NETA®

ELECTRICAL TESTING TECHNICIAN CERTIFICATION PROGRAM

STUDY GUIDE 2017

ELECTRICAL TESTING TECHNICIAN
CERTIFICATION PROGRAM STUDY GUIDE

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This study guide is intended for NETA Accredited Company use.

The ETT Certified Assistant Level 2 performs limited testing and service work while generally requiring direct supervision.

The individual has sufficient knowledge and experience to be qualified for assuring the safety of him/herself.

Safety knowledge includes an understanding of lockout/tagout procedures and requirements, arc-flash and shock hazard analyses, and other facets of hazardous electrical energy control procedures. The ETT Certified Assistant

Level 2 generally requires direct supervision of a Level 3 ETT Certified Technician or Level 4 Certified Senior Technician.

To gain a more complete understanding of the requirements of this certification, the ANSI/NETA ETT and Level 2 Detailed Content Outline should be reviewed in detail.

Education and Training

- 40 hours of safety
- 160 hours of electrical

Related Experience

- Two years*
- Candidates for Level 2 must have met the qualifications for Level 1
- *Completion of two or more years of technical education in an electrical field shall be equivalent to a maximum of one year of related experience

Examination

- 100-item, multiple-choice, closed-book, onsite proctored examination
- Two hours allowed to complete exam
- Passing score of 410 or higher on a scale of 200 to 500

Exam Composition

- 15% of Exam - Safety
- 25% of Exam - Electrical Testing Fundamentals and Theory
- 55% of Exam - Component Testing
- 5% of Exam - Systems and Commissioning

The ETT Certified Level 3 is capable of supervising ETT Trainee Level I and ETT Certified Assistant Level 2.

Typical duties include, but are not limited to, performance and management of routine and moderately complex tasks and projects, record keeping, evaluation of test data, and responsibility for the safety of others.

Individual is qualified to provide guidance and is capable of performing electrical power switching.

To gain a more complete understanding of the requirements of this certification, the ANSI/NETA ETT and Level 3 Detailed Content Outline should be reviewed in detail.

Education and Training

- 24 hours of safety in addition to Level 2 requirements (64 hours total)
- 240 hours of electrical in addition to Level 2 requirements (400 hours total)

Related Experience

- Five years*
- Candidates for Level 3 must have met the qualifications for Levels 1 and 2 in successive order
- *Completion of two or more years of technical education in an electrical field shall be equivalent to a maximum of one year of related experience

Examination

- 100-item, multiple-choice, closed-book, onsite proctored examination
- Two hours allowed to complete exam
- Passing score of 410 or higher on a scale of 200 to 500

Exam Composition

- 13% of Exam - Safety
- 23% of Exam - Electrical Testing Fundamentals and Theory
- 47% of Exam - Component Testing
- 17% of Exam - Systems and Commissioning

The ETT Certified Senior Technician, Level 4, supervises large projects and multiple crews and can work independently.

Individual performs complex investigations, tests, and evaluations, and prepares written reports as needed.

To gain a more complete understanding of the requirements of this certification, the ANSI/NETA ETT and Level 4 Detailed Content Outline should be reviewed in detail.

Education and Training

- 40 hours of safety in addition to Level 2 and Level 3 requirements (104 hours total)
- 200 hours of electrical in addition to Level 2 and Level 3 requirements (600 hours total)

Related Experience

- Ten years*
- Candidates for Level 4 must have met the qualifications for Levels 1, 2, and 3 in successive order
- *Completion of two or more years of technical education in an electrical field shall be equivalent to a maximum of one year of related experience

Examination

- 65-item, multiple-choice, closed-book, onsite proctored examination
- Two hours allowed to complete exam
- Passing score of 410 or higher on a scale of 200 to 500

Exam Composition

- 10% of Exam - Safety
- 15% of Exam - Electrical Testing Fundamentals and Theory
- 55% of Exam - Component Testing
- 20% of Exam - Systems and Commissioning

What separates NETA Accredited Companies from other testing companies?

Two key characteristics:

1. NETA accredits the company
2. NETA certifies electrical testing technicians

NETA promises the public that using a NETA Accredited Company provides quality assurance. To maintain quality, it is very important for NETA to ensure the presence of accreditation and certification of all its member companies.

Helpful hints for preparation, as suggested by NETA Accredited Companies:

- The NETA exam is not a "book smart" test but a field test.

- The test is based on the ANSI/NETA standards; no matter what formal education a person has, he will not know the requirements of the standards and specifications unless he has worked in the field using the ANSI/NETA standards. It is important to study the ANSI/NETA standards.

- Because NETA Technicians are expected to have broad-based knowledge, it is important to study sections of the specifications that concern procedures not normally performed by your company.

- In study sessions, it is important to review each section of the specifications; understand the equipment on which tests are being performed and how the tests are done.

- The NETA World Tech Quiz is a good basis for theory, and can be helpful in studying. The questions on the quiz should not be confused with actual test questions.

- Several of the questions are based on National Electrical Code.

- Field engineers often think they don't need to do calculations; however, they need to be able to answer questions in the field without calling a PE.

- "Cramming" does little good. Regular technical review sessions are needed.

- One company holds hourly sessions each week, choosing a specific topic to review. The Representative states that this continuing education is excellent for all company technicians as a whole, not just the ones preparing for the exam, for it allows technical reinforcement. He states, "For us to put individuals into a classroom all day is tough, but the 45-minute blocks work well."

- One company has a 7:00 - 8:30 session every Monday morning for safety, status reports, and review of a section of the NETA specifications. They review the NETA requirements in every section along with their own data sheets. If all technicians are involved in these sessions, you are assured that your company can provide uniform testing and uniform procedures for your clients.

- Owners and managers assist their technicians in how to take a test. For example, before beginning the examinee should carefully read the front page of the exam. This sheet suggests that the examinee read the entire question, including all possible answers.

- The exam does allow test takers to make comments on individual items as well as at the end of the exam. These comments will not receive a response, nor do they have an impact on the overall score, but they are reviewed by the NETA Exam Committee and used as a means of assuring that the exams remain technically accurate.

- Non-technical comments, such as, “I was not trained in this,” or “My company doesn’t do this,” or, “I don’t understand the question” are only valid if more information is provided – what in the wording is confusing? Can you explain your answer based on the way you understand the question? Additional insight into your thought process is necessary to fully assess and evaluate the validity of a comment.

- As in the field, sometimes negatively stated items are used on the exam – questions which ask which answer NOT correct. While these items are used sparingly, this is a real aspect of field work when troubleshooting an issue.

- There are questions on the exam that ask about specific values listed in NETA Specifications. The Specifications are the basis for a large portion of the test. While the Specifications explain which tests to perform, the exam expects the technician to also know how to perform those tests, how to interpret the results, and what to do with the results. They need to understand the whole process.

- One company hires a trainer from another NETA Accredited Company to conduct in-house training.

- Technicians should practice good test-taking skills. Additional tips on developing test-taking skills are covered on the next page.

1. **Visit the Certification tab on the NETA website at www.netaworld.org.**

2. **Review the number of test items and time allowed and pace yourself.** For example, if a test has 100 items (questions) and you are given two hours to take the test, you should allow yourself an average of 1.2 minutes per question. Some questions may take a more or less time, but on average that can be your pace.

3. **Take the tutorial at the beginning of the exam.** The tutorial is designed to allow test takers to become familiar with the computer-based testing environment and the tools available during the exam. Using what you saw in the tutorial, make notes of anything you think you might forget. Write down things that you used in learning the material that might help you remember.

4. **If you're stuck, skip it and move on**. Make your best attempt at answering the question, or come back to it when you are less pressured for time. Use the "bookmark" function to mark questions that you want to come back to at the end of your exam.

5. **Look at the answer choices BEFORE you actually read the question.** That will help you screen for information related to the answers provided. It may also help you interpret questions more appropriately.

6. **Read the entire question.** Pay attention to key words in the stem of the question so you fully understand what the item is about.

7. **Don't try to remember all the answer options as you read through them.** Turn each answer option into a true/false statement. In your mind, think about whether the option fits the situation described in the stem.

8. **Answer all questions.** You have a twenty-five percent chance of getting the question right.

9. **Use all of the time allotted for the test.** If you have extra time, cover up your answers and actually rework the question.

10. **Start out right.** Get a good night's sleep and be sure to eat breakfast on the day of the test.

11. **If you get off track…Take a brain break.** Relax, take a few deep breaths, and clear your mind.

Comments are allowed on individual test questions. Always reread the question completely. Be sure you understand the question prior to submitting a comment.

Comments do not have an impact on test scores.

Some criteria for commenting on a test question include when a question:

- *Is difficult to read due to a computer display issue*
  If you experience computer issues, alert the exam proctor at the test center immediately so they can address the issue. They may relocate you to another test terminal, or restart your computer. If your issues are not addressed by the proctor, make a comment on the item as well as at the end of the exam, and email the NETA Office at neta@netaworld.org so the issue can be addressed with the exam provider.

- *Is missing its figure or has an incorrect figure*
  Reread the question completely. Be sure you understand the question. If you are sure the correct answer is not available, complete a comment by stating the basis for your comment.

- *Lacks essential information*
  Reread the question completely. Be sure you understand the question. If you are still sure the essential information is not available, complete a comment by identifying the missing information and briefly explain its value in arriving at a correct answer.

- *Has wording which is confusing or misleading*
  Reread the question completely. Be sure you understand the question. If you are still sure the correct answer is not available, complete a comment by stating what about the wording of the item is confusing or misleading and offer wording that would make the item more clear to you.

- *Has answer choices which do not include the answer you are sure is correct*
  Reread the question completely. Be sure you understand the question. If you are still sure the correct answer is not available, complete a comment by stating your answer and the basis for reaching it.

Test takers should keep in mind that each exam item has been carefully verified and proofread to assure that it is not only technically correct but that it is also psychometrically sound. Errors are possible, of course, but before commenting on a question the test taker should reread the question completely and be sure he understands the question and the potential answers.

Examples of comments that are not technically sound:

- My company does not perform this service.

- I am unfamiliar with this piece of equipment.

- The equipment referenced is old, hardly anyone uses it anymore.

Profile of Electrical Testing Technicians

TITLE: LEVEL:	**Trainee Technician** **Level 1**	**Certified Assistant Technician** **Level 2**	**Certified Technician** **Level 3**	**Certified Senior Technician** **Level 4**
EDUCATION AND TECHNICAL TRAINING:	High School / GED	Electrical 160 hours	Electrical 240 hours	Electrical 200 hours
SAFETY TRAINING:	8 hours [electrical]	40 hours	24 hours	40 hours
RELATED EXPERIENCE:	None	Two Years*	Five Years*	Ten Years*
TYPICAL ABILITY:	Requires supervision	Requires limited supervision	Lead technician	Supervisor
TYPICAL DUTIES:	• Responsible for safety of self.	• Understands hazardous electrical energy control procedures.	• Supervises Levels I and II. • Routine and moderately complex projects. • Record keeping. • Safety of others. • Switching. • Evaluations.	• Supervises large projects, multiple crews. • Works independently. • More complex investigations, tests, and evaluations.
TYPICAL ACTIVITIES:	• Assists. • Basic measurements. • Test equipment set up and removal. • Basic maintenance and cleaning.	• Inspects. • Tests. • Data collection. • Test for de-energized locked out/tagged out equipment.	• Lockout/tagout, safety grounding. • Performs moderately complex tasks. • Interacts with other skills and operations. • Writes reports. • Troubleshooting.	• Recommends corrective actions. • Performs very complex tests. • Interacts with engineers and managers. • Reviews reports.
EXAMINATION:	By employer	By certification body	By certification body	By certification body

NOTE: Candidates must have met the qualifications and training requirements for all previous levels.

*** Completion of two or more years of technical education in an electrical field shall be equivalent to a maximum of one year of experience.**

Certification Exams

Detailed Content Outlines

Level 2 Certified Assistant Technician

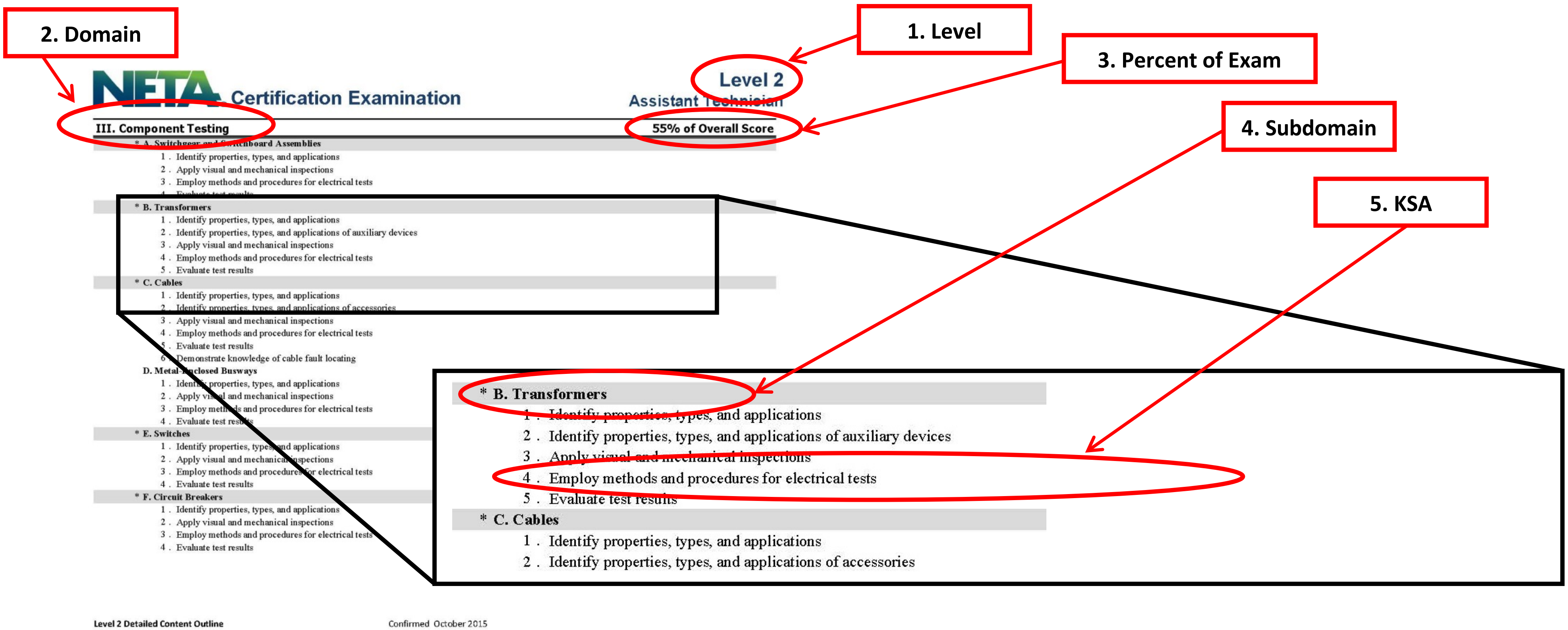
Level 3 Certified Technician

Level 4 Certified Senior Technician

These Detailed Content Outlines (DCOs) were developed in accordance with certification industry standards and best practices by subject matter experts and certified electrical testing technicians with the guidance of examination development professionals. The DCOs should be used in conjunction with the ANSI/NETA ETT *Standard for Certification of Electrical Testing Technicians* when preparing for the NETA Certification Exams.

Each outline is divided into different areas to help you determine what subject matter to study as you prepare for your exam.

1. Level
2. Domains
3. Percent of Exam Content
4. Subdomains
5. KSAs (knowledge, skills, abilities)



Levels

- NETA offers three levels of certification that are achieved through meeting pre-requisites designated in the ANSI/NETA ETT, by achieving a passing score on the certification exams, and by maintaining employment with a NETA Accredited Company or NETA Approved Military Organization
- Level 2 – Certified Assistant Technician
- Level 3 – Certified Technician
- Level 4 – Certified Senior Technician

Domains

- Domains are designated by a Roman numeral, I, II, III, or IV, on the DCO
  - I. Safety
  - II. Electrical Testing Fundamentals and Theory
  - III. Component Testing
  - IV. Systems and Commissioning
- Each Domain also has a corresponding percentage of content on each exam
- These percentages vary by exam level

Subdomains

- Subdomains are designated by an Arabic numeral under each Domain on the exam
- Subdomains may vary depending on exam level
- Some subdomains are designated as core subjects within the Component Testing subdomain

Core Subjects Within Domain III., Component Testing

* B. Transformers
1. Identify properties, types, and applications
2. Identify properties, types, and applications of auxiliary devices
3. Apply visual and mechanical inspections
4. Employ methods and procedures for electrical tests
5. Evaluate test results

* C. Cables
1. Identify properties, types, and applications
2. Identify properties, types, and applications of accessories

Core Subjects Within Domain III., Component Testing

- Certain Subdomains within Domain 3, Component Testing, have been identified as core subjects and therefore will be found on every certification exam for that particular level of certification.
- These core subjects are identified with an asterisk and are highlighted in grey.
- For example, the Level 2 Certification Exam will always contain questions within the Subdomains of Switchgear and Switchboard Assemblies, Transformers, Cables, Switches, Circuit Breakers, Protective Relays, Instrument Transformers, Grounding Systems, Ground-Fault Protection Systems, Motor Control Centers and Motor Starters, Direct-Current Systems, Insulating Liquids and Gasses, and Fuses.
- **NOTE: to achieve a passing score, it is important to focus on all areas within the detailed content outlines, not just the subdomains that are designated as core competencies**

KSAs

- KSAs are specific sets of knowledge, skills, and abilities that have been identified as pertinent to each specific exam level, domain, and subdomain
- The KSAs provide detailed descriptions of the types of questions a technician may see on the certification exam

I. Safety — 15% of Overall Score

A. Risk Assessment

1. Identify safe work practices with regard to hazards encountered on the job
2. Identify requirements to create a safe work environment
3. Determine the location and implications of shock and arc-flash protection boundaries

B. Establishing an Electrically Safe Work Condition

1. Apply requirements of *NFPA 70E, Article 120: Establishing an Electrically Safe Work Condition*

C. Lockout/Tagout Procedures

1. Apply OSHA lockout/tagout requirements

D. Personal Protective Equipment

1. Recognize and assess Arc-Flash Hazard/Risk Categories and Shock Protection Boundaries
2. Apply correct use, storage, and testing of personal protective equipment

E. Safety Equipment Selection

1. Identify the safety equipment needs of the project (e.g., hotstick, voltage detectors, insulated tools, fire extinguisher, etc.)

F. Confined Space

1. Recognize confined space and its hazards
2. Recognize when a confined space becomes a permit-required confined space along with the associated requirements
3. Apply OSHA requirements

G. Switching and Temporary Protective Grounding

1. Select and apply correct voltage detection equipment
2. Select and apply correct temporary protective grounding equipment
3. Interpret and apply system switching procedures

H. Incident Energy Analysis

1. Interpret field-marked equipment labels
2. Identify hazards where no field-marked labels exist
3. Demonstrate knowledge of incident energy calculation methods
4. Demonstrate knowledge of the variables involved in incident energy calculation methods

I. Codes and Standards

1. Apply standards and regulatory organizations (e.g., OSHA, ANSI, ASTM, IEEE, NETA, NFPA, NEMA, etc.)
2. Recognize key provisions of NFPA 70 (e.g., Articles 90, 110.16, 110.21, 225.56, 230.95(C), 250, and 310) and 70E (i.e. Chapter 1: Safety-Related Work Practices and Chapter 2: Safety-Related Maintenance Requirements, etc.)
3. Apply technical requirements of ANSI/NETA Acceptance and Maintenance Testing Standards
4. Practice compliance with manufacturer's published data

II. Electrical Testing Fundamentals and Theory — 25 % of Overall Score

A. Fundamentals of Electricity

1. Define and apply terms and concepts from physics, electricity, heat, and chemistry
2. Recognize and define the standard units used to describe electrical circuits, energy, and power
3. Identify series and parallel circuits
4. Recognize the sources and effects of electromagnetic fields
5. Demonstrate knowledge of dielectric properties of various types of insulations
6. Demonstrate knowledge of phasing and phase rotation

B. Electrical Calculations

1. Perform mathematical calculations utilizing basic algebra, geometry, and trigonometry
2. Apply fundamental electrical laws to simple circuits (e.g., Ohm's law, Kirchhoff's law, etc.)
3. Apply conversions between units (e.g., microhms to milliohms, horsepower to kilowatts, etc.)

C. AC and DC Circuits

1. Calculate simple single-loop ac circuits with RLC components
2. Calculate equivalent resistance of and power consumed by resistive circuits
3. Calculate equivalent capacitance and inductance
4. Apply methods for measuring and calculating impedance and power
5. Demonstrate knowledge of complex ac and dc circuits (e.g., voltage drop, current flow, power, etc.)
6. Demonstrate knowledge of phase angle, power factor, and vectors

D. Insulation Testing

1. Employ methods and procedures for insulation tests and analyze results

E. Resistance Testing

1. Employ methods and procedures for resistance tests and analyze results (e.g., winding resistance, contact resistance, bolted connections, etc.)

F. Thermographic Survey

1. Employ methods and procedures for thermographic surveys and analyze results (e.g., emissivity, reflection, delta-T, etc.)

