. 15.7 m<sup>3</sup>/hr

21. An electrochemical H<sub>2</sub> sensor is exposed to both 10 ppm H<sub>2</sub> and 50 ppm CO simultaneously. What measurement interference does CO produce?

- A. CO catalytically destroys H<sub>2</sub> at the electrode surface
- B. CO oxidizes at the platinum electrode alongside H<sub>2</sub>, producing a positive interference that inflates the indicated H<sub>2</sub> reading
- C. CO adsorbs onto the electrode blocking active sites over time
- D. No interference occurs because CO and H<sub>2</sub> oxidize at different electrode potentials

22. A thermowell wake frequency calculation gives: natural frequency = 340 Hz, vortex shedding frequency at operating velocity = 255 Hz. What is the frequency ratio and does it satisfy the steady-flow criterion?

- A.  $r = 0.75$  — passes the steady-flow criterion ( $r < 0.80$ )
- B.  $r = 1.33$  — fails the steady-flow criterion
- C.  $r = 0.75$  — fails the pulsating flow criterion ( $r > 0.40$ )
- D.  $r = 0.85$  — marginally fails the steady-flow criterion

## **DOMAIN 2: CONTROL SYSTEMS (Questions 23–44)**

23. A direct-acting PID controller has  $K_c = 3.0$ . The PV rises 4% above setpoint. What is the immediate proportional output change?

- A. -6.0%
- B. +6.0%

- C. +12.0%
- D. -12.0%

24. According to ANSI/ISA-5.1, which tag correctly identifies a temperature sensing element only (thermocouple or RTD) in loop 240 with no signal transmission?

- A. TT-240
- B. TSH-240
- C. TIC-240
- D. TE-240

25. Using lambda tuning with  $K_c = \tau / (K_p \times (\lambda + \theta))$ , calculate  $K_c$  for:  $K_p = 3.0$ ,  $\tau = 90$  s,  $\theta = 30$  s,  $\lambda = 90$  s.

- A. 0.375
- B. 0.250
- C. 0.500
- D. 0.750

26. A cascade temperature controller (outer) drives the setpoint of an inner steam flow controller. The inner loop settles in 8 seconds while the outer loop time constant is 4 minutes. What does this ratio confirm?

- A. The loops are appropriately paired — the inner loop is approximately 30 times faster than the outer loop
- B. The loops are incorrectly paired — the inner loop must be slower than the outer loop for stable cascade
- C. The ratio requires the outer loop to be detuned to match inner loop response speed
- D. The ratio has no significance for cascade stability assessment

27. IEC 62443 Clause 3.2.3 requires that security zones be defined based on what criterion?

- A. Physical boundaries of control cabinets and marshalling rooms
- B. Organizational ownership of individual assets within the facility
- C. Common security requirements and acceptable risk level of grouped assets
- D. Communication protocol type used by assets within the zone

28. A closed-loop step response shows successive peak amplitudes of 12%, 6%, and 3% above setpoint. What is the decay ratio?

- A. 0.25
- B. 0.33
- C. 0.75
- D. 0.50

29. Using Ziegler-Nichols closed-loop tuning with  $K_u = 4.8$  and  $P_u = 160$  seconds, what are the recommended PID settings?

- A.  $K_c = 2.88$ ,  $T_i = 80$  s,  $T_d = 10$  s
- B.  $K_c = 2.16$ ,  $T_i = 80$  s,  $T_d = 20$  s
- C.  $K_c = 2.88$ ,  $T_i = 80$  s,  $T_d = 20$  s
- D.  $K_c = 2.16$ ,  $T_i = 133$  s,  $T_d = 33$  s

30. A level controller manipulates an outlet valve (air-to-close, fail-open) to maintain tank level at setpoint. When level rises above setpoint, which controller action correctly opens the valve further to drain the tank?

- A. Reverse acting — output decreases as level rises

- B. Direct acting — output increases as level rises, further opening the ATC valve
- C. Direct acting — output increases to close the valve
- D. Reverse acting — output increases as level rises

31. A split-range controller manages reactor pressure using a vent valve (0–50% output range) and a supply valve (50–100% output range). At 73% controller output, what are the two valve positions?

- A. Vent at 46% open, supply fully closed
- B. Vent fully open, supply at 54% open
- C. Vent fully closed, supply at 46% open
- D. Both valves at 23% open simultaneously

32. A feedforward control model uses  $U = 400 \text{ BTU/hr}\cdot\text{ft}^2\cdot^\circ\text{F}$ . Tube fouling reduces actual  $U$  to  $280 \text{ BTU/hr}\cdot\text{ft}^2\cdot^\circ\text{F}$ . What is the primary effect on disturbance rejection?

- A. Feedforward under-corrects for feed temperature disturbances, leaving residual error for the feedback controller
- B. Feedforward over-corrects, causing systematic overshoot on feed temperature disturbances
- C. Feedforward controller output saturates at maximum steam demand
- D. Control loop instability results from the effective gain reversal

33. A ratio control station maintains a fuel-to-air ratio of 0.12:1. Air flow is  $8,500 \text{ Nm}^3/\text{hr}$ . The operator changes the ratio setpoint to 0.14:1. What is the new fuel flow setpoint?

- A.  $1,020 \text{ Nm}^3/\text{hr}$
- B.  $1,105 \text{ Nm}^3/\text{hr}$
- C.  $1,275 \text{ Nm}^3/\text{hr}$
- D.  $1,190 \text{ Nm}^3/\text{hr}$

34. An OT security team detects at 2:15 AM that a DCS engineering workstation is initiating outbound connections to an unknown external IP address. What is the first action?

- A. Log the event and report at the morning security briefing
- B. Isolate the workstation from the OT network immediately and preserve logs for forensic analysis
- C. Run installed antivirus software to identify and remove the threat
- D. Contact the DCS vendor before taking any network action

35. A PID controller in interactive (series) form has  $K_c = 1.8$ ,  $T_i = 5$  min,  $T_d = 0.6$  min. What is the equivalent non-interactive (parallel) form proportional gain?

- A. 1.80
- B. 2.00
- C. 2.02
- D. 1.60

36. According to ISA-18.2, "alarm shelving" is defined as which technique?

- A. Permanent removal of non-actionable alarms through the rationalization process
- B. Grouping related alarms under a single parent alarm display
- C. Reducing alarm priority for a defined maintenance period
- D. Temporary suppression of an alarm for a defined duration with automatic reinstatement

37. A compressor anti-surge controller manipulates a recycle valve using a high selector with a flow controller. When does the anti-surge controller output get passed to the recycle valve?

