



NATIONAL INSTITUTE FOR CERTIFICATION IN ENGINEERING TECHNOLOGIES®
sponsored by the National Society of Professional Engineers

Industrial Instrumentation Engineering Technology
INDUSTRIAL INSTRUMENTATION

PROGRAM DETAIL MANUAL

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Effective upon issuing a new edition of any program detail manual, all previous editions of that program detail manual become obsolete.

This manual may be freely copied in its entirety.

Field Code: 023
Subfield Code: 01

Third Edition
June 2009

IMPORTANT INFORMATION

The Institute occasionally makes changes in its certification programs that will significantly affect the currency of individual program detail manual. These changes could include any or all of the following:

- deletion, modification, or addition of work elements
- modification to the Examination Requirements Chart
- modification to crossover work element credit
- changes to the work experience requirement
- changes to the verification requirement

Such changes could affect the requirements for certification. Therefore, if this manual is more than a year old, NICET highly recommends that you check www.nicet.org (or, if you don't have access to the Internet, call NICET at 888-476-4238) to make sure that you have the current edition of the Program Detail Manual before applying for an examination. The date of publication of this manual is June 2009.

IT IS THE APPLICANT'S RESPONSIBILITY TO MAKE SURE HE/SHE IS USING THE CURRENT EDITION OF THE MANUAL.

**KEEP YOUR
MANUALS
CURRENT**

This third edition of the Industrial Instrumentation Engineering Technology program detail manual does not contain any substantive changes from the second edition. Only the following changes have been made:

- minor updates to the front text.
- updated information regarding the posting of crossover credit.
- updates to information regarding policies about recertification and retesting failed work elements
- updates to "Testing" section and "Selected General References" page information regarding allowable reference materials at NICET's paper-and-pencil test centers
- revision to the description for work element 15014

Whenever an exam requirement changes, individuals who are already certified and do not intend to upgrade their level of certification do not need to comply with any changes for the level(s) of certification they have already been awarded.

Individuals who wish to upgrade must satisfy any "new" exam or other certification requirements for the higher level once the deadline has been passed.

DELETION OF TEST RECORDS

All test records for an individual certification area will be purged from the database after 5 years if no further testing is done in that certification area and you are not certified in that certification area. See Policy #26 on the website (www.nicet.org).

Industrial Instrumentation Engineering Technology

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General Information

This Program Detail Manual contains the information needed to apply for the NICET certification examination in the field of Industrial Instrumentation Engineering Technology.

This manual does not contain all of the rules and procedures for obtaining certification. For this, you must refer to the website (www.nicet.org).

**National Institute for Certification
in Engineering Technologies (NICET)
1420 King Street, Alexandria, Virginia 22314-2794
1-888-IS-NICET ((staff response - 9am to 4pm
all other times, voice mail available)**

This certification program is for industrial instrumentation technicians who are engaged in a combination of the following instrumentation system activities:

design assistance, installation and maintenance of industrial measurement and control systems, and the installation and maintenance of a variety of electrical, electronic, and pneumatic instruments used within systems.

This program recognizes situations in which the principle activities of the technician may be concentrated in-plant environments, laboratories, or engineering offices. It also recognizes the situation in which the technician routinely has job tasks in all areas of instrumentation and control and thus is considered a generalist rather than a specialist. Areas covered include knowledge of the principles and operation of instruments and instrumentation systems (pneumatic, electrical, and electronic), standard maintenance procedures, specialized repair facility and field maintenance procedures, applications, installation practices, recordkeeping, and reports.

This program became operational in 1988. Development of the program was initiated in 1985 with technical guidance from the Instrument Society of America.

Certification Requirements

There are four criteria that must be met to be certified at any level:

- complete the written examination requirement
- work element verification by the immediate supervisor
- technician recommendation by an acceptable recommender
- appropriate employment history

The last three components MUST be accepted and approved in order to achieve certification. Simply passing the examination does not guarantee certification.

Level I is designed for entry-level technicians with very limited relevant work experience in the technical subfield. The Institute recommends that persons with eighteen or more months of relevant work experience set their initial certification goal at Level II. Certification at Levels II, III, and IV does not require prior certification at a lower level. The Examination Requirements Chart shows how many work elements must be passed to meet the exam requirement for Levels I, II, III and IV.

Work Element Examination

Industrial Instrumentation

The typical job duties and associated responsibilities of industrial instrumentation engineering technicians have been broken down into discrete elements which form the basis for an evaluation of the candidate's knowledge. Each work element is written in sufficient detail to permit candidates who have the appropriate work experience to make reasonable assumptions about the types of questions likely to be asked.

In addition, the supervisor verifying the experience of the candidate should be able to interpret the scope of the activities associated with each work element.

Identification Numbers

In order for us to prepare individualized examinations for each applicant, identification numbers have been assigned to each technical field and to each work element. Each technical field is represented by a 3-digit number. The technical field code number for Industrial Instrumentation Engineering Technology is 023.

The identification number assigned to each work element is 5 digits long. The first digit normally identifies the technical subfields within each field. At this time, the field of Industrial Instrumentation Engineering Technology is **not** divided into subfields.

(1) Industrial Instrumentation

The second digit identifies the level (Levels I through IV) and the work element type (General or Special):

GENERAL WORK ELEMENTS

- (1) Level I General
- (3) Level II General
- (5) Level III General
- (7) Level IV General

SPECIAL WORK ELEMENTS

- (2) Level I Special
- (4) Level II Special
- (6) Level III Special
- (8) Level IV Special

The third, fourth and fifth digits identify the individual work element within each category. A sample of this numbering system is illustrated below for work element number 023/15001:

Technical Field Code:	023	Industrial Instrumentation Engineering Technology
Subfield:	1	Industrial Instrumentation
Level/Type:	5	Level III General
Work Element Number:	001	BUSINESS COMMUNICATIONS

This eight-digit identification number is needed when using the application form to request an examination or provide work element verification.

Selection

1. Refer to Examination Requirements Chart on the following page
2. Select the appropriate box for the level of certification desired.
3. Note the number/type of work elements required for certification, by category, as shown in the selected box.
4. Turn to the Work Element Listing section and carefully select work elements from the required categories, paying attention at each level to whether they are classified as **General** or **Special** work elements. When possible, select a few extra in each category so that failing one or more work elements leaves enough passed work elements to satisfy the examination requirements.
5. The maximum number of work elements for any single examination sitting is 34, due to time restrictions.
6. The Institute recommends that the maximum number of work elements (34) be selected for each examination. This provides the greatest opportunity for successful completion of the examination requirements with the least number of subsequent examinations. Recognize, however, that all elements selected on an exam application **will be scored**, even if no attempt is made to answer the questions. That is, a score of "0" will be assigned to the work element even if the questions are not answered and the work element will have one failure marked against it.
7. If the requirement for the desired level is more than 34, it is advisable to test first all lower-level work elements needed to achieve certification. Save the upper-level work elements for a subsequent examination.
8. Examination candidates should keep copies of their applications for their records.
9. It is not necessary to retest failed work elements if there are other work elements, in the appropriate categories, which can be selected. If you need to retest a failed work element, you must wait 120 days from the last time you failed it before you will be permitted to test that element again. Retesting a failed work element or Part A/B exam will be limited to three attempts in a two-year span to achieve a passing score.
10. If an adequate number of work elements has been selected to meet the desired certification requirement (with a few extra selected to provide a cushion), and there is room on the exam application to add more elements, it is appropriate to include work elements that will satisfy the examination requirement of the next level of certification or to include work elements from another field/subfield.

Examination Requirements Chart

(Subfield: Industrial Instrumentation)

You must pass the number of work elements shown in each box to complete the exam requirement for certification at that level.

Level I

Level I - General	- 8
Level I - Special	- 2
TOTAL	10

You must pass this many work elements to complete the **Level I** exam requirement

Level II

Level I - General	- 12a
Level I - Special	- 3
Level II - General	- 12c
Level II - Special	- 10
TOTAL	37b

You must pass this many work elements to complete the **Level II** exam requirement
Note (b)

Level III

Level I - General	- 12a
Level I - Special	- 3
Level II - General	- 12c
Level II - Special	- 16
Level III - General	- 15
Level III - Special	- 7
TOTAL	65b

You must pass this many work elements to complete the **Level III** exam requirement
Note (b)

Level IV

Level I - General	- 12a
Level I - Special	- 3
Level II - General	- 12c
Level II - Special	- 16
Level III - General	- 15
Level III - Special	- 10
Level IV - General	- 16
Level IV - Special	- 7
TOTAL	91b

You must pass this many work elements to complete the **Level IV** exam requirement
Notes (b) and (d)

NOTES:

- Work Element #11005, "Basic Metric Units and Conversions", must be passed to achieve certification at Levels II, III, and IV.
- Time restrictions dictate that no more than 34 work elements can be scheduled for any single examination sitting. Therefore, at least two examination sittings will be needed in order to complete this requirement.
- All core work elements in this category must be passed to complete the exam requirement at this level.
- Read very carefully the two sections applicable to Level IV certification in this manual before seeking Level IV certification.

