Board of Building Standards

ELECTRICAL SAFETY INSPECTOR ADVISORY COMMITTEE MEETING AGENDA

DATE: MAY 06, 2022
TIME: 10:00 AM
LOCATION: NO MEETING THIS MONTH
REQQUEST FOR RECOMMENDATIONS

Personnel Certification Applications

P-1 Barbour, James BI, ESI
Certification ID: 8785
Current certs: none
Staff notes: Appears to meet requirements for ESI: recommend approval
ESIAC Recommendations:
Committee recommendation:

P-2 Francis, R Brandon ESI T
Certification ID# 8759
Current Certifications: RBI
Staff Notes: Holds RBI, working for Safebuilt, has all sponsor forms.
ESIAC Recommendations:
Committee Recommendation:

P-3 Kizer, Joshua ESI, EPE
Certification ID# 8810
Current Certifications: none
Staff Notes: OCILB Electrical Contractor, recommend approval.
ESIAC Recommendations:
Committee Recommendation:

P-4 Zinn Sr., Randall - ESI, PI, MI
Certification ID: 8801
Current Certifications: none
Staff Notes: Holds OCILB license in HVAC and refrigeration. Per application, has been installing all components of refrigeration and mechanical systems for 24 years. Recommend approval.
ESIAC Recommendation:
Committee Recommendation:

Continuing Education Applications for Review

ER-1 Grounding and Bonding, 2020 NEC (Dayton Area Electrical JATC)
EPE, ESI, RBO, EPE (two 6-hour sessions)
Staff Notes:
ESIAC Recommendation:
Committee Recommendation:

File Attachments for Item:

P-1 Barbour, James BI, ESI

Certification ID: 8785

Current certs: none

Staff notes: Appears to meet requirements for ESI: recommend approval

ESIAC Recommendations:

Committee recommendation:

Board of Building Standards Application for Interim Certification, Building Department Personnel

Barbour	James	
Last Name	*First Name*	*BBS Certification ID*

SECTION 1: CHECK INTERIM CERTIFICATION(S) BEING REQUESTED

☐ Building Official	☐ Master Plans Examiner	■ Building Inspector	■ Electrical Safety Inspector	☐ Fire Protection Inspector
☐ Building Plans Examiner	☐ Plumbing Plans Examiner	☐ Mechanical Plans Examiner	☐ Electrical Plans Examiner	☐ Fire Protection Plans Examiner
	☐ Plumbing Inspector	☐ Mechanical Inspector	☐ Non-Residential Industrial Unit Inspector	

SECTION 2: LIST ANY OHIO LICENSE, CERTIFICATE, OR REGISTRATION HELD

(Mark "T" If Trainee)

Description			Certificate Number	Date Received
Architectural Registration				
P.E. Registration				
Res	Non-Res			
☐	☐	Building Official Certification		
☐	☐	Plans Examiner Certification		
☐	☐	Building Inspector Certification		
☐	☐	Mechanical Inspector Certification		
Building Plans Examiner Certification				
Mechanical Plans Examiner Certification				
Fire Protection Plans Examiner Certification				
Electrical Plans Examiner Certification				
Plumbing Plans Examiner Certification				
Fire Protection Inspector Certification				
Electrical Safety Inspector Certification				
Plumbing Inspector Certification				
Fire Safety Inspector Certification				
Fire Protection System Designer Certification				
Medical Gas Piping Inspector Certification				

Barbour | James

Last Name | *First Name* | *BBS Certification ID*

SECTION 3: EMPLOYMENT/EDUCATION

Formal Education	Date Graduated
Maysville High School (Diploma)	5/1989
ITT Technical College (Associates)	2/2015
Related Vocational or Technical Training	Years' Experience
U.S. Military construction experience (MOS or other designation):	Years' Experience
Place of Employment:	Years' Employed
Muskingum County Building Department	Less than 1

SECTION 4: APPLICANTS REQUESTING MEDICAL GAS INSPECTOR CERTIFICATION

***Attach proof** of certification by an ASSE recognized third-party certifier in accordance with ASSE standard 6020.*

SECTION 5: OBC BUILDING INSPECTION EXPERIENCE PERFORMED FOR A BBS CERTIFIED BUILDING DEPARTMENT

BBS Certified Building Department	BBS Certified Position/Title	Duties	Date of Service, Length of Time (MM/DD/YY)
N/A			