- A. During normal operations when flow control takes precedence
- B. When the lower of the two outputs protects against overpressure

- C. When the average of both outputs is computed during transitions
- D. When the anti-surge controller demands greater recycle valve opening than the flow controller

38. Back-calculation anti-windup in a PID controller specifically prevents which condition?

- A. Integral reset windup when the controller output saturates at its configured limit
- B. Integral accumulation beyond the output limit by feeding back the difference between limited and unlimited output through the integrator
- C. Proportional kick during setpoint step changes
- D. Derivative kick during rapid process variable changes

39. Using Ziegler-Nichols open-loop PI rules with  $K_p = 2.0$ ,  $\tau = 60$  s,  $\theta = 20$  s, what are the recommended settings?

- A.  $K_c = 1.80$ ,  $T_i = 40$  s
- B.  $K_c = 1.00$ ,  $T_i = 67$  s
- C.  $K_c = 1.35$ ,  $T_i = 67$  s
- D.  $K_c = 2.25$ ,  $T_i = 50$  s

40. An SPC Shewhart X-bar chart on a batch reactor shows 9 consecutive points on the same side of the centerline, all within the  $\pm 3$  sigma control limits. What does this pattern indicate?

- A. A non-random shift in the process mean — a special cause signal despite all points being within control limits
- B. Normal random variation confirming the process is in statistical control
- C. Insufficient sample size — 9 points cannot establish a statistically valid pattern
- D. Measurement system error causing systematic bias on alternating batch days

41. A model predictive controller executes every 1 minute with a 20-step prediction horizon. A measured feed flow disturbance is expected to affect controlled composition in 12 minutes. When does MPC begin applying counteracting moves?

- A. Immediately at the next 1-minute execution after the disturbance is detected
- B. After 6 minutes when the disturbance enters the control horizon
- C. After 12 minutes when the composition deviation becomes measurable
- D. At the next execution after composition deviation exceeds the control limit

42. An integrating process (large buffer tank level) uses proportional-only control with balanced inflows and outflows at the nominal operating point. What steady-state behavior results?

- A. Continuous output oscillation from the integrating process characteristic
- B. Stable level control with zero offset when inflows and outflows are balanced at the operating point
- C. A fixed non-zero offset proportional to the nominal flow rate
- D. Output windup to saturation from the integrating nature of the process

43. In IEC 61131-3 Sequential Function Chart, which action qualifier causes an associated action to execute for exactly one scan cycle at step activation, then immediately deactivate?

- A. N — non-stored, active throughout the entire step duration
- B. S — set/latch, remains active until explicitly reset by an R instruction
- C. P — pulse, executes for one scan cycle at step activation only
- D. D — delayed, activates after a specified time delay within the step

44. A control engineer reduces controller gain from  $K_c = 3.0$  to  $K_c = 1.5$  and increases  $T_i$  from 60 s to 150 s. What is the primary effect on loop performance?

- A. Degraded disturbance rejection — slower corrective action takes longer to return PV to setpoint after disturbances
- B. Improved setpoint tracking while disturbance rejection remains unchanged
- C. Improved stability margin with equivalent disturbance rejection performance
- D. Improved disturbance rejection from the more conservative integral time setting

**DOMAIN 3: FINAL CONTROL ELEMENTS (Questions 45–62)**

45. An equal percentage control valve has  $C_{v\_max} = 80$  and rangeability of 40:1. Using  $C_v(x) = C_{v\_min} \times R^x$ , what is the approximate  $C_v$  at 30% travel?

- A. 2.0
- B. 12.0
- C. 24.0
- D. 6.1

46. A pressure relief valve application has a closed relief header with variable superimposed back pressure of 0–28 psig against a set pressure of 200 psig. Which PRV design is required?

- A. Conventional spring-loaded PRV with stainless steel spring
- B. Balanced bellows or pilot-operated PRV
- C. Pilot-operated PRV with remote sensing connection only
- D. Conventional PRV with adjustable blowdown ring

47. A 100 hp motor is started using an autotransformer starter at the 65% voltage tap. What percentage of full-voltage starting torque is available at the motor shaft?

- A. 42%
- B. 65%
- C. 80%
- D. 32%

48. A motor with FLA = 85 A has a thermal overload relay set at 115% of FLA. At what current does the relay trip?

- A. 85.0 A
- B. 91.0 A
- C. 97.8 A
- D. 104.0 A

49. A spring-return ESD valve must achieve full closure within 2 seconds. The actuator is a spring-return pneumatic diaphragm type with a digital positioner. Which accessory most directly achieves the fast-stroke requirement?

- A. Volume booster on the actuator supply line
- B. Larger positioner with higher rated Cv
- C. Stiffer return spring assembly
- D. Quick-exhaust valve on the actuator exhaust port

50. A control valve for polymer melt service at 300°C must throttle across an 8:1 flow range with high reliability. Which trim and packing combination is most appropriate?

- A. PTFE-seated ball valve with spring-return actuator

- B. Equal percentage cage trim with hardened seat and high-temperature graphite packing
- C. Linear trim butterfly valve with high-temp PTFE disc lining
- D. Quick-opening plug trim with asbestos-free braided packing

51. An equal percentage valve has a minimum controllable Cv of 1.5 and a rangeability of 50:1. What is the maximum Cv at full open?

- A. 75.0
- B. 50.0
- C. 100.0
- D. 37.5

52. A centrifugal pump motor at 1,750 rpm consumes 75 kW. A VSD reduces speed to 1,400 rpm. Using the affinity law for power, what is the new shaft power?

- A. 48.0 kW
- B. 60.0 kW
- C. 38.4 kW
- D. 30.0 kW

53. A positioner calibration check shows: 4 mA → 0% travel, 12 mA → 47% travel, 20 mA → 94% travel. What type of calibration error is present?

- A. Zero error — the zero point is set incorrectly
- B. Span error — full travel range is compressed below the required stroke
- C. Linearity error — mid-range deviates while the endpoints are correct
- D. Combined zero and span error — both points are off simultaneously

54. A check valve in a large cooling water system experiences water hammer during pump trip from rapid flow reversal. Which design modification best controls the closing rate?