GENERAL NOTES:

- Work elements passed which are in excess of the requirement for a particular type and level, but which are needed to meet the requirement at the next higher level are automatically applied to that higher level requirement.
- Use the Personal Tally Worksheet in this manual to keep track of the number of work elements you have successfully passed.

Verification of Work Elements

Verification must be provided by the examinee's immediate supervisor as identified by the examinee in the employment history section of the NICET Test Application form. Verification of work elements is the acknowledgement that the verifier has personally observed the examinee repeatedly and correctly perform the task or utilize the knowledge required by the particular work element.

The verifier should read each work element description and then initial each work element. The verifier also completes and signs the statement of understanding that is part of the NICET Test Application form.

Lack of verification does not prevent testing a work element. However, work elements tested without verification are not counted for certification until acceptable verification is received and approved by the Institute.

If the examinee's immediate supervisor does NOT have technical expertise in the specialty area, or if the examinee has no supervisor, verification must be obtained from an individual who does have technical expertise in the specialty area AND has first-hand knowledge of the examinee's specific job skills. There is space on the application form (Section VII) for the verifier or examinee to explain how the verifier has been in a position to supervise, inspect and approve the work.

Technician Recommendation Form

This form is available on the Website. It must be completed by a person who is familiar with the examinee's technical capabilities and background.

A valid Technician Recommendation form MUST be on file to award certification at Levels III and IV. It is valid for one year from the date shown next to the recommender's signature.

Employment History

Your work experience will not be evaluated until a written exam requirement has been met. Carefully consider your actual experience before testing in a technical area where you have limited or no experience -- **meeting an exam requirement does not guarantee certification.**

- NICET certification is only awarded to persons performing engineering **technician** level work. This must be documented in the examinee's Employment History in the Test Application form.
- A preponderance of the work experience must be acquired while residing in the United States and its territories, employing U.S. standards and work practices.
- A significant proportion of the relevant work experience must be recent.

Level IV Work Experience Requirement

Ten years or more of employment in the certification area, by itself, is **not** sufficient for the granting of Level IV. An absolute requirement for certification at Level IV is senior-level involvement in a major project which is **directly related to the subfield in which Level IV certification is sought**. The major project selected must be completed, must be recent (within the past 3-4 years), and must have taken place well into your career in the certification area. A write-up submitted too early (for example, after only 5 or 6 years in the certification area) will not be reviewed.

The write-up on each of the projects should include such information as:

- 1. type of operation using the instrumentation system;**
- 2. type of instrumentation and control system;**
- 3. size of system (number of loops);**
- 4. length of time in job assignment;**
- 5. your responsibilities (interaction with others, supervision of others, approval of work);**
- 6. the range of your experiences with each system as related to reduction of down-time, product quality, productivity, inspection, analysis, and record-keeping of instrument and control system performance and reliability. If all of these components cannot be documented for a single system, they may be accumulated over several more narrowly focused systems.**

Your write-up must address the Level IV requirement that your level of responsibility demonstrates independent senior engineering technician work, including delegated responsibilities and duties for which engineering precedent exists. The pertinent work experience must be described in depth by you personally -- official job descriptions or testimonials from others will not be evaluated.

In order to avoid lengthy delays in processing your Level IV certification, this documentation should be sent with the Level IV examination application.

Early Testing and Verification Of Level IV Work Elements

Although we permit testing of Level IV work elements prior to satisfying the work experience requirement, we reserve the right to question the validity of Level IV work elements passed by, and verified for, persons with little work experience. If, for example, a technician with a total of 3 years of experience passes Level IV work elements, we may require documentation of how this higher level knowledge was obtained without accumulating the requisite work experience. NICET may require specific work elements to be tested and passed again, at the candidate's expense, at the time of the Level IV certification decision.

In addition, we reserve the right to require reverification of work elements designated for meeting the Level IV examination requirement if the verifications were signed more than three years prior to the time of the Level IV certification decision.

Testing

The NICET written examinations are designed by the individual who has performed the work elements associated with the program. Preparation for this examination should be minimal.

When work elements are keyed directly to specific industry-wide standards, the standard will be identified by a normally used notation at the end of the work element description.

When a specific publication is used as an authoritative source, the title will be listed at the end of the work element. Refer to the "Selected General References" in this manual.

Standards and other references that are cited in the work element descriptions are permitted in NICET's paper-and-pencil test centers. Other references will be allowed at the test centers only if they have been pre-approved by NICET. (See the approved reference list on NICET's website.)

Training

NICET does not endorse, certify, or accredit training programs. The Institute does, however, provide information on the certification procedures and objectives so that training courses can be developed specifically to help persons planning to take a NICET certification exam.

In the back of this manual is a list of "Selected General References" that contains information relevant to this program.

Expiration of Certificate

The first certificate(s) awarded to all new NICET certificants will have an expiration date of three years from the date of award. The certificate(s) will expire at the end of that three-year period unless renewed through recertification. A consequence of the certificate going into Expired Status will be deletion of all records for that certification, including test history.

Upgrading the certificate or adding a certificate in a different technical area does not change your 3-year expiration date.

Recertification Policy

All certificants should read Policy #30, "Continuing Professional Development." At the end of each 3-year period, all certificants must demonstrate that they have accumulated sufficient Continuing Professional Development (CPD) points within the certification area(s) held to renew the certificate(s) for another 3 years. Once renewed, the certificate is valid for an additional three-year period. The recertification fee must be paid when submitting the recertification application form.

Crossover Work Elements

Individuals who have tested in other NICET subfields may be eligible to receive crossover credit towards the examination requirement. On NICET's website (www.nicet.org), crossover listings can be ordered free of charge.

NICET "Crossover" work elements are identified as identical or nearly identical in topic coverage and test questions to work elements in other selected fields/subfields. Almost all NICET certification programs have "generic" crossover work elements covering communication skills, mathematics, physical science and other basic areas of knowledge. Once a crossover work element is passed on an examination, it does not normally have to be taken again on any other examinations. Crossover credit for the passed elements will be assigned to an examinee's record as follows:

- **First Time Testing in New Subfield:** When you test work elements in a new subfield (at least one element), any crossover credit from previously tested subfields will automatically be assigned to the new subfield. At the same time, any crossover credit from the new subfield will automatically be assigned to previously tested subfields. This assignment of crossover credit will occur every time a new subfield is tested.
- **Additional Testing in Previously Tested Subfield:** When you test new work elements or retest failed work elements from a previously-tested subfield, any crossover credit from the newly-passed work elements will automatically be assigned to all previously-tested subfields.
- No crossover credit will be assigned to a subfield until you **test at least one work element** from that subfield.
- Crossover credit will not be assigned to or from work elements if the certification is in Delinquent or Expired Status.
- The 120-day waiting period policy, which applies to, failed work elements also applies to all work elements that have crossover credit to that work element (see Policy #20).
- The following documents are available. Use the Decal and Personal Records Order Form on the Website.
 - **Personal Crossover Evaluation** lists your "potential" crossover credit to a designated **untested** subfield.
 - **Crossover Listing** lists all current crossovers between three specified subfields.
 - **Official Personal Transcript** lists all work elements presently credited to the examinee's testing record (including those passed on an exam and those achieved through crossover) for a designated subfield.

WARNING

Revisions to certification programs can occasionally eliminate previous crossovers relationships or create new ones. Thus, crossover credit shown on the "Personal Crossover Evaluation" and on any "Crossover Listing" cannot be assumed to be permanent.

The Personal Crossover Evaluation is a "potential" list. Only when a new subfield is tested and the crossover credit is posted to the test record does it become permanent. The Official Personal Transcript shows the crossover credit actually awarded.

Work Element Listing

Industrial Instrumentation Engineering Technology

Level I - General Work Elements

(Work at Level I Is Performed under Direct Supervision)

CORE WORK ELEMENTS (See Note 1)

ID No. Work Element Title and Description

11005^ BASIC METRIC UNITS AND CONVERSIONS
Perform conversions to and from basic metric (SI) units. (ASTM E 380)

NON-CORE WORK ELEMENTS

11001^ BASIC COMMUNICATION SKILLS
Use proper punctuation, vocabulary, spelling, & sentence structure. Follow written instructions. (See basic grammar references.)

11002^ BASIC INDIVIDUAL SAFETY
Follow standard safety practices in performing job tasks. Recognize & call attention to improper safety practices at the worksite.

11003^ FIRST AID PROCEDURES
Understand the basic rules and procedures of first aid. (See general handbooks on first aid.)