G. Current Testing

1. Employ methods and procedures for current tests and analyze results (e.g., overcurrent pickup, circuit burden, voltage drop,

H. System Tests, Analysis, and Operation

1. Interpret electrical one-line diagrams
2. Interpret ac and dc schematic diagrams, ac three-line diagrams, and connection and interconnection drawings
3. Identify electrical symbols and ANSI device numbers
4. Interpret time-current curves
5. Recognize essential components of short-circuit and coordination studies (e.g., cable size and length, available protective device settings, raceway type, utility fault contribution, etc.)
6. Demonstrate knowledge of short-circuit and coordination studies

III. Component Testing — 55% of Overall Score

*** A. Switchgear and Switchboard Assemblies**

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

*** B. Transformers**

1. Identify properties, types, and applications
2. Identify properties, types, and applications of auxiliary devices
3. Apply visual and mechanical inspections
4. Employ methods and procedures for electrical tests
5. Evaluate test results

*** C. Cables**

1. Identify properties, types, and applications
2. Identify properties, types, and applications of accessories
3. Apply visual and mechanical inspections
4. Employ methods and procedures for electrical tests
5. Evaluate test results
6. Demonstrate knowledge of cable fault locating

D. Metal-Enclosed Busways

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

*** E. Switches**

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

*** F. Circuit Breakers**

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

III. Component Testing (Continued)

G. Circuit Switchers

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

H. Network Protectors

1. Identify properties, types, and applications

* **I. Protective Relays**

1. Identify types and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

* **J. Instrument Transformers**

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

K. Metering Devices

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

L. Regulating Apparatus

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections

* **M. Grounding Systems**

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results
5. Employ methods of enhancing effectiveness of grounding systems

* **N. Ground-Fault Protection Systems**

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

III. Component Testing (Continued)

O. Rotating Machinery

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

* **P. Motor Control Centers and Motor Starters**

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

Q. Adjustable-Speed Drive Systems

1. Identify properties, types, and applications

* **R. Direct-Current Systems**

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

S. Surge Arresters

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

T. Capacitors and Reactors

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

U. Outdoor Bus Structures

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

V. Emergency Systems

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

III. Component Testing (Continued)

W. Automatic Circuit Reclosers and Line Sectionalizers

1 . Identify properties, types, and applications
2 . Apply visual and mechanical inspections

X. Fiber-Optic Cables

. Recognize and correctly handle fiber-optic cables

* **Y. Insulating Liquids and Gases**

1 . Identify properties, types, and applications
2 . Apply sampling procedures
3 . Employ methods and procedures in compliance with ASTM
4 . Evaluate test results

* **Z. Fuses**

1 . Identify properties, types, and applications
2 . Apply visual and mechanical inspections
3 . Employ methods and procedures for electrical tests
4 . Evaluate test results

IV. Systems and Commissioning 5% of Overall Score

A. Troubleshooting

1. Investigate power or protective system faults or malfunctions to determine cause and corrective action required

B. Functional Testing

1. Employ methods and procedures for system-function tests upon completion of the individual component tests defined, as system conditions allow
2. Apply concepts of functionality for electrical systems

I. Safety — 13% of Overall Score

A. Risk Assessment

1. Identify safe work practices with regard to hazards encountered on the job
2. Identify requirements to create a safe work environment
3. Determine the location and implications of shock and arc-flash protection boundaries

B. Establishing an Electrically Safe Work Condition

1. Apply requirements of *NFPA 70E, Article 120: Establishing an Electrically Safe Work Condition*

C. Lockout/Tagout Procedures

1. Apply OSHA lockout/tagout requirements

D. Personal Protective Equipment

1. Recognize and assess Arc-Flash Hazard/Risk Categories and Shock Protection Boundaries
2. Apply correct use, storage, and testing of personal protective equipment

E. Safety Equipment Selection

1. Identify the safety equipment needs of the project (e.g., hotstick, voltage detectors, insulated tools, fire extinguisher, etc.)

F. Confined Space

1. Recognize confined space and its hazards
2. Recognize when a confined space becomes a permit-required confined space along with the associated requirements
3. Apply OSHA requirements

G. Switching and Temporary Protective Grounding

1. Select and apply correct voltage detection equipment
2. Select and apply correct temporary protective grounding equipment
3. Interpret and apply system switching procedures

H. Incident Energy Analysis

1. Interpret field-marked equipment labels
2. Identify hazards where no field-marked labels exist
3. Demonstrate knowledge of incident energy calculation methods
4. Demonstrate knowledge of the variables involved in incident energy calculation methods

I. Codes and Standards

1. Apply standards and regulatory organizations (e.g., OSHA, ANSI, ASTM, IEEE, NETA, NFPA, NEMA, etc.)
2. Recognize key provisions of NFPA 70 (e.g., Articles 90, 110.16, 110.21, 225.56, 230.95(C), 250, and 310) and 70E (i.e. Chapter 1: Safety-Related Work Practices and Chapter 2: Safety-Related Maintenance Requirements, etc.)
3. Apply technical requirements of ANSI/NETA Acceptance and Maintenance Testing Standards
4. Practice compliance with manufacturers' published data

II. Electrical Testing Fundamentals and Theory — 23% of Overall Score

A. Fundamentals of Electricity

1. Define and apply terms and concepts from physics, electricity, heat, and chemistry
2. Recognize and define the standard units used to describe electrical circuits, energy, and power
3. Identify series and parallel circuits
4. Recognize the sources and effects of electromagnetic fields
5. Demonstrate knowledge of dielectric properties of various types of insulations
6. Demonstrate knowledge of phasing and phase rotation

B. Electrical Calculations

1. Perform mathematical calculations utilizing basic algebra, geometry, and trigonometry
2. Apply fundamental electrical laws to simple circuits (e.g., Ohm's law, Kirchhoff's law, etc.)
3. Apply conversions between units (e.g., microhms to milliohms, horsepower to kilowatts, etc.)

C. AC and DC Circuits

1. Calculate simple single-loop ac circuits with RLC components
2. Calculate equivalent resistance of and power consumed by resistive circuits
3. Calculate equivalent capacitance and inductance
4. Apply methods for measuring and calculating impedance and power
5. Calculate variables of complex ac and dc circuits (e.g., voltage drop, current flow, power, etc.)
6. Calculate phase angle, power factor, and vectors

D. Insulation Testing

1. Employ methods and procedures for insulation tests and analyze results

E. Resistance Testing

1. Employ methods and procedures for resistance tests and analyze results (e.g., winding resistance, contact resistance, bolted connections, etc.)

F. Thermographic Survey

1. Employ methods and procedures for thermographic surveys and analyze results (e.g., emissivity, reflection, delta-T, etc.)

G. Current Testing

1. Employ methods and procedures for current tests and analyze results (e.g., overcurrent pickup, circuit burden, voltage drop, etc.)

II. Electrical Testing Fundamentals and Theory (Continued)

H. System Tests, Analysis, and Operation

1. Interpret electrical one-line diagrams
2. Interpret ac and dc schematic diagrams, ac three-line diagrams, and connection and interconnection drawings
3. Identify electrical symbols and ANSI device numbers
4. Interpret time-current curves
5. Recognize essential components of short-circuit and coordination studies (e.g., cable size and length, available protective device settings, raceway type, utility fault contribution, etc.)
6. Apply data extracted from short-circuit and coordination studies
7. Recognize cause and effects of power system harmonics

III. Component Testing — 47% of Overall Score

*** A. Switchgear and Switchboard Assemblies**

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

*** B. Transformers**

1. Identify properties, types, and applications
2. Identify properties, types, and applications of auxiliary devices
3. Apply visual and mechanical inspections
4. Employ methods and procedures for electrical tests
5. Evaluate test results

*** C. Cables**

1. Identify properties, types, and applications
2. Identify properties, types, and applications of accessories
3. Apply visual and mechanical inspections
4. Employ methods and procedures for electrical tests
5. Evaluate test results
6. Demonstrate knowledge of cable fault locating

D. Metal-Enclosed Busways

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

E. Switches

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

*** F. Circuit Breakers**

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

G. Circuit Switchers

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

III. Component Testing (Continued)

H. Network Protectors

1. Identify properties, types, and applications of protection and control
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

* **I. Protective Relays**

1. Identify types and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

* **J. Instrument Transformers**

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

K. Metering Devices

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

L. Regulating Apparatus

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

* **M. Grounding Systems**

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results
5. Employ methods of enhancing effectiveness of grounding systems

* **N. Ground-Fault Protection Systems**

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

III. Component Testing (Continued)

*** O. Rotating Machinery**

1 . Identify properties, types, and applications
2 . Apply visual and mechanical inspections
3 . Employ methods and procedures for electrical tests
4 . Evaluate test results

P. Motor Control Centers and Motor Starters

1 . Identify properties, types, and applications
2 . Apply visual and mechanical inspections
3 . Employ methods and procedures for electrical tests
4 . Evaluate test results

Q. Adjustable-Speed Drive Systems

1 . Identify properties, types, and applications
2 . Apply visual and mechanical inspections
3 . Employ methods and procedures for electrical tests
4 . Evaluate test results

*** R. Direct-Current Systems**

1 . Identify properties, types, and applications
2 . Apply visual and mechanical inspections
3 . Employ methods and procedures for electrical tests
4 . Evaluate test results

S. Surge Arresters

1 . Identify properties, types, and applications
2 . Apply visual and mechanical inspections
3 . Employ methods and procedures for electrical tests
4 . Evaluate test results

T. Capacitors and Reactors

1 . Identify properties, types, and applications
2 . Apply visual and mechanical inspections
3 . Employ methods and procedures for electrical tests
4 . Evaluate test results

U. Outdoor Bus Structures

1 . Identify properties, types, and applications
2 . Apply visual and mechanical inspections
3 . Employ methods and procedures for electrical tests
4 . Evaluate test results

*** V. Emergency Systems**

1 . Identify properties, types, and applications
2 . Apply visual and mechanical inspections
3 . Employ methods and procedures for electrical tests
4 . Evaluate test results

III. Component Testing (Continued)

W. Automatic Circuit Reclosers and Line Sectionalizers

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

X. Fiber-Optic Cables

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections

* **Y. Insulating Liquids and Gases**

1. Identify properties, types, and applications
2. Apply sampling procedures
3. Employ methods and procedures in compliance with ASTM
4. Evaluate test results

Z. Fuses

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

IV. Systems and Commissioning — 17% of Overall Score

A. Troubleshooting

1. Investigate power or protective system faults or malfunctions to determine cause and corrective action required

B. SCADA

1. Recognize basic requirements, equipment, and configuration of SCADA/DCS systems

C. Monitoring/DCS Systems

1. Apply procedures for microprocessor-based power monitoring and control systems

D. Functional Testing

1. Employ methods and procedures for system-function tests upon completion of the individual component tests defined, as system conditions allow
2. Apply concepts of functionality for electrical systems

I. Safety — 10 % of Overall Score

A. Risk Assessment

1 . Identify safe work practices with regard to hazards encountered on the job
2 . Identify requirements to create a safe work environment
3 . Determine the location and implications of shock and arc-flash protection boundaries

B. Establishing an Electrically Safe Work Condition

1 . Apply requirements of *NFPA 70E, Article 120: Establishing an Electrically Safe Work Condition*

C. Lockout/Tagout Procedures

1 . Apply OSHA lockout/tagout requirements

D. Personal Protective Equipment

1 . Recognize and assess Arc-Flash Hazard/Risk Categories and Shock Protection Boundaries
2 . Apply correct use, storage, and testing of personal protective equipment

E. Safety Equipment Selection

1 . Identify the safety equipment needs of the project (e.g., hotstick, voltage detectors, insulated tools, fire extinguisher, etc.)

F. Confined Space

1 . Recognize confined space and its hazards
2 . Recognize when a confined space becomes a permit-required confined space along with the associated requirements
3 . Apply OSHA requirements

G. Switching and Temporary Protective Grounding

1 . Select and apply correct voltage detection equipment
2 . Select and apply correct temporary protective grounding equipment
3 . Interpret and apply system switching procedures

H. Incident Energy Analysis

1 . Interpret field-marked equipment labels
2 . Identify hazards where no field-marked labels exist
3 . Demonstrate knowledge of incident energy calculation methods
4 . Demonstrate knowledge of the variables involved in incident energy calculation methods

I. Codes and Standards

1 . Apply standards and regulatory organizations (e.g., OSHA, ANSI, ASTM, IEEE, NETA, NFPA, NEMA, etc.)
2 . Recognize key provisions of NFPA 70 (e.g., Articles 90, 110.16, 110.21, 225.56, 230.95(C), 250, and 310) and 70E (i.e. Chapter 1: Safety-Related Work Practices and Chapter 2: Safety-Related Maintenance Requirements, etc.)
3 . Apply technical requirements of ANSI/NETA Acceptance and Maintenance Testing Standards
4 . Practice compliance with manufacturer's published data

II. Electrical Testing Fundamentals and Theory — 15 % of Overall Score

A. Fundamentals of Electricity

1 . Define and apply terms and concepts from physics, electricity, heat, and chemistry
2 . Recognize and define the standard units used to describe electrical circuits, energy, and power
3 . Identify series and parallel circuits
4 . Recognize the sources and effects of electromagnetic fields
5 . Demonstrate knowledge of dielectric properties of various types of insulations
6 . Demonstrate knowledge of phasing and phase rotation

B. Electrical Calculations

1 . Perform mathematical calculations utilizing basic algebra, geometry, and trigonometry
2 . Apply fundamental electrical laws to simple circuits (e.g., Ohm's law, Kirchhoff's law, etc.)
3 . Apply conversions between units (e.g., microhms to milliohms, horsepower to kilowatts, etc.)

C. AC and DC Circuits

1 . Calculate simple single-loop ac circuits with RLC components
2 . Calculate equivalent resistance of and power consumed by resistive circuits
3 . Calculate equivalent capacitance and inductance
4 . Apply methods for measuring and calculating impedance and power
5 . Calculate variables of complex ac and dc circuits (e.g., voltage drop, current flow, power, etc.)
6 . Calculate phase angle, power factor, and vectors

D. Insulation Testing

1 . Employ methods and procedures for insulation tests and analyze results

E. Resistance Testing

1 . Employ methods and procedures for resistance tests and analyze results (e.g., winding resistance, contact resistance, bolted connections, etc.)

F. Thermographic Survey

1 . Employ methods and procedures for thermographic surveys and analyze results (e.g., emissivity, reflection, delta-T, etc.)

G. Current Testing

1 . Employ methods and procedures for current tests and analyze results (e.g., overcurrent pickup, circuit burden, voltage drop, etc.)

H. System Tests, Analysis, and Operation

1 . Interpret electrical one-line diagrams
2 . Interpret ac and dc schematic diagrams, ac three-line diagrams, and connection and interconnection drawings
3 . Identify electrical symbols and ANSI device numbers
4 . Interpret time-current curves
5 . Recognize essential components of short-circuit and coordination studies (e.g., cable size and length, available protective device settings, raceway type, utility fault contribution, etc.)
6 . Apply data extracted from short-circuit and coordination studies
7 . Recognize cause and effects of power system harmonics

III. Component Testing — 55% of Overall Score

A. Switchgear and Switchboard Assemblies

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

* **B. Transformers**

1. Identify properties, types, and applications
2. Identify properties, types, and applications of auxiliary devices
3. Apply visual and mechanical inspections
4. Employ methods and procedures for electrical tests
5. Evaluate test results

C. Cables

1. Identify properties, types, and applications
2. Identify properties, types, and applications of accessories
3. Apply visual and mechanical inspections
4. Employ methods and procedures for electrical tests
5. Evaluate test results
6. Demonstrate knowledge of cable fault locating

D. Metal-Enclosed Busways

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

E. Switches

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

* **F. Circuit Breakers**

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

III. Component Testing (Continued)

G. Circuit Switchers

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

H. Network Protectors

1. Identify properties, types, and applications of protection and control
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

* **I. Protective Relays**

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2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

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2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

L. Regulating Apparatus

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results

M. Grounding Systems

1. Identify properties, types, and applications
2. Apply visual and mechanical inspections
3. Employ methods and procedures for electrical tests
4. Evaluate test results
5. Employ methods of enhancing effectiveness of grounding systems

III. Component Testing (Continued)

N. Ground-Fault Protection Systems

1 . Identify properties, types, and applications
2 . Apply visual and mechanical inspections
3 . Employ methods and procedures for electrical tests
4 . Evaluate test results

* **O. Rotating Machinery**

1 . Identify properties, types, and applications
2 . Apply visual and mechanical inspections
3 . Employ methods and procedures for electrical tests
4 . Evaluate test results

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T. Capacitors and Reactors

1 . Identify properties, types, and applications
2 . Apply visual and mechanical inspections
3 . Employ methods and procedures for electrical tests
4 . Evaluate test results

III. Component Testing (Continued)

U. Outdoor Bus Structures

1 . Identify properties, types, and applications
2 . Apply visual and mechanical inspections
3 . Employ methods and procedures for electrical tests
4 . Evaluate test results

* **V. Emergency Systems**

1 . Identify properties, types, and applications
2 . Apply visual and mechanical inspections
3 . Employ methods and procedures for electrical tests
4 . Evaluate test results

W. Automatic Circuit Reclosers and Line Sectionalizers

1 . Identify properties, types, and applications
2 . Apply visual and mechanical inspections
3 . Employ methods and procedures for electrical tests
4 . Evaluate test results

X. Fiber-Optic Cables

1 . Identify properties, types, and applications
2 . Apply visual and mechanical inspections
3 . Employ methods and procedures for optical tests
4 . Evaluate test results

* **Y. Insulating Liquids and Gases**

1 . Identify properties, types, and applications
2 . Apply sampling procedures
3 . Employ methods and procedures in compliance with ASTM
4 . Evaluate test results

Z. Fuses

1 . Identify properties, types, and applications
2 . Apply visual and mechanical inspections
3 . Employ methods and procedures for electrical tests
4 . Evaluate test results

IV. Systems and Commissioning — 20% of Overall Score

A. Troubleshooting

1. Investigate power or protective system faults or malfunctions to determine cause and corrective action required

B. SCADA

1. Recognize basic requirements, equipment, and configuration of SCADA/DCS systems

C. Monitoring/DCS Systems

1. Apply procedures for microprocessor-based power monitoring and control systems

D. Functional Testing

1. Employ methods and procedures for system-function tests upon completion of the individual component tests defined, as system conditions allow
2. Apply concepts of functionality for electrical systems

The NETA Exam Committee recommends that Technicians review and study following documents when preparing for the NETA Level 2 Exam.

Safety - Intermediate Safety

Occupational Safety and Health Standard**s**

- 1910.25 - *Walking-Working Surfaces, Portable Wood Ladders*
- 1910.134 - *Personal Protective Equipment, Respiratory Protection*
- 1910.146 - *General Environmental Controls, Permit-Required Confined Spaces*
- 1910.147 - *General Environmental Controls, The Control of Hazardous Energy (lockout/tagout).*
- 1910.155 - *Fire Protection*
- 1910.333 - *Electrical, Selection and Use of Work Practices*
- 1910.334 - *Electrical, Use of Equipment*

Safety - Confined Space

Occupational Safety and Health Standards

- 1910.146 - *General Environmental Controls, Permit-Required Confined Spaces*

Safety - Electrical Personal Protective Equipment

ASTM International

- D120 - *Standard Specification for Rubber Insulating Gloves*

Occupational Safety and Health Standards (OSHA)

- 1910.134 - *Personal Protective Equipment, Respiratory Protection*
- 1910.137 - *Personal Protective Equipment, Electrical Protective Devices.*
- 1910.138 - *Personal Protective Equipment, Hand Protection*
- 1910.269 - *Special Industries, Electric Power Generation, Transmission, and Distribution.*
- 1910.333 - *Electrical, Selection and Use of Work Practices*

Safety - Switching and Grounding

ASTM International

- F855 - *Standard Specifications for Temporary Protective Grounds to Be Used on De-energized Electric Power Lines and Equipment*

Occupational Safety and Health Standards (OSHA)

- 1910.333 - *Electrical, Selection and Use of Work Practices*

Communications - Read and Record Data

IEEE

- *The Authoritative Dictionary of IEEE Standards Terms*

Tools and Equipment - Basic Test Equipment

IEEE

- 43 - *IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery*

System Analysis and Operation - Basic Drawings and Diagrams

IEEE

- C37.2 - *Electrical Power System Device Function Numbers and Contact Designations*

American Codes and Standards - Standards-Making Organizations

National Fire Protection Association (NFPA)

- NFPA 70: National Electrical Code, Article 90 - *Introduction*
- NFPA 70: National Electrical Code, Article 384 - *Strut-Type Channel Raceway*

American Codes and Standards – ANSI/NETA Standards
InterNational Electrical Testing Association (NETA)

- ANSI/NETA MTS *Standard for Maintenance Testing Specifications for Electrical Power Equipment and Systems*
- ANSI/NETA ATS *Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems*
- ANSI/NETA ECS *Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems*

Wires, Cables, Buses - Properties and Types
Insulated Cable Engineers Association (ICEA)

- Standards

Insulating Liquid and Gases - Properties, Types and Sampling Procedures
IEEE

- C57.111 - *IEEE Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers*

The NETA Exam Committee recommends that Technicians review and study the following documents, in addition to those listed in previous sections, when studying for the Level 3 NETA Exam.

Communications - Prep of Technical Reports

IEEE

- The Authoritative Dictionary of IEEE Standards Terms

InterNational Electrical Testing Association (NETA)

- *Acceptance Testing Specifications, Appendix A - Definitions*
- *Maintenance Testing Specifications, Appendix A - Definitions*

Tools and Equipment (Selection)

- See any good article on measurement of resistance with equipment such as Kelvin and Wheatstone bridges.
- Review the instruction manuals for insulation resistance test sets (such as Megger's).

Electrical & Physical Theory - Intermediate Electrical Terms and Definitions

IEEE

- C57.105 - *IEEE Guide for Application of Transformer Connections in Three-Phase Distribution Systems*

McGraw-Hill Companies (publisher)

- *The American Electrician's Handbook* by Croft & Summers - Division 9
- *Standard Handbook for Electrical Engineers* by D. Fink and Beaty - Section 16

American Codes and Standards - Knowledge of Codes and Standards

ASTM International

- D3487 - *Standard Specification for Mineral Insulating Oil Used in Electrical Apparatus*

National Fire Protection Association (NFPA)

- *NFPA 70: National Electrical Code, Article 230 - Services*
- *NFPA 70: National Electrical Code, Article 250 - Grounding and Bonding*
- *NFPA 70: National Electrical Code, Article 700 - Emergency Systems*
- *NFPA 70: National Electrical Code, Table 110.26A - Working Spaces*

General Test Equipment - Insulation Tests

- *A Stitch in Time* - published by Biddle Instruments (Now Megger)

IEEE

- 43 - *IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery*

InterNational Electrical Testing Association (NETA)

- ANSI/NETA MTS *Standard for Maintenance Testing Specifications for Electrical Power Equipment and Systems*
- ANSI/NETA ATS *Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems*
- ANSI/NETA ECS *Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems*

General Test Equipment - Thermographic Survey

See web address for Arizona State University:
http://emma.la.asu.edu/MARS_SURVEYOR/MGSTES/TES_emissivity.html

General Test Equipment - Ratio and Relative Polarity

IEEE

- 0081P - *IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System Part I: Normal Measurements*
- C57.13.1 - *IEEE Guide for Field Testing of Relaying Current Transformers*

General Test Equipment - Power-Factor/Dissipation-Factor Testing

- Refer to the instruction manual of a quality power factor test set such as Doble or Megger.
- Refer to the instruction manual of a dissipation-factor test set such as Megger.