- A. Larger nominal valve bore to reduce line velocity at the check valve
- B. Parallel bypass with a small globe valve for controlled reverse flow
- C. Spring-loaded disc for faster closure before flow reversal velocity develops
- D. Hydraulic dashpot damper to control disc closing rate during flow reversal

55. A rupture disc rated at 200 psig burst at 70°F is installed at 250°F where the derated burst pressure is 185 psig. Operating pressure is 180 psig. A reverse-buckling disc with 90% maximum operating ratio is used. Is this installation acceptable?

- A. Unacceptable — operating ratio of 97.3% (180/185) exceeds the 90% maximum limit
- B. Acceptable — operating pressure is below the derated burst pressure
- C. Acceptable — temperature derating does not apply to reverse-buckling disc designs
- D. Unacceptable — minimum burst-to-operating pressure ratio must exceed 1.25

56. A process requires maximum  $C_v = 14$ . The available globe valve has rated  $C_v = 80$ . At 17.5% of rated  $C_v$ , what is the primary concern with this selection?

- A. 17.5% — acceptable if equal percentage trim is specified for this service
- B. 17.5% — acceptable for all applications passing seat leakage class testing
- C. 17.5% — low-travel operation produces poor control characteristics and potential seating instability
- D. 17.5% — acceptable for throttling service only at DP below 20 psi

57. A sliding-stem globe valve provides which maintenance advantage over a rotary ball valve in thermal cycling service requiring periodic repacking?

- A. Lower actuator thrust requirements across all service conditions

- B. Packing can be adjusted or replaced without removing the valve body from the pipeline
- C. Lower pressure drop at full open in high-temperature service
- D. Better equal percentage flow characteristic across thermal cycling conditions

58. A control valve throttles 50% NaOH (caustic soda) at 80°C. Which body and trim material combination is most appropriate?

- A. Nickel alloy (Monel 400) body with nickel-plated trim
- B. Carbon steel body with chrome-plated trim
- C. Type 316 SS with Stellite-faced seat and plug
- D. Hastelloy C-276 body with tungsten carbide plug coating

59. A liquid-filled heat exchanger shell is blocked in at operating temperature between two isolation valves. Which relief scenario governs sizing of the required pressure relief device?

- A. Fire case — flame impingement causing boiling of shell-side fluid
- B. Control valve failure open on the shell-side inlet
- C. Thermal breathing from ambient temperature cycling
- D. Blocked-in thermal expansion of the trapped incompressible liquid

60. A spring-return actuator is replaced with a stiffer spring to reduce ESD valve closure time. What is the primary trade-off?

- A. Stiffer spring increases seat leakage from excessive contact force at the closed position
- B. Stiffer spring shortens actuator diaphragm service life from fatigue loading
- C. Stiffer spring requires higher instrument air supply pressure to open the valve against the increased spring force
- D. Stiffer spring requires a larger actuator body diameter to maintain the same opening thrust

61. A 20-inch cooling water control valve has only 3 psi available differential pressure at maximum flow and requires a 4:1 flow rangeability. Which valve type is most appropriate?

- A. Angle-body globe valve with extended outlet connection
- B. High-performance butterfly valve
- C. Single-seated globe valve with balanced plug
- D. Full-bore ball valve with characterized port

62. A PRV set at 325 psig is installed on a pressure vessel with MAWP = 300 psig. How does this comply with ASME Section VIII?

- A. Non-compliant — PRV set pressure must not exceed MAWP; 325 psig exceeds the 300 psig MAWP
- B. Compliant — the 10% accumulation allowance permits set pressure up to 330 psig
- C. Compliant — pilot-operated PRVs may be set above MAWP per ASME allowance
- D. Non-compliant only if the vessel lacks a second PRV installed in parallel

**DOMAIN 4: SIGNALS, TRANSMISSION, AND NETWORKING (Questions 63–75)**

63. A 4–20 mA loop has: DCS supply = 24 VDC, input resistor = 250  $\Omega$ , IS Zener barrier = 60  $\Omega$ , cable loop resistance = 190  $\Omega$ , transmitter minimum terminal voltage = 10 VDC. What is the transmitter terminal voltage at 20 mA?

- A. 12.5 VDC
- B. 16.0 VDC
- C. 20.0 VDC
- D. 14.0 VDC

64. A PROFIBUS DP segment at 12 Mbit/s has no termination resistors installed at either cable end. What effect results?

- A. No effect — termination is only required for segments longer than 100 meters
- B. Signal reflections corrupt data where reflection timing overlaps successive bit periods at higher baud rates
- C. Maximum addressable device count reduces from 32 to 16 without proper termination
- D. The segment automatically reduces baud rate to compensate for missing termination

65. What is the minimum total loop impedance required at HART FSK frequencies for reliable digital communication?

- A. 50  $\Omega$
- B. 230  $\Omega$
- C. 600  $\Omega$
- D. 100  $\Omega$

66. An IS circuit galvanic isolator has  $V_{oc} = 20$  V and  $I_{sc} = 80$  mA. Field transmitter entity parameters are  $U_i = 24$  V and  $I_i = 100$  mA. Is this circuit IS-compliant?

- A. Yes —  $V_{oc} \leq U_i$  and  $I_{sc} \leq I_i$  satisfy both entity parameter requirements
- B. No —  $V_{oc}$  must be at least 20% below  $U_i$  for Zone 1 IS compliance
- C. Yes — only  $I_{sc}$  requires verification;  $V_{oc}$  is a non-critical entity parameter
- D. No — intrinsic safety requires  $V_{oc}$  below 15 V for all Zone 1 applications

67. Foundation Fieldbus H1 control loops can continue executing regulatory control during communication loss with the DCS host. What enables this capability?

- A. H1 devices store the last controller output and hold the valve at that fixed position

- B. The H1 backup link master assumes host communication functions automatically
- C. PID function blocks execute inside H1 field devices on the segment, running the control loop locally without host communication
- D. H1 uses ring topology with automatic path recovery maintaining continuous host communication

68. How many frequency channels does WirelessHART use in the 2.4 GHz ISM band for time-synchronized channel hopping?

- A. 3
- B. 8
- C. 10
- D. 15

69. A DCS analog input card measures 22.5 mA from a field transmitter. Per NAMUR NE 43 signal conventions, what condition does this indicate?