11004^ BASIC MATHEMATICS
Solve mathematical problems requiring simple addition, subtraction, multiplication, division, and raising numbers to exponential powers. Round to the correct number of significant figures, calculate percentages, read graphs, and use simple geometric definitions and formulas. (See general mathematics textbook.)

11006^ BASIC PHYSICAL SCIENCE
Apply terms, definitions, and concepts from mechanics, electricity, heat, and chemistry. (Solutions may involve simple formulas found in basic physics textbooks, but will not involve algebraic manipulation or trigonometry.)

11007 NOMENCLATURE
Recognize and understand definitions and abbreviations used in electrical, electronic, pneumatic and hydraulic instrumentation technologies. (ISA-S51.1, S75.05, S37.1, S42.1)

11008 PNEUMATIC, HYDRAULIC, ELECTRIC AND ELECTRONIC SCHEMATIC DIAGRAMS
Read schematics and wiring diagrams. Understand calibration sheets, instrument specification sheets and installation details. Recognize standard symbols. (JEDEC: STANDARD 77)

11009 FUNDAMENTALS OF PNEUMATICS
Apply the principles of pneumatics as used in industrial instrumentation. Understand terminology (PSIG, PSIA, supply air, instrument air, signal); components (links, levers, flapper or baffle, nozzle, relay, vents, filters); pneumatic circuitry. (ISA-S7.4)

11010 BASIC ELECTRICAL AND ELECTRONIC QUANTITIES AND COMPONENTS
Understand and recognize electrical and electronic units of measurement such as volts, amps, watts, ohms, hertz, farads, etc.; basic components (batteries, voltage sources, current sources, resistors, capacitors, inductors, transistors and integrated circuits). Recognize various types of diodes (signal, power, zener, varactor, tunnels) and gain devices (bipolar transistors, FETs, operational amplifiers). (IEEE: Dictionary; STD 216)

NOTE 1: General work elements are categorized as either Core or Non-Core Work Elements. Work element #11005, "Basic Metric Units and Conversions", is mandatory for certification at Levels II, III and IV.

GENERAL NOTE: See "Selected General References" page in this manual for information on listed publications.

(^) Generic crossover credit exists in other fields for this work element. Read information on crossover work elements on pgs 4 and 5.

(Level I - General Work Elements continued on the next page)

(Level I - General Work Elements continued)

- 11011 **WORK ELEMENT DELETED.** Credit is maintained by those who previously passed it.
- 11012 **BASIC TOOLS AND TEST EQUIPMENT**
Select proper tools and equipment for a particular instrument repair job. Be familiar with the safe usage of hand and power tools, pneumatic test equipment, and electronic test instruments. Be familiar with manufacturers' literature, including instructions for use and maintenance.
- 11013[^] **BASIC DRAFTING**
Recognize and describe standard manual drafting techniques. Describe the characteristics and proper usage of standard drafting equipment. (See basic technical drawing textbooks.)
- 11014 **DC CIRCUITS**
Understand the current-voltage-resistance relationships in direct current circuits. Apply Ohm's Law. (ASME: PTC 19.6; IEEE: Dictionary; STD 216)
- 11015 **AC CIRCUITS**
Understand the current-voltage-impedance relationships in alternating current circuits. (ASME: PTC 19.6 ; IEEE: Dictionary; STD 216)

Level I - Special Work Elements

- 12001 **MANUFACTURERS' PRODUCT DOCUMENTS**
Understand manufacturers' documents and instructions. Select, locate and use appropriate documents and instructions for testing, calibration, troubleshooting, maintenance or repair.
- 12002 **PNEUMATIC INSTRUMENTS - TEST EQUIPMENT, CALIBRATION, REPAIR**
Understand the operation of pneumatic test equipment (dead weight testers, manometers, pressure calibrators, vacuum pumps, regulators, pressure and vacuum test gages); calibration procedures for pneumatic transmitters, controllers, and control valve actuators; bench repair of various pneumatic instruments and components (baffle/nozzle assemblies, standard relays, fluidic relays, bellows, diaphragms, receiver elements, transmitter elements, restrictors, filters and pneumatic circuits); hardware and test equipment connections for calibration and repair; selection of appropriate test equipment and proper techniques for assembling instrument tubing fittings. (ISA-RP7.1, S7.3, S7.4, RP7.7, RP42.1; ASTM: E 425-84a)
- 12003 **KIRCHOFF'S LAWS**
Utilize Kirchoff's Laws to determine the relationship of current at junction and voltages around closed loops in a network.
- 12004 **OPERATIONAL AMPLIFIER AND TRANSISTOR CIRCUITS**
Recognize and understand basic transistor amplifier configurations (common emitter, common base, differential input) and their operation; calculate circuit parameters (voltage gain, current gain, and input and output impedance). Recognize and understand basic op amp circuit configurations (noninverting amplifier, inverting amplifier, voltage follower, summer, integrator), their operation, and how feedback operates in a circuit. Calculate circuit parameters of multistage amplifiers. Recognize and understand the operation of oscillators. Recognize the differences and operation of various power amplifier configurations. (IEEE: STD 216; ANSI: C100.6-3)
- 12005 **ELECTRONIC INSTRUMENTS - TEST EQUIPMENT, CALIBRATION, REPAIR**
Understand the operation of basic electric/electronic test equipment (DC power supplies, milliamp calibrators, millivolt calibrators, multimeters, signal sources, function generators, oscilloscopes, decade boxes, wheatstone bridges, impedance testers and frequency generators); calibration procedures for electric and electronic transmitters, controllers and control valve actuators; bench repair of various electric and electronic instruments and components (circuit boards, power supplies, relays, receiver and transmitter elements). Inspect and replace power cords and distribution cables. Locate and replace faulty resistors, capacitors, inductors, transistors, IC units, and printed circuit (PC) boards. Use appropriate test equipment, soldering techniques, wire wrap techniques, hand tools, component and wire identification documentation. (ISA-S12.4, S12.10, S12.11, S12.12; EIA: RS-186-E, RS-186-9E & 10E, RS-359; IEEE: STD 316; NEMA: ICS 2; UL 508, 1244, 1437; ANSI C33.76)

Level II - General Work Elements

(Work at Level II Is Performed under General Supervision)

CORE WORK ELEMENTS (See Note 2)

- 13001 PRESSURE MEASUREMENT PRINCIPLES
Understand the basic principles of pressure and its measurement (relationship between force and pressure; atmospheric, absolute, gage and differential pressure; and vacuum).
- 13002 LEVEL MEASUREMENT PRINCIPLES
Understand the basic principles of level and its measurement (relationship between force and pressure, head pressure, atmospheric pressure, and displacement and differential pressures). (ASTM D 1408-65)
- 13003 FLOW MEASUREMENT PRINCIPLES
Understand the basic principles of flow and its measurement (relationship between fluid flow and pressure, temperature, viscosity, density, friction and specific gravity). Know and define general flow measurement terminology (incompressible flow, compressible flow, laminar flow, turbulent flow, mass flow, steady flow, unsteady flow, transitional flow, pulsating flow, static pressure, stagnation pressure, dynamic pressure, working pressure, differential pressure, pressure loss, Reynolds number and the physical laws that apply to the flow of fluids and their measurement).
- 13004 TEMPERATURE MEASUREMENT PRINCIPLES
Understand basic thermodynamics, thermal time constants, principles of temperature measurement, temperature sensors, temperature transducers, transmitters and scales (Celsius, Fahrenheit, and Kelvin). (ASTM: E 1, E 77, E 230, E 235)
- 13005 CONTROL VALVES AND FINAL CONTROL DEVICES
Understand the importance of final control elements in a process control loop, the interrelations of control valve components and the proper operation of each. Describe the various types of control valve bodies (globe, gate, diaphragm, butterfly, ball) and the preferred application for each. Be familiar with valve trim and the selection for specific processes (C_v , linear, equal percentage, parabolic, quick-opening, characterization guiding, balancing forces and sealing); bonnets and stem packing (bonnet connections, steam bonnets, stem seals, packing, stuffing box design, follower, packing materials). (ISA-S75.05)
- 13006 PNEUMATIC CONTROLLERS, OPERATION
Understand the concepts and principles of pneumatic automatic process controllers, control modes, input/output relationships and calibration techniques. Define modes of control, the action of each mode at the input/output level (manual, on-off, proportional action, integral action, derivative action).
- 13007 ELECTRONIC CONTROLLERS, OPERATION
Understand the concepts of electronic automatic process controller hardware, control modes, input/output relationships, and calibration techniques. Define modes of control, the action of each mode at the input-output level (manual, on-off, proportional action, integral action, derivative action). (UL 1437; API: RP 550, Section 5)

NON-CORE WORK ELEMENTS

- 13008[^] INTERMEDIATE MATHEMATICS
Perform mathematical calculations utilizing basic algebra (fundamental laws, algebraic expressions), geometry, and the trigonometric functions or right triangles. (See basic textbooks on algebra and trig.)
- 13009 BASIC DIGITAL CIRCUITS
Understand basic digital principles and techniques commonly used in digital process instrument systems (binary numbering systems; binary/hexadecimal/decimal conversions; AND, NAND, OR, and NOR gates; NAND gate circuit schematics and specifications; TTL loading rules; NAND and NOR latches; D type flip-flops; binary counting and decoding; J-K flip-flops; ring counter; divide by 10 counter; open collector; tri-state logic; multiplexers/demultiplexers). Know how to connect TTL elements from schematics.