Barbour	James	
Last Name	*First Name*	*BBS Certification ID*

SECTION 6: ELECTRICAL SAFETY INSPECTOR (ESI) - SPECIFIC EXPERIENCE QUALIFICATIONS

Applicants for Electrical Safety Inspector Only Must Complete This Item

Section 3783 of the Ohio Revised Code specifies that an applicant for a Certificate of Competency as an Electrical Safety Inspector must meet on of the following to qualify to take required examination. Please check the qualification that applies:

1. ☐ Have been a journeyman electrician or equivalent for four years, two of which were as an electrician foreman, and have had two years' experience as a building department electrical inspector trainee;
2. ☐ Have been a journeyman electrician or equivalent for four years and have had three years' experience as a building department electrical inspector trainee;
3. ☐ Have had for four years' experience as a building department electrical inspector trainee;
4. ■ Have been a journeyman electrician or equivalent for six years;
5. ☐ Am a graduate electrical engineer and registered in the State of Ohio. Registration number: _____
6. ■ Applicant authorizes all testing organizations including ICC to provide test results to the BBS.

SECTION 7: EXPERIENCE *(DO NOT SUBSTITUTE WITH OTHER RESUMES)*.

Refer to Experience Requirements Listed in O.A.C. 4101:7-3-01 and O.R.C. 3783

Below, list the specific projects you worked on, and the specific work you performed, your typical duties for each project, and dates of this work. You **must** demonstrate that you have the required number of months (years) of actual, practical experience for the certification requested (see matrix).

Provide letters from certified inspectors, employers, or contractors verifying your experience. Submit copies of any certificates, diplomas, or licenses. Remove all personal information.

SECTION 7 CONT.: EXPERIENCE

List Each Construction Project AND Specific Type of Work Performed	Name of Employer, Contact, Address, Telephone Number	Project Time: From_ To _ (MM/YY)
Example: *Children's Hospital, Toledo* *Structural steel work on addition* Circuit City- Columbus, Ohio Apprentice Electrician. Commercial Electrical Install. Installed conduit, wire, fixtures, devices, etc. Bob Evans- Pickerington, Ohio Foreman Electrician. Commercial Electric Install. Oversaw/ran project from start to finish. Installed conduit, wire, fixtures, devices, etc. Site lighting, underground conduit, service. Per NEC. Bob Evans- Polaris, Columbus, Ohio. Foreman Electrician. Commercial Electric Install. Oversaw/ran project from start to finish. Installed conduit, wire, fixtures, devices, etc. Site lighting, underground conduit, service. Per NEC. Various commercial projects for X-F Electric as a Foreman or Journeyman. Installed fire alarm system, motor controls. Installed conduit, wire, fixtures, devices, etc. Site lighting, underground conduit, service. Per NEC.	*Homer Steel and Trade* *125 Anytown Street* *My City, OH, 45454* *(419)555-1212* X-F Electric 1120 Claycraft Rd. Gahanna, Ohio 43230 614-575-2700 All These Projects worked at X-F Electric.	*July 2013-May 2014* *(10 months)*
Total Experience on This Page (In Months):		42

Barbour James

Last Name *First Name* *BBS Certification ID*

List Each Construction Project AND Specific Type of Work Performed	Name of Employer, Contact, Address, Telephone Number	Project Time: From_ To _ (MM/YY)
Speedway Truck stop- Circleville, Ohio. Foreman Electrician.Commercial Electric Install. Oversaw/ran project from start to finish. Installed conduit, wire, fixtures, devices, etc. Site lighting, underground conduit, service. Per NEC.	X-F Electric 1120 Claycraft Rd. Gahanna, Ohio 43230 614-575-2700	11/99 - 03/00 (5 Months)
Various commercial projects for X-F Electric as a Foreman or Journeyman. Installed fire alarm system, motor controls. Installed conduit, wire, fixtures, devices, etc. Site lighting, underground conduit, service. Per NEC.	X-F Electric 1120 Claycraft Rd. Gahanna, Ohio 43230 614-575-2700	03/00 - 06/03
Glenford Elementary School- Glenford, Ohio. Worked as journeyman. Installed fire alarm system, motor controls. Installed conduit, wire, fixtures, devices, etc. Site lighting, underground conduit, service. Per NEC.	X-F Electric 1120 Claycraft Rd. Gahanna, Ohio 43230 614-575-2700	06/03 - 11/03
Chiller North Ice Hockey Rink- Lewis Center, Ohio. Oversaw/ran project from start to finish. Installed fire alarm system, motor controls. Installed conduit, wire, fixtures, devices, etc. Site lighting, underground conduit, service. Per NEC.	Titan Electric (the original) Gahanna, Ohio 43230	04/2004 - 10/2004
Refugee Rd. Apartments- Pickerington Ohio. 4 Buildings 24 apartments in each. Oversaw/ran project from start to finish. Installed fire alarm system. Installed conduit, wire, fixtures, devices, etc. Site lighting, underground conduit, service. Per NEC	Titan Electric (the original) Gahanna, Ohio 43230	10/2004 - 04/2005
	Total Experience on This Page (In Months):	60