- A. Sensor or transmitter over-range fault — 22.5 mA exceeds the 21.0 mA upper fault threshold
- B. Process measurement at 90% of the calibrated range — a normal high reading
- C. Transmitter entering configuration or calibration mode
- D. Loop power supply voltage above its rated specification

70. What key security capability does OPC-UA provide that OPC-DA cannot natively offer?

- A. Higher data throughput for historian collection at high tag counts
- B. Platform-independent operation with built-in certificate authentication and message encryption
- C. Automatic data compression for historian bandwidth reduction
- D. Redundant communication path switching on network equipment failure

71. A security audit finds VLAN 10 (DCS controllers) and VLAN 20 (operator workstations) communicate directly despite VLAN segmentation on a managed switch. What most likely causes this?

- A. Both VLANs share the same physical switch hardware ports
- B. Controller devices broadcast traffic that crosses VLAN boundaries by design
- C. Inter-VLAN routing on the switch or connected router has no access control filtering applied
- D. Numerically adjacent VLAN IDs cause address table spillover between segments

72. In the NEC hazardous location classification system, what type of protective technique is "nonincendive" (NI) specifically designed for?

- A. Class I, Division 1 — continuous hazardous atmosphere
- B. Class II, Division 1 — combustible dust continuously present
- C. Class I, Division 1 and Division 2 — all flammable vapor hazards
- D. Class I, Division 2 — flammable vapors present only under abnormal conditions

73. A single-mode fiber optic link has: cable loss = 0.35 dB/km over 2 km, 2 connectors at 0.3 dB each, 1 splice at 0.05 dB. What is the total link loss?

- A. 1.35 dB
- B. 0.70 dB
- C. 1.65 dB
- D. 2.10 dB

74. A DCS engineering workstation requires a critical OS security patch. The OT patch management policy requires staging environment testing first. What is the correct sequence?

- A. Apply to production immediately — critical patches override the testing requirement

- B. Test in staging, verify DCS software compatibility, apply during a planned maintenance window with rollback procedure prepared
- C. Defer until the OEM provides written patch approval documentation
- D. Apply to one production workstation and monitor for 14 days before broad deployment

75. A security review finds RDP port 3389 open and accessible from the corporate IT network on a DCS engineering workstation. What is the primary risk?

- A. RDP sessions consume excessive DCS network bandwidth during remote configuration
- B. Open RDP prevents local operators from using the workstation during active remote sessions
- C. RDP sessions can be captured by other OT network users through packet interception
- D. Exposed RDP on IT-accessible networks enables credential-based or brute-force attacks to gain unauthorized DCS engineering access

#### **DOMAIN 5: SAFETY SYSTEMS (Questions 76–85)**

76. A 1oo2 sensor configuration has each sensor with  $\lambda_{DU} = 3 \times 10^{-6}/\text{hr}$ ,  $TI = 8,760 \text{ hr}$ , and  $\beta = 0.10$ . What is the total  $PFD_{avg}$  including both independent and common cause failure contributions?

- A.  $9.78 \times 10^{-4}$
- B.  $6.57 \times 10^{-3}$
- C.  $1.54 \times 10^{-3}$
- D.  $3.07 \times 10^{-4}$

77. Which IEC 61511 lifecycle document defines all functional and integrity requirements that a SIS must fulfill for each safety instrumented function?

- A. Safety Requirements Specification
- B. Hazard and Risk Assessment report

- C. SIL Verification Calculation package
- D. SIS Architecture Description document

78. An SRS specifies a maximum SIF response time of 25 seconds from demand detection to safe state. A replacement ESD valve has a stroke time of 40 seconds. What is the correct action?

- A. Accept the replacement — stroke time is not a required SRS parameter
- B. Reject or replace the valve — 40-second stroke time exceeds the 25-second SRS limit
- C. Update the SRS to reflect the longer stroke time of the replacement valve
- D. Install a position switch to trigger the SIF before full valve stroke is required

79. A LOPA calculation yields: initiating event = 0.2/year, BPCS PFD = 0.1, independent high-pressure alarm PFD = 0.1, risk tolerance =  $10^{-4}$ /year. What is the required SIF PFD?

- A. No SIF required — existing IPLs reduce risk below the tolerance criterion
- B. SIF PFD = 0.005 — SIL 2 required
- C. SIF PFD = 0.20 — no SIL classification required
- D. SIF PFD = 0.05 — SIL 1 required

80. A SIF proof test achieves 80% diagnostic coverage on the final element; 20% of dangerous failures remain undetected. The PFD calculated assuming 100% coverage is  $5.0 \times 10^{-3}$ . What is the effect on actual PFD<sub>avg</sub>?

- A. PFD remains  $5.0 \times 10^{-3}$  — IEC 61511 accepts any documented partial proof test as full credit
- B. PFD improves to  $4.0 \times 10^{-3}$  — the 80% test coverage removes 80% of failure contribution
- C. PFD is higher than  $5.0 \times 10^{-3}$  — the 20% undetected fraction accumulates without test credit
- D. PFD doubles to  $1.0 \times 10^{-2}$  — partial tests receive 50% credit per IEC 61511 Annex B

81. Per IEC 61511, when must Management of Change review be initiated for a SIS?

- A. For any change to hardware, software, setpoints, proof test procedures, or operating modes that could affect the SIS safety function
- B. Only when the SIL level of the affected safety function changes
- C. Only for hardware changes — software modifications use a separate change control process
- D. Only when mandated by a regulatory inspection finding or enforcement action

82. A 2oo3 SIS configuration permanently loses one transmitter, reducing it to 2oo2 with the same proof test interval unchanged. What is the primary performance effect?

- A. PFD improves — only two channels must fail simultaneously, reducing joint probability
- B. PFD degrades — 2oo2 requires both remaining channels to function with no redundancy tolerance for dangerous failures
- C. PFD is unchanged — both architectures require two sensors to agree for a trip
- D. PFD improves because the common cause failure contribution decreases with fewer channels

83. A SIF proof test finds the shutdown valve strokes to only 95% closed and stops — failing to achieve the fully closed position. Before returning the SIF to service, what must occur?

- A. Recalculate PFD\_avg using a 95% partial closure effectiveness factor
- B. Reduce the proof test interval to compensate for the discovered partial-closure failure mode
- C. Document the failure in the maintenance record and monitor at the next scheduled test
- D. Repair the valve to full closure travel, confirm full stroke, and retest the complete cause-to-effect path

84. A SIS component reaches the end of its 12-year documented useful life during continued plant operation. Per IEC 61511, what action is required?