NOTE 2: Level II General Work Elements are categorized as Core and Non-Core Work Elements. All Level II Core Work Elements constitute a mandatory requirement for certification at Levels II, III and IV.

(Level II - General Work Elements continued on the next page)

(Level II - General Work Elements continued)

- 13010 **PRIMARY PRESSURE SENSORS AND TRANSDUCERS**
Know the function of and identify the primary sensors and transducers for pressure measurement (manometers, barometers, bourdon tubes, spiral elements, helix elements, stiff diaphragms, bellows, potentiometers, differential transformers, strain gages (bonded and unbonded), silicon diaphragm, inductive, capacitance, vibrating diaphragm and piezoelectric). Select appropriate pressure sensors for specific applications. (ISA-S37.3, S37.6, S37.8, S37.10, S37.12; ASME: PTC 19.2; ANSI: MC88.1, B40.1; UL 144, 404)
- 13011 **OBSOLETE NUMBER.** Work Element re-numbered as 14016.
- 13012 **PRIMARY LEVEL SENSORS AND TRANSDUCERS**
Know the function of and identify the primary sensors and transducers for level measurement (sight glasses, float systems, displacers, head pressure, differential pressure, dip pipes, elevation and suppression, capacitance, thermal, resistance, sonic, solid level measurement and nuclear devices). Select appropriate level sensors for specific applications. (ISA-S37.1, S37.12; UL 180)
- 13013 **OBSOLETE NUMBER.** Work Element re-numbered as 14017.
- 13014 **PRIMARY FLOW SENSORS AND TRANSDUCERS**
Understand the function of and identify the sensors and transducers for the measurement of flow (positive displacement meters, restriction flow meters, orifice plates, venturi, Dall flow tube, target meter, vortex shedding, Pitot tubes, annubar, weir, magnetic flow meters, turbine meters, mass flow meters, variable area flow meters, ultrasonic flow meters and anemometers). Select appropriate flow sensors for specific applications. (ISA-S37.1, S37.12; ASME: PTC 19.5; UL 25, 252)
- 13015 **OBSOLETE NUMBER.** Work Element re-numbered as 14018.
- 13016 **PRIMARY TEMPERATURE SENSORS AND TRANSDUCERS**
Understand how various types of sensors measure temperature and the application of each (expansion thermometers, mercury in glass thermometers, vapor pressure thermometers, resistance thermometers, RTDs, thermistors, self-heating resistance sensors, thermocouples, reference junctions [above ambient and below ambient], thermopiles, bi-metallic elements, thermostats, extension wire and temperature ranges for different sensors). Select appropriate temperature sensors for specific applications. (ISA-S37.1, S37.12; ASME: PTC 19.3; EIA: RS-275-A, RS-309; ANSI C83.27; IEEE: STD 261; ISA/ANSI MC96.1; UL 873)
- 13017 **OBSOLETE NUMBER.** Work Element re-numbered as 14019.
- 13018 **CONTROL VALVE ACTUATORS AND POSITIONERS**
Know the different types of control valve actuators, the purpose of positioners and the application of each (spring and diaphragm, piston, rolling diaphragm, double acting, air to open, air to close, positioner characterization, electro-mechanical actuators, electro-hydraulic actuators and electric actuators). Explain the use of alternative final control devices and the advantages or disadvantages of each (positive displacement pumps, variable speed pumps). (ISA-S75.13, S26; UL 429, 1002)
- 13019 **OBSOLETE NUMBER.** Work Element re-numbered as 14020.
- 13020 **OBSOLETE NUMBER.** Work Element re-numbered as 14021.
- 13021 **OBSOLETE NUMBER.** Work Element re-numbered as 14022.
- 13022 **OBSOLETE NUMBER.** Work Element re-numbered as 14023.

Level II - Special Work Elements

- 14001 **ANALYTICAL INSTRUMENTATION**
Understand the principles of operation, terminology, safety considerations and applications for common analytical instruments used in industry (chromatography, pH, conductivity, ultraviolet, infrared, oxygen, dissolved oxygen, turbidity, ambient air analysis, etc.). (ASTM: E 70-77, E 337-84, E 355-77; ASME: PTC 19.16, 19.17; AVS: 2.3; GPA: Standard 2165)
- 14002 **PNEUMATIC SIGNAL TRANSMISSION**
Understand types of pneumatic instrument communication signals (3-15 PSIG, 6-30 PSIG, etc.) and methods of transmission (piping, tubing type, tubing sizes, multi-tube bundles, connections, fittings and safety considerations). (ISA-S7.4, RP7.7)
- 14003 **ELECTRONIC SIGNAL TRANSMISSION**
Understand types of electronic instrument communication signals (4-20 mA, 10-50 mA, 1-5 V, etc.) and methods of transmission including wire type, size, shielding, grounding, cables, connections and safety considerations). (ISA-S50.1)
- 14004 **FIBER OPTICS**
Understand the operating principles and use of fiber optic signal transmission (cables, fittings, connections, installation, application, special considerations and advantages).
- 14005 **SIGNAL TRANSDUCERS**
Understand the need for and use of various signal transducers (I/P, P/I, E/I, I/E, MV/I, A/D, D/A and frequency). Maintain, calibrate and repair electronic and pneumatic transducers. (IEEE Dictionary)
- 14006 **MICROPROCESSORS**
Understand the general structure and functional role of microprocessor architecture and bus structure, basics of programming, addressing modes, data transfer, interrupt processing modes, data acquisition and transmission. Convert values in binary, octal, decimal and hexadecimal into one or more different base systems. Identify file management methods. Enter and execute programs from a keyboard and write a source code program. (ISA-S5.2; IEEE: STD 583, 796)
- 14007 **MICROPROCESSOR TROUBLESHOOTING**
Understand maintenance philosophies for unit, board and component level troubleshooting; use flow charts; describe sequences of operations that include decisions; and complete a truth table for single bit AND, OR, NAND, NOR, XOR logic operations. Perform logic operations and describe the basic function of selected memory map areas. Describe criterion for troubleshooting microprocessor based systems, develop simple software diagnostics to use in data acquisition operations on a typical microprocessor based system. Be familiar with block diagram usage, troubleshooting techniques, test equipment, procedures and safe work practices that prevent damage to components or injury to personnel. (EIA: RS-422-A, RS-423-A)
- 14008 **PROCESS INSTRUMENTATION DIAGRAMS AND SYMBOLS**
Recognize and interpret the symbols and standard practices used in the preparation of process and instrument flow diagrams. For example: functional identification, loop identification, identification letters, letter combinations, function blocks, function designations, instrument line symbols, general instrument or function symbols, control valve body and actuator symbols, primary element symbols and complex combinations. (ISA-S51.1, S5.1, S5.3, S5.4; ANSI C85.1)
- 14009 **SINGLE LOOP FEEDBACK CONTROL**
Understand basic feedback control loops that use transmitters, controllers, control valves and auxiliary devices and their function in industrial control. Describe feedback control, open loop control, closed loop control using standard instrument symbols and terminology. (ISA-S51.1)
- 14010 **PROGRAMMABLE LOGIC CONTROLLERS**
Understand the operating principles and applications of Programmable Logic Controllers (PLC).
- 14011 **PLC NUMBERING SYSTEMS AND CODES**
Understand PLC numbering systems and codes, number conversions, one's and two's complement and register format. (ISA-S5.2)
- 14012 **PLC - LOGIC CONCEPTS**
Understand the logic concepts applied to PLC's (binary concept, AND OR NOT functions, principles of Boolean algebra and hard-wired to programmed logic). (ANSI/IEEE: STD 91-84)

(Level II - Special Work Elements continued on the next page)

(Level II - Special Work Elements continued)