IEEE

- *The Authoritative Dictionary of IEEE Standards Terms*

InterNational Electrical Testing Association (NETA)

- *Acceptance Testing Specifications*
- *Acceptance Testing Specifications*

Transformers: Power Transformers - General

Doble Engineering

- *Bushing Field-Test Guide*

IEEE

- C57.19.03 - *IEEE Standard Requirements, Terminology, and Test Code for Bushings for DC Applications*

Wires, Cables, Buses - Inspection and Maintenance

IEEE

- 141, Clause 12.2.4.1. - *IEEE Recommended Practice for Electrical Power Distribution for Industrial Plants (IEEE Red Book)*

Circuit Breakers and Circuit Switches - Inspection and Maintenance

IEEE

- C37.06, Table 8 - *AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis-Preferred Ratings and Related Required Capabilities*
- C37.13 - *Standard for Definite Purpose Switching Devices for Use in Metal Enclosed Low Voltage Power Circuit Breaker Switchgear*
- C37.95 - *Guides and Standards for Circuit Breakers, Switchgear, Relays, Substations, and Fuses*
- C37.100 - *Standard Definitions for Power Switchgear*

Circuit Breakers and Circuit Switches: Testing (A)

- See any of the manufacturer's application guides for ground fault protection.

Electrical Protective Devices - Low-Voltage Breakers

- Read the instruction manuals of various manufacturers and from various vintage trip units.
- Review the instruction manuals for modern microprocessor-based trip units like the Cutler Hammer Digitrip.

Electrical Protective Devices - Current Relays (A)

- See the appropriate instruction manuals.

Electrical Protective Devices - Differential Relays

- See any transformer differential relay instruction manual.

Grounding Systems - Types, Application, and Testing (A)
IEEE
- 0081P - *IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System Part I: Normal Measurements*
- 142 - *IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE Green Book)*
- 43 - *IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery*

Rotating Machinery - Types, Inspection, and Testing
See battery manufacturer recommendations

InterNational Electrical Testing Association (NETA)
- ANSI/NETA MTS *Standard for Maintenance Testing Specifications for Electrical Power Equipment and Systems*
- ANSI/NETA ATS *Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems*
- ANSI/NETA ECS *Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems*

IEEE
- C37.96 - *IEEE Guide for AC Motor Protection*

Direct Current Systems - Servicing and Testing
IEEE
- *450 - IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications*,

InterNational Electrical Testing Association (NETA)
- *Acceptance Testing Specifications*

Capacitor, Reactor, Surge Protection - Use, Application, and Testing
IEEE
- C57.16 - *IEEE Standard Requirements, Terminology, and Test Code for Dry-Type Air-Core Series-Connected Reactors*
- C62.33 - *IEEE Standard Test Specifications for Varistor Surge-Protective Devices*

Insulating Liquid and Gases - Tests and Evaluation
IEEE
- C57.104 - IEEE *Guide for the Interpretation of Gases Generated in Oil-Immersed Transformers*
- C57.106 - IEEE *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*
- C57.111 - IEEE *Guide for Acceptance of Silicone Insulating Fluid and Its Maintenance in Transformers*
- C57.121 **-** *IEEE Guide for Acceptance and Maintenance of Less-Flammable Hydrocarbon Fluid in Transformers*

ASTM International
- D877 - *Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes*
- D923 - *Standard Practices for Sampling Electrical Insulating Liquids*
- D974 - *Standard Test Method for Acid and Base Number by Color-Indicator Titration*
- D3487 - *Standard Specification for Mineral Insulating Oil Used in Electrical Apparatus*

Environmental Protection Agency
- *Code of Federal Regulations (40 CFR), 761 - Protection of Environment*

The NETA Exam Committee recommends that Technicians review and study the following documents, in addition to those listed in previous sections, when studying for the Level 4 NETA Exam.

American Codes and Standards - Knowledge of Codes and Standards
National Fire Protection Association (NFPA)

- *NFPA 70: National Electrical Code, Article 215 - Feeders*

General Test Equipment
InterNational Electrical Testing Association (NETA)

- ANSI/NETA MTS *Standard for Maintenance Testing Specifications for Electrical Power Equipment and Systems*
- ANSI/NETA ATS *Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems*
- ANSI/NETA ECS *Standard for Electrical Commissioning Specifications for Electrical Power Equipment and Systems*

Grounds and Grounding Systems
IEEE

- 142 - *IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE Green Book)*

NETA World Journal Tech Quizzes

Disclaimer

The following pages contain reproductions of the Tech Quizzes that have appeared in past issues of NETA World Journal, NETA's quarterly technical publication.

While these quizzes were written by subject matter experts and reviewed by NETA's technical editors, these quizzes have not undergone the same process as NETA's certification exams. Tech Quizzes are not intended to replicate the experience of taking the NETA Certification Exams and should not be considered equivalent to the NETA Certification Exams.

Since these quizzes are not updated after they are published in NETA World Journal, it is important for technicians studying this material to refer to the most recent edition of industry codes and standards referenced to assure that the correct answers listed are still accurate. It is possible that references have been updated, and that values and procedures have changed since these quizzes were published.

The intent of providing these quizzes in one location is to allow individuals preparing for the NETA Certification Exams access relevant concepts that may appear on the certification exams.

Quiz #75

TECH Quiz

General Electrical Safety

by Jim White
Shermco Industries

I have no idea how to create a quiz about educating the technician, so I'll cover some general topics within electrical safety.

1. What is the full-load current and available short-circuit current for a 2,000 kVA, three-phase transformer with a 208-volt secondary and 5 percent impedance?
   A. Full-load current is 2,776 A; short-circuit current is 55,520 A
   B. Full-load current is 9,600 A; short-circuit current is 88,000 A
   C. Full-load current is 5,552 A; short-circuit current is 111,104 A
   D. Full-load current is 2,406 A; short-circuit current is 48,120 A

2. Define the Limited Approach Boundary.
   A. An approach limit at a distance from an exposed live part within which a shock hazard exists. Unqualified workers and anything conductive that they are carrying must stay beyond this boundary.
   B. The closest a qualified worker can get to exposed, energized conductors or parts if he/she is wearing rubber insulating PPE, using insulated tools, or has energized parts guarded for the voltage.
   C. The same as making contact. No part of the body can cross; only hands in rubber insulating PPE rated for the voltage, voltage rated tools, or live-line tools.
   D. The distance from exposed, energized conductors that would result in a 2nd degree burn to unprotected skin.

3. Define the Flash Protection Boundary.
   A. The closest a qualified worker can be to exposed, energized conductors or parts without wearing rubber insulating PPE.
   B. The closest an unqualified worker can get to exposed, energized conductors or parts.
   C. The distance from exposed, energized parts that would result in the onset of a 2nd degree burn to unprotected skin.
   D. The distance from exposed, energized conductors or parts that would result in a 3rd degree burn to unprotected skin.

4. Once placed into service, rubber gloves must be cleaned, inspected and electrically tested every ____________ months.
   A. 2
   B. 4
   C. 6
   D. 12

5. When circuits or equipment are placed in an Electrically-Safe Work Condition, they are disconnected, locked-out and tagged-out, and _____
   A. verified by a supervisor.
   B. tested to insure the absence of voltage, and grounded, if determined necessary.
   C. barricaded so unqualified persons cannot approach.
   D. nothing else, (LOTO is all OSHA requires).

Answers

1. Transformer full load current can be found on the nameplate. If calculations are necessary, say for sizing personal protective grounds or for determining the arc flash boundary, they can be using the following formula:

$$I_{FL} + \frac{kVA}{\sqrt{3}\ X\ kV_{L\text{-}L}} = \frac{2000}{1.732\ X\ 0.208} = 5552\ \text{Amperes}$$

To determine the maximum available fault current from a transformer, divide 100 by the transformer impedance, in percent, and multiply that result by the full load current.

$$I_{Fault} = I_{FL}\ X\ \frac{100}{\%\ Z} = 5552\ X\ \frac{100}{5} = 111{,}104\ \text{Amperes}$$

2. Answer A is correct. The first sentence is verbatim from the NFPA 70E-2004.

3. Answer C is correct. This is equivalent to 1.2 cal/cm^2 incident energy exposure. Stay outside this distance if you are not wearing arc flash protective PPE.

4. C is correct. Tested rubber gloves are a main protection for shock hazard. Take care of them.

5. B is correct. NFPA 70E-2004 defines Electrically-Safe Work Condition. OSHA doesn't use those words, but calls for the same steps to be taken. Lock-out/Tag-out, alone, is not adequate for electrical systems. Backfeed and induced potential make our lives much more difficult. While grounding may not be strictly required by NFPA 70E, when properly done, it can save lives.

Tech Quiz #76

Acceptance Testing & Test Equipment

by Jim White
Shermco Industries

These are general questions regarding testing and test equipment. Answers can be found in the ATS-03 if you get stumped.

1. Why do manufacturers of vacuum circuit breakers recommend using ac instead of dc voltage to perform the vacuum bottle integrity test?
   A. Most manufacturers sell a vacuum bottle integrity test set.
   B. A dc voltage does not properly stress a vacuum bottle used in an ac circuit.
   C. Vacuum bottles cannot be used in a dc system; therefore they cannot be tested using dc.
   D. Some dc high potential test sets are not properly filtered resulting in a voltage spike that can damage the bottle.

2. When performing an instantaneous pickup test on a molded-case circuit breaker with an adjustable trip, what is the pickup tolerance?
   A. ± 10%
   B. ± 25%
   C. + 30%; -40%
   D. +40%; -30%

3. What is the recommended acceptance test voltage for a 5 kV cable with a 133 percent insulation level?
   A. 18 kV ac
   B. 23 kV ac
   C. 35 kV ac
   D. 44 kV ac

4. What is the recommended insulation resistance for a 4,160V dry-type transformer?
   A. 100 MΩ
   B. 1,000 MΩ
   C. 5,000 MΩ
   D. 10,000 MΩ

5. What is the recommended maximum insulation power factor on new, liquid insulated power transformers?
   A. 0.25%
   B. 0.5%
   C. 1%
   D. 2%

Answers

1. Answer D is correct. Many dc high potential test sets do not fully filter their outputs and a voltage spike can be created that is three times the value read on the test set's voltmeter. Even though it is a momentary spike, it can cause bottle failure. Check with the test set manufacturer to be certain that the test set used has full-wave rectification before using it on a vacuum bottle.

2. Answer D is also correct on this one. This comes from NEMA AB-4 and is a much wider tolerance than many technicians would expect. The best information to use is directly from the manufacturer's time-current characteristic curves.

3. B. If the cable has 100 percent insulation level the recommended test voltage would be 18 kV ac.

4. Answer C. If this were a liquid-filled transformer the insulation resistance would be 1,000 MΩ.

5. New medium-voltage liquid insulated power transformers should have an insulation power factor no greater than 0.5 percent. The higher the rated voltage of the winding, the lower the expected insulation power factor should be.

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Tech Quiz #77

Medium-Voltage Cable Analysis

by Jim White
Shermco Industries

These are general questions regarding testing and test equipment. Answers can be found in the NETA Acceptance Testing Specification ATS-03 if you get stumped.

1. List four test methods for medium-voltage power cables?
   A. ________________________
   B. ________________________
   C. ________________________
   D. ________________________

2. A dc overpotential test for in-service testing (if performed incorrectly) could cause damage to what type of cables?
   A. EPR
   B. XLPE
   C. Oil-insulated
   D. It is safe for all cables

3. What is the recommended acceptance test voltage for a dc overpotential test on a 15 kV cable with a 133 percent insulation level?
   A. 18 kV dc
   B. 23 kV dc
   C. 35 kV dc
   D. 44 kV dc

4. What could cause damage to cables when tested by a dc high potential test set?
   A. DC voltage causes electrons to become unstable, forcing them through the insulation.
   B. Negative ionization of insulation
   C. Flashover either during testing or when grounding at the end of the test
   D. None of the above

5. What is the minimum discharge time recommended at the end of cable testing?
   A. 3 minutes
   B. 5 minutes
   C. Twice the test period
   D. Four times the test period

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Answers

1. DC overpotential, very low frequency (VLF), partial discharge (PD) and insulation power factor (ac)

2. Answer B. Cross-linked polyethylene cable could be damaged if incorrectly tested using the dc overpotential test method.

3. Answer B. If the cable has 100 percent insulation level, the recommended test voltage is 18 kV ac.

4. Answer C. Tests under controlled conditions have shown that flashovers when grounding cables at the end of the tests without using a discharge resistor can cause damage to type PE and XLPE cables. Using a discharge resistor, thereby limiting the discharge current to ground, does not typically cause damage to the cable insulation system.

5. Answer D. Four times the amount of time the cable was under test using a discharge resistor. See the answer to question 4 above.

Tech Quiz #78

Protective Relaying

by Jim White
Shermco Industries

Protective relays perform a critical function in power system protection. Below are some questions to test your general knowledge of these devices.

1. Identify the device number with its function:
   A. 59 ________________________
   B. 27 ________________________
   C. 50/51 ______________________
   D. 87T ________________________

2. Reverse power relays operate under what conditions?
   A. Reversal of voltage polarity and phase angle falling in the operate zone.
   B. Reversal of current flow and phase angle falling in the operate zone.
   C. Both current and voltage must reverse polarity
   D. This relay is not polarity sensitive

3. Electromechanical phase directional overcurrent and power relays typically use what quantity to polarize the relay?
   A. Voltage
   B. Residual current
   C. Neutral current
   D. Phase current

4. What conditions must a 67 device see in order to close its contacts?
   A. Overcurrent
   B. Overvoltage
   C. Overcurrent in a predetermined direction
   D. Overcurrent and undervoltage

5. An overcurrent relay is connected to a 200:5 CT with a minimum pickup of 4 amperes. What primary current will cause the relay to respond?
   A. 200 A B. 180 A
   C. 160 A D. 120 A

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Answers

1. *A. 59 Overvoltage B. 27 Undervoltage C. 50/51 Instantaneous overcurrent / time overcurrent D. 87T Transformer differential*
2. *Typically, reverse power relays look for a reversal of current flow, much like directional overcurrent relays do. The phase angle between voltage and current must fall in the operate zone which is frequently 90 degrees either side of the maximum torque angle. However, unlike directional overcurrent relays, reverse power relays do not use a directional unit to torque control an overcurrent unit's operation. The directional element operates the timing and tripping functions directly.*
3. *Phase directional and power relays usually use voltage as a polarizing quantity. In order for the relay to "see" what direction the current is flowing, it must have a stable reference point which the voltage provides.*
4. *A 67 device is a directional overcurrent relay and must see both an overcurrent condition and current flow in a predetermined direction. The directional contacts typically split the shading coils on the overcurrent relay controlling its operation.*
5. *160 amperes is the correct answer. A 200:5 CT has a 40:1 ratio. Multiply the CT ratio by the relay's minimum pickup setting.*

Tech Quiz #79

Fuses

by Jim White
Shermco Industries

1. Which of the following fuse types is not current-limiting?
   A. Fuse class J
   B. Fuse class RK-5
   C. Fuse class H
   D. They are all current-limiting fuses

2. Which of the following fuse types is not listed by UL for low-voltage fuses?
   A. Fuse class RK
   B. Fuse class L
   C. Fuse class E
   D. Fuse class K5

3. The letter class of a fuse denotes what characteristic?
   A. The maximum amount of time required to melt at a specified current overload
   B. The speed of operation during a short-circuit condition
   C. The dimensions of the fuse, including diameter and length
   D. None of the above

4. An R-rated fuse is designed to protect
   A. Feeder circuits
   B. Transformers
   C. Motors
   D. Branch circuits

5. The photo below shows a medium-voltage expulsion fuse in three stages of operation. Which is the fuse filled to aid arc-quenching?
   A. A very fine silica-based mixture that includes sodium, beryllium, and oxides
   B. Boric acid
   C. Sand and nonconductive ash
   D. Most manufacturers keep this as proprietary information

Photo Courtesy Cooper-Bussmann®

Answers
1. Class H fuses are renewable, general purpose fuses and are not current-limiting. All the other types listed are current-limiting.
2. Class E fuses are used for medium-voltage applications only.
3. The letter classification of a fuse denotes the maximum amount of time required for it to melt at specified overloads.
4. R-rated fuses are used for motor protection.
5. Boric acid, as in Twenty Mule Team Borax™

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Low-Voltage Power Circuit Breakers

by Jim White
Shermco Industries

Low-voltage power circuit breakers are virtually everywhere. These devices are a critical part of the protective system but are often overlooked and much abused. Even though they are so critical, many equipment owners know almost nothing about them. How much do you know?

1. List the positions a circuit breaker goes through when being racked out:
   A. ______________________
   B. ______________________
   C. ______________________
   D. ______________________

2. List four overcurrent functions typically found on solid-state or digital low-voltage power circuit breaker overcurrent trip devices?
   A. ______________________
   B. ______________________
   C. ______________________
   D. ______________________

3. Arcing contacts perform what function?
   A. Ensures the circuit is made solidly
   B. Prevents rebound of the main contacts
   C. Prevents damage to the main contacts
   D. None of the above

4. Which of the following is not a standard dc power source voltage?
   A. 48 volts
   B. 96 volts
   C. 125 volts
   D. 250 volts

5. List the standard timing test values for the following overcurrent device tests?
   A. Long-Time Delay ____________
   B. Short-Time Delay ____________
   C. Ground Fault ______________
   D. Instantaneous ______________

Answers

1. A. Connected, B. Test, C. Disconnected, D. Withdrawn

2. A. Long-time delay, B. Short-time delay, C. Ground fault, D. Instantaneous

3. C. Arcing contacts are made of a harder alloy than the mains and are designed to carry the arc, thereby saving the mains from damage when opening or closing.

4. B. 48, 125 and 250 volts dc are common and standard control voltages.

5. A. LTD – 3 times LTD pickup, B. STD – 1.5 times STD pickup, C. GF – 1.5 times GF pickup, D. Inst – Minimum pickup only. Typically no timing test is

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Fall 2007

Fall 2007
Electrical Safety

1. Define the Flash Protection Boundary.
   a. The closest a qualified worker can be to exposed, energized conductors or parts without wearing rubber insulating PPE.
   b. The closest an unqualified worker can get to exposed, energized conductors or parts.
   c. The distance from exposed, energized parts that would result in the onset of a second degree burn.
   d. The distance from exposed, energized conductors or parts that would result in a third degree burn.

2. You are about to begin work on an energized section of switchgear. The Flash Protection Boundary is 27 inches, the Limited Approach Boundary is 42 inches, the Restricted Approach Boundary is 12 inches and the Prohibited Approach Boundary is 1 inch. Where do you set the boundary for the Safe Work Zone?
   a. Limited Approach Boundary
   b. Restricted Approach Boundary
   c. Prohibited Approach Boundary
   d. Flash Protection Boundary

3. What is the Limited Approach Boundary for a 4,160-volt system?
   a. 26 inches
   b. 38 inches
   c. 42 inches
   d. 60 inches

4. When electrical systems or equipment are placed in an electrically-safe work condition, they are locked out, tagged out and what else?
   a. Checked for the absence of voltage and grounded, if necessary.
   b. A supervisor must check and make certain it is de-energized.
   c. Nothing. OSHA says LOTO is all that's needed.
   d. Rubber insulating shielding is placed so that no contact can be made with an energized part.

5. What is the Restricted Approach Boundary for a 480-volt system?
   a. 1 inch
   b. 12 inches
   c. 26 inches
   d. 42 inches

Fall 2007 Answers

1. **C.** The on-set of a second degree burn would possibly result in blisters similar to a severe sun burn. This type of burn occurs when1.2 cal/cm^2 of heat energy impacts the surface of the body Note that the procedures required in NFPA 70E are not intended to prevent injury, but to make an injury survivable.

2. **A.** The Safe Work Zone is established as either the Flash Protection Boundary or the Limited Approach Boundary, whichever is farthest out. Thus, in this example it is the Limited Approach Boundary.

3. **D.** The Limited Approach Boundary for a 4160 volt fixed circuit part is 60 inches (5 feet, 0 inches.)

4. **A.** Lockout/tagout does not go far enough to protect a person working on electrical systems. Often, circuits and components remain energized or become re-energized, even though they are believed to be locked out. They must be proven de-energized and preferably grounded.

5. **B.** Typically, this means a qualified electrical worker would have to put on rubber insulating gloves rated for the voltage to cross this boundary.

Winter 2007
Power Transformers

1. When performing an insulation power factor test on a 5 MVA, 34.5 kV:480 V transformer, the measured insulation resistance was 0.75 percent. Is this an acceptable reading on a new power transformer of this size and why?
   a. Yes. New power transformers can have up to a 1.0 percent insulation power factor.
   b. Yes. It is a little high, but is not so high as to be of concern.
   c. No. The maximum insulation power factor should be less than 0.5 percent.
   d. No. The maximum insulation power factor should be less than 0.75 percent.

2. You are testing a 50 MVA power transformer. The ambient temperature is 800F, and the oil temperature gauge reads 850C. The nameplate lists the maximum temperature rise as 650C. Is the transformer temperature too high?
   a. Yes
   b. No

3. What is the maximum deviation allowed on a TTR test when compared to nameplate ratio?
   a. 2%
   b. 1.5%
   c. 1%
   d. 0.5%

4. When operating a no-load tap-changer:
   a. Open the secondary (load side) when changing taps.
   b. Disconnect any loads. The secondary can stay energized.
   c. De-energize the transformer completely before changing taps.
   d. The taps can be changed while under load.