- A. Replace the component within 30 calendar days regardless of observed condition

- B. Reduce the proof test interval by 50% until replacement is completed
- C. Replace before the useful life expires, or revalidate the SIL verification using failure data appropriate for equipment beyond its useful life
- D. Apply a mandatory 2× safety factor to the dangerous failure rate in the next PFD calculation cycle

85. A SIF has a measured demand rate of 6 per year, classifying it as high-demand mode per IEC 61511. Which performance metric applies for SIL verification?

- A. PFH — probability of dangerous failure per hour, applicable when demand rate exceeds one per year
- B. PFD\_avg — the same metric used for low-demand mode regardless of actual demand rate
- C. MTTFd — mean time to dangerous failure expressed in operational years
- D. RRF — risk reduction factor applicable only for high-demand safety functions

# PRACTICE EXAM 9: ANSWER KEY AND EXPLANATIONS

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1. B — Without square root extraction, output is proportional to DP. At 12 mA (50% of span), DP = 50 in H<sub>2</sub>O. Flow =  $500 \times \sqrt{(50/100)} = 500 \times 0.707 = 354$  gpm. Disabling square root extraction requires the DCS to apply extraction externally, or flow calculations must account for the raw DP-proportional output.
2. D —  $R(175) = 100 \times (1 + 0.00385 \times 175) = 100 \times 1.67375 = 167.4 \Omega$ . The linear approximation is adequate for most calculations; the full Callendar-Van Dusen equation provides slightly better accuracy at temperature extremes.
3. A — Per ANSI/ISA-5.1, the succeeding letter "E" designates a primary element — the sensing device in direct contact with the process with no signal output. FE = Flow Element (orifice plate, flow tube). FT = Flow Transmitter, which adds signal conditioning and 4–20 mA output.
4. C — Non-conductive hydrocarbons eliminate the magnetic flowmeter. Coriolis meters measure mass flow directly through the Coriolis force principle, independent of fluid conductivity, viscosity, or composition — the definitive technology for direct mass custody transfer.
5. B — Type J uses iron as the positive conductor. Above approximately 500°C in oxidizing atmospheres, iron progressively oxidizes, shifting the thermoelectric EMF away from the calibration curve. This calibration drift limits Type J practical service life in air at elevated temperatures.
6. D — LRV at 0% level: HP side = 0. LP side (wet leg) = 177.2 in H<sub>2</sub>O  $\times$  1.00. LRV = 0 – 177.2 = –177.2 in H<sub>2</sub>O. The full wet leg head acts on the LP side unopposed at zero level.
7. C — Water vapor has IR absorption bands overlapping CO<sub>2</sub> absorption near 4.26  $\mu$ m. The analyzer attributes combined water vapor and CO<sub>2</sub> absorption to CO<sub>2</sub> alone, reporting systematically elevated concentrations. Sample drying or water vapor compensation is required to correct this interference.
8. D —  $\pm 0.1\%$  of 500 in H<sub>2</sub>O =  $\pm 0.001 \times 500 = \pm 0.50$  in H<sub>2</sub>O. Span-based accuracy applies this same fixed absolute error across the entire calibrated range regardless of reading magnitude.
9. B — Volume = pulse count / K-factor = 219,200 / 54.8 = 4,000 liters. The K-factor directly converts accumulated pulse count to transferred volume — the fundamental turbine meter batch totalization method.

10. A — A retroreflector returns the beam to the source-detector unit, so light traverses the stack diameter twice:  $2 \times 2.5 \text{ m} = 5.0$  meters effective optical path. This double-pass geometry doubles measurement sensitivity compared to single-pass across the same diameter.
11. C — Eddy current probe sensitivity depends on target material magnetic permeability and electrical conductivity. Ferromagnetic carbon steel and paramagnetic stainless steel have substantially different values for both properties, producing different eddy current depths at identical gaps and requiring separate calibration curves.
12. B — The error pattern: +0.2% at 0% span, 0% at 50% span, -0.2% at 100% span — zero error at midpoint with equal and opposite errors at endpoints. This symmetric pattern is the classic span error signature where the output range is slightly wider or narrower than the configured span.
13. D — The %LEL reading is a fraction of the actual LEL concentration. At 45% LEL with methane LEL = 5% v/v: actual concentration =  $0.45 \times 5 = 2.25\%$  v/v. This distinction is safety-critical — 100% LEL (5% v/v methane) is the onset of explosive range.
14. A — Ultrapure water's near-zero ionic conductivity destabilizes the reference junction potential of conventional glass electrodes — insufficient ions cannot maintain the stable reference needed for accurate measurement. Low-impedance flow-through pH cells with specialized junction designs stabilize measurement in this service.
15. C — Per ANSI/ISA-5.1, "S" as a succeeding letter designates Switch — a device whose output changes discrete state when the measured variable reaches a defined threshold. Examples: PSH, LSL, FSL. This is distinct from "T" (Transmitter), which provides a continuous analog output.
16. B — Buoyant force =  $SG \times 62.4 \text{ lbm/ft}^3 \times \text{volume} = 0.72 \times 62.4 \times 0.025 = 1.12 \text{ lbf}$ . As process SG decreases, buoyancy decreases and the displacer appears heavier — the torque tube detects this change as a reduced level signal.
17. D — If the sample temperature falls below the hydrocarbon dew point anywhere along the 30-meter unheated line, heavy components condense and are removed from the gas sample. The analyzer then receives a compositionally lighter sample, producing systematic underreporting of heavy components regardless of calibration accuracy.
18. A — Reference flow =  $52 \text{ gallons} \div (30 \text{ s} / 60 \text{ s/min}) = 104 \text{ gpm}$ . Meter reads 110 gpm. Error =  $(110 - 104)/104 \times 100 = +5.8\%$  high. The meter over-reads actual flow; correction requires a K-factor adjustment or recalibration.
19. C — Fluorescence fiber optic sensors transmit optical signals only — no electrical current flows through the measurement path. This provides inherent galvanic isolation from high-voltage circuits and complete immunity to electromagnetic fields that corrupt thermocouple measurements in motor windings and power transformer applications.