- 14013 PLC - HARDWARE COMPONENTS
Know hardware components and their function in a typical PLC (the central processing unit, input/output system, programming and peripheral devices). (EIA: RS-281-B, RS-408)
- 14014 PLC - INSTALLATION, START-UP, AND MAINTENANCE
Understand PLC installation, start-up and maintenance procedures (systems layout, I/O installation, installation/maintenance tools and test equipment). (IEEE: STD 796; NEMA: ICS 3)
- 14015 INTERNAL CONTROL DOCUMENTATION
Understand the procedures to complete work orders, requisitions, purchase orders, etc.
- 14016 PRESSURE TRANSMITTERS AND CALIBRATION
Understand the types of pneumatic and electronic transmitters used in pressure measurement, the calibration of each and the test instruments used. Connect pneumatic and electronic pressure sensors and transducers for accurate calibration.
- 14017 LEVEL TRANSMITTERS AND CALIBRATION
Understand the types of pneumatic and electronic transmitters used in level measurement, the calibration of each and the test instruments used. Connect pneumatic and electronic level sensors and transducers for accurate calibration. (ANSI B88.2; AVS: 6.5; UL 632)
- 14018 FLOW TRANSMITTERS AND CALIBRATION
Know the types of pneumatic and electronic transmitters used in flow measurement, the calibration of each and the test instruments used. Connect pneumatic and electronic flow sensors, transmitters and transducers for accurate calibration. (AWWA: C701, C702, C706, C708; UL 632)
- 14019 TEMPERATURE TRANSMITTERS AND CALIBRATION
Know the types of pneumatic and electronic transmitters used for temperature measurement, the calibration of each and the test instruments used. Connect pneumatic and electronic temperature sensors, transmitters and transducers for accurate calibration. (UL 632)
- 14020 CONTROL VALVE BODY REPAIR
Understand bench repair procedures, tools and test equipment required to maintain and repair control valve bodies, bonnets, packing, trim and trim "lapping." (ISA-S75.14)
- 14021 ACTUATOR AND POSITIONER REPAIR
Know the calibration procedures, test equipment, tools and connections required to maintain and repair control valve actuators and positioners.
- 14022 PNEUMATIC CONTROLLERS, HARDWARE AND REPAIR
Understand pneumatic controller hardware and adjustments (nozzle-baffle assembly, restrictor, pilot relays, direct and reverse action, air consumption, feedback mechanisms, control mode arrangements, stacked diaphragm controllers, "blind" controllers, pneumatic set, ratio mechanisms, auto-manual transfer, zero, span and angularity adjustments).
- 14023 ELECTRONIC CONTROLLERS, HARDWARE AND REPAIR
Understand electronic controller hardware, adjustments and repair (zero adjustment, span adjustment, linearity adjustment, circuit boards, power supplies, relays, receiver elements, output elements, resistors, capacitors, inductors, transistors, IC units, printed circuit (PC) boards; basic transistor amplifier configurations, common emitter, common base, differential input; calculate circuit parameters, voltage gain, current gain and input and output impedance; basic op amp circuit configurations, non-inverting amplifier, inverting amplifier, voltage follower, summer, integrator, feedback, multistage amplifiers, oscillators, power amplifiers).

Level III - General Work Elements

- 15001[^] **BUSINESS COMMUNICATIONS**
Use the rules of syntax and style to write clear sentences and paragraphs in preparing routine correspondence and reports. Follow standard business communications procedures. (See basic grammar and writing handbooks.)
- 15002 **TECHNICAL LIBRARIES**
Use technical libraries to determine state-of-the-art methods for instrument selection, application, sizing, maintenance, troubleshooting and problem analysis.
- 15003 **TROUBLESHOOTING AND PROBLEM ANALYSIS**
Review plans and specifications to determine applicability to specific jobs. Recognize design deficiencies and mistakes. Analyze needs of job to determine appropriate corrective action. Prepare detailed recommendations for presentation to the appropriate person in charge.
- 15004 **WORK ELEMENT DELETED.** Credit is maintained by those who previously passed it.
- 15005 **SYSTEM OPERATING PROCEDURES**
Understand control system operating parameters, safety requirements, documentation and permissions to prevent any problems in operation or safety while work is being performed.
- 15006 **SAFETY REGULATIONS**
Be familiar with and responsible for assuring compliance with federal, state and facility safety regulations. Recognize unsafe working conditions and know the proper authority for reporting unsafe conditions. Know appropriate emergency procedures.
- 15007 **FIRST AID RESPONSIBILITY**
Know the first aid materials required for different types of projects and the numbers of personnel involved. Set up cyclic review of materials to ensure continuing availability. Know safe method of transporting injured persons. Have knowledge of CPR techniques.
- 15008 **MULTIVARIABLE CONTROL LOOPS**
Be familiar with the elements in control schemes other than feedback control (multivariable loops such as cascade, ratio, feedforward, adaptive, deadtime and interactive loops). Understand how each is used in process control, use block diagrams, and know the advantages obtained. (ISA-S51.1)
- 15009 **PROCESS DIAGRAMS**
Read and interpret system flow sheets and piping and instrument diagrams (P&ID), installation wiring diagrams, process diagrams and documentation. Know the operation of the process loop as well as the control system loop. (ISA-S5.1, S5.2, S5.3, S5.4)
- 15010 **CONTROL SYSTEMS TROUBLESHOOTING PRINCIPLES - PNEUMATIC**
Know the principles and concepts of pneumatic instrument, process system and control-loop troubleshooting. Diagnose manufacturing hardware or control-loop malfunctions. Determine the problem area. Repair any individual instrument or control-loop malfunction.
- 15011 **ISOLATING PROBLEMS - TROUBLESHOOTING PNEUMATIC CONTROL LOOPS**
Apply proper troubleshooting techniques and maintenance procedures to complete measurement and control loops in-plant situations. Describe the procedure for isolating problems in a pneumatic process control loop; make sure there is a problem, define and locate the problem, repair the malfunction, make sure the loop is functioning properly and take steps to minimize the reoccurrence of the problem. (ISA-S71.1, S71.4, S26, S7.3, S7.4, RP7.1, RP7.7)
- 15012 **CONTROL SYSTEMS TROUBLESHOOTING PRINCIPLES - ELECTRONIC**
Know the principles and concepts of electronic instruments, process system and control-loop troubleshooting. Diagnose manufacturing hardware or control loop malfunctions. Determine the problem area. Repair any individual instrument or control loop malfunction. (IEEE: STD 518)

(Level III - General Work Elements continued on the next page)

(Level III - General Work Elements continued)

- 15013 **ISOLATING PROBLEMS - TROUBLESHOOTING ELECTRONIC CONTROL LOOPS**
Apply proper troubleshooting techniques and maintenance procedures to complete measurement and control loops in in-plant situations. Be familiar with the procedure for isolating problems in an electronic process control loop; make sure there is a problem, describe and locate the problem, repair the malfunction, make sure the loop is functioning properly and take steps to minimize reoccurrence of the problem. (ISA-S26, S12.4, S12.10, S12.11, S12.12; IEEE: STD 336, 446)
- 15014 **PROCESS DYNAMICS**
Understand the interrelations of system components and how process dynamics affect operation of a control system (including first-order lags, time constants, higher-order lags, deadtime, etc.).
- 15015 **CONTROL TUNING CONCEPTS**
Be familiar with control, tuning principles, closed loop control, feedback, adaptive, and cascade. Define process gain, controller gain, proportional gain, integral (reset time) and derivative (rate).
- 15016 **CLOSED LOOP TUNING METHODS**
Understand the Ziegler-Nichols ultimate tuning method. Define ultimate gain and ultimate period and how they are used in control loop tuning. Know the formulas for tuning a proportional only controller, proportional plus integral (PI) controller and a proportional plus integral plus derivative (PID) controller.
- 15017 **TRIAL AND ERROR TUNING**
Describe the systematic procedure for tuning a P, PI and PID loop using the trial and error tuning method.
- 15018 **OPEN LOOP TUNING**
Understand "Process Reaction Curve" and how it is used for open loop controller tuning. Be familiar with the reaction rate formulas used to calculate the tuning parameters for a P, PI and PID controller.
- 15019 **WORK ELEMENT DELETED.** Credit is maintained by those who previously passed it.
- 15020 **FLUIDS**
Solve problems involving density and specific gravity, buoyancy and Archimedes' principle, gauge and absolute pressure, manometers, pressure as related to depth in a fluid, Bernoulli's principle, and fluid velocity (as related to pipe diameter). Define and use the terminology of fluids.