5. You have a delta-connected transformer bank, and one transformer is taken out of service. What percentage of load can the remaining two transformers carry when connected open-delta?
   a. 75%
   b. 66%
   c. 58%
   d. 37%

Winter 2007 Answers

1. **C.** The maximum allowable insulation power factor is 0.5 percent on new power transformers.

2. **B.** No. To determine if the transformer is operating at too high a temperature, the temperature rise must be calculated. Temperature rise is the ambient temperature subtracted from the top oil temperature (indicted on the temperature gauge). In our example the top oil temperature is 85°C and the ambient is 80°F or about 27°C:

   85°C - 27°C = 58°C

   The maximum allowable temperature rise is 65°C, which is greater than the calculated temperature rise.

3. **D.** The maximum allowable deviation from nameplate ratio is 0.5 percent for a turns ratio test.

4. **C.** No-load or off-load tap-changers, as they are sometimes called, can only be operated when the transformer is completely de-energized.

5. **C.** Transformers operated open-delta can only be loaded to 57.7 percent of the full three transformer bank load.

Spring 2008
Motors

1. You perform a polarization index on a generator winding. The polarization index test result is 1.1. How would you evaluate its condition?
   a. Poor
   b. Fair
   c. Good
   d. Excellent

2. A motor has a nameplate rating of 460 volts and is connected to a 230 volt source. What torque will the motor produce in percent of rated torque?
   a. 25%
   b. 100%
   c. 75%
   d. 50%

3. An induction motor has 40 kVA input power, a power factor of 82 percent, and an efficiency of 92 percent. What is its horsepower?
   a. 30.2 HP
   b. 40.5 HP
   c. 53.6 HP
   d. 44.4 HP

4. The ANSI/NETA MTS-07 lists several tests for ac motors. Which of the following tests is not one of the tests listed?
   a. Insulation resistance
   b. Insulation power factor or dissipation factor
   c. ac high potential
   d. Surge comparison

5. One horsepower is equivalent to which of the following?
   a. 35% power factor
   b. 746 watts
   c. one kilowatt
   d. 1.732 voltamperes

Spring 2008 Answers

1. **The answer is A.** A P.I. of 1.1 is a poor value for dry insulation. Good insulation should have a P.I. of 2.0 or higher.

2. **A is correct again.** 25% torque is all you'll get. Torque is related to the square of the voltage difference: 230/460 = 0.5; 0.52 = 0.25 = 25%.

3. **B is correct, 40.5 HP.** 40 kVA x 0.82 power factor gives the real input power. Multiply the input power by the efficiency, 0.92, to get output power. Now divide the output kilowatts by 0.746 kW/HP to get the output horsepower, 40.5.

4. **C is the correct answer.**

5. **B.** In case you didn't read the answer to question 3, one horsepower is equal to 746 watts.

Summer 2008
Batteries

1. When should an equalize charge be given to a lead-acid wet cell battery bank?
    a. After about 10 deep discharge/charge cycles
    b. When sulfating of the plates occurs
    c. When the electrolyte stratifies with higher concentration of acid at the bottom
    d. When there is a significant difference in the individual cell voltages
    e. All of the above

2. Each cell in a lead-acid battery produces how much voltage (approximately)?
    a. 1 volt
    b. 2 volts
    c. 10 volts
    d. 20 volts

3. Four twelve-volt, 150 ampere-hour batteries are connected in series to form a bank. What is the bank rating?
    a. 12 volts, 600 ampere-hours
    b. 48 volts, 150 ampere-hours
    c. 8 volts, 600 ampere-hours
    d. 12 volts, 150 ampere-hours

4. What is the cell voltage deviation from the bank average that indicates an equalizing charge is needed?
    a. 1 volt
    b. 0.5 volt
    c. 0.05 volt
    d. 0.005 volt

5. List 4 common maintenance items performed on a periodic basis on battery banks:
    a. ________________________________
    b. ________________________________
    c. ________________________________
    d. ________________________________

Summer 2008 Answers

1. **E.** All of the above. Batteries should not be given an equalize charge until it is needed, usually after a heavy discharge. Frequent equalizing shortens battery life, increases water usage, and increases the overall cost. Batteries in float service with infrequent discharge cycles may sulfate, requiring an equalize charge to remove the sulfur from the lead plates.

2. **B.** Each battery cell produces only about two volts. The typical 12-volt auto battery has six cells.

3. **B.** 48 volts, 150 ampere-hours. Connecting in series increases the voltage by the sum of the cells, but the current remains the same. A parallel connection would increase the current, not the voltage.

4. **C.** 0.05 volt from the average of all the cells according to NETA ATS and MTS.

5. Possible answers:
    a. Specific gravity of pilot cells
    b. Volts per cell of pilot cells
    c. Battery charger output voltage
    d. Electrolyte level of pilot cells
    e. Temperature measurement
    f. Verify all alarms are functional
    g. Intercell connectors are tight
    h. Internal impedance of pilot cells
    i. Thermographic survey

Fall 2008
Grounding

1. According to ANSI/NETA MTS-07, how often should ground systems be electrically tested?
    a. Once a year
    b. Once every two years
    c. Once every three years
    d. Only every four years

2. The maximum ground resistance of an industrial facility should be
    a. 1 ohm
    b. 2 ohms
    c. 4 ohms
    d. 5 ohms

3. The maximum ground resistance of a generating station shoul be
    a. 1 ohm
    b. 2 ohms
    c. 4 ohms
    d. 5 ohms

4. What IEEE standard is used as a reference for fall-of-potential testing?
    a. Standard 71
    b. Standard 81
    c. Standard 99
    d. Standard 101

5. For a ground system with fairly uniform soil and test electrodes driven at sufficient spacing relative to the size of that ground system, what distance from the tested electrode should the potential electrode be placed to measure the theoretically correct ground resistance when performing a fall-of-potential test?
    a. 20 feet.
    b. 100 feet.
    c. 62% of the distance between the current electrode and the tested electrode
    d. 57.7% of the distance between the current electrode and the tested electrode

Fall 2008 Answers

1. **B.** With average reliability and average condition, the table in Appendix B indicates a test interval of 24 months. This time recommendation changes according to criticality and condition.

2. **D.** Section 7.13 gives a maximum of 5 ohms for an industrial facility. In grounding, though, the lower the better.

3. **A.** Section 7.13 shows 1 ohm maximum for generating and transmission facilities.

4. **B.** The ANSI/IEEE Standard 81, “IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System” is the reference.

5. **C.** If the soil is fairly homogeneous in content, the distance the voltage electrode, P2, is driven is usually 62%. Often that may not provide the true resistance, though. The best procedure is to drive P2 in several locations, in line with the tested electrode, C1, and the test current electrode, C2. Obtain test data for P2 positions beginning about 50% of the distance from C1 to C2 until about 70% of that distance. Plot the resulting earth resistances relative to the P2 distance from C1. Where the plotted values level off is the true earth resistance. If the plotted values do not level off, that indicates more distance is needed between C1 and C2 and the tests need to be run again.

Winter 2008
Power Electronics

1. A poultry plant had to replace bearings in one of their motors about three times a year. The application is a variable-speed drive (VFD) for an oven fan. The belt tension was always found to be set properly. Mechanically, everything was in proper order. What was happening and how could it be solved?

2. A maintenance technician added several more 120 Vac outputs on a PLC for a machine expansion. Rather than adding a larger control power transformer to handle the new I/O, he pulled a single wire carrying 120 Vac from an adjacent panel to feed the new outputs. Over time the neutral wire in the existing PLC control panel burned up. Why?

3. A dc drive had failed and was too costly to repair, so it was replaced with a new digital drive. Several days went by and the customer noticed that the motor oscillated in speed and drew slightly more current than it used to. Why would a new drive cause this?

4. A newspaper in East Texas decided to upgrade its printing press with two new digital dc drives and change all control relay logic with a PLC. The PLC used the same 120 Vac power that fed their computer server room. Every Tuesday and Thursday evening between 9:00 PM and 10:30 PM the PLC would lose its memory and program. The servers, however, would be fine. What was the problem?

Winter 2008 Answers

1. Bearings in motors that are powered by VFDs sometimes fail due to common mode shaft voltage causing current to pass through the bearings. Because pulse width modulated (PWM) voltages do not sum instantaneously to zero with respect to ground, there is potential for CM voltage to build up on the shaft causing current flow through motor bearings. The air gap and grease in the bearing act like a dielectric. When the shaft voltage exceeds the dielectric strength of the bearing lubricant, an arc occurs. This arcing causes pitting in the bearing race and the rolling elements thus leading to premature failure. One possible solution is to reduce the “carrier frequency” of the PWM. Also, make sure that the motor is VFD compatible. (See NEMA MG-1, Section IV, Part 31.)

2. Although both new and old I/Os were supplied by 120 Vac potential, the sources were not out of phase from one another, causing the existing neutral to carry the current for both the existing and new outputs. If the two hot wires measure zero volts between them, then they are in phase with one another and the neutral has to carry the current for both hot conductors. If the two hot conductors measure 240 Vac between them, then the currents cancel each other and only the difference flows through the neutral.

3. A3. If you are thinking drive to motor tuning, that would be an obvious place to start. However, if this fails to correct the problem, check the polarity of the motor armature conductors between the drive and motor. On all stabilized shunt-wound dc motors the series field lead (labeled S2) must be connected to the negative output of the drive and the shunt field wire (labeled F2 or F4 depending on field wiring) must be connected to the negative side of the field supply. If the rotation of the motor needs to be changed, then swap either A1 or A2 leads with the S1 lead. When stabilized shunt-wound motor connects are not polarized properly the motor can exhibit higher than normal armature current and unstable speed operation. IMPORTANT NOTE: if the motor is going to be used on a regenerative drive, it would a good idea to drop the S1 and S2 connections out of the circuit and tape them off.

4. A4. On those evenings the company that cleaned the offices for the newspaper would plug a vacuum cleaner in an outlet in the server room in order to vacuum the carpet in the hall. The servers were not affected because they were on a UPS which filtered out the EMI from the vacuum cleaner.

Spring 2009
NFPA 70E

1. Article 110 states that CPR must be certified by the employer at a specific interval. What is it?
    a. Every three years, just like the American Heart Association recommends
    b. Every two years
    c. Every year
    d. The interval is left up to the employer's discretion.

2. In Article 100 there is a new requirement for training for a qualified electrical worker. What is it?
    a. All training must be certified by the authority having jurisdiction.
    b. Qualified workers must now be trained to select an appropriate voltage detector and demonstrate how to use it.
    c. Training must include proper application of ground clusters, including setting up an equipotential zone.
    d. Qualified workers must be able to determine incident energy using IEEE 1584 or other industry-recognized software.

3. Hazard/Risk Category 1 contains new PPE requirements. What are they?
    a. Arc-rated face shield and hearing protection
    b. Minimum arc rating of clothing raised to 6 cal/cm2
    c. Arc-rated gloves required for operating circuit breakers with the doors open
    d. Hearing protection and arc-rated gloves required for all tasks

4. 130.3(C) contains a new requirement. What is it?
    a. Equipment shall be labeled with the arc-flash protection boundary from an arc-flash study and shock protection approach boundaries..
    b. Equipment labeling shall include minimum safe approach distances for arc flash only.
    c. Equipment shall be field marked with either the incident energy or the required level of PPE.
    d. Equipment labels shall be uniform in size and color. There are too many confusing designs.

5. In question 4 above, to what equipment does the new requirement pertain?
    a. All electrical equipment, including motors and light switches
    b. Only equipment with an ampacity above 25,000 amperes
    c. Electrical equipment covered by 110.16 in the NEC
    d. No such requirement

Spring 2009 Answers

1. **C.** Every year (annually). CPR is a life safety skill that needs to be reinforced annually in the opinion of the 70E committee. In 110.6(D)(1)(d), which is the paragraph above the requirement, it states that “Tasks that are performed less often than once per year shall require retraining…”. This would certainly apply to something most people have never done in real life circumstances.

2. **B.** Training must include how to select the proper voltage detector, demonstrate how to use it, and understand its indications and its limitations of use.

3. **A.** It didn’t make sense to say that incident energy above 1.2 cal/cm2 would cause the onset of a second degree burn (limit of safe approach for the arc-flash hazard) and then say it’s okay to exceed that on your face, up to 4 cal/cm2. This requirement makes PPE for thermal protection uniform for the entire body. The hearing protection was added because the 70E committee was presented information indicating that even HRC 0 events could cause sound above 140 db, which will damage hearing.

4. **C.** Most electrical workers do not have the information at their disposal or the tools necessary to determine what is needed to protect themselves from the arc-flash hazard. This requirement provides minimum information.

5. **C.** Some people choose to interpret this as pertaining to all electrical equipment; a huge undertaking. It only applies to the equipment addressed by NEC 110.16.

Summer 2009
SF_6 Circuit Breakers

1. What is the primary advantage of sulfur hexafluoride gas as an insulator?
    a. costs a lot less than mineral oil
    b. if released into the atmosphere it causes no harm
    c. it is not affected by moisture
    d. its insulating strength increases with pressure

2. List four risk categories of SF6 gas contamination:
    a. ____.
    b. ____.
    c. ____.
    d. ____.

3. What is added to SF_6 gas for cold climates?
    a. hydrogen (H_2) and/or freon-14 (CF_4)
    b. acetylene (C_2H_2) and nitrogen (N_2).
    c. nitrogen (N_2) and/or freon-14 (CF_4)
    d. None of the above

4. When arcing occurs in SF_6 , what is one hazardous byproduct?
    a. metal fluorides.
    b. sulfur dioxide.
    c. hexadecimals.
    d. None. SF6 is inert and doesn't react to arcing.

5. What is meant by a "dead-tank breaker"?
    a. The breaker operating mechanism is deenergized.
    b. The contacts are arranged in such a manner that they extend through the porcelain housing.
    c. They are safe to rack in or out while under load; no PPE is needed.
    d. The external tank is grounded making it "dead".

Summer 2009 Answers

1. **D.** SF_6 has a number of advantages, so the primary one is open to opinion. The dielectric strength of SF_6 increases with pressure so smaller breakers can be used at higher voltages. The breakers have a smaller footprint, so they use less real estate which can be very expensive. They are very reliable and require less maintenance than air blast or oil breakers and can operate at higher voltages effectively.

2. Answers:
   - New gas – in cylinders from the gas manufacturer
   - Non-arced – has been used or handled, but contains no arcing byproducts
   - Normally arced – corrosive byproducts less than 200 ppm
   - Heavily arced – contains arcing byproducts greater than one percent by volume

   Editor's Note: Jim has referenced CIGRÉ Task Force B3.02.01 SF_6 Recycling Guide for this question.

3. **C.** Nitrogen and freon-14. They are added to keep the SF_6 gasified at lower temperatures. SF_6 has a tendency to liquefy and pool at colder temperatures. This reduces the internal pressure, which reduces the dielectric strength.

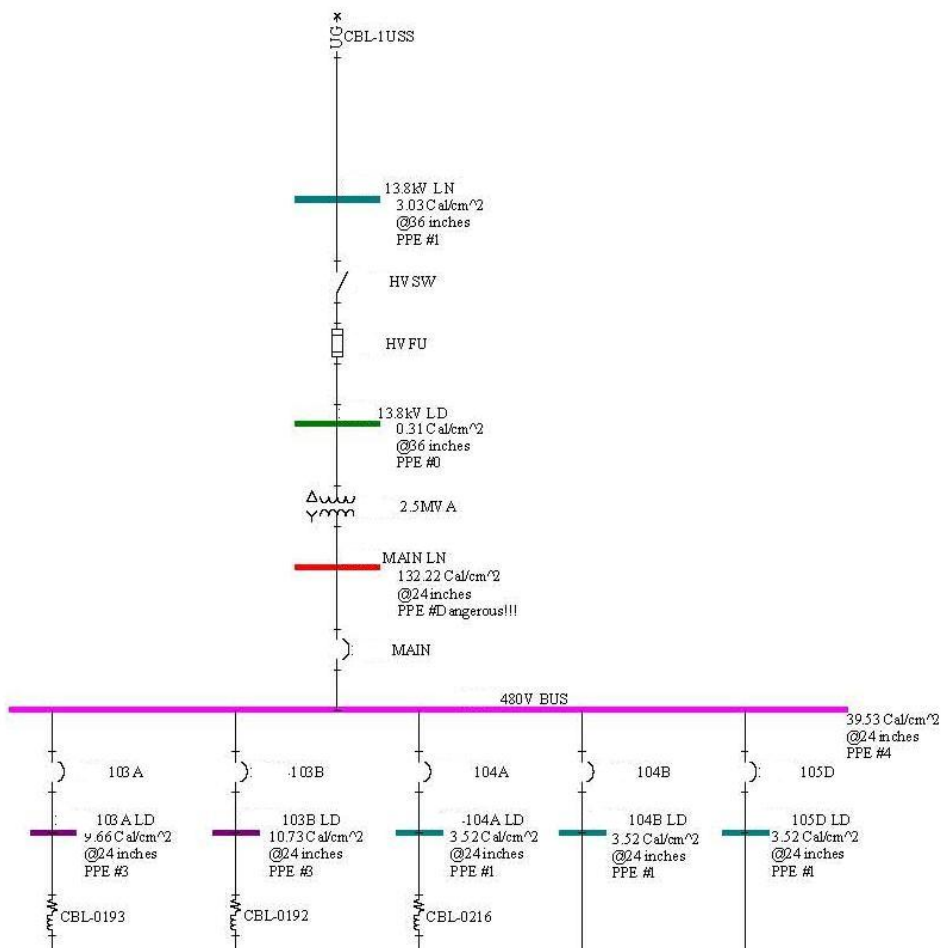
4. **A.** Metal fluorides. As SF_6 decomposes during arcing metal fluorides are created, which are corrosive. When servicing SF_6 breakers that have been faulted, full body protection and oxygen-fed respirators may be needed to prevent the fluorides from contacting the skin or being inhaled. Any moisture on or in the body will create hydrofluoric acid.

5. **D.** Dead tank breakers have grounded tanks. Live tank breakers use the insulating column to house the mechanism and contact assemblies, so they are energized at system voltage (live).

Fall 2009
Hazard/Risk Analysis

1. An electrical hazard/risk analysis only looks at the hazards involved with performing energized work.
   True
   False

2. Based upon the figure, what is the safest method of racking the 480 V main breaker?



   a. Suiting up in an 80 cal/cm^2 suit
   b. Use a remote racking device
   c. Use an extended racking handle
   d. Open the 13.8 kV switch first

3. You arrive at a job site to perform maintenance on a power system. Your partner completes the JSA and the two of you begin work. What's wrong with this scenario?

Fall 2009
Hazard/Risk Analysis

4. You are about to perform absence-of-voltage testing on a 480 V panelboard. There has been no arc-flash study done and there are no labels. You can determine from the transformer nameplate of the transformer feeding the panelboard that the short-circuit current will be less than 50,000 amperes, and the breaker feeding this panel is an MCCB with an instantaneous trip unit and a clearing time of less than two cycles. What is the flash protection boundary?
   a. 42”
   b. 48”
   c. 60”
   d. There’s no way to tell

5. When is it not necessary to complete an energized electrical work permit?
   a. Voltage testing, troubleshooting, or like activities
   b. Tightening terminal strips and lugs
   c. Replacing a 15 A molded-case circuit breaker
   d. All the above

Fall 2009 Answers

1. **False.** Many people actually perform only a hazard analysis. They check the label or use the tables in the NFPA 70E and don't give the job another thought. Whether the tables are used or the equipment has arc-flash labels, the risk must also be assessed.
   (See NFPA 70E, Annex F.)

2. **D.** Even though the switch has a voltage of 13.8 kV, there is only 3.03 cal/cm^2 incident energy at that point. The other alternatives will expose the worker to much higher incident energy than operating the switch in answer D.

3. Often on job sites one technician fills out the safety paperwork and the other has already started the task(s) before the safety analysis is completed. All workers need to be involved in the job safety analysis. Having one person complete the paperwork without the others reviewing it will result in some of the workers not being informed of the hazards and risks.

4. **B.** NFPA 70E Article 130.3(A)(1) allows the use of a 48" FPB if there is 50 kA short-circuit current or less and a clearing time of no more than .033 second (2 cycles). Check the OCPD feeding the equipment about to be worked on to determine that it has an instantaneous element that interrupts in 2 cycles or less. Calculate the available short circuit current from the transformer feeding the circuit to verify that it is 50 kA or less. If both of those requirements are met, the four foot FPB can be used.

5. **A.** NFPA 70E Article 130.1(B)(3) "Exemptions to Work Permit" includes voltage measurement in these exemptions, although the worker must still wear the correct PPE and establish a safe work zone. The other tasks listed in question 5 are considered energized work, and require a permit

Winter 2009
Transformer Accessories and Condition Assessment

1. The liquid level indicator is calibrated to__________ at normal operating conditions.
   a. Center line of gauge
   b. High or low gauge
   c. Temperature at 25°C
   d. Type of insulating liquid

2. To change voltage levels for seasonal changes, a __________ is used.
   a. deenergized load tap-changer
   b. tapped transformer
   c. load tap transformer
   d. autotransformer

3. An internal fault can be discovered earliest using which gas test method?
   a. Total combustible gases detector
   b. Gas collector relay
   c. Nitrogen blanket analysis
   d. Dissolved-gas analysis

4. Sample valves should be flushed with _____ of waste liquid before collecting a transformer liquid sample?
   a. One quart
   b. Two quarts
   c. Three quarts
   d. Four quarts

5. The power factor of new mineral oil should be __________ % or less.
   a. 0.01
   b. 0.05
   c. 0.1
   d. 0.5

Winter 2009 Answers

1. **C.** When full, the gauge will indicate at 25°C when the top oil temperature is 25°C. Insulating oil will expand and contract with temperature changes, so nameplates will often state how much change in liquid level there will be due to temperature. The best rule-of-thumb is to not add oil unless the level is below the LOW mark.