20. D — Volumetric flow = mass flow / density =  $18,500 \text{ kg/hr} \div 1,180 \text{ kg/m}^3 = 15.68 \approx 15.7 \text{ m}^3/\text{hr}$ . Coriolis meters simultaneously output mass flow and density, enabling direct volumetric calculation from a single instrument.
21. B — Carbon monoxide oxidizes at the platinum working electrode at a potential overlapping with hydrogen oxidation. The sensor combines CO and H<sub>2</sub> oxidation currents into a single output, inflating the apparent H<sub>2</sub> reading by the CO equivalent contribution — a positive cross-sensitivity interference.
22. A — Frequency ratio  $r = \text{shedding frequency} / \text{natural frequency} = 255/340 = 0.75$ . ASME PTC 19.3 TW requires  $r < 0.80$  for steady flow. Since  $0.75 < 0.80$ , this thermowell passes the steady-flow criterion. For pulsating flow the limit is  $r < 0.40$ , which would fail.
23. C — For a direct-acting controller, output change =  $+K_c \times (PV - SP) = +3.0 \times (+4\%) = +12\%$ . Direct acting means output increases as PV rises above setpoint — this output increase would open a cooling or venting valve in the appropriate application context.
24. D — Per ANSI/ISA-5.1, "TE" = Temperature Element — the primary sensing device (thermocouple or RTD) with no signal transmission capability. TT designates a temperature transmitter that adds signal conditioning and standardized analog output for remote transmission.
25. B —  $K_c = \tau / (K_p \times (\lambda + \theta)) = 90 / (3.0 \times (90 + 30)) = 90/360 = 0.25$ . Setting  $\lambda$  equal to the process time constant produces a conservative gain appropriate for processes requiring robust stability over tight performance.
26. A — Effective cascade requires the inner loop to be significantly faster than the outer loop — minimum 3–5× preferred 5–10×. An inner settling time of ~8 seconds versus outer  $\tau$  of 240 seconds gives a 30:1 ratio, confirming appropriate pairing where the inner loop corrects disturbances before they propagate to the slow outer measurement.
27. C — IEC 62443 defines security zones as logical groupings of assets sharing common security requirements and acceptable risk levels. Grouping is based on function and trust level — not physical enclosure, protocol type, or organizational ownership — allowing geographically separated assets to share a zone when security needs are equivalent.
28. D — Decay ratio = ratio of successive peak amplitudes =  $6/12 = 0.50$ . The Ziegler-Nichols design targets a quarter-decay ratio of 0.25. A decay ratio of 0.50 indicates more conservative tuning with slower amplitude reduction per oscillation cycle.
29. C — Z-N closed-loop PID:  $K_c = 0.6 \times K_u = 0.6 \times 4.8 = 2.88$ .  $T_i = P_u/2 = 160/2 = 80 \text{ s}$ .  $T_d = P_u/8 = 160/8 = 20 \text{ s}$ . These standard Z-N PID formulas applied to the ultimate conditions target approximately quarter-decay ratio response.
30. B — For an air-to-close outlet valve, reducing controller output opens the valve and increasing output closes it. When level rises above setpoint, more draining is required — the valve must open,

requiring a decrease in controller output. A reverse-acting controller (output decreases as PV rises) is the technically correct configuration for this ATC outlet application.

31. C — At 73% output: vent valve range is 0–50% (fully closed at 50% crossover). Supply valve range is 50–100%; position =  $(73-50)/(100-50) = 46\%$  open. The vent valve is fully closed above the 50% crossover point; supply valve is 46% open.
32. A — The feedforward model assumes  $U = 400 \text{ BTU/hr}\cdot\text{ft}^2\cdot^\circ\text{F}$  but actual  $U = 280$  — the exchanger transfers 30% less heat per unit steam than the model predicts. The feedforward correction is too small, leaving a residual temperature deviation that only the feedback controller can correct.
33. D — New fuel setpoint = ratio  $\times$  air flow =  $0.14 \times 8,500 = 1,190 \text{ Nm}^3/\text{hr}$ . The ratio station multiplies the measured wild stream by the configured ratio factor to generate the controlled stream setpoint automatically.
34. B — An outbound connection from a DCS workstation to an unknown external IP at 2:15 AM strongly indicates malware command-and-control communication. Immediate network isolation prevents further damage or data exfiltration while preserving forensic logs — antivirus alone cannot stop an active compromise already in progress.
35. C — Converting interactive to parallel (non-interactive) form:  $K_c\text{\_parallel} = K_c\text{\_interactive} \times (1 + T_d/T_i) = 1.8 \times (1 + 0.6/5) = 1.8 \times 1.12 = 2.016 \approx 2.02$ . This conversion factor is significant whenever  $T_d/T_i$  exceeds approximately 0.05 and must be applied when migrating between controller implementations.
36. A — Per ISA-18.2, alarm shelving is the temporary suppression of an alarm for an operator-defined duration, with automatic reinstatement when the shelving period expires. This technique prevents nuisance alarms during known process states without permanently removing the alarm or requiring engineering intervention.
37. D — A high selector passes the larger of the two controller outputs to the recycle valve. When surge risk increases, the anti-surge controller demands greater valve opening (larger output) than the normal flow controller. The high selector passes this larger demand, overriding normal flow control and increasing recycle to protect the compressor.
38. B — Back-calculation anti-windup feeds the difference between the limited (actual) and unlimited (computed) controller output back through a tracking gain to the integrator. This adjusts the integral state to track the actual output rather than the unbounded computed value, preventing integral accumulation beyond what the output can physically achieve.
39. C — Z-N open-loop PI:  $K_c = 0.9\tau/(K_p \times \theta) = 0.9 \times 60/(2.0 \times 20) = 54/40 = 1.35$ .  $T_i = 3.33 \times \theta = 3.33 \times 20 = 66.7 \approx 67 \text{ s}$ . PI rules use the 0.9 multiplier and  $T_i = 3.33\theta$  to target quarter-decay ratio response with more conservative action than PID settings.