Level III - Special Work Elements

- 16001 **FINAL CONTROL ELEMENT SELECTION AND SIZING**
Understand the factors that influence control valve sizing and selection (cavitation, noise, abrasion, erosion, extreme temperature or pressure, capacity, body types, trim types, materials of construction and application). (ISA-S75.05, S75.06, S75.11)
- 16002 **CONTROL VALVE SELECTION**
Know how to get and document valid design data. Select a valve to avoid damaging cavitation, extensive resonant noise or other undesirable situations. (ISA-S75.03, S75.04)
- 16003 **CONTROL VALVE SIZING**
Size a valve for a selected flow (liquid, gas, steam, or liquid/vapor combination) using a hand-held calculator, a personal computer with sizing software, manufacturer's valve sizing slide rule, or other acceptable method. (ISA-S75.01, S75.02)
- 16004 **FLOW MEASUREMENT - ADVANCED TECHNIQUES**
Understand the sciences, arts, methods, hardware and philosophies used in the measurement of the flow of gases and liquids. Evaluate methods of unattended continuous flow measurement and control. Describe the standards of flow measurement and control required by industry. (ASTM D 1750-62)

(Level III - Special Work Elements continued on the next page)

(Level III - Special Work Elements continued)

- 16005 FLOW MEASUREMENT HARDWARE
Know the types of hardware used for flow measurement: differential pressure and non-differential pressure.
- 16006 INSTALLATION OF PRIMARY DEVICES
Understand the correct installation of flow measurement primary devices and transmitters for various types of processes (gas, liquid, steam, solids, slurries, turbulent flow, pulsating flow, high temperatures and low temperatures).
- 16007 DIFFERENTIAL PRESSURE FLOWMETER PRIMARY ELEMENT SELECTION
Select a differential producer best suited to a specific application (gas, liquid, slurries, high viscosity liquids, or steam) and prepare the necessary specifications and installation recommendations to completely instrument a system to measure and control a flow.
- 16008 PROCESS ANALYZERS
Understand the principles of operation and applications for on-stream analytical instruments used in industry including sampling systems and sampling techniques. Know analytical terminology, safety, types of analysis (on-stream gas and liquid chromatography, mass spectrometers, pH, conductivity, refractometers, oxygen, dissolved oxygen, turbidity and ambient air analysis). Be familiar with process and on-stream analyzer sample systems (valves, sample conditioning, multi-stream systems, safety considerations and applications). (ASTM D 1071, D 1145, D 1247, D 1945, D 1946, E 137; E 275; ASME: PTC 19.10; GPA: Standard 2174)
- 16009 **WORK ELEMENT DELETED.** Credit is maintained by those who previously passed it.
- 16010 TUNING MULTIVARIABLE LOOPS
Know the tuning concepts and procedures for tuning multivariable loops including cascade, ratio, feedforward and deadtime control.
- 16011 SMART TRANSMITTERS
Understand "Smart Transmitters" (capabilities, use, configuration, rangeability, span, installation, input signals, output signals, hand-held calibrators, diagnostics, off-line calibration, on-line calibration and maintenance).
- 16012 ADAPTIVE TUNING
Understand nonlinear processes and be familiar with how adaptive tuning capabilities can improve control of these processes.
- 16013 SINGLE-LOOP/STAND-ALONE DIGITAL CONTROLLERS
Be familiar with single-loop, stand-alone digital controllers (application, function, capabilities, configuration, function blocks, networking, input signals, output signals, self-diagnostics).
- 16014 SELF-TUNING CONTROLLERS
Understand the function and advantages of self-tuning controllers. Be familiar with the configuration procedures and steps required to apply a typical self-tuning controller to a specific process construction and application.
- 16015 ADVANCED DIGITAL CIRCUITS FOR MEASUREMENT AND TRANSMISSION
Understand how various digital elements and systems are used for A/D and D/A converters. Explain serial data transmission standards, applications, peripheral connections, protocols, and their relationship to process and manufacturing equipment. (IEEE: STD 162)
- 16016 ADVANCED DIGITAL CIRCUITS FOR CONTROL
Understand the concepts and operation of integrated logic circuitry controllers on a chip and the supportive digital circuits required for built-in redundancy and reliability. Troubleshoot and operate a single loop digital controller. (IEEE: STD 162)

Level IV - General Work Elements

NOTE: Certification at Level IV requires that the candidate must have occupied a senior position of responsibility in connection with at least one instrumentation system of substantial complexity in an industrial manufacturing or process facility. There are no exceptions to this requirement.

- 17001 PROGRAMMABLE LOGIC CONTROLLERS
Understand the operating principles of Programmable Logic Controllers (PLC) including utilization and areas of application (petrochemical, manufacturing, materials handling, machining, mining, pulp and paper, lumber, food, beverage, metals and power).
- 17002 PLC - SOFTWARE COMPONENTS
Understand programming language concepts and the meaning of programming languages, PLC instruction summary, ladder diagram language, Boolean language, functional blocks, programming language and English statement language. (IEEE: STD 828, 829, 830)
- 17003 **WORK ELEMENT DELETED.** Credit is maintained by those who previously passed it.
- 17004 PLC - DATA HIGHWAYS
Understand the general principles, topologies, access methods, transmission media, protocols, testing and troubleshooting of PLC data highway systems. (EIA: RS-232-C; IEEE: STD 488, 583, 796)
- 17005 COMPUTER CONTROL SYSTEMS - GENERAL
Understand the characteristics and major components of computer control systems (processor, process interface, operator interface, process control software, algorithms and peripheral equipment). (IEEE: STD 162)
- 17006 DATA HIGHWAYS AND MULTIPLEXERS
Understand data highway systems and multiplexers used in computer control technologies (multiplexing and scanning, multiplexer designs, system configurations, remote stations, super communication, subcommuni- cation and digital signal transmission). (ISA-S72.01; IEEE: STD 171, 585, 596, 695, 696, 802.2, 802.4)
- 17007 **WORK ELEMENT DELETED.** Credit is maintained by those who previously passed it.
- 17008 **WORK ELEMENT DELETED.** Credit is maintained by those who previously passed it.
- 17009 **WORK ELEMENT DELETED.** Credit is maintained by those who previously passed it.
- 17010 **WORK ELEMENT DELETED.** Credit is maintained by those who previously passed it.
- 17011 SUPERVISORY CONTROL
Understand the architecture, operation, hardware arrangement, programming, advantages, limitations and peripherals in a supervisory control system. Be familiar with use and areas of application (petrochemical, manufacturing, materials handling, machining, mining, pulp and paper, lumber, food, beverage, metals and power).
- 17012 **WORK ELEMENT DELETED.** Credit is maintained by those who previously passed it.
- 17013 **WORK ELEMENT DELETED.** Credit is maintained by those who previously passed it.
- 17014 DIGITAL CONTROL SYSTEM TESTING
Understand computer and digital measurement and control systems. Recommend modification, replacement or repair.
- 17015 PROJECT PLANNING
Assist in the implementation of planning and supervision of computer control projects. Understand specifications and be able to recommend alternatives.

(Level IV - General Work Elements continued on the next page)

(Level IV - General Work Elements continued)

- 17016 CREW SCHEDULING
Understand maintenance and production requirements. Maintain effective management of crew schedules.
- 17017 TEST AND MAINTENANCE PROCEDURES
Establish maintenance schedules and procedures. Recommend corrective measures and alternatives.
- 17018 COMPUTER DIAGNOSTICS
Understand computer diagnostics and program software as they apply to maintenance functions and recordkeeping.
- 17019 PERSONAL COMPUTERS
Be familiar with personal computers as they are applied to plant operations and recordkeeping (hardware, software and compatibility).
- 17020 INSTRUMENT RELIABILITY
Take appropriate action for the maintenance of equipment with a consideration of personnel cost and time weighted against cost and continued outage. (IEEE: STD 446)
- 17021 MAINTENANCE RECORDS
Know proper forms to report measurement and control equipment failure and be able to write a concise, informative account of the failure.
- 17022 COST SAVING MAINTENANCE METHODS
Assist in the development of new, economical equipment maintenance methods.
- 17023 INVENTORIES
Set up and activate methods of parts inventory control and recordkeeping.
- 17024 DISTRIBUTED SYSTEMS - SHARED CONTROLS
Understand the general requirements for the installation of Distributed Systems. Set-up and manipulate controller data acquisition files. Provide system documentation. Configure a DCS networking system's operating software. Configure, design and set-up an operator interface. (ISA-S5.3)
- 17025 DISTRIBUTED SYSTEMS - MAINTENANCE
Understand DCS maintenance philosophies, and test and troubleshooting procedures for software/configuration problems. Prepare maintenance documentation. Perform testing of peripheral devices. (ISA-S5.3)
- 17026 DIGITAL SYSTEMS INSTALLATION AND START-UP
Understand digital system wiring practice, process control safety considerations, and safe work practices, including physical and electrical hazards, hazard identification, and process cautions. Interpret installation and start-up documentation, including P&I, loop, and wiring diagrams. (ISA-RP55.1, S71.01, S71.04; IEEE: STD 583)
- 17027 DIGITAL SYSTEMS MAINTENANCE
Understand digital system troubleshooting and maintenance procedures and philosophies concerning trouble location and test procedures, anti-static grounding requirements, and IC chip and circuit board replacement practices. Understand software diagnostics, debugging, modification, and documentation methods. Select and use proper test equipment for hardware and software diagnostics and repair. (ISA-RP55.1, S71.01, S71.04; IEEE: STD 583)