Barbour James

Last Name *First Name* *BBS Certification ID*

List Each Construction Project AND Specific Type of Work Performed	Name of Employer, Contact, Address, Telephone Number	Project Time: From_ To _ (MM/YY)
Owner of company. Oversaw/ran projects from start to finish. Oversaw employees. Estimation. Installed fire alarm system and motor controls. Installed conduit, wire, fixtures, devices, etc. Site lighting, underground conduit, service. Per NEC	Premier Wiring Services Zanesville, Ohio 43701	04/05 - 02/07
Commercial Lighting- Grove City, Ohio. Project Manager/ Estimator.Oversaw/ran projects from start to finish. Oversaw employees. Estimation.	Commercial Lighting 1798 Killdeer Dr. Grove City, Ohio 43123 614-653-2009	02/07 - 05/09
Edgewood Electric- Columbus Ohio. Project Manager/ Estimator. Managed Columbus office. Oversaw/ran projects from start to finish. Oversaw employees. Estimation.	Edgewood Electric 939 Dudley Rd. Edgewood, Ky. 41017 859-341-4433	10/2010 - 03/2016
Indco Electric- Sunbury Ohio. Project Manager/ Field Supervisor. Oversaw/ran projects from start to finish. Oversaw employees.	Indco Electric 130 Stelzer Ct. Sunbury, Ohio 43074 740-965-9212	06/2016 - 02/2018
Ables Electric- Zanesville Ohio. Project Manager/ Estimator. Oversaw/ran projects from start to finish. Oversaw employees. Estimation	Ables, Inc. 330 East Pike Zanesville, Ohio 43701 740-453-6015	02/2018 - 07/2021
	Total Experience on This Page (In Months):	175

Barbour | James

Last Name | *First Name* | *BBS Certification ID*

List Each Construction Project AND Specific Type of Work Performed	Name of Employer, Contact, Address, Telephone Number	Project Time: From_ To _ (MM/YY)
Please note that I have worked on and supervised many other projects. I've worked in residential, commercial, and industrial settings. I've also acheieved an Associates Degree in networking. I started in the the trade in 1996 with X-F Electric and worked my way up as an estimator/ project manager. I hold a City of Zanesville Master Electrician License, State of Ohio Fire Alarms License, and an Ohio Electrical Contractor License.		05/96 - present
	Total Experience on This Page (In Months):	310

Barbour	James	
Last Name	*First Name*	*BBS Certification ID*

SECTION 8: PERSONAL HISTORY

1. Have you ever been convicted of any felony, or any crime involving moral turpitude? ☐ Yes ■ No

   If you answered "Yes" please explain below:

2. Have you served in the U.S. armed services? (If No, skip question 3) ☐ Yes ■ No
3. If YES, were you discharged under honorable conditions? ☐ Yes ☐ No

   If you answered "No" please explain below:

SECTION 9: CERTIFICATION

I certify the information contained in this application is true and complete, and I understand that providing false information may be grounds for not granting certification or for immediate termination of certification at any point in the future. If granted I authorize the investigation of all statements contained herein and release all parties from all liability for any damage that may result from furnishing the same to Ohio Board of Building Standards. Falsification is a violation of section 2921.13 of the Ohio Revised Code and is punishable as a misdemeanor of the first degree.

Signature of Applicant: Jan S. Barbour

Subscribed and duly sworn before me according to law, by the above named applicant this day 1 of March in the year 2022 at ~~Muskingum~~ North Valley Bank, County of Muskingum and State of Ohio

Notary Public: Stephanie L. Davis

NOTARY PUBLIC STATE OF OHIO

STEPHANIE L DAVIS
Notary Public
State of Ohio
My Comm. Expires
October 13, 2026

ITT TECHNICAL INSTITUTE

Certifies that

JAMES P BARBOUR

has successfully completed the prescribed program of

NETWORK SYSTEMS ADMINISTRATION

and, based on the recommendation of the faculty, is awarded this

ASSOCIATE OF APPLIED SCIENCE DEGREE

Given at Indianapolis, Indiana, this 1st day of February, 2015.

Dean

ITT Technical Institute

ITT

Director

City of Zanesville
401 Market Street
Zanesville, OH 43701
www.coz.org
(740) 617-4890

PROFESSIONAL LICENSE CERTIFICATE

This License/Registration is not transferable.