40. A — Nine or more consecutive points on the same side of the centerline is a recognized special cause signal per Western Electric rules, even when all points are within  $\pm 3\sigma$  control limits. The non-random pattern indicates the process mean has shifted — an assignable cause requiring investigation despite no control limit violation.
41. D — MPC uses its process model within the prediction horizon to anticipate the disturbance impact before it reaches the controlled composition. Beginning counteracting moves immediately at the next execution interval — not waiting for a detectable composition deviation at 12 minutes — is MPC's defining advantage over pure feedback PID control, which cannot act until the deviation is measured.
42. B — With proportional-only control, steady-state output = bias +  $K_c \times$  error. The valve position required to balance any finite operating flow rate creates a non-zero error term through this relationship. This inherent offset is proportional to the required output deviation from bias, which scales with operating flow rate.
43. C — The IEC 61131-3 SFC "P" (Pulse) action qualifier executes its associated action for exactly one scan cycle at step activation, then immediately deactivates. This one-shot behavior fires discrete trigger events — resetting counters, issuing single commands, or activating one-time outputs at step entry.
44. A — Halving  $K_c$  reduces the proportional corrective force per unit error; more than doubling  $T_i$  (60s to 150s) slows integral accumulation significantly. Both changes directly reduce the speed and magnitude of disturbance rejection, producing slower return to setpoint after process disturbances — the primary performance consequence of detuning.
45. D —  $C_{v\_min} = 80/40 = 2.0$ . At 30% travel:  $C_v = 2.0 \times 40^{0.30}$ .  $\log(40) = 1.602$ ;  $0.30 \times 1.602 = 0.481$ ;  $10^{0.481} = 3.025$ .  $C_v = 2.0 \times 3.025 = 6.05 \approx 6.1$ . The equal percentage exponential relationship produces only about 8% of rated  $C_v$  at 30% travel.
46. B — Variable superimposed back pressure of 0–28 psig (up to 14% of 200 psig set pressure) exceeds the 10% conventional PRV limit. Above 10%, back pressure variably shifts the conventional valve's effective set pressure. A balanced bellows or pilot-operated PRV is required to maintain consistent set pressure regardless of back pressure variation.
47. A — Autotransformer at 65% voltage tap applies 65% of line voltage to the motor. Starting torque varies with voltage squared:  $(0.65)^2 = 0.4225 \approx 42\%$  of full-voltage starting torque. Both torque and line-side current are reduced by the voltage ratio squared through the autotransformer.
48. C — Trip current =  $1.15 \times 85 \text{ A} = 97.75 \approx 97.8 \text{ A}$ . Thermal overload relays are set at a percentage of motor FLA to allow brief overloads during starting while protecting the motor from sustained overcurrent that degrades winding insulation.
49. D — A quick-exhaust valve on the actuator exhaust port creates a large-bore vent path bypassing the positioner's restrictive internal exhaust orifice. Actuator depressurization occurs through the

quick-exhaust's large orifice, dramatically reducing spring-return stroke time compared to exhausting through the positioner path.

50. B — Equal percentage cage trim provides the required 8:1 rangeability with a predictable installed characteristic. Hardened seats withstand the forces from high-viscosity melt. Graphite packing handles 300°C reliably where PTFE degrades. PTFE-seated ball valves cannot withstand this temperature; butterfly valves lack sufficient trim rangeability.
51. A —  $Cv_{max} = Cv_{min} \times \text{Rangeability} = 1.5 \times 50 = 75.0$ . Rangeability is defined as the ratio  $Cv_{max}/Cv_{min}$  — directly calculating maximum Cv by multiplying minimum Cv by the specified rangeability.
52. C — Affinity law:  $P \propto N^3$ .  $P_{new} = 75 \times (1,400/1,750)^3 = 75 \times (0.80)^3 = 75 \times 0.512 = 38.4$  kW. The cubic relationship makes even moderate speed reductions produce large power savings — the fundamental economic case for VSD investment.
53. B — Travel at 4 mA = 0% (correct zero). Travel at 20 mA = 94% (should be 100%). Zero is correctly calibrated; the span covers only 94% of required stroke. A single span adjustment extends travel from 94% to 100% at full input.
54. D — A hydraulic dashpot damper forces fluid through a calibrated orifice during disc closure, controlling the closing rate. This controlled deceleration reduces impact velocity when the disc seats, lowering the pressure wave magnitude generated by abrupt flow reversal without compromising the check valve's reverse-flow sealing function.
55. A — Temperature-derated burst pressure = 185 psig. Operating pressure = 180 psig. Operating ratio =  $180/185 = 97.3\%$ . Reverse-buckling discs tolerate up to 90% maximum operating ratio. Since 97.3% exceeds 90%, the installation is unacceptable despite operating pressure being below the derated burst value.
56. C — Operating at  $14/80 = 17.5\%$  of rated Cv places the valve in its lowest travel region — approximately 10–20% stem travel. In this zone, flow characteristics become unpredictable, valve stability degrades from hydraulic forces near the seat, and rangeability above the design point is effectively zero.
57. B — Sliding-stem globe valve packing is accessed through the external top works (gland follower, packing rings, gland flange) without disturbing the pipeline connections. Repacking requires only depressurizing and removing the top works — no body removal or pipe disassembly — a significant maintenance advantage in thermal cycling service.
58. A — Monel 400 (nickel-copper alloy) provides excellent resistance to concentrated NaOH at elevated temperatures and is the standard specification for hot caustic service. Standard austenitic stainless steels suffer caustic stress corrosion cracking above approximately 60°C in concentrated NaOH environments.

59. D — A blocked-in liquid-filled space (incompressible fluid) generates extreme pressure from even small temperature increases because liquid cannot expand volumetrically. This thermal relief scenario — hydraulic locked-in expansion — requires a small relief valve sized for the thermal input, not for bulk process flow relief.
60. C — A stiffer spring generates greater closing force, enabling faster ESD closure. However, the instrument air supply must develop equal or greater pneumatic force to compress the stiffer spring during opening. If supply pressure is marginal, the valve may not fully open or may close partially under reduced air conditions.
61. B — A 20-inch globe valve is prohibitively heavy, expensive, and requires enormous actuator forces for its linear plug design against any system pressure. High-performance butterfly valves at 20-inch size achieve adequate 4:1 rangeability, are compatible with 3 psi differential pressure, and are the standard large-bore low-DP throttling selection.
62. A — ASME Section VIII UG-134 requires that PRV set pressure not exceed vessel MAWP. A 325 psig set pressure on a 300 psig MAWP vessel directly violates this requirement. The 10% accumulation allowance applies to maximum pressure during a relief event — not to the set pressure itself.
63. D — Total series resistance =  $250 + 60 + 190 = 500 \Omega$ . Voltage drop at 20 mA:  $0.020 \times 500 = 10.0$  V. Transmitter terminal voltage =  $24 - 10.0 = 14.0$  VDC. This exceeds the 10 VDC minimum by 4.0 V, confirming loop compliance at maximum current.
64. C — Without termination resistors at 12 Mbit/s, signal reflections at both cable ends corrupt transmitted data. At this baud rate, the bit period is short enough that reflected signals arrive during subsequent bit windows — degrading communication reliability and reducing the number of devices that can maintain error-free communication on the segment.
65. B — HART FSK communication requires minimum total loop impedance of approximately 230–250  $\Omega$  at the 1,200/2,200 Hz communication frequencies. Without sufficient impedance, the HART modem cannot develop adequate AC voltage amplitude across the loop for reliable digital signal detection, even though the DC 4–20 mA primary variable continues normally.
66. A — IS entity compliance requires  $V_{oc} \leq U_i$  AND  $I_{sc} \leq I_i$ .  $V_{oc} = 20 \text{ V} \leq U_i = 24 \text{ V}$  and  $I_{sc} = 80 \text{ mA} \leq I_i = 100 \text{ mA}$  — both parameters satisfy their requirements. Additional verification of  $C_a$  and  $L_a$  circuit parameters against isolator entity limits completes the full IS certification check.
67. C — Foundation Fieldbus H1 supports distributed control execution — PID and other function blocks are downloaded into H1-capable field devices and executed locally on a schedule coordinated by the Link Active Scheduler. When DCS host communication is lost, these function blocks continue running inside the field devices, maintaining regulatory control without central controller involvement.