2. **A.** We used to call this a no-load tap-changer, but that really was not accurate and misled some people to try to change taps by just opening the secondary of the transformer. A transformer always draws current from the power system (excitation current) even with the secondary open. This current establishes and maintains the flux within the core. Always isolate both the primary and secondary of a transformer before operating this type of tap-changer.

3. **D.** Dissolved gas analysis or gas-in-oil analysis provides the earliest detection of internal problems in a liquid -insulated transformer. Most transformer problems originate under the oil and will usually create some type of combustible gas. DGA takes a sample of oil and injects it into a gas chromatograph. Combustible gases are detected in parts per million and are compared to standards to evaluate the condition of the transformer; however, DGA does not provide indication of remaining life in a transformer.

4. **B.** At one time it was one quart, but that may not be enough for larger transformers or transformers with a lot of gunk (that’s a technical term) inside the sample valve, so now it is two quarts. If the transformer is already low on oil, do not take a sample until it has been topped off and allowed to sit for at least a few days so the oil can mix.

5. **B.** Mineral oil has a relatively low power factor when it is new. It will increase with age, but a higher power factor does not necessarily mean the oil is bad. Bushing compound, sealants, and gasketing may increase power factor without harming the oil’s insulating properties. The cause of an increased power factor should be determined.

Spring 2010
Electrical Hazard/Risk Analysis

1. Which OSHA regulation requires an hazard/risk analysis of the workplace?
   a. 1910.132
   b. 1926.222
   c. 1910.335
   d. 1910.147

2. List four of the five items OSHA requires employers to do as part of a hazard/risk assessment:
   a. ______________________________
   b. ______________________________
   c. ______________________________
   d. ______________________________

3. In your own words, state the relationship between incident energy and time:

4. List two sources of information for a hazard/risk analysis:
   a. ____________________
   b. ____________________

5. List four factors to consider when evaluating risk in an electrical power system:
   a. __________________________
   b. __________________________
   c. __________________________
   d. __________________________

Spring 2010 Answers

1. **A.** 1910.132 covers assessing hazards. In 1910.132(d)(1) OSHA states, “The employer shall assess the workplace to determine if hazards are present, or are likely to be present, which necessitate the use of personal protective equipment (PPE). If such hazards are present, or likely to be present, the employer shall:
   1910.132(d)(1)(i)
      Select, and have each affected employee use, the types of PPE that will protect the affected employee from the hazards identified in the hazard assessment;
   1910.132(d)(1)(ii)
      Communicate selection decisions to each affected employee; and,
   1910.132(d)(1)(iii)
      Select PPE that properly fits each affected employee. Note: Non-mandatory Appendix B contains an example of procedures that would comply with the requirement for a hazard assessment.”

2. Any four of the requirements listed below are correct.
   a. Perform a hazard assessment if there are hazards requiring the use of PPE.
   b. Select PPE that is appropriate for the hazard.
   c. Ensure employees are using the PPE they are given.
   d. Tell each employee what PPE is required for the hazards they will face.
   e. Make certain that the PPE fits the employee properly.

3. **A.** Incident energy is directly proportional to time. If the time of exposure is doubled, the incident energy is also doubled. This is why maintenance and testing of overcurrent protective devices (OCPD) is a safety issue.

4. The NFPA 70E provides some guidance for hazard/risk analysis, but ANSI/AHIA Z10 has additional information, including assessing the residual risk (risk that cannot be eliminated or reduced by other measures).
   a. NFPA 70E
   b. ANSI/AIHA Z10

5. Any four of the below listed factors should be considered. Depending on the specific installation and environment, other factors may also need to be considered.
   a. Equipment condition
   b. Equipment age
   c. Equipment loading
   d. History of failure
   e. Environment
   f. Maintenance history
   g. Potential for backfeed or induced voltages
   h. Power system configuration/design
   i. Skill level of personnel doing the work

Summer 2010
Medium-Voltage Circuit Breakers

1. When is the danger of an arc flash the greatest for drawout circuit breakers?
    a. When opening the circuit breaker
    b. When closing the circuit breaker
    c. When racking the circuit breaker in
    d. When racking the circuit breaker out
    e. Both C and D

2. What electrical test can help determine the condition of the contact pivot's lubrication state?
    a. Insulation power factor
    b. Contact resistance
    c. Insulation resistance
    d. Vacuum bottle integrity test
    e. DC overpotential

3. When evaluating insulation-resistance test results on a medium-voltage, air-magnetic circuit breaker, what quantity is evaluated?
    a. Percent power factor
    b. Capacitance
    c. Insulation watts-loss
    d. Megohms

4. What dangerous energy could be released during a vacuum bottle integrity test?
    a. Gamma rays
    b. Nuclear radiation
    c. X-rays
    d. None
    e. Both A and C

5. What are the insulation power factor tests typically performed on a medium-voltage, air-magnetic circuit breaker?
    a. Six guarded-specimen tests and three ungrounded-specimen tests
    b. Three ungrounded-specimen tests and six grounded-specimen tests
    c. Three guarded-specimen tests and six grounded-specimen tests
    d. Six ungrounded-specimen tests and three guarded-specimen tests

Summer 2010 Answers

1. **E.** Racking the circuit breaker, whether racking in or racking out, presents the greatest hazard. Whenever a bus connection is made or broken (and there are no arc chutes or extinguishers), there is an increased hazard from arc flash.

2. **B.** The contact resistance test is almost like having x-ray vision. As the lubricants in the contact pivot dry out (from the heat created by current passing through the contact structures), the resistance of the pivot increases. If this is trended the resistance can be seen to increase each year the circuit breaker is in service.

3. **C.** According to Doble® Engineering, insulation watts-loss is used when the device being tested is mostly resistive.

4. **C.** X-rays could be released if a vacuum bottle fails during the vacuum bottle integrity test. The amount of radiation is small and can be blocked by putting the circuit breaker between yourself and the bottle being tested.

5. **A.** The guarded-specimen tests measure the insulation quality from each pole unit to ground and the ungrounded-Specimen tests measures the insulation quality across the arc chute.

Fall 2010
Medium-Voltage Motor Starters

A. According to ANSI/NETA MTS, there are four adjustments to check on medium-voltage motor starters. What are they?
   a. ____________________
   b. ____________________
   c. ____________________
   d. ____________________

B. When performing an overpotential test on the insulation, what is an acceptable value?
   a. One megohm/kV + one megohm
   b. 100 megohms
   c. 5,000 megohms
   d. No sign of failure

C. What is the maximum deviation allowable between fuse resistances?
   a. 10%
   b. 15%
   c. 20%
   d. 50%

D. What is the maximum deviation between resistance measurements on bolted connections?
   a. 25%
   b. 30%
   c. 50%
   d. 75%

E. Medium-voltage motor starters use blowout coils. What do these do?
   a. Blow a puff of air between the contacts to force the arc up into the arc chute
   b. Extinguish the arc using a strong burst of air
   c. Create a magnetic field that helps draw the arc into the arc chute
   d. Create a resistance in the arc path that causes the arc to diminish, thereby making it easier to extinguish.

Fall 2010 Answers

1. Answers:
    a. Contact gap
    b. Contact pressure
    c. Contact wipe
    d. Contact alignment

2. **D.** No sign of failure. The one megohm/kV + one megohm is old school for insulation resistance test values. This value is much too low for good insulation.. Use Table 100.1 instead.

3. **B.** 15% for all power fuses.

4. **C.** 50% for all bolted connections.

5. **C.** As the arc current passes through the blowout coil a magnetic field is created that pulls the arc into the chute. The same thing happens on medium-voltage air circuit breakers.

Winter 2010
Diagnostics

1. Waveform harmonic power quality problems are usually caused by equipment with:
    a. Nonlinear loads
    b. Large motor starting
    c. Mother Nature
    d. all of the above

2. On a three-phase, full-wave rectifier with six poles, the harmonic currents generated by the rectifier are:
    a. Harmonics of prime number (5,7,11,13,17,19….)
    b. Triplen harmonics(3,6,9,…)
    c. A and B both
    d. None of the above.

3. _______________ occurs when the harmonic currents injected by nonlinear loads interact with system impedance to produce high harmonic voltages:
    a. Sag
    b. Swell
    c. Interruption
    d. Resonance

4. If there are issues with a VFD on a three-phase, three-wire system, it is necessary to monitor line to ground voltages.

    True
    False

5. When installing filtered capacitor banks to improve power quality, which of the following items are necessary for proper tuning:
    a. Harmonic load and harmonic spectrum at the site
    b. Short-circuit current or kVA of the transformer feeding the site
    c. Other capacitor banks installed at the site
    d. More than one of the above

Winter 2010 Answers

1. **A.** Nonlinear loads like soft starters, rectifiers, etc., produce harmonics because of the SCR/diode commutation. Motor starting generally causes the system voltage to sag but the associated vacuum contactors will introduce spikes while switching. Mother Nature delivers lighting strikes which causes ground planes to shift or high voltage spikes.

2. **A.** According to IEEE-519-1992

3. **D.** Capacitor banks often cause resonance due to interaction between capacitive and inductive impedances.

4. **True.** Many VFD manufacturers still use line-to-ground voltage for SCR control, surge protection, and filtering.

5. **D.** To properly tune a filtered capacitor banks all of the above and many other factors must be considered.

ARC-FLASH MITIGATION | BY JIM WHITE *Shermco Industries*

The topic of electrical arc flash has been an important issue for several years now. Engineers have been creating and manufacturers are producing innovative new solutions for this life-threatening problem. This month's Tech Quiz will cover issues related to electrical arc flash.

Jim White *is the Training director for Shermco Industries and the principal Shermco representative on the NFPA 70B committee. Jim is the alternate NETA representative on the NFPA 70E committee and serves as the NETA representative on the IEEE/NFPA Arc-Flash Hazard Work Group (RTPC) Ad Hoc Committee. He served as the Chairman of the 2008 IEEE Electrical Safety Workshop. Jim is a NETA Certified Level IV Electrical Testing Technician and a member of the NETA Safety Committee.*

1. Electrical systems rated less than 240 volts fed by a transformer with a capacity of <125 kVA are not considered an arc-flash hazard.
   a. True, according to IEEE 1584
   b. False

2. Arc -flash protective clothing and equipment are rated to:
   a. Provide protection to the value indicated as the "arc rating" or "ATPV"
   b. Provide a 50% probability of a burn at the arc rating or ATPV
   c. Provide protection in excess of the arc rating or ATPV
   d. Allow a person to safely work on an energized electrical power system

3. Which of the following is NOT a rule-of thumb concerning arc flash:
   a. Incident energy decreases by the inverse square of the distance
   b. Incident energy is proportional to time
   c. Each layer of clothing under arc-rated reduces the heat to the body by ~ 50%
   d. Incident energy is inversely proportional to short circuit current

4. At what voltage does the arc flash hazard not exist?
   a. 480 volts
   b. 277 volts
   c. 208 volts
   d. None of the above

5. When wearing an arc-rated face shield, what is the correct body position when operating electrical equipment?
   a. Extend the left arm and turn the face away from the hazard
   b. Extend the right arm and turn the face away from the hazard
   c. Extend either arm and turn your face towards the hazard
   d. Get an apprentice to do it for you

See answers on page 105.

ANSWER 1

B - FALSE – I get this question a lot. Just because the IEEE 1584 says that calculations may not be necessary, that does not automatically mean there is no hazard concerning arc flash. Firstly, that portion of the 1584 guide only applies to three-phase power systems fed by a transformer rated less than 125 kVA and less than 240 volts. A single-phase transformer can have more arc energy. Secondly, there is a hazard to the hands and arms, even at the lower energy levels, not to mention the hazard of flying molten metal that could be ejected from the equipment. The hazard is reduced, not eliminated. These calculations are less than convincing, especially at the lower voltages. The new IEEE/NFPA Joint Collaboration Project should shed some new light on this area.

ANSWER 2

B – According to ASTM F1959, arc-rated clothing and equipment are rated to allow a 50 percent probability of a second-degree burn if that clothing is exposed to the rated incident energy for 1/10th second. Some clothing could experience break-open at its rating.

ANSWER 3

D – The other three are good rules-of-thumb to keep in mind when working on exposed, energized electrical conductors or circuit parts. Keep in mind that if the incident energy decreases by the inverse square of the distance, it will also increase by the square of the distance as you go nearer to an arc source.

ANSWER 4

D – Trick question! At the October NFPA 70E ROP meeting David Wallis with OSHA presented two instances where people suffered serious injury at 120/240 volts. One worker received significant third-degree burns to his chest, hand, and arm.

ANSWER 5

C – Actually, I would go for "d", but apprentices can be in short supply at times. I like to follow what I call the hinge-side rule. I stand on the side with the hinge, extend whichever arm is appropriate, face the hazard and operate the equipment. Some people fault that approach, reasoning that the PPE is designed to protect you, but I would say arc-rated PPE is designed to protect you if its rating is not exceeded. Who knows if the OCPD is going to function correctly? The door will probably blow open and could strike the operator, causing injury. However, I will take a concussion or broken arm over being crispy-fried. Main point, face the hazard so the face shield does not become a heat scoop.

NFPA Disclaimer: *Although Jim White is a member of the NFPA Technical Committee for both NFPA 70E "Standard for Electrical Safety in the Workplace" and NFPA 70B "Recommended Practice for Electrical Equipment Maintenance", the views and opinions expressed in this message are purely the author's and shall not be considered an official position of the NFPA or any of its Technical Committees and shall not be considered to be, nor be relied upon as, a formal interpretation or promotion of the NFPA. Readers are encouraged to refer to the entire text of all referenced documents.*

SWITCHGEAR & CIRCUIT BREAKERS |

BY JIM WHITE
Shermco Industries

Many companies don't maintain their switchgear in the manner they should which can lead to problems and safety issues. We have seen instances where the protective relays have been calibrated, but the switchgear and circuit breakers have not been maintained. A lot of maintenance is driven by insurance company dictates, but that does not ensure a safe or efficient electrical system. The following questions will help sharpen your maintenance knowledge:

__Jim White__ is the Training director for Shermco Industries and the principal Shermco representative on the NFPA 70B committee. Jim is the alternate NETA representative on the NFPA 70E committee and serves as the NETA representative on the IEEE/NFPA Arc-Flash Hazard Work Group (RTPC) Ad Hoc Committee. He served as the Chairman of the 2008 IEEE Electrical Safety Workshop. Jim is a NETA Certified Level IV Electrical Testing Technician and a member of the NETA Safety Committee.

1. You are a facility maintenance manager and you have several sections of medium-voltage switchgear. This equipment has a high reliability requirement and is in good condition. According to ANSI/NETA MTS-2011, how often should it be electrically tested and maintained?
   a. 6 months
   b. 12 months
   c. 18 months
   d. 24 months

2. Cable connected to bus using lugs is always an issue. My experience has been that when checked for tightness every three years, roughly 50 percent of the connections require retorquing. What three methods does ANSI/NETA MTS-2011 recommend for checking for connection problems?
   a. ________________
   b. ________________
   c. ________________

3. Using ANSI/NETA ATS-2009 as a reference, what is the minimum voltage to be used for performing a dc overpotential test on 15 kV switchgear?
   a. 15 kV
   b. 25 kV
   c. 27 kV
   d. 37 kV

4. ANSI/NETA ATS-2009 recommends what maximum value of leakage current when performing the dc overpotential test on 15 kV switchgear?
   a. 1 Megohm/kV test voltage plus 1 Megohm
   b. 1.0 microampere
   c. 100 microamperes
   d. No failure of insulation

5. What is the minimum insulation resistance of control wiring in switchgear based on ANSI/NETA MTS-2007?
   a. 1 Megohm
   b. 2 Megohm
   c. 4 Megohm
   d. No failure of insulation

See answers on page 107.

ANSWER 1

1. You are a facility maintenance manager and you have several sections of medium-voltage switchgear. This equipment has a high reliability requirement and is in good condition. According to ANSI/NETA MTS-2011, how often should it be electrically tested and maintained?
   a. 6 months
   b. Using Appendix B, switchgear with a high reliability requirement and in good condition would have a multiplication factor of 0.5. The recommended interval for electrical testing and maintenance is 24 months, so it would be 0.5 x 24 months = 12 months.
   c. 18 months
   d. 24 months

ANSWER 2

2. Cable connected to bus using lugs is always an issue. My experience has been that when checked for tightness every three years, roughly 50 percent of the connections require retorquing. What three methods does ANSI/NETA MTS-2011 recommend for checking for connection problems?
   a. Using a microhmmeter
   b. Using a calibrated torque wrench
   c. Performing a thermographic survey

ANSWER 3

3. Using ANSI/NETA ATS-2009 as a reference, what is the minimum voltage to
be used for performing a dc overpotential
test on 15 kV switchgear?
   a. 15 kV
   b. 25 kV
   c. 27 kV
   d. 37 kV

ANSWER 4

4. ANSI/NETA ATS-2009 recommends
what maximum value of leakage current
when performing the dc overpotential test
on 15 kV switchgear?
   a. 1 Megohm/kV test voltage plus 1 Megohm
   b. 1.0 microampere
   c. 100 microamperes
   d. No failure of insulation

ANSWER 5

5. What is the minimum insulation resistance of control wiring in switchgear based on ANSI/NETA MTS-2007?
   a. 1 Megohm
   b. 2 Megohm
   c. 4 Megohm
   d. No failure of insulation

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No. 96

WEATHER-RELATED FATALITIES

BY JIM WHITE
Shermco Industries

With summer fast approaching (at least in Texas) I thought it might be a good time to do a little weather trivia and IQ. Answers are from the National Weather Service.

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1. Which state had the most heat-related fatalities in 2010?
   a. Texas
   b. Nevada
   c. Pennsylvania
   d. Florida

2. Which state had the most cold weather-related fatalities?
   a. Wisconsin
   b. South Carolina
   c. Florida
   d. Illinois

3. Which state had the most weather-related fatalities in 2010?
   a. Tennessee
   b. Arkansas
   c. Illinois
   d. Pennsylvania

4. What are the signs of heatstroke?
   a.______________________
   b.______________________
   c.______________________
   d.______________________

5. What steps should you take to treat heatstroke?
   a.______________________
   b.______________________
   c.______________________
   d.______________________

See answers on page 107.

No. 96

ANSWERS

ANSWER 1

1. Which state had the most heat-related fatalities in 2010?
   In order from highest to lowest:
   a. Nevada 23
   b. Pennsylvania/ Tennessee (tied) 22
   c. Mississippi/ New York (tied) 10
   d. Arkansas 7

Texas had four and Florida had 1. Louisiana and Maryland both had 6. These numbers were quite a surprise.

ANSWER 2

2. Which state had the most cold weather-related fatalities?
   In order from highest to lowest:
   a. Illinois 18
   b. Tennessee 6
   c. Mississippi 3
   d. Florida 2

Indiana, Kentucky, Louisiana, South Carolina and Wisconsin all had 1 each. What's going on in Illinois?

ANSWER 3

3. Which state had the most weather-related fatalities in 2010?
   In order from highest to lowest:
   a. Tennessee 53
   b. Arkansas 36
   c. Illinois 29
   d. Mississippi, Texas and Pennsylvania 27

ANSWER 4

4. What are the signs of heatstroke?
   Recognizing the symptoms of heatstroke is important to surviving heatstroke.
   a. Skin is hot to the touch
   b. Rapid strong pulse
   c. Severe headache
   d. Nausea
   e. Possible unconsciousness

ANSWER 5

5. What steps should you take to treat heatstroke?
   If someone you are working with exhibits the symptoms of heatstroke, do the following:
   a. Move them into the shade
   b. Call 911
   c. Lie on your back with the head and shoulders elevated
   d. Remove outer layers of clothing, if possible
   e. Wet underlayers with tepid water (not warm or cool)
   f. Drip water on skin to cool slowly
   g. Rehydrate with small sips of water once temperature comes down some (if conscious)

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No. 97

PLACING EQUIPMENT IN AN ELECTRICALLY-SAFE WORK CONDITION

BY JIM WHITE, *Shermco Industries*

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1. List the seven steps involved with placing equipment in an electrically-safe work condition:
   a. ________________
   b. ________________
   c. ________________
   d. ________________
   e. ________________
   f. ________________
   g. ________________

2. Which OSHA regulation contains the requirements for electrical lockout/tagout?
   a. 1910.147
   b. 1910.335
   c. 1910.333
   d. 1910.137

3. How does electrical lockout/tagout differ from mechanical lockout/tagout?
   a. Equipment is not considered deenergized until it has been tested.
   b. Electrical equipment has to be disconnected from energy sources.
   c. Electrical lockout/tagout requires the use of nylon cable ties or their equivalent.
   d. They are the same.

4. Which NFPA 70E article covers placing equipment in an electrically-safe work condition?
   a. Article 100
   b. Article 110
   c. Article 120
   d. Article 130

5. Name the hazard involved with placing an electrical system in an electrically-safe work condition.
   a. Backfeeds
   b. Induced voltages
   c. Misreading single-lines or inaccurate single-lines
   d. Inaccurate or incomplete procedures
   e. Assumptions made by workers and employers
   f. All the above

See answers on page 113.

No. 97

ANSWERS

ANSWER 1

1. List the seven steps involved with placing equipment in an electrically-safe work condition:

The seven steps are:

a. Determine all possible sources of electrical energy.
b. After properly interrupting the load, open the disconnecting device for each source.
c. When possible, visually verify all blades or contacts are open.
d. Apply lockout/tagout devices.
e. Operate the circuit or device, if possible, to ensure deactivation.
f. Test each conductor for the absence of voltage.
g. If necessary, ground the circuit.

ANSWER 2

2. Which OSHA regulation contains the requirements for electrical lockout/tagout?

c. 1910.333

1910.147 covers lockout/tagout of mechanical equipment, while 1910.333(b) covers lockout/tagout of electrical equipment.