Level IV - Special Work Elements

- 18001 **PROCESS CONTROL APPLICATIONS**
Assist in the design and application of control systems for industrial plant instrument engineering projects, including determining the process operating variables, engineering, control equipment specification, and project wrap-up. All activities directed to an optimized control system. (IEEE: STD 467, 518)
- 18002 **APPLICATION - ROTATING MACHINERY**
Assist in the analysis of process system requirements and make recommendations for control loop structure to achieve optimum performance. Use vibration analysis and infrared techniques to predict possible breakdown or repair requirements. Recognize potential applications for advanced control loop strategies, evaluate the benefits and make a realistic assessment of the trade-off of those benefits vs. the increased control loop complexity required for the control of centrifugal and reciprocating pumps, compressors, turbines and other rotating machinery.
- 18003 **APPLICATION - COOLING TOWERS, CHILLERS, HVAC**
Assist in the analysis of process system requirements and make recommendations for control loop structure to achieve optimum performance. Recognize potential applications for advanced control loop strategies, evaluate the benefits and make a realistic assessment of the trade-off of those benefits vs. the increased control loop complexity required for the optimization of cooling tower operation, water pressure control, fan control, humidity control and temperature control.
- 18004 **APPLICATION - HEAT EXCHANGERS**
Assist in the analysis of process system requirements and make recommendations for control loop strategies, evaluate the benefits and make a realistic assessment of the trade-off of those benefits vs. the increased control loop complexity required for the control of steam heaters, reboilers and liquid-liquid exchangers.
- 18005 **APPLICATION - EVAPORATORS AND CONDENSERS**
Assist in the analysis of process system requirements and make recommendations for control loop structure to achieve optimum performance. Recognize potential applications for advanced control loop strategies, evaluate the benefits and make a realistic assessment of the trade-off of those benefits vs. the increased control loop complexity required for the control of multiple effect evaporators and condensers.
- 18006 **APPLICATION - BOILER CONTROL, FURNACES**
Assist in the analysis of process system requirements and make recommendations for control loop structure to achieve optimum performance. Recognize potential applications for advanced control loop strategies, evaluate the benefits and make a realistic assessment of the trade-off of those benefits vs. the increased control loop complexity required for the control of combustion safety, feed water controls, fuel and air flow, desuperheater control, pressure control, process heaters, reformers, cracking furnaces, H₂S analysis, fuel density, bed control and special boilers.
- 18007 **APPLICATION - DISTILLATION**
Assist in the analysis of process system requirements and make recommendations for control loop structure to achieve optimum performance. Recognize potential applications for advanced control loop strategies, evaluate the benefits and make a realistic assessment of the trade-off of those benefits vs. the increased control loop complexity required for the control of batch, binary columns, composition, reflux, interaction, multiple column units, energy and product mix.
- 18008 **APPLICATION - BATCH REACTORS**
Assist in the analysis of process system requirements and make recommendations for control loop structure to achieve optimum performance. Recognize potential applications for advanced control loop strategies, evaluate the benefits and make a realistic assessment of the trade-off of those benefits vs. the complexity required to control batch reactors (pressure, temperature, level, flow, feedback, cascade, feedforward, ratio and adaptive).
- 18009 **pH, ORP, SPECIFIC ION CONTROL**
Assist in the analysis of process system requirements; make recommendations for control loop structure to achieve optimum performance. Recognize potential applications for advanced control loop strategies, evaluate the benefits, make a realistic assessment of the trade-off of those benefits vs. the increased control loop complexity required for pH, ORP and specific ion control (non-linearities, batch and continuous, waste treatment, turndown, ratio and cascade, feedforward, adaptive, buffering, self-tuning).

(Level IV - Special Work Elements continued on the next page)

(Level IV - Special Work Elements continued)

18010 INDUSTRIAL ROBOTS

Know the four types of industrial robots and understand the geometry of motion for each (Cartesian Coordinate Robot, Cylindrical Coordinate Robot, Spherical Coordinate Robot and Jointed Arm Robot).

18011 STRUCTURE ELEMENTS OF AN INDUSTRIAL ROBOT

Be familiar with the elements of an articulated arm robot and the types of energy involved in robotic action (electrical, hydraulic, pneumatic and kinetic). Recognize the following terms and understand the function and action of each of its elements: "manipulator" (arm, base, shoulder, elbow, wrist, upper arm, forearm, end effector, gripper and links); "actuator" (effector, hydraulic motor, cable drive, servovalve, stepper motor, stop, limit switch, interlock); "control system" (controller, open-loop control, closed-loop control, servo-controlled robot, continuous path control, point-to-point control, step point control, sequence control, trajectory control, pick and place control, computer numerical control, direct numerical control and hierarchical control); "sensor" (internal, external, force, contact, proximity, tactile, touch, vision, temperature, pressure, flow, weight and concentration). (EIA: RS-281-B; IEEE: STD 796, 802.2)

18012 INDUSTRIAL ROBOT PROGRAMMING

Be familiar with the various types of robot programming and the definition and application of each (manual, off-line, on-line, walk-through, lead-through and teach programming). Understand the types of motions that are programmed (translational, rotational, continuous-path, point-to-point, world coordinates, work coordinates, relative coordinates and fixed coordinates). (IEEE: STD 488)

18013 APPLICATION - ROBOTS

Be familiar with a typical robot application; type of robot, function (material handling, welding, assembly, etc.), programming method (personal computer, PLC, DCS, other), operation, maintenance requirements, sensors, adaptability, flexibility, programmability, modularity and reliability. (IEEE: STD 696)

18014 PERSONNEL DEVELOPMENT

Assist in the development of training programs designed to ensure the knowledge and proficiency of the facility instrument technicians. Supervise training and teach courses as required. Guide the development of personnel as they advance through the levels of instrument technology. Conduct continuous on-the-job training as part of job responsibility.

Personal Tally Sheet

Passed Work Elements in Industrial Instrumentation

- o Put a checkmark next to the appropriate work element number when you receive a passing score on your Examination Score Report.
- o Put a "C" next to the appropriate work element number if you have crossover credit from another field of testing.

<u>Level I</u>	<u>Level II</u>	<u>Level II</u>	<u>Level III</u>	<u>Level III</u>	<u>Level IV</u>	<u>Level IV</u>
<u>General</u>	<u>General</u>	<u>Special</u>	<u>General</u>	<u>Special</u>	<u>General</u>	<u>Special</u>
<input type="checkbox"/> _11001	<input type="checkbox"/> _13001 (Core)	<input type="checkbox"/> _14001	<input type="checkbox"/> _15001	<input type="checkbox"/> _16001	<input type="checkbox"/> _17001	<input type="checkbox"/> _18001
<input type="checkbox"/> _11002	<input type="checkbox"/> _13002 (Core)	<input type="checkbox"/> _14002	<input type="checkbox"/> _15002	<input type="checkbox"/> _16002	<input type="checkbox"/> _17002	<input type="checkbox"/> _18002
<input type="checkbox"/> _11003	<input type="checkbox"/> _13003 (Core)	<input type="checkbox"/> _14003	<input type="checkbox"/> _15003	<input type="checkbox"/> _16003	<input type="checkbox"/> _17003*	<input type="checkbox"/> _18003
<input type="checkbox"/> _11004	<input type="checkbox"/> _13004 (Core)	<input type="checkbox"/> _14004	<input type="checkbox"/> _15004*	<input type="checkbox"/> _16004	<input type="checkbox"/> _17004	<input type="checkbox"/> _18004
<input type="checkbox"/> _11005 (Core)	<input type="checkbox"/> _13005 (Core)	<input type="checkbox"/> _14005	<input type="checkbox"/> _15005	<input type="checkbox"/> _16005	<input type="checkbox"/> _17005	<input type="checkbox"/> _18005
<input type="checkbox"/> _11006	<input type="checkbox"/> _13006 (Core)	<input type="checkbox"/> _14006	<input type="checkbox"/> _15006	<input type="checkbox"/> _16006	<input type="checkbox"/> _17006	<input type="checkbox"/> _18006
<input type="checkbox"/> _11007	<input type="checkbox"/> _13007 (Core)	<input type="checkbox"/> _14007	<input type="checkbox"/> _15007	<input type="checkbox"/> _16007	<input type="checkbox"/> _17007*	<input type="checkbox"/> _18007
<input type="checkbox"/> _11008	<input type="checkbox"/> _13008	<input type="checkbox"/> _14008	<input type="checkbox"/> _15008	<input type="checkbox"/> _16008	<input type="checkbox"/> _17008*	<input type="checkbox"/> _18008
<input type="checkbox"/> _11009	<input type="checkbox"/> _13009	<input type="checkbox"/> _14009	<input type="checkbox"/> _15009	<input type="checkbox"/> _16009*	<input type="checkbox"/> _17009*	<input type="checkbox"/> _18009
<input type="checkbox"/> _11010	<input type="checkbox"/> _13010	<input type="checkbox"/> _14010	<input type="checkbox"/> _15010	<input type="checkbox"/> _16010	<input type="checkbox"/> _17010*	<input type="checkbox"/> _18010
<input type="checkbox"/> _11011*	<input type="checkbox"/> _13012	<input type="checkbox"/> _14011	<input type="checkbox"/> _15011	<input type="checkbox"/> _16011	<input type="checkbox"/> _17011	<input type="checkbox"/> _18011
<input type="checkbox"/> _11012	<input type="checkbox"/> _13014	<input type="checkbox"/> _14012	<input type="checkbox"/> _15012	<input type="checkbox"/> _16012	<input type="checkbox"/> _17012*	<input type="checkbox"/> _18012
<input type="checkbox"/> _11013	<input type="checkbox"/> _13016	<input type="checkbox"/> _14013	<input type="checkbox"/> _15013	<input type="checkbox"/> _16013	<input type="checkbox"/> _17013*	<input type="checkbox"/> _18013
<input type="checkbox"/> _11014	<input type="checkbox"/> _13018	<input type="checkbox"/> _14014	<input type="checkbox"/> _15014	<input type="checkbox"/> _16014	<input type="checkbox"/> _17014	<input type="checkbox"/> _18014
<input type="checkbox"/> _11015		<input type="checkbox"/> _14015	<input type="checkbox"/> _15015	<input type="checkbox"/> _16015	<input type="checkbox"/> _17015	
		<input type="checkbox"/> _14016 (was 13011)	<input type="checkbox"/> _15016	<input type="checkbox"/> _16016	<input type="checkbox"/> _17016	
		<input type="checkbox"/> _14017 (was 13013)	<input type="checkbox"/> _15017		<input type="checkbox"/> _17017	
		<input type="checkbox"/> _14018 (was 13015)	<input type="checkbox"/> _15018		<input type="checkbox"/> _17018	
		<input type="checkbox"/> _14019 (was 13017)	<input type="checkbox"/> _15019*		<input type="checkbox"/> _17019	
		<input type="checkbox"/> _14020 (was 13019)	<input type="checkbox"/> _15020		<input type="checkbox"/> _17020	
		<input type="checkbox"/> _14021 (was 13020)			<input type="checkbox"/> _17021	
		<input type="checkbox"/> _14022 (was 13021)			<input type="checkbox"/> _17022	
		<input type="checkbox"/> _14023 (was 13022)			<input type="checkbox"/> _17023	
					<input type="checkbox"/> _17024	
					<input type="checkbox"/> _17025	
					<input type="checkbox"/> _17026	
					<input type="checkbox"/> _17027	
<u>Level I</u>						
<u>Special</u>						
<input type="checkbox"/> _12001						
<input type="checkbox"/> _12002						
<input type="checkbox"/> _12003						
<input type="checkbox"/> _12004						
<input type="checkbox"/> _12005						

