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NCEES Principles and Practice of Engineering Examination
CONTROL SYSTEMS CBT Exam Specifications

Effective Beginning October 1, 2022

- The exam topics have not changed since October 2019 when they were originally published.
- The exam is computer-based. It is closed book with an electronic reference. Design standards applicable to the PE Control Systems exam are shown on the last page.
- Examinees have 9.5 hours to complete the exam, which contains 85 questions. The 9.5-hour time includes a tutorial and an optional scheduled break. Examinee works all questions.
- The exam uses both the International System of units (SI) and the U.S. Customary System (USCS).
- The exam is developed with questions that will require a variety of approaches and methodologies, including design, analysis, and application.
- The knowledge areas specified as examples of kinds of knowledge are not exclusive or exhaustive categories.

Number of Questions

1. Measurement **17–27**

A. Sensors
1. Sensor technologies applicable to general measurement (e.g., flow, pressure, level, temperature, counters, motion)
2. Sensor technologies applicable to general analytical instruments and sampling systems (e.g., pH, ORP, density, O_2, conductivity, effects of sampling systems, GC)
3. Sensor technologies applicable to fire and gas detection
4. Sensor technologies applicable to machinery monitoring and protection (e.g., vibration, bearing temperature, lube oil pressures, thrust, speed)
5. Sensor characteristics (e.g., rangeability, accuracy and precision, temperature effects, response times, reliability, repeatability, maintenance, calibration)
6. Sensor selection (e.g., plugging service, process severity, environmental effects and constraints, costs)
7. Material compatibility
8. Installation details (e.g., process, pneumatic, electrical, location, maintenance, calibration)

B. Flow, Level, and Pressure Calculations
1. Flow (e.g., element sizing, pressure-temperature compensation, mass/volume)
2. Level
3. Pressure drop

C. General Calculations
1. Unit conversions
2. Velocity
3. Square root extraction and interpolation
4. Variables involved in wake frequency calculations (e.g., thermowell length/ diameter, velocity, natural frequency, wake frequency)

2. Control Systems 17–27

A. Drawings
   1. Drawings (e.g., process flow diagrams, P&IDs, loop diagrams, ladder diagrams, logic drawings, cause and effects drawings, electrical drawings, schematics, wiring diagrams)

B. Theory
   1. Basic control of processes (e.g., pumps, compression, combustion, evaporation, distillation, hydraulics, reaction, dehydration, heat exchangers, crystallization, filtration, refrigeration, fluidization)
   2. Process dynamics (e.g., loop response, pressure-volume-temperature relationships, simulations)
   3. Basic control (e.g., regulatory control, feedback, feedforward, cascade, ratio, PID, split-range, gap control)
   4. Discrete control (e.g., relay logic, Boolean algebra, aliasing)
   5. Sequential control (e.g., batch, assembly, conveying, CNC, state machine, sequential function chart)

C. Implementation
   1. HMI (e.g., graphics, alarm management, trending, historical data, operator panels)
   2. Equipment layout (e.g., human factors engineering, physical control room arrangement, panel layout)
   3. Limited variability programming languages for DCS and PLC (e.g., IEC 61131-3 languages/ladder diagrams, function blocks, sequential function charts, structured text, instruction list)
   4. System design comparisons and compatibilities (e.g., advantages and disadvantages of system architecture, distributed architecture, remote I/O, buses, wireless)
   5. Installation requirements (e.g., shielding, constructability, I/O termination, environmental, heat load calculations, power load requirements, purging, lighting, maintainability)
   6. System testing (e.g., factory acceptance test, integrated system test, site acceptance test)
   7. Commissioning (e.g., performance tuning, loop checkout)
   8. Performance evaluation (e.g., troubleshooting, root cause failure analysis and correction)

D. Security of Industrial Automation and Control Systems
   1. Security (e.g., physical, cyber, network, firewalls, routers, switches, protocols, hubs, segregation, access controls)
   2. Security life cycle (e.g., assessment, controls, audit, management of change)
   3. Requirements for a security management system
   4. Security risk assessment and system design
   5. Product development and requirements
   6. Verification of security levels (e.g., level 1, level 2)

3. Final Control Elements 14–23

A. Valves
  1. Types (e.g., globe, ball, butterfly)
  2. Trim characteristics (e.g., linear, low noise, equal percentage, seat leakage class)
  3. Calculation (e.g., sizing, split range, noise, actuator, response time, pressure drop, air/gas consumption)
  4. Selection of motive power and failure mode (e.g., hydraulic, pneumatic, electric, spring)
  5. Applications of fluid dynamics (e.g., cavitation, flashing, choked flow, Joule-Thompson effects, two-phase)
  6. Material selection based on process characteristics (e.g., erosion, corrosion, plug, extreme pressure, temperature, material compatibility)
  7. Accessories (e.g., limit switches, solenoid valves, positioners, transducers, air regulators, servo amp, boosters, quick exhaust)
  8. Environmental constraints (e.g., fugitive emissions, packing, special sealing, fire rating)
  9. Installation practices (e.g., vertical, horizontal, bypasses, location, flow direction)