ANSWER 3

3. How does electrical lockout/tagout differ from mechanical lockout/tagout?

a. Equipment is not considered deenergized until it has been tested.

a. is the correct answer. 1910.147 requires that energy sources be blocked or restrained, and it also requires that a nylon cable tie or its equivalent be used for tags. The main difference is that electrical lockout/tagout requires a test to verify the absence of voltage. Until this test is performed, it must be considered energized.

ANSWER 4

4. Which NFPA 70E article covers placing equipment in an electrically-safe work condition?

c. Article 120

Article 100 covers definitions, Article 110 covers general requirements, Article 120 covers placing equipment in an electrically-safe work condition, and Article 130 covers work involving electrical hazards.

ANSWER 5

5. Name the hazard involved with placing an electrical system in an electrically-safe work condition.

f. All the above

f. There are specific hazards associated with the different configurations of electrical power systems. Double-ended substations have twice the incident energy if both main breakers and the tie breaker are closed. Ring bus or loop systems will usually have energized stabs on the end breakers. Tie breakers can have both sets of stabs energized. The important thing is to be aware of the configuration of the system and expect the unexpected. In other words, don't make assumptions.

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No. 98

SYMMETRICAL COMPONENTS AND PROTECTIVE RELAYING

BY JIM WHITE, *Shermco Industries*

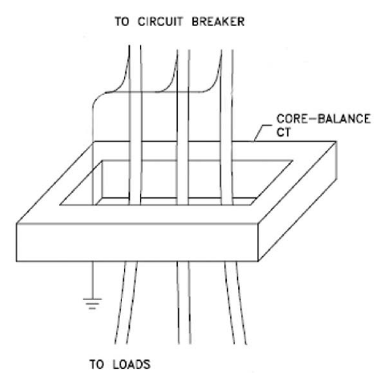
__Jim White__ is the Training Director for Shermco Industries and the principal Shermco representative on the NFPA 70B committee. Jim is the alternate NETA representative on the NFPA 70E committee and serves as the NETA representative on the IEEE/NFPA Arc-Flash Hazard Work Group (RTPC) Ad Hoc Committee. He served as the Chairman of the 2008 IEEE Electrical Safety Workshop. Jim is a NETA Certified Level IV Electrical Testing Technician and a member of the NETA Safety Committee.

1. What is a phasor?
   a. Last seen on Star Trek, the Search for Spock, a phasor is a weapon that can be set for stun or kill.
   b. Similar to a vector, a phasor is used to indicate both amplitude and phase angle. Phasors can represent any quantity that can be represented by a sinusoid.
   c. An instrument used to determine the phase angle between voltage and current.
   d. The angular difference between the voltage and current commonly referred to as theta.

2. A negative sequence relay is used to:
   a. determine if the generator is supplying an unbalanced load.
   b. determine when current flow is in the incorrect direction within an intertied bus system.
   c. determine when the phase rotation of a motor is incorrect.
   d. determine when the impedance of a generator's rotor increases to above normal values.

3. A three-phase bolted fault will primarily produce what type of current?
   a. Positive sequence current
   b. Zero sequence current
   c. Negative sequence current
   d. Midrange sequence current

4. The diagram below shows a core-balance CT. What is another name for this type of CT?



   a. Positive sequence
   b. Negative sequence
   c. Zero sequence
   d. Phase fault protection

5. Identify the following three currents:
   a. I_O ____________
   b. I_2 ____________
   c. I_1 ____________

See answers on page 107.

No. 98

ANSWERS

ANSWER 1

1. What is a phasor?

   b. Similar to a vector, a phasor is used to indicate both amplitude and phase angle. Phasors can represent any quantity that can be represented by a sinusoid.

My personal answer would be A, but that's not correct. The correct answer is B. A phasor is used to show amplitude (magnitude) and phase angle. Using phasors to analyze a three-phase system is much easier than trying to use sine waves.

ANSWER 2

2. A negative sequence relay is used to:

   a. determine if the generator is supplying an unbalanced load.

Negative sequence relays detect unbalanced currents and can cause a trip operation to prevent overheating of the generator.

ANSWER 3

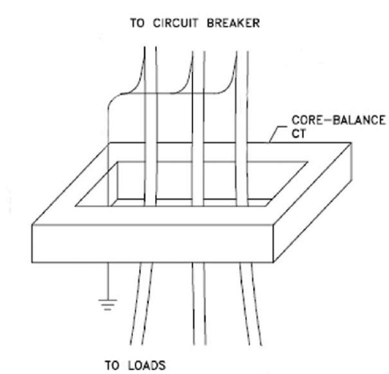
3. A three-phase bolted fault will primarily produce what type of current?

   a. Positive sequence current

A three-phase bolted fault will produce primarily positive sequence currents, while a phase-to-ground fault will cause equal values of positive, negative, and zero sequence current. Any imbalance in the electrical system causes some negative sequence current.

ANSWER 4

4. The diagram below shows a core-balance CT. What is another name for this type of CT?



   c. Zero sequence

A core-balance CT is often referred to as a zero-sequence CT.

ANSWER 5

5. Identify the following three currents:

   a. I_O – zero sequence current
   b. I_2 – negative sequence current
   c. I_1 – positive sequence current

Although we have used current as the example in these questions, positive, negative and zero sequence voltages can also be present in the electrical system.

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No. 99

LUBRICANTS USED IN CIRCUIT BREAKERS AND SWITCHES

BY JIM WHITE, *Shermco Industries*

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Electrical equipment consists mostly of mechanical components. In low- and medium-voltage switches, circuit breakers and disconnects these components have parts that slide, rotate and wear against each other. Lubricants reduce the effects of this wear and prevent binding and seizing.

1. Circuit breaker contacts should be lubricated:
   a. every six months.
   b. only in corrosive atmospheres.
   c. to prevent burning.
   d. only in hospitals.

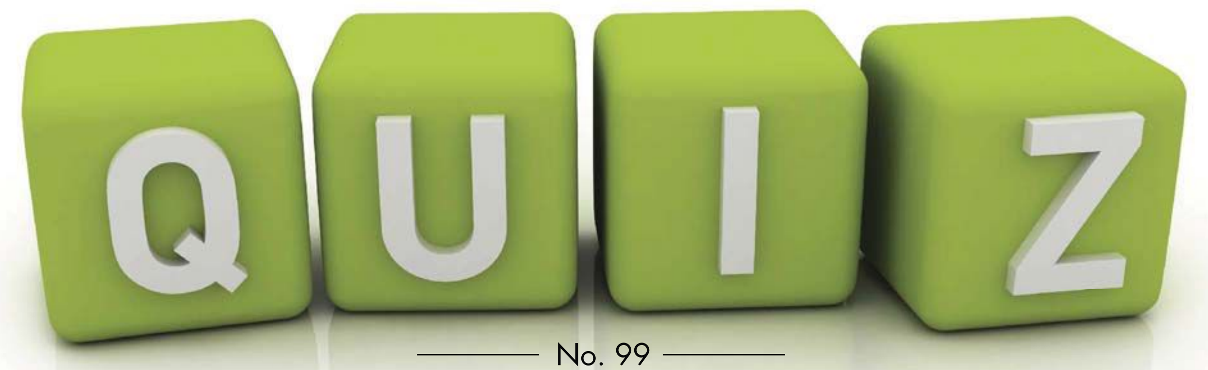
2. Conventional grease is typically composed of:
   a. emulsifiers and oil.
   b. long-chain hydrocarbons.
   c. natural esters and emulsifiers.
   d. finely ground bronze and oil.

3. List three important areas to lubricate on circuit breakers and switches.
   a. ______________________________
   b. ______________________________
   c. ______________________________

4. Which single lubricant is acceptable for use in both the conductive and mechanical areas of circuit breakers and switches?
   a. D50H38® (zinc chromate-based)
   b. No-Ox-Id A-Special®
   c. Mobil 28®
   d. Molykote®

5. List the three types of lubricants (not the specific lubricant) and where they are used in a circuit breaker:
   a. ______________________________
   b. ______________________________
   c. ______________________________

See answers on page 117.



No. 99

ANSWERS

ANSWER 1

1. Circuit breaker contacts should be lubricated:
   b. Circuit breaker contacts usually should not be lubricated. The heat from the current flow through the contacts breaks the lubricant down and causes contact resistance to increase. Each time the contacts are opened or closed, arcing takes place on the contact surfaces, breaking the lubricant down even more quickly. Bolted pressure switches, however, often recommend lubricating their main contacts. There are some greases that add different ingredients to obtain better characteristics, such as graphite, zinc chromate or silver. They still use an emulsifier, which dries out over time.

ANSWER 2

2. Conventional grease is typically composed of:
   a. Conventional greases, that is, greases made from petroleum compounds, are made from emulsifiers and oil. Emulsifiers keep the oil in suspension and allow it to cling to surfaces. The oil does the actual lubrication. As the grease ages and/or is heated, the oil evaporates, leaving only the emulsifiers, which get gummy.

ANSWER 3

3. List three important areas to lubricate on circuit breakers and switches.
   a. Contact pivot
   b. Linkages
   c. Operating mechanism

ANSWER 4

4. Which single lubricant is acceptable for use in both the conductive and mechanical areas of circuit breakers and switches?
   c. Each manufacturer recommends a specific lubricant for the mechanical components such as the operating mechanism and one for the conductive areas such as the contact pivot. These lubricants cannot be mixed. For example, on GE circuit breakers D50H38 was recommended for use only in the conductive areas, while D50H15 was used in the mechanical areas. Mobile 28, a red, synthetic lubricant, is acceptable to most manufacturers for use in both the conductive and mechanical areas. Before substituting lubricants, always contact the manufacturer for your specific application. This may sound like a dodge on my part, but Mobil 28 may not be the best lubricant at some temperatures or environmental or load conditions for every circuit breaker or switch. Also, when using a synthetic lubricant, such as Mobil 28, take special care not to overlubricate. It should be applied in a very thin coating; just enough to see on the surface. Overlubrication will cause it to liquefy and run, which in turn attracts dirt, unlike the thicker greases, which have more "cling".

ANSWER 5

5. List the three types of lubricants (not the specific lubricant) and where they are used in a circuit breaker:
   a. Conductive. For use in the contact pivot, primary and secondary disconnects and other conductive areas. These can consist of zinc chromate, silver, graphite or other compounds.
   b. Nonconductive. For use on latches, bearings and bearing surfaces. Usually petroleum-based, but can be lithium-based.
   c. Oil. For use on linkages. Typically a 20-30 weight oil is recommended.

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No. 100

BATTERIES AND BATTERY CHARGERS

BY JIM WHITE, *Shermco Industries*

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Batteries and the supporting charging equipment can easily be overlooked until they are needed. Most facilities use a battery bank to supply dc operating current for opening and closing circuit breakers, spring-charging motors, and indicators. Without the dc supply, circuit breakers will not operate.

1. An indication that a vented lead-acid battery is in trouble is when its internal impedance increases ___% above its as-installed impedance.
   a. 5%
   b. 20%
   c. 30%
   d. 45%

2. Which of the following is not an example of a VRLA (valve-regulated lead-acid) battery?
   a. nickel-metal hydride
   b. gel cells
   c. absorbed glass mat
   d. maintenance free

3. Sulfation in flooded-cell, lead-acid batteries is indicated by:
   a. streaks of oil on the surface of the electrolyte.
   b. brownish nodules adhering to the case.
   c. white salts appearing on the surface of the plates.
   d. white milky substance that appears on the cells and jar.

4. When performing a load test on a battery bank, what percent remaining capacity indicates the need to replace the batteries?
   a. 20%
   b. 40%
   c. 60%
   d. 80%

5. The only repair for sulfation is to:
   a. equalize and increase float voltage.
   b. use a mixture of boric acid and potassium hydroxide.
   c. replace the batteries with new ones.
   d. retighten all intercell connections.

See answers on page 107.

No. 100

ANSWERS

ANSWER 1

1. An indication that a vented lead-acid battery is in trouble is when its internal impedance increases ___% above its as-installed impedance.
   b. When the internal impedance of a cell increases by more than 20%, it is an indication that the battery is starting to deteriorate and should be monitored more closely. This test is often referred to as the ohmic test and is performed by applying an ac voltage across the battery and measuring the internal impedance of the battery.

ANSWER 2

2. Which of the following is not an example of a VRLA (valve-regulated lead-acid) battery?
   a. VRLA batteries (valve-regulated lead-acid) are increasingly used for various standby electrical power applications including emergency generators and switchgear. The most common types of VRLA batteries are gel cells and absorbed glass mat. These batteries are often referred to as *maintenance free*, although *low maintenance* would better describe them.

ANSWER 3

3. Sulfation in flooded-cell, lead-acid batteries is indicated by:
   c. Sulfation results from the battery being in an undercharged state for an extended period of time. As the battery discharges, the active lead material on the plates will react with the sulfates in the electrolyte and form a lead sulfate on the plates. This appears as a white, granular deposit on the plates.

ANSWER 4

4. When performing a load test on a battery bank, what percent remaining capacity indicates the need to replace the batteries?
   d. When battery capacity decreases to 80% of its initial rating, it is time to look for a replacement.

ANSWER 5

5. The only repair for sulfation is to:
   a. Since sulfation occurs when a battery is in a discharged state, equalizing is the cure. The problem is that all of the sulfates usually do not recombine and the battery loses some capacity. This is a normal part of the charge/discharge cycle, but when a battery stays in a low state of charge, sulfation can be permanent.
   Battery shedding will also increase as the discharged electrolyte now contains more water and will soften the lead plate material. If that shedded material builds up to about halfway to the plates, a constant discharge begins between the shedded material and the plates, which results in a battery that will not maintain a charge.

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No. 101

TESTING CIRCUIT BREAKERS

BY JIM WHITE, *Shermco Industries*

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Circuit breakers must be tested to ensure that they function in accordance with the manufacturer's specifications. This issue of the NETAWorld Journal covers many of the newer technologies for proving that circuit breakers will function when called upon.

1. *First-Out Timing* is performed to ensure:
   a. the circuit breaker that should trip first will do so. It's also known as selective coordination .
   b. the circuit breaker will rack out smoothly and without hesitation.
   c. the circuit breaker will open within specifications after being closed for an extended period of time.
   d. all phases of the circuit breaker open within 25milli-seconds of each other.

2. What two quantities are usually measured with a circuit breaker motion analyzer?
   a. Velocity and displacement.
   b. Speed and direction.
   c. Distance and force.
   d. Angle and pressure.

3. Partial discharges are created by:
   a. ionization of air pockets within the insulation.
   b. moisture that is trapped within the insulation.
   c. deep discounting at the Dollar General store.
   d. carbon deposits vibrating within the insulation.

4. What test will indicate the serviceability of a medium-voltage vacuum interrupter?
   a. Vacuum Bottle Integrity Test
   b. Magnetron Atmosphere Condition Test
   c. Insulation Power Factor (Doble)
   d. Partial Discharge Testing

5. When performing insulation power factor tests on medium-voltage circuit breakers, what quantity is normally measured?
   a. Watts loss
   b. Percent power factor
   c. Total amperage
   d. Cosine of the angle theta

See answers on page 117.

No. 101

ANSWERS

ANSWER 1

1. *First-Out Timing* is performed to ensure:

   c. Circuit breakers often sit for extended periods of time without operating. As they sit, current is flowing through them, drying out their lubricants. When they are called on to operate, maybe they will or maybe they won't. The problem is that they will often work just fine after a few operations, but what will they do on that very first trip? That's the one that really counts.

ANSWER 2

2. What two quantities are usually measured with a circuit breaker motion analyzer?

   a. Circuit breaker time/travel analyzers can measure many things; contact bounce, overtravel and contact wipe. Their primary purpose though, is to measure the distance the contacts travel (displacement) and how fast they move (velocity).

ANSWER 3

3. Partial discharges are created by:

   a. Voids and air pockets in insulation can have electrical discharges (ionization) when they are in high-voltage fields. This discharge can be measured and monitored, either while the equipment is energized (for continuous monitoring) or during specific tests.

ANSWER 4

4. What test will indicate the serviceability of a medium-voltage vacuum interrupter?

   a. Vacuum bottle integrity test. The vacuum bottle integrity test will detect vacuum bottles that have insufficient vacuum to safely interrupt fault-level current.

ANSWER 5

5. When performing insulation power factor tests on medium-voltage circuit breakers, what quantity is normally measured?

   a. Because the device is mostly resistive, the specimen's watts loss is usually recorded, instead of percent power factor.

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No. 102

WIND POWER

BY JIM WHITE, *Shermco Industries*

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Wind power generation sites have become common throughout the U.S. Wind generation presents some unique challenges for maintenance personnel, as well as for safety concerns.

1. Which state has the most wind generation capacity (in MW)?
a. Illinois
b. California
c. Iowa
d. Texas

2. The most common cause of failure in a wind turbine is:
a. Gearboxes
b. Blades
c. Control system
d. Electrical system

3. The largest commercially-available wind generator produces:
a. 8.0 MW
b. 7.6 MW
c. 6.6 MW
d. 5.0 MW

4. On average, wind generators produce power ___ % of the time.
a. 30
b. 50
c. 60
d. 90

5. The cost to install a wind generator is approximately ___ to ___ per MW of installed nameplate capacity.
a. $800,000 to $1,200,000.
b. $1,000,000 to $1,300,000.
c. $1,500,000 to $2,000,000.
d. $1,300,000 to $2,200,000.

See answers on page 120.

No. 102

A N S W E R S

ANSWER 1

1. Which state has the most wind generation capacity (in MW)?

d. Texas currently has the largest installed wind generation capacity at 10,929 MW, per Wikipedia. California has 4,570 MW, Iowa has 4,536 MW, and Illinois has 3,055 MW. The Alta Wind Energy Center in Kern County, California is the largest US wind site with 1,020 MW of generation, and the Roscoe Wind farm in Nolan County, Texas is second with 781 MW of generation.

ANSWER 2

2. The most common cause of failure in a wind turbine is:

d. Failure of the gearbox is a major concern due to the downtime involved, but the electrical system is the primary cause of failure for wind generators. Figure 1 shows relative failure rates of components based on a study performed by B. Hahn, Institut für Solare Energieversorgungstechnik in a paper titled Reliability Assessment of Wind Turbines in Germany. Other studies have shown a similar pattern.

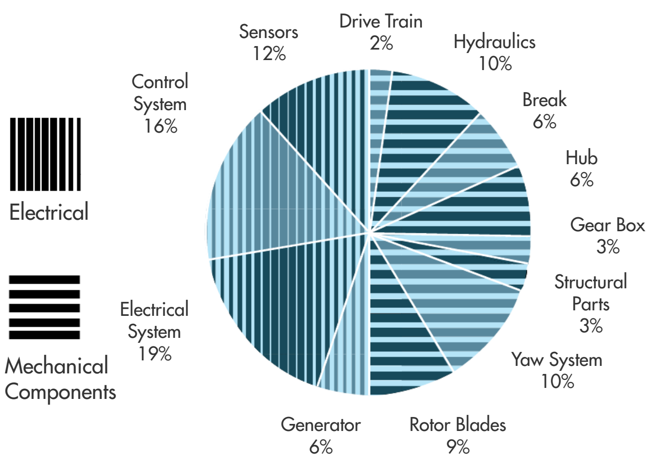

Figure 1: *Component Failure for Wind Turbines*

ANSWER 3

3. The largest commercially-available wind generator produces:

b. Vestas is set to manufacture an 8 MW wind turbine in 2015, but the current winner goes to Enercon at 7.58 MW. It has a rotor diameter of 127 meters and is not used for offshore applications, although the Vestas turbine will be.

ANSWER 4

4. On average, wind generators produce power ___ % of the time.

a. In the US, wind generators produce power at about 30 percent of the time (source Energy Information Agency). In Europe, it is closer to 13 percent of the time. Once a wind generator's speed falls below its optimum output speed, the power it produces falls rapidly. As an example, for every halving of wind speed a wind generator's output falls by a factor of 8. Most wind generators produce maximum power at about 25 to 30 mph.

ANSWER 5

5. The cost to install a wind generator is approximately ___ to ___ per MW of installed nameplate capacity.

d. According to Windustry, the cost per MW of installed capacity is between $1,300,000 and $2,200,000. This cost has gone down substantially over the last few years. The larger the turbine, the more cost effective it becomes.

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No. 103

OVERCURRENT COORDINATION

BY JIM WHITE, *Shermco Industries*

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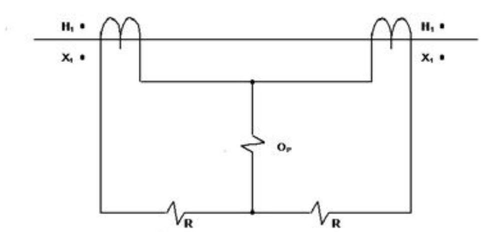
This Tech Quiz looks at alternatives to overcurrent protective relaying due to coordination issues. Depending on the specific type of system, there can be many choices.

1. Differential protective relay schemes typically have their zones established by current transformers. In the figure below, at the instant current flows into ______, it also flows out of______.

a. H1 – X2
b. H2 – X1
c. H1 – X1
d. H2 – X2



2. Calculate the following values for a percentage differential relay with a 25 percent slope characteristic:

- Restraint current 1 = 100A
- Restraint current 2 = 75A
- Operating current = ______
- Percent slope = ______
- Relay will / will not operate ______

3. Pilot wire relay schemes are a form of:

a. Directional overcurrent
b. Impedance relaying
c. Differential relaying
d. Zone interlocking

4. Directional overcurrent relays have a characteristic known as the maximum torque angle. How is the MTA determined during testing?

a. Find the zero torque angles and divide by two.
b. Plot the characteristic circle and find the minimum current to close the contacts.
c. Apply rated voltage and increase the current slowly until contact closure.
d. Maintain the restraint current and increase the operating current until contact closure.

5. Directional overcurrent relays must see two conditions in order to operate. What are they?

a. Current below the overcurrent unit set point and the polarizing quantity at an angle that closes the directional unit contact.
b. Current above the overcurrent unit set point and the polarizing quantity at an angle that opens the directional unit contact.
c. Current below the overcurrent unit set point and the polarizing quantity at an angle that opens the directional unit.
d. Current above the overcurrent unit set point and the polarizing quantity at an angle that closes the directional unit.