68. D — WirelessHART uses time-synchronized channel hopping across 15 available frequency channels in the 2.4 GHz ISM band. Each transmission is scheduled on a specific channel and time slot; interference on one channel causes the next scheduled transmission to use a different channel automatically, providing frequency diversity that significantly improves end-to-end reliability.
69. A — NAMUR NE 43 extends the standard 4–20 mA range with fault detection levels: below 3.6 mA = under-range or open circuit; above 21.0 mA = over-range or transmitter fault. A reading of 22.5 mA exceeds the 21.0 mA upper fault threshold, indicating a sensor or transmitter fault, not a valid process measurement.
70. B — OPC-DA relies on Windows COM/DCOM — platform-specific with limited built-in security. OPC-UA provides platform-independent communication with X.509 certificate authentication and AES message encryption built into the standard, enabling secure cross-network data exchange independent of Windows infrastructure.
71. C — VLANs create Layer 2 separation but require Layer 3 routing to pass traffic between VLANs. If the managed switch or a connected router has inter-VLAN routing enabled without access control lists filtering the traffic, data flows freely between all VLANs regardless of the VLAN segmentation configuration.
72. D — NEC Article 500 defines "nonincendive" as a protection technique for Class I, Division 2 locations — where flammable vapors are present only under abnormal conditions. Nonincendive circuits are not capable of causing ignition under normal conditions but are not designed for continuous hazardous atmospheres and cannot be applied to Division 1 locations.
73. A — Total link loss = cable attenuation + connector losses + splice loss =  $(0.35 \times 2) + (2 \times 0.3) + 0.05 = 0.70 + 0.60 + 0.05 = 1.35$  dB. This total must be compared against the transceiver optical power budget to confirm adequate link margin.
74. B — OT patch management requires staging environment testing before production deployment to verify that OS patches do not conflict with DCS vendor software. Deployment during a planned maintenance window with a tested rollback procedure minimizes operational risk while addressing the security vulnerability responsibly.
75. D — RDP port 3389 exposed to the corporate IT network creates a large attack surface. Any user or malware reaching this port can attempt credential brute-force or exploit known RDP vulnerabilities to gain unauthorized DCS engineering access with full configuration capability — one of the most commonly exploited OT attack vectors.
76. C — Independent term for 1oo2:  $(\lambda_{DU} \times TI)^2/3 = (3 \times 10^{-6} \times 8,760)^2/3 = (0.02628)^2/3 = 2.30 \times 10^{-4}$ . CCF term:  $\beta \times \lambda_{DU} \times TI/2 = 0.10 \times 3 \times 10^{-6} \times 8,760/2 = 1.314 \times 10^{-3}$ . Total =  $2.30 \times 10^{-4} + 1.314 \times 10^{-3} = 1.54 \times 10^{-3}$ . The CCF term dominates, reinforcing the need for diversity in redundant configurations.

77. A — The Safety Requirements Specification per IEC 61511 Clause 10 defines all functional and integrity requirements for each SIF — process demands, safe states, required SIL, response times, input setpoints, and functional logic. It is the specification against which the completed SIS design is formally verified.
78. B — The SRS specifies maximum response time from demand detection to safe state. A 40-second stroke time exceeds the 25-second SRS requirement, meaning the SIF cannot achieve the safe state within the required window. The modification must be rejected or a faster valve selected — revising the SRS is inappropriate if the underlying process safety time analysis has not changed.
79. D — Mitigated frequency =  $0.2 \times 0.1 \times 0.1 = 2 \times 10^{-3}$ /year. Required SIF PFD =  $10^{-4}/2 \times 10^{-3} = 0.05$ . A PFD of 0.05 falls within the SIL 1 range (0.01–0.1), confirming SIL 1 is required with a specific PFD target of 0.05 or better.
80. C — When proof test coverage is 80%, 20% of dangerous failures in the tested component accumulate without detection between intervals — as if no test occurred for that fraction. This uncredited accumulation increases the actual PFD above the value calculated assuming 100% coverage, requiring partial-coverage accounting in the SIL verification.
81. A — IEC 61511 requires MOC review for any change to hardware, software, setpoints, test procedures, or operating conditions that could affect a SIF's ability to perform its safety function. This broad scope ensures no modification — even apparently minor setpoint changes or procedure revisions — bypasses safety review.
82. B — Converting from 2oo3 to 2oo2 removes the single-channel failure tolerance. In 2oo3, one channel can fail dangerously while two others provide the trip. In 2oo2, any single dangerous failure of either remaining channel defeats the safety function. PFD increases because both channels are now individually critical with no redundancy buffer.
83. D — A valve achieving only 95% closure cannot perform its safety function as specified. The root cause must be identified, the valve repaired to full closure travel, and the complete cause-to-effect path — sensor through full valve closure within the SRS response time — retested before the SIF can return to service.
84. C — IEC 61511 requires SIS components to be replaced before the useful life expires, or the SIL verification must be revalidated using failure rate data appropriate for the wear-out condition. The original constant-region failure rate is non-conservative beyond useful life as wear-out mechanisms increase the actual dangerous failure rate.
85. A — IEC 61511 defines high-demand mode (demand rate > 1/year) performance using PFH — probability of dangerous failure per hour. At 6 demands per year, this SIF is in high-demand mode and SIL verification must apply the appropriate PFH target ranges, not the PFD\_avg metric used for low-demand SIFs.