B. Pressure Relieving Devices
  1. Pressure relieving valve types (e.g., conventional spring, balanced bellows, pilot operated)
  2. Pressure relieving valve characteristics (e.g., modulating, pop action)
  3. Pressure relieving valve calculations (e.g., sizing considering inlet pressure drop, back pressure, multiple valves)
  4. Material selection based on process characteristics
  5. Pressure relieving valve installation practices (e.g., linking valves, sparing the valves, accessibility for testing, car sealing inlet valves, piping installation, combination devices)
  6. Rupture discs and buckling pin valves (e.g., types, characteristics, application, calculations)

C. Motor Controls
  1. Types (e.g., motor starters, variable-speed drives)
  2. Applications (e.g., speed control, soft starters, motor-operated valve actuators)
  3. Calculations (e.g., sizing, tuning, location)
  4. Accessories (e.g., encoders, positioners, relays, limit switches)

D. Other Final Control Elements
  1. Motion (e.g., damper controls, types, orientation, actuators, servos, encoders)
  2. Solenoid valves (e.g., types, sizing)
  3. On-off devices/relays (e.g., types, applications, energize and de-energize to trip)
  4. Self-regulating devices (e.g., types, sizing, pressure, temperature, level, and flow regulators)

4. Signals, Transmission, and Networking **11–18**

A. Signals
1. Pneumatic, electronic, optical, hydraulic, digital, analog, buses, wireless, thermocouple
2. Transducers (e.g., analog/digital [A/D], digital/analog [D/A], current/pneumatic [I/P] conversion, current/current [I/I], splitters, filters)
3. Hazardous area classification and instrument installation techniques (e.g., intrinsically safe [IS] barriers, cabinet purges, non-incendive)
4. Grounding, shielding, segregation, electromagnetic interference
5. Basic signal circuit design (e.g., two-wire, four-wire, isolated outputs, loop powering, buses)
6. Circuit calculations (voltage, current, impedance, power)
7. Unit conversion calculations

B. Transmission
1. Different communication systems architecture and protocols (e.g., fiber optics, coaxial cable, wireless, paired conductors, buses, transmission control protocol/internet protocol [TCP/IP], OPC)
2. Distance considerations versus transmission medium (e.g., data rates, sample rates)

C. Networking
1. Routers, bridges, switches, firewalls, gateways, network loading, error checking, bandwidth, crosstalk, parity, hubs

5. Safety Systems **11–19**

A. Documentation
1. Basic documentation required (e.g., process hazards analysis, safety requirements specification [SRS], logic diagrams/narratives, test procedures, SIL selection report, SIL verification report, safety life-cycle plan)

B. Theory
1. Reliability and availability (e.g., bathtub curve, failure rates types, voting, proof test intervals, common cause and diversity)
2. SIL selection (e.g., safety layer matrix, risk graph, LOPA)

C. Implementation
1. Safety system design (e.g., SRS, I/O assignments, redundancy, segregation, logic design, failure direction)
2. SIL verification calculations (e.g., failure rates types, voting, proof test intervals, common cause and diversity)
3. Installation, commissioning, and validation (e.g., methods, procedures, test records)

D. Safety Life-Cycle Management
1. Modifications (e.g., management of change, scope of change, impact of change, documentation)
2. Operations and maintenance (e.g., methods, procedures, test records, partial stroke testing, demand tracking, bypass and override management, failure analysis, validation of design assumptions)

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CONTROL SYSTEMS Design Standards
Effective Beginning with the October 2022 Examinations

In addition to the *PE Control Systems Reference Handbook*, the following codes and standards will be supplied in the exam as searchable, electronic pdf files with links for easy navigation.

Solutions to exam questions that reference a standard of practice are scored based on this list and the revision year shown. Solutions based on other standards will not receive credit.

NCEES does not sell design standards or printed copies of the NCEES handbook. The NCEES handbook is accessible from your MyNCEES account. Design standards are available through the publisher or a bookseller.

ABBREVIATION	DESIGN STANDARD TITLE
ANSI/ISA-5.1	*Instrumentation Symbols and Identification*, 2009, International Society of Automation, Research Triangle Park, NC, www.isa.org.
ISA/IEC 61511	*Functional Safety – Safety Instrumented Systems for the Process Industry Sector*, *Part 1: Framework, definitions, system, hardware and application programming requirements*, 2018, International Society of Automation, Research Triangle Park, NC, www.isa.org.