See answers on page 120.

No. 103

ANSWERS

ANSWERS

1. Differential protective relay schemes typically have their zones established by current transformers. In the figure below, at the instant current flows into ______, it also flows out of ______.

c. H1 – X1. It's the rule of instantaneous current flow. Current in the electrical system changes direction instantaneously 120 times each second (60 cycles). As it changes direction it does so throughout the entire system. As current flows into H1, it flows out of X1 on the positive half-cycle. On the next half-cycle, it flows into H2 and out X2, maintaining the relative instantaneous polarity of the differential scheme.

2. Calculate the following values for a percentage differential relay with a 25 percent slope characteristic:

The operating current is the difference between the two restraining currents (differential), so it would be 25A. The calculated imbalance (percent slope) of this example would be:

$$\frac{25\ A}{75\ A} x\ 100\% = 33\%$$

Under these conditions the relay would close its contacts since the percent slope characteristic has been exceeded.

3. Pilot wire relay schemes are a form of:

c. Pilot wire relays are a form of differential relaying.

4. Directional overcurrent relays have a characteristic known as the maximum torque angle. How is the MTA determined during testing?

a. A typical directional overcurrent relay has a directional unit and an overcurrent unit. Both units must close their contacts in order to cause a trip. The directional unit is frequently constructed to have maximum closing torque when the voltage and current are in quadrature, i.e. 90 degrees apart. Theoretically, the closing zone of the directional unit is +/- 90 degrees from the maximum torque angle. From a practical standpoint, the closing zone is dependent on the maximum available test current. Thus, the maximum torque angle can be calculated as being in the center of the two extreme closing angles.

5. Directional overcurrent relays must see two conditions in order to operate. What are they?

d. Directional overcurrent relays must have sufficient current to close the overcurrent contact and at an angle relative to the applied polarizing quantity to cause the directional unit to close its contact.

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No. 104

PROTECTION SCHEMES FOR LOW-VOLTAGE CIRCUIT BREAKERS

BY JIM WHITE, *Shermco Industries*

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Back in the day, circuit breaker protection schemes meant long-time delay (LTD), short-time delay (STD) and maybe ground fault. The concept of integrating low-voltage circuit breakers into a protection scheme was on the horizon, but all through the 1960's and 1970's, even into the 1980's, low-voltage circuit breakers were pretty much stand-alone devices. With new technology comes new methods of applying circuit breakers, and this Tech Quiz will see what your IQ is on the subject.

1. Identify the low-voltage protection scheme shown in Figure 1:

a. Residual ground fault
b. Percentage differential protection
c. Zone selective interlocking
d. Directional carrier blocking

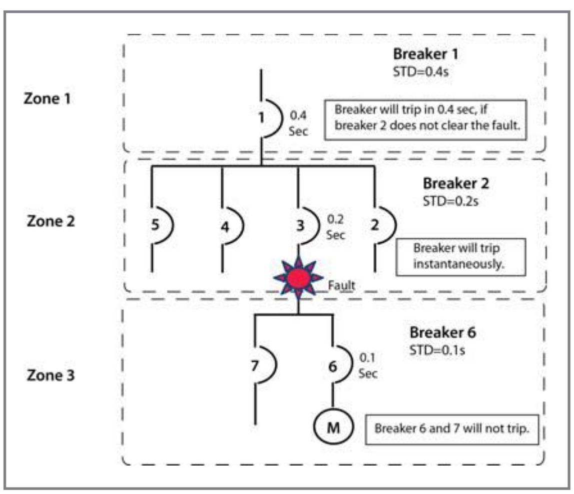

Figure 1: *Low-Voltage Circuit Breaker Protective Scheme*

2. Thermal-magnetic molded-case circuit breakers have an inherent characteristic known as:

a. Thermal imaging
b. Thermal memory
c. Reactance recovery
d. Shunt tripping

3. In the protection scheme shown in Figure 1, label the action taken by each circuit breaker. Possible actions are trip and restrain.

a. Circuit breaker number 1 __________
b. Circuit breaker number 2 __________
c. Circuit breaker number 3 __________

4. Reduced current let-through can be accomplished by which two technologies (one older and one newer)? Mark two answers.

a. Magnetic repulsion of the contacts
b. Shorter opening distances for contacts
c. Lowered pickup setting on the instantaneous
d. Current-limiting fuses

5. Thermal imaging is used by what type of overcurrent protective device (OCPD)?

a. Thermal-magnetic
b. Oil dashpot
c. Digital/microprocessor
d. Air dashpot

See answers on page 120.

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1. C. Zone selective interlocking requires that the circuit breakers in a downstream zone communicate with breakers in the next upstream zone. If the downstream breaker sees fault current, it sends a restraint signal to all breakers in the next upstream zone. The restraint signal keeps the breaker receiving it from tripping with no intentional delay (instantaneously) and that breaker will trip in its set time delay, if the downstream breaker fails to clear the fault. A breaker seeing fault current, but not receiving a restraint signal, will trip instantaneously, regardless of its delay setting.

2. B. The bimetal element in a molded-case circuit breaker has a characteristic known as thermal memory. This characteristic allows the bimetal element to respond to current on the same basis that the conductor will be heated by the current. As the current passes through the bimetal element, it will begin to deflect, based on the value of the current. If the current drops (such as in a motor starting), the bimetal will slow, then reset to an appropriate level for the current. If the current stays at that higher level, it may stop or, if the current magnitude is high enough, continue to deflect until it trips the breaker. Older solid-state OCPDs did not incorporate any method to mimic this characteristic and could false trip if the load fluctuated.

3. A. Breaker 1 will restrain. Breaker 2 will communicate with it and send a restraint signal, telling Breaker 1 that it sees the fault current.
B. Breaker 2 will trip instantaneously. It does not receive a restraint signal from Breaker 3, since Breaker 3 does not see the fault current.
C. Breaker 3 will restrain. It does not see the fault current and the absence of a restraint signal from it allows Breaker 2 to trip instantaneously.

Breaker 1 will go into STD mode, and if Breaker 2 does not trip, it will trip after the set delay. Breaker 2 will trip on Instantaneous mode as it is the breaker closest to the fault. The advantage of zone selective interlocking is that there can be a time delay for protective devices coordination, but the breaker closest to the fault will function as an instantaneous trip breaker. Since Breaker 3 does not see any fault current, it will restrain and not trip.

4. A and D. Current-limiting circuit breakers often use the magnetic force of the fault current to blow the contacts apart. The greater the fault current, the more magnetic force is applied to the parting of the contacts. This action limits both the operating time and short circuit pass-through current. At lower-level currents the breaker acts like a normal LTD function breaker. Although old technology, current-limiting fuses provide a highly reliable method of decreasing operating time and the short circuit pass-through current. With both technologies, the short-circuit current has to be great enough to be in the current-limiting characteristic or they will respond as time delay devices.

5. C. Digital and microprocessor-controlled OCPD employ thermal imaging to mimic thermal memory that is a characteristic of thermal bimetal breakers.

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No. 105

FIELD TESTING TECHNIQUES FOR LOW-VOLTAGE CIRCUIT BREAKERS

BY JIM WHITE, *Shermco Industries*

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Low-voltage circuit breaker testing technology is moving forward, albeit at a relaxed pace, it seems. Field testing can include a number of different test methods and types of test equipment. Your task, if you choose to accept it, will be to successfully answer the Tech Quiz questions this issue. As always, choose the most correct answer.

1. Figure 1 shows a jumper cable used to:
- a. defeat the zone selective interlocking function.
- b. increase the bias current through the programmer.
- c. change the phase angle of the primary injection current.
- d. defeat the ground fault function.

2. When the thermal memory is switched on for digital overcurrent protective devices (OCPDs) used on low-voltage circuit breakers, what effect will it have on the long time delay (LTD) operating time?
- a. It has no effect on LTD.
- b. It will decrease LTD somewhat.
- c. It will increase LTD somewhat.
- d. It will cause the trip unit to operate on the instantaneous element.

3. When performing primary injection testing of a circuit breaker that has zone selective interlocking, current is injected into individual phases on the tested breaker. What should be the result?
- a. The breaker should trip by its short-time delay (STD) function.
- b. The breaker should trip instantaneously and send blocking signals from its ZSI OUT terminals.
- c. The breaker should trip and send a text saying it has operated.
- d. The breaker should set an alarm and, if the current continues, trip after a set time delay.

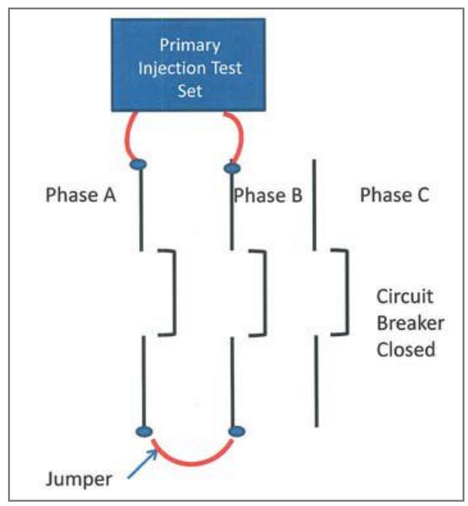

Figure 1: *Low-Voltage Circuit Breaker Testing Scheme*

4. What type of light source can be used to field test arc-flash detection relays?
- a. Compact point-and-shoot camera flash
- b. 200W light bulb or LED
- c. Professional-style flash
- d. Lighting a book of matches all at once

5. The light source used to field test arc-flash detection relays generally needs to have an output duration of ____ ms, or more.
- a. 1
- b. 2
- c. 3
- d. 4

See answers on page 122.

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1. D. Figure 1 shows a test connection designed to defeat the trip unit ground fault (GF) function by injecting current in one phase and out in the opposite direction through a second phase. This causes the GF element to see a net current of zero. There are various methods to defeat GF, depending on manufacturer, model and generation of the OCPD. Older GF elements were often defeated by placing a jumper between two terminals on the trip unit. Later, a cable was needed to defeat the GF element. Some manufacturers required using a secondary injection test set. A better way to defeat GF during primary injection is similar to that in Figure 1, except that the return is through the two other poles in parallel. The reason to go through the extra work is to cause test current in other poles to be substantially lower than the one being tested.

I might be jaded, but I see a trend of increasing costs for no additional benefit. The loop method will defeat the GF on any circuit breaker OCPD. Bus bar may be required instead of cable.

2. B. Thermal memory in modern circuit breaker trip units provides a tripping characteristic similar to bimetallic thermal trips. The bimetal element in a molded-case circuit breaker inherently has thermal memory. This characteristic allows the bimetal element to respond to current on the same basis that the conductor will be heated by the current. As the current passes through the bimetal element, it will begin to deflect, based on the value of the current. If the current drops (such as in a motor starting) the bimetal will slow, then reset to an appropriate level for the current. If the current stays at that higher level, it may stop or, if the current magnitude is high enough, continue to deflect until it trips the breaker. Older solid-state OCPDs did not incorporate any method to mimic this characteristic and would not trip for load fluctuations above and below the trip point, because they would instantaneously reset when the current dropped below the trip level.

3. B. Zone Selective Interlocking should cause the breaker that is supposed to trip change from a STD function to an Instantaneous one, while it also sends a blocking signal to upstream breakers. If it does not trip, the next breaker upstream will operate.

4. C. Some manufacturers have a field test module that synchronizes a burst of light with an overcurrent that is injected into the overcurrent control relay. Even in those field test modules, it is necessary to supply the light source, which is recommended to be a professional style camera flash. Point-and-shoot cameras apparently do not have the intensity to trigger the light detector.

5. A. One of the characteristics listed in several of the manufacturer's test specifications for the light source is that it must have a minimum duration of 1ms.

No. 106

ROTATING MACHINERY AND PROTECTION

BY JIM WHITE, *Shermco Industries*

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Low-voltage circuit breaker testing technology is moving forward, albeit at a relaxed pace, it seems. Field testing can include a number of different test methods and types of test equipment. Your task, if you choose to accept it, will be to successfully answer the Tech Quiz questions this issue. As always, choose the most correct answer.

1. With electromechanical relay motor protection, what two types of relays were not provided for induction motor protection?
   a. Overcurrent and undervoltage
   b. Differential and overvoltage
   c. Current balance and thermal replica
   d. Loss-of-field and sync-check

2. The biggest enemy to insulating systems is heat. Current magnitude during most of the starting acceleration time is very close to locked-rotor current. What is the typical current range for locked-rotor current of a large induction motor?
   a. 2 to 4 times rated current
   b. 4 to 6 times rated current
   c. 6 to 8 times rated current
   d. 8 to 10 times rated current
   e. 10 to 12 times rated current

3. Digital motor protection relays contain several functions that mimic older electromechanical protective relays. Which function uses thermal damage characteristics (I^2t) for motor protection?
   a. Thermal replica
   b. Locked rotor
   c. Overcurrent
   d. All the above
   e. None of the above

4. Which of the following functions do not use the thermal damage characteristics?
   a. Overcurrent (50/51)
   b. Current Unbalance (46)
   c. Differential (87)
   d. Number of Starts Per Time Period (66)
   e. Time Between Starts

5. During normal operation of a motor, when is a locked rotor condition produced?
   a. During starting
   b. If a phase is dropped to the motor
   c. If the gearbox or coupling is misaligned
   d. If there is a short circuit in the motor windings
   e. When more than rated voltage is applied to the motor

See answers on page 122.

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1. Since induction motors were specified, loss-of-field and sync-check would not be useful. The correct answer is d.

2. The best answer in this grouping is c. Many large induction motors will draw 6 to 8 times their full-load current during locked rotor conditions.

3. D is probably the best answer, but modern microprocessor relays generally have start limitations, thermal algorithms more sophisticated than simple thermal memory, RTDs that provide temperature limits as well as biasing of the thermal algorithm, negative sequence current calculations that alter the overload point, and other protection functions. The I^2t (thermal) characteristic applies to almost any current-based protective relay. Figure 1 shows a typical thermal damage/limit characteristic curve. Any time-current that exceeds the thermal damage characteristic will cause some thermal damage. This damage is cumulative and will add to any previous thermal degradation. Eventually the insulation becomes brittle and will fail due to electrical or mechanical forces.

4. The correct answer for this question is c. All the other protective functions are preventing the motor temperature from exceeding either the rotor thermal limit or the stator thermal limit.

5. Locked-rotor current is the current that flows in a motor when rated voltage is applied to the motor when the rotor is at a standstill. As it turns out, nearly that same current occurs through most of the motor's acceleration period. The correct answer is a.

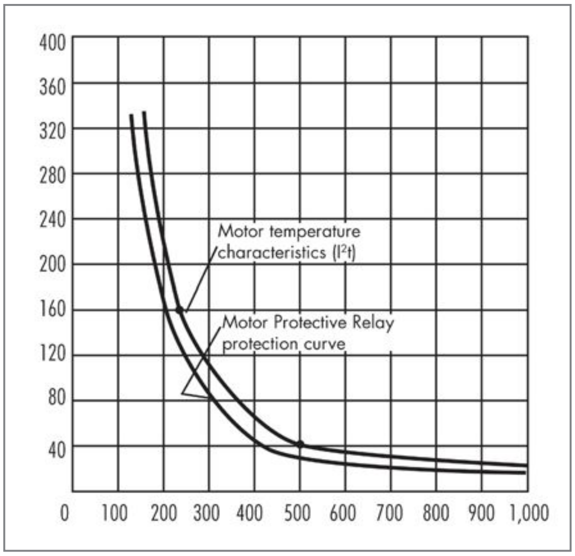

Figure 1: *Thermal Damage Characteristic Courtesy Omron Industrial Automation*

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No. 107

MEDIUM-VOLTAGE CIRCUIT BREAKERS

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Medium-voltage circuit breakers can cover multiple types of arc-extinguishing methods. If they misoperate, they can be extremely hazardous due to their higher voltages. Some new technologies have been introduced that can help detect problems and help ensure safe operation. As with low-voltage circuit breakers, medium-voltage circuit breakers require maintenance and testing to prevent accidents.

1. The vacuum bottle Integrity test provides an indication of:

a. remaining life of a vacuum bottle
b. how many short circuits the vacuum bottle can handle
c. the vacuum pressure inside a vacuum bottle
d. the current state of the vacuum bottle

2. The term medium voltage typically refers to what voltage range?

a. 1,000 V to 100,000 V
b. 1,000 V to 34,500 V
c. 1,000 V to 25,000 V
d. 1,000 V to 15,000 V

3. Medium-voltage circuit breakers are usually identified by their arc interruption method. List five of those common interrupting methods:

a. ______________________________
b. ______________________________
c. ______________________________
d. ______________________________
e. ______________________________

4. To what does anti-pump refer?

a. The ability of a circuit breaker to withstand the available short circuit current
b. The circuit breaker can only be closed once for an operation of the control switch to the close position
c. The method the circuit breaker operating mechanism operates
d. A test to measure the velocity and displacement of a circuit breaker

5. What is the recommended level of PPE from NFPA 70E Table 130.7(C)(15)(a) for racking a circuit breaker in or out of its cubicle?

a. HRC 1
b. HRC 2
c. HRC 3
d. HRC 4

See answers on page 108.

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1. d. Vacuum bottle integrity tests can only show that the vacuum bottle has sufficient vacuum to prevent arcing across the open contacts at a specified voltage. The Magnetron atmospheric condition test, which is new on the market, provides an indication of remaining interrupter life.

2. a. Although IEEE standards use 1,000 V to 100,000 V, the nominal voltages for medium-voltage equipment is usually 2,300 V to 69,000 V.

3. a. Oil
b. Gas or SF6
c. Air or air magnetic
d. Vacuum
e. Air blast (these have been mostly replaced with gas circuit breakers)

4. b. The anti-pump circuit is often referred to as the "X-Y scheme". An anti-pump scheme is important for circuit breakers because it prevents the circuit breaker from repeatedly reclosing into a fault. A set of contacts from the anti-pump relay seals in the anti-pump coil causing it to remain energized as long as the close command continues. Another contact from the anti-pump relay interrupts the closing coil circuit. This prevents a reclose until the close command is released and the anti-pump relay drops out.

5. d. Whether it is a low-voltage or medium-voltage circuit breaker, HRC 4 is always required when inserting or removing (racking) a circuit breaker.

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No. 108

NFPA 70E

BY JIM WHITE, *Shermco Industries*

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With this NETAWorld Journal's focus on NFPA 70E, it's only appropriate to have the Tech Quiz look at some of the finer points of it. I hope everyone scores 100% on this one.

1. In order to be considered a qualified worker, list five demonstrated skills or knowledge required:

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

2. How often does the 70E require retraining for qualified persons?

a. Every year
b. Every 2 years
c. Every 3 years
d. Every 4 years
e. Every 5 years

3. Using the given information, determine the approximate short circuit current available at a transformer's secondary:

Voltages:	13.8 kV to 277Y/480 V
Impedance:	5%
kVA:	2,500

a. 60,000 A
b. 54,500 A
c. 42,000 A
d. 37,500 A
e. 25,000 A

4. State the Limited and Restricted Approach Boundaries for the following voltages:

a. 208 V
Limited __________
Restricted __________

b. 480 V
Limited __________
Restricted __________

c. 4.16 kV
Limited __________
Restricted __________

d. 13.8 kV
Limited __________
Restricted __________

d. 25 kV
Limited __________
Restricted __________

5. When can an unqualified person enter the Limited Approach Space?

a. When continuously escorted
b. When performing minor housekeeping duties
c. They are never allowed within the Limited Approach Space
d. When monitored by the site electrical safety compliance manager
e. After the proper JSA and energized electrical work permits have been completed

See answers on page 118.

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1. To be a qualified worker (having the skills and knowledge required to work on or near energized electrical conductors and circuit parts) is not a simple thing. Many workers believe that they are qualified if they have the technical skills needed for the job. That is only half right. OSHA and 70E require a level of electrical safety knowledge and skill, as well. Without those, a person is unqualified. Reference NFPA 70E Section 110.2(D)(1).

a. Skills and techniques to determine energized parts from deenergized parts
b. Skills and techniques to determine the nominal voltage
c. Skills and techniques to determine the minimum safe approach distances to energized conductors and circuit parts
d. Correct use of precautionary techniques
e. Correct use of PPE, including arc flash suit
f. Correct use of insulating and shielding materials
g. Correct use of insulated and insulating tools
h. Ability to determine the degree and extent of the hazard and be able to plan the job safely

2. c. Retraining is required every three years. Note that retraining is required, not just refresher training. Refresher training can take place at shorter intervals (and should), but the intent of this section was to have people receive training that would cover the changes in NFPA 70E and any changes to procedures or their electrical safety program that needed to be communicated. Reference Section 110.2(D)(3).

3. a. Everyone should be able to perform this calculation. Sometimes accurate information is just not available and the nearest upstream transformer has to be used to determine the available short circuit current. It is a conservative method, but that is not a bad thing in this case. The equation is:

$$\frac{\text{Transformer Full-Load Current}}{\left[\dfrac{\text{Transformer \% Impedance}}{100}\right]} = \text{Short-Circuit Current}$$

A simple way to determine the full-load current of a 480 V transformer is that for every 500 kVA of transformer size, there is approximately 600 A of full-load current. Our example 2,500 kVA transformer would then have about 3,000 A capacity. The percent impedance of the transformer is divided by 100 to make it an actual impedance, so 5% becomes 0.05. Plugging the numbers in:

$$\frac{\text{2,500 kVA}}{\left[\dfrac{5\%}{100}\right]} = \text{60,000 A short-circuit available current at the secondary.}$$

4. This is another piece of knowledge every field service technician should know. The approach distances for the following voltages:

a. 208 V
Limited – 42" (3' 6") Restricted - Avoid contact
b. 277Y/4890 V
Limited – 42" (3' 6") Restricted -12" (1')
c. 4.16 kV
Limited – 60" (5') Restricted - 26" (2' 2")
d. 13.8 kV
Limited – 60" (5') Restricted – 26" (2' 2")
e. 25 kV
Limited – 72" (6') Restricted – 31" (2' 7")

5. a. By definition an unqualified person cannot determine the hazards or be able to avoid them. The only time an unqualified person can be in the Limited Space (the space between the Limited and Restricted Approach Boundaries) is if they are continuously escorted. Continuously is the key word. If their escort leaves the Limited Space, the unqualified person must also leave it. An unqualified person can not cross the Restricted Approach Boundary under any circumstances.