Level I and II General Work Elements are categorized as Core or Non-Core Work Elements. All Level I and II Core Work Elements constitute a mandatory requirement for certification at Level II, III and IV.

***Work Element Deleted. Credit is maintained by those who previously passed it.**

Standards Issuing Organizations

ANSI	American National Standards Institute, New York, NY
API	American Petroleum Institute, Washington DC
ASME	American Society of Mechanical Engineers, New York, NY
ASTM	American Society for Testing and Materials, Philadelphia, PA
AVS	American Vacuum Society, New York, NY
AWWA	American Water Works Association, Denver, CO
EIA	Electronic Industries Association, Washington, DC
GPA	Gas Processors Association, Tulsa, OK
IEEE	Institute of Electrical and Electronics Engineers, New York, NY
ISA	Instrument Society of America, Research Triangle Park, NC
JEDEC	Joint Electron Device Engineering Council, Washington, DC
NEMA	National Electrical Manufacturers Association, Arlington, VA
UL	Underwriters Laboratories, Inc., Northbrook, IL

Selected General References - Industrial Instrumentation*

These publications were recommended by the committee who developed and/or updated the program. They can provide some of the job knowledge required by an Industrial Instrumentation engineering technician.

The following publications are permitted in NICET's paper-and-pencil test centers:

- Considine, Douglas M. Process Instruments and Controls Handbook. McGraw-Hill Book Company. New York, NY.
- Driskell, L.M. Introduction to Control Valves and Other Final Control Devices. Instrument Soc. of America. Research Triangle Park, NC.
- Farmer, Edward J. Modernizing Control Systems. Instrument Society of America. Research Triangle Park, NC.
- Gilbert R.A. and J. Llewellyn. Programmable Controllers Practices and Concepts. Industrial Training Corporation. Rockville, MD.
- Gillum, D.R. Industrial Level Measurement. Instrument Society of America. Research Triangle Park, NC.
- Gillum, D.R., Kerlin, T.W., & R.L. Shepard. Industrial Pressure Measurement. Instrument Soc. of America. Research Triangle Park, NC.
- Herb, S.M. & J.A. Moore. Understanding Distributed Process Control (Revised). Instrument Soc. of America. Research Triangle Park, NC.
- Humpheries, J.T., and L.P. Sheets. Industrial Electronics, 2nd Edition. Breton Publishers. Boston, MA.
- Johnson, Curtis D. Process Control Instrumentation Technology, 2nd Edition. John Wiley & Sons. New York, NY.
- Kallen, Howard. Handbook of Instrumentation and Controls. McGraw-Hill Book Company. New York, NY.
- Kerlin, T.W., and R.L. Shepard. Industrial Temperature Measurement. Instrument Society of America. Research Triangle Park, NC.
- Liptak, Bela G., and Kriszta Venzel. Instrument Engineers Handbook, Process Control. Chilton Book Company. Radnor, PA.
- Liptak, Bela G., and Kriszta Venzel. Instrument Engineers Handbook, Process Measurement. Chilton Book Company. Radnor, PA.
- McMillan, Gregory K. Tuning and Control Loop Performance. Instrument Society of America. Research Triangle Park, NC.
- Moore, J.A. Digital Control Devices: Equipment & Applications. Instrument Society of America. Research Triangle Park, NC.
- Murrill, P.W. Fundamentals of Process Control Theory, 2nd Edition. Instrument Society of America. Research Triangle Park, NC.
- Patton, J.D., Jr. Maintainability and Maintenance Management, 2nd Ed. Instrument Soc. of America. Research Triangle Park, NC.
- Patton, J.D., Jr. Preventive Maintenance. Instrument Society of America. Research Triangle Park, NC.
- Smith, Ernest. Principles of Industrial Measurement for Control Applications. Instrument Soc. of America. Research Triangle Park, NC.
- Spitzer, D.W. Industrial Flow Measurement, 2nd Edition. Instrument Society of America. Research Triangle Park, NC.
- Standards and Practices for Instrumentation. Instrument Society of America. Research Triangle Park, NC.
- Sydenham, P.H. Basic Electronics for Instrumentation. Instrument Society of America. Research Triangle Park, NC.
- Sydenham, P.H. Handbook of Measurement Science. John Wiley and Sons. New York, NY.
- Weyrick, Robert C. Fundamentals of Automatic Control. McGraw-Hill Book Company. New York, NY.

In all cases, the most recent version of the listed publication should be used. On its website, NICET maintains a comprehensive listing of all publications that are permitted in its paper-and-pencil test centers.

Other Resources

Other resources, though NOT permitted in NICET's test centers, might be useful to Industrial Instrumentation technicians:

- Industrial Instrumentation Technician Assessment: Study Guide, Level II. Instrument Society of America. Research Triangle Park, NC.
- Industrial Instrumentation Technician Assessment: Study Guide, Level III & IV. Instrument Soc. of America. Research Triangle Park, NC.

Note: NICET does not monitor or endorse training providers or materials.

***This listing is not intended to be complete or representative.**



NATIONAL INSTITUTE FOR CERTIFICATION IN ENGINEERING TECHNOLOGIES

sponsored by the National Society of Professional Engineers

1420 King Street, Alexandria, Virginia 22314 (703) 684-2835

EXAMINATION SCORE REPORT

SAMPLE

Exam No. 99999

Examinee: JOHN EXAMINE

Test Date: 06/17/08

Report Date: 07/11/08

Work Element Number and Title

Score (%) Pass/Fail

INDUSTRIAL INSTRUMENTATION

2315002	Technical Libraries	65.00	P
2315003	Troubleshooting	80.00	P
2315004	Equipment	35.00	F*
2315005	System Operating Procedures	65.00	P
2315006	Safety Regulations	80.00	P
2316002	Control Valve Sizing	100.0	P
2316012	Adaptive Tuning	20.00	F**
2316014	Self-Tuning Controllers	90.00	P
2316016	Advanced Digital Circuits for Control	45.00	F***

* This failed work element cannot be retested prior to 120 days after the test date shown on this score report.

** This is your second failure for this work element. It cannot be retested prior to 120 days after the test date shown on this score report.

JOHN DOE

1420 King Street

Alexandria, Virginia 22314-2714