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No. 109

COMMISSIONING

BY JIM WHITE, *Shermco Industries*

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Commissioning involves many aspects of testing and operability verification. Commissioning ensures the electrical power system and all connected devices will function in the way it was designed.

1. One aspect of commissioning is acceptance testing. List three primary purposes of commissioning (wording does not have to be exact):

a. ______________________________

b. ______________________________

c. ______________________________

2. Before acceptance testing begins, what steps should be taken as part of the commissioning process?

a. Inspect devices for proper settings and installation completeness
b. Perform a seismic drop test on each device to be installed
c. Inspect devices for variations from design specifications
d. Both b and c
e. Both a and c

3. The series of checks that verify all parts of a system are working together is known as:

a. End-to-end testing
b. Acceptance testing
c. Maintenance testing
d. System functional testing
e. "Ringing out" the wires

4. When energizing a substation after commissioning, what is one of the most important safety steps that should be taken?

a. Restrict access to only those directly involved in the energization process
b. Make sure all the test equipment has been properly calibrated within the last year
c. Verify that all employees have a current electrical safety orientation sticker
d. Move everyone back from the substation a minimum of 100 feet from the area

5. There are several steps that should be taken after energization. Which one of the following would not be one of those?

a. Remove personal protective grounds
b. Obtain post-energization oil and gas analysis on applicable devices
c. Verify temperature monitoring and protective devices are set up to established criteria and parameters
d. Perform thermographic survey of equipment

See answers on page 126.

No. 109

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1. a. To verify proper functioning of the equipment/system after installation
b. To verify the installed equipment meets design and manufacturer's specifications
c. To capture and record performance data of the installation as the baseline for future operation and maintenance

2. e. The seismic drop test is dropping a component from a 3 foot height and then sweeping the pieces up. Not recommended for NETA test companies. Answer e is the most correct answer. Both of these (a and c) go to the heart of the commissioning process; verify settings against specifications and inspect devices for deviations from specifications. It's amazing (maybe not once you've been in the field for a while) how often the wrong part or device gets shipped, and no one seems to catch it until the drop dead date.

3. d. Once the components and devices are installed, they must be functionally tested to ensure they will operate as a system. The name may change somewhat from region to region, but the idea is to test the system for functionality.

4. Personally, I'd vote for answer d, but answer a is the correct answer. The larger the number of people present, the greater the chance for things to go wrong. Limiting access also limits the number of people who might be injured if something should go wrong.

5. a. It would really be a good plan to remove personal protective grounds prior to energizing. The other items may be included post-energiziation.

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No. 110

HIGH-VOLTAGE SUBSTATIONS

BY JIM WHITE, *Shermco Industries*

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This month we will have some questions related to high-voltage substations. Put on your thinking cap and see how well you can do.

1. Medium-voltage is defined as:

a. >1,000 V to 35,000 V
b. 2,400 V to 69,000 V
c. >1,000 V to 100,000 V
d. None of the above

2. What are four classes of lightning arresters?

a. ______________________________
b. ______________________________
c. ______________________________
d. ______________________________

3. ANSI/NETA MTS specifies a maximum of ____ ppm moisture for in-service SF_6 gas.

a. 40
b. 70
c. 110
d. 200

4. There is one optional test given for microprocessor protective relays in Section 7.9.2 of ANSI/NETA MTS. What is it?

a. Insulation resistance of each circuit to ground
b. Functional operation of each element
c. Apply voltage or current to analog inputs
d. Control verification

See answers on page 124.

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1. Take your pick (except for answer d). It seems what is medium-voltage depends on which standard you read (and even how you interpret a given standard). IEEE gives >1,000 V to 35,000 V in one standard, then >1,000 V to 100,000 V in another. NETA uses >1,000 V to 100,000 V, while ANSI C84 gives 2,400 V to 69,000 V. So what's the right answer – well the NETA Standards of course! (answer c).

2. a. Secondary Class. For low-voltage systems. These provide some protection to homes and businesses from lightning strikes.
b. Distribution Class. Lowest cost and least durable of power equipment surge protection devices. Often found on transformers rated 1,000 kVA or less. Not available for equipment rated higher than 1,000 kVA.
c. Intermediate Class. Designed primarily for medium-voltage applications (see question 1, above, to be confused). Application includes utility substations, transformers, and other equipment that merits better than distribution-class protection
d. Station Class. Most expensive and durable surge arresters (and physically largest). Used for high-voltage substations and transformers. Also used on medium-voltage equipment, that due to application or importance/cost, require the highest level of protection.

Lightning or surge arresters typically divert the lightning strike or overvoltage-to-ground to prevent the equipment from being damaged.

3. d. In-service SF_6 gas should have no more than 200 ppm moisture using a hygrometer (reference ANSI/NETA MTS Table 100.13). New SF_6 gas should have no more than 71 PPMv (parts per million by volume) moisture or about 8.76 PPMw (parts per million by weight). PPMw = PPMv/8.1. (Reference *IEEE Guide for Moisture Measurement and Control in SF_6 Gas-Insulated Equipment* – IEEE Standard 1125). Each manufacturer sets the allowable moisture limits for their equipment, which can vary considerably.

4. b. Functional operation. This test is used to verify that the protection elements of the relay are correctly set and working as intended.

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No. 111

BATTERIES AND BATTERY CHARGERS

BY JIM WHITE, *Shermco Industries*

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Batteries and their supporting charging equipment can easily be overlooked — until they're needed. Many facilities use a battery bank to supply dc operating current for opening and closing circuit breakers, spring-charging motors, and indicators. Without the dc supply available, circuit breakers will not operate.

1. One indication that a vented lead-acid battery is in trouble is when its internal impedance increases ___ percent above its as-installed impedance.

a. 5 percent
b. 20 percent
c. 30 percent
d. 45 percent

2. Which of the following is not an example of a valve-regulated lead-acid (VRLA) battery?

a. Nickel-Metal Hydride
b. Gel cell
c. Absorbed glass mat
d. Maintenance free

3. Sulfation in flooded-cell lead-acid batteries is indicated by:

a. Streaks of oil on the surface of the electrolyte
b. Brownish nodules adhering to the case
c. White salts appearing on the surface of the plates
d. White milky substance that appears on the cells and jar

4. When performing a load test on a battery bank, what percent remaining capacity indicates the need to replace the batteries?

a. 20 percent
b. 40 percent
c. 60 percent
d. 80 percent

5. The only repair for sulfation is to:

a. Equalize and increase float voltage
b. Use a mixture of boric acid and potassium hydroxide
c. Replace the batteries with new ones
d. Retighten all intercell connections

See answers on page 122.

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1. b. When the internal impedance of a cell increases by more than 20 percent, it is an indication that the battery is starting to deteriorate and should be monitored more closely. This test is often referred to as the ohmic test and is performed by applying an ac voltage across the battery and measuring the internal impedance of the battery.

2. a. Increasingly, VRLA batteries are used for various stand-by electrical power applications, including emergency generators and switchgear. The most common types of VRLA batteries are gel cells and absorbed glass mat. These batteries are often referred to as "maintenance free," although "low maintenance" would better describe them.

3. c. Sulfation results from the battery being in an under-charged state for an extended time. As the battery discharges, the active lead material on the plates will react with the sulfates in the electrolyte and form a lead sulfate on the plates. This appears as a white, granular deposit on the plates.

4. d. When battery capacity decreases to 80 percent of its initial rating, replacement is needed. It probably won't last a year without problems.

5. a. Since sulfation occurs when a battery is in a discharged state, equalizing is the cure. The problem is that all of the sulfates usually don't recombine, and the battery loses some capacity. This is a normal part of the charge/discharge cycle; but when a battery stays in a low state of charge, sulfation can be permanent. Battery shedding will also increase, as the discharged electrolyte now contains more water and will soften the lead plate material. If that shedded material builds up about half-way to the plates, a constant discharge begins between the shedded material and the plates, resulting in a battery that won't maintain a charge.

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No. 112

POWER TRANSFORMERS

BY JIM WHITE, *Shermco Industries*

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Power transformers have no moving parts (except for accessories such as fans, pumps, or LTCs), and yet, they are very complex electrical devices. This month's Tech Quiz asks questions on general power transformer knowledge — some from the MTS, some not. Let's see how you do:

1. Power transformer cooling designations underwent changes a few years ago. Match up the old designation with the new:

a. FA	ONAF/ODAF
b. FOA	ONAN
c. OA/FOA	ODAF or OFAF
d. OA	ONAF

2. Buchholz relays are used on transformers to detect:

a. Winding over temperature
b. Over pressure of tank
c. Change in oil temperature
d. Internal faults

3. Sudden pressure relays operate on a:

a. Rapid increase in main tank
b. Pressure set point in lbs/in^2
c. Difference in pressure between main tank and tap changer tank
d. Rapid increase in conservator pressure

4. What type of sensing element can measure a transformer's hottest-spot (winding) temperature directly?

a. Fiber optic cable
b. Thermocouples
c. Platinum RTDs
d. Oil well monitor

5. Hydrogen is often the primary gas used for field monitoring of combustible gases. Check all the answers that apply:

a. Hydrogen is the smallest molecule, so it passes through membranes when others won't.
b. Hydrogen can be tinted to make it more visible, allowing easier detection by optical sensors.
c. Hydrogen is always present when combustible gases are generated.
d. Hydrogen has a distinct odor, allowing the use of olfactory detectors.

See answers on page 128.

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1.

a. OA	ONAN (self-cooled)
b. FA	ONAF (forced-air/air-cooled) — two stages of cooling would be ONAN/ONAF/ONAF.
c. FOA	ODAF or OFAF (forced-air/air-cooled) — these transformers have no self-cooled rating and must run their pumps.
d. OA/FOA	ONAN/ODAF (self-cooled, with one stage of directed-oil pumping, with fans).

2. a. Buchholz relays are used with conservator tank transformers and detect internal faults by responding to combustible gas generation directly or by abnormal oil flows created by rapid gas generation.

3. a. Sudden pressure relays won't operate on a gradual increase in main tank pressure; instead, they will operate on a rapid increase in pressure. This is often due to arcing under the oil, but sometimes can be caused by other events. For example, a utility once experienced false tripping on one of its transformers with a sudden pressure relay. They found that the workers installing the nitrogen bottles were using their feet to push the bottle into its cabinet. The bottle would hit the back of the tank, causing a false trip.

4. a. Only a fiber optic cable can be used to directly measure the hottest-spot temperature. The hot-spot temperature is (theoretically) two-thirds up and one-third into the high-voltage winding. Any metallic object or sensor would cause a short circuit between windings or turns. Don't expect to see many fiber optic hot-spot temperature detectors in the field. Most will be the type where oil in a separate well is heated by an auxiliary CT and heating element. This is calibrated to approximate the hot-spot temperature.

5. a and c. Hydrogen is so small that some types of hydrogen detection systems use a membrane that only allows it to pass through, while excluding other gases. Hydrogen is always present when combustible gases are created, so it is a reliable method of combustible gas detection.

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No. 113

GENERAL TESTING AND MAINTENANCE

BY JIM WHITE, *Shermco Industries*

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This issue's Tech Quiz will challenge your general testing and maintenance knowledge. NETA Technicians need a good understanding of testing and test results interpretation. Let's see how you do.

1. First-out timing is performed to ensure:
a. All phases of the circuit breaker open within 25 milliseconds of each other.
b. The circuit breaker that should trip first will do so. This is also known as selective coordination.
c. The circuit breaker will rack out smoothly and without hesitation.
d. The circuit breaker will open within specifications after being closed for an extended period of time.

2. Partial discharges are created by:
a. Moisture that is trapped within the insulation
b. Ionization of air pockets within the insulation
c. Deep discounting at the Dollar General store
d. Carbon deposits vibrating within the insulation

3. What is considered a typical percent power factor for a new/in-service medium-voltage oil-filled power transformer?
a. 0.5%/1.0%
b. 1.0%/2.0%
c. 0.5%/2.0%
d. 1.0%/3.0%

4. When performing a VLF (very low frequency) test for in-service cable, what is the recommended test voltage for 15 kV-class power cable (per MTS-2015)?
a. 7 kV rms
b. 10 kV rms
c. 16 kV rms
d. 23 kV rms

5. What is the recommended minimum insulation resistance test value for a 2,300 V motor manufactured after 1970?
a. 50 MΩ
b. 75 MΩ
c. 100 MΩ
d. 200 MΩ
e. 500 MΩ

6. At what frequency is a VLF test performed?
a. 0.1 Hz
b. 0.2 Hz
c. 0.5 Hz
d. 1 kHz

7. What is the recommended moisture limit for in-service SF6 gas?
a. ≤ 500 ppm
b. ≤ 300 ppm
c. ≤ 200 ppm
d. ≤ 100 ppm

See answers on page 118.

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1. d. Circuit breakers often sit for extended periods of time without operating. As they sit, current is flowing through them, drying out their lubricants. When called on to operate, maybe they will do so correctly or maybe they won't. The problem is that they will often work just fine after a few operations, but what will they do on that very first trip? That's the one that really counts.

2. b. Voids and air pockets in insulation can have electrical discharges (ionization) when they are in high-voltage fields. This discharge can be measured and monitored, either while the equipment is energized (for continuous monitoring) or during specific tests.

3. a. 0.5%/1%pf. Usually I look for 0.5% on a new transformer, per Doble recommendations, but there are variations between specimens. Some transformers can have higher percent power factors and be perfectly fine. That is why the insulation power factor test is not considered to be rigidly interpreted test. It is more of a screening test to show that here may be a problem. Further testing can make a final determination.

4. c. 16 kV rms

5. c. 100 MΩ

6. a. VLF testing is typically performed at 0.1 Hz. The advantage of this test is that it does not create treeing inside power cable insulation. The downside is it can cause existing treeing to grow, possibly failing the cable under test.

7. c. Unless there is a different value provided by the manufacturer, ≤ 200 ppm is recommended.

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No. 114

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PROTECTIVE RELAYING FOR ELECTRICAL POWER SYSTEMS

BY JIM WHITE, *Shermco Industries*

This issue's Tech Quiz looks at protective relaying for electrical power systems. Testing protective relays is a huge part of the protection scheme, and, if not done accurately, can cause false tripping or worse — a no-trip condition. Most protective relays today are digital and have eliminated many of the problem areas associated with electromechanical relays, but they still need to have the calibration and functions verified.

1. Match the device number with the relay function:

a. 50	____	1. Differential
b. 86	____	2. Undervoltage
c. 87	____	3. Instantaneous overcurrent
d. 27	____	4. Lockout
e. 25	____	5. Directional overcurrent
f. 67	____	6. Synch check

2. A percentage differential relay with a 25 percent slope characteristic has 4.9 A in one restraint coil and 4.2 A in the other.

a. What is the calculated imbalance?
_______ percent

b. Will this relay operate with this imbalance?
Yes / No

c. Based on its characteristic, what is this relay most likely protecting? _______ or _______

3. What type of protective relay requires two voltages that can have their magnitudes and phase angles varied from each other?

a. Undervoltage
b. Overvoltage
c. Percent differential
d. Synch check
e. Directional power

4. A type 21 protective relay would be a:

a. Distance
b. ac reclosing
c. Pilot wire
d. Ground detector
e. Excitation

See answers on page 120.

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1.

a. 50	3. Instantaneous overcurrent
b. 86	4. Lockout
c. 87	1. Differential
d. 27	2. Undervoltage
e. 25	6. Synch check
f. 67	5. Directional overcurrent

2. a. What is the calculated imbalance?
16.6 percent
b. Will this relay operate with this imbalance?
Yes / No
For this relay to operate, the percent slope characteristic must be exceeded, which is not the case in this example. The relay will restrain.
c. Based on its characteristic, what is this relay most likely protecting? Transformer or generator

3. d. Synch check relays require two voltages. One voltage is used as the nominal (rated) voltage and the other voltage is varied. The characteristic in Figure 1 shows how the two voltages are used to check the size of the circle. For a relay rated at 120 V, one voltage is typically set to 120 V at zero degrees, while the second voltage is set to 120 V and the phase angle is varied to find its operating angles. At the 60-degree circle setting (the largest of the circles) and at 120 V, the relay will close its contacts at 60 degrees plus-or-minus the tolerance of the relay, which is usually 10 percent. Note that 120 V is in the center of the circle, and at zero-degree phase angle difference, the relay contacts will flicker if the second voltage is increased to 480 V (with the first voltage at 120 V). The timing test is performed by setting both voltages at zero-degree phase angle. One voltage is usually set to 120 V (or rated voltage), while the second voltage is set to zero V and the relay timed (see Figure 2).

4. a. A type 21 relay is any type of distance relay, but not blocking or unblocking relays.

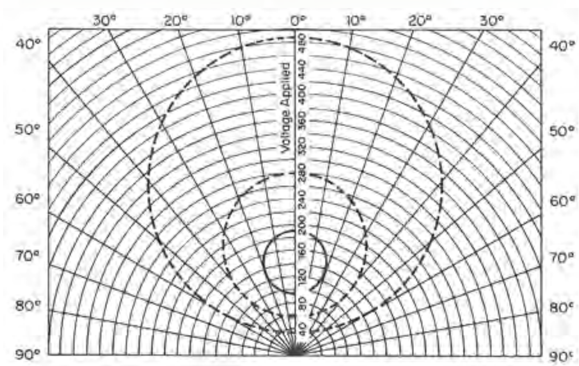

Figure 1: *Synch Check Relay Circle Characteristic*

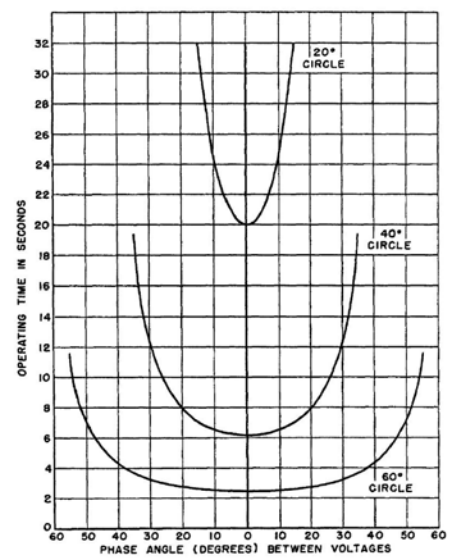

Figure 2: *Synch Check Timing Characteristic*

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No. 115

ELECTRICAL RISK ASSESSMENT

BY JIM WHITE, *Shermco Industries*

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NFPA 70E can be a useful resource for performing and understanding electrical risk assessments. This month's quiz mostly comes from the 70E, but also requires some problem-solving on your part.

1. NFPA 70E Section 110.1(G) contains Informational Note 2 specifying three items that may be required in a risk assessment. What are they?

a. PPE, equipment, and the experience of the second person
b. Training, equipment, and certification
c. Equipment, experience, and PPE
d. Training, PPE, and certification
e. PPE, training, and experience

2. What one step could a technician in the field take to reduce the possibility of electrical accidents?

a. Test for the absence of voltage
b. Inspect the equipment carefully
c. Get the supervisor's approval
d. Complete a safety checklist

3. Who does OSHA hold responsible for performing a risk assessment?

a. The employee
b. The site safety specialist
c. Anyone involved in the task(s)
d. The safety backup
e. The employer

4. In NFPA 70E Section 130.4, Shock Risk Assessment, if additional protective measures are required, what should be identified (mark all correct answers)?

a. The design of the electrical equipment, including its over-current protective device
b. The voltage to which personnel will be exposed
c. The minimum arc rating of protective equipment
d. Personal and other protective equipment required
e. The boundary requirements

5. NFPA 70E provides ____________.

a. Electrical and mechanical safe work practices
b. Industry-best safe work practices
c. International safe work practices
d. Exceptional safe work practices
e. Minimum safe work practices

See answers on page TK.

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1. e. NFPA 70E specifies the requirements for a safety backup or standby person (second person). The electrical safety program should specify what PPE, training, and experience that person should have. Informational Notes cannot contain requirements but are used to clarify and provide additional direction as to the committee's thinking on a subject. Even though Informational Note No. 2 says that such information may be specified, this information should be considered whenever a safety backup is used.

2. a. In all the electrical incidents I have seen over the years, one step might have prevented 90 percent of these incidents. If technicians would faithfully perform an absence-of-voltage test — whether they think the circuit is energized or not — they could save themselves and their families a lot of pain, suffering, and grief. It is the single most important safety task to perform.

3. e. OSHA uses what is called a single point of responsibility. That single point is the employer. OSHA will always hold the employer responsible for their employees' safety. Job safety assessments, risk assessments, etc., are all required to be completed by the employer. This may simplify OSHA's task of assessing responsibility, but the fact of the matter is that the employee is the one who suffers from a mishap. No employer can be everywhere a technician is about to work, nor can that employer be at the site in front of the equipment to assess risk. Only the technician preparing to perform a task can make the final risk assessment. This is especially true for NETA Field Service Technicians.

4. a., d., and e. NFPA 70E Section 130.4 covers the shock hazard and risk assessment, while Section 130.5 covers arc flash. Additional protective measures could include guarding the energized conductors or circuit parts, setting up safety barrier tape, identification of look-alike equipment, or other measures as called out by NFPA 70E.

5. e. This is a topic that comes up frequently at NFPA 70E committee meetings. Some committee members believe that the 70E should provide best safe work practices. As NETA Board President Ron Widup once stated, if that were the case, the 70E could be boiled down into one sentence: Turn it off!

What the 70E really provides is the minimum acceptable safe work practices, much as OSHA regulations do. Employers and employees are expected to exceed these minimum requirements to protect their safety. Unfortunately, many people take the 70E at face value and do not do what is needed to prevent themselves or others from being injured.

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