Issued To:	JAMES BARBOUR
Mailing Address:	2225 PINKERTON LN ZANESVILLE, OH 43701
License Number:	ELECCNTR-0390-2019
Issued Date:	11/26/2019
Expiration Date:	12/31/2021
License Type:	Electrical Contractor
Classification:	Master
Fees Paid:	~~$30.00~~ waived

Director of Public Safety

This License/Registration is valid for the dates stated above unless sooner revoked on proof of cause.

TO BE POSTED IN A CONSPICUOUS PLACE

Any changes in information must be submitted within 30 days to:

Bureau of Testing & Registration
PO BOX 529
Reynoldsburg, Ohio 43068
614-752-7126
614-995-4206 (fax)
webfmtr@com.state.oh.us

This license shall be carried on your person while performing the listed activities.

State of Ohio
Department of Commerce
Division of State Fire Marshal

FIRE PROTECTION LICENSE
JAMES P BARBOUR

54.25.3479

Expiration Date: 01/02/2023

Signature

This card shall be on your person while performing listed activities.

Ohio Department of Commerce
Division of State Fire Marshal
Bureau of Testing & Registration
8895 E Main Street, PO Box 529
Reynoldsburg, Ohio 43068

JAMES P BARBOUR

[redacted]

JAMES P BARBOUR

is duly registered and is entitled to the practice in the State of Ohio. License categories are for Servicing, Testing, Repairing, and Installing.

Fire Alarms / Detection

Department of Commerce

Division of Industrial Compliance
Ohio Constructions Industry
Licensing Board O.C.I.L.B.

Mike DeWine
Sheryl Maxfield

BARBOUR, JAMES P
[redacted]

Mike DeWine
Governor

Electrical
CONTRACTOR'S LICENSE

Sheryl Maxfield
Director

Ohio License # 37817 Expiration Date: 04/04/2023

JAMES P BARBOUR
PRO LIGHTING LLC
EMPLOYEE

Carol A. Ross
Board Secretary

William Koester
Administrative Chairperson

This is YOUR license. Plan Approvals obtained with YOUR license and posting of YOUR license indicates that YOU and YOUR liability insurance are assuming all responsibility for any projects performed under this license.

Mike DeWine
Governor

Sheryl Maxfield
Director

LICENSE MUST BE POSTED ON JOB SITE

Electrical

CONTRACTOR'S LICENSE

JAMES P BARBOUR

PRO LIGHTING LLC

EMPLOYEE

Ohio License# **37817**

Expiration Date: **April 04, 2023**

LICENSE MUST BE POSTED ON JOB SITE

Carol Ross

William Koester

File Attachments for Item:

P-2 Francis, R Brandon ESI T

Certification ID# 8759

Current Certifications: RBI

Staff Notes: Holds RBI, working for Safebuilt, has all sponsor forms.

ESIAC Recommendations:

Committee Recommendation:

Board of Building Standards Application for Trainee Certification, Building Department Personnel

Francis (Last Name) | Ralph (First Name) | 8759 (BBS Certification ID)

SECTION 1: CHECK TRAINEE CERTIFICATION(S) BEING REQUESTED

☐ Master Plans Examiner	☐ Building Plans Examiner	☐ Electrical Plans Examiner	☐ Fire Protection Plans Examiner	☐ Mechanical Plans Examiner
☐ Plumbing Plans Examiner	☐ Building Inspector	☑ Electrical Safety Inspector	☐ Fire Protection Inspector	☐ Mechanical Inspector
☐ Plumbing Inspector	☐ Non-Residential Industrial Unit Inspector			

☐ Res. Plans Examiner	☐ Res. Building Inspector
☐ Res. Industrial Unit Inspector	☐ Res. Mechanical Inspector

SECTION 2: LIST ANY OHIO LICENSE, CERTIFICATE, OR REGISTRATION HELD
(Mark "T" If Trainee)

Description			Certificate Number	Date Received
Architectural Registration				
P.E. Registration				
Res	Non-Res			
☐	☐	Building Official Certification		
☐	☐	Plans Examiner Certification		
☑	☐	Building Inspector Certification	8759	11/31/2022
☐	☐	Mechanical Inspector Certification		
Building Plans Examiner Certification				
Mechanical Plans Examiner Certification				
Fire Protection Plans Examiner Certification				
Electrical Plans Examiner Certification				
Plumbing Plans Examiner Certification				
Fire Protection Inspector Certification				
Electrical Safety Inspector Certification				
Plumbing Inspector Certification				
Fire Safety Inspector Certification				
Fire Protection System Designer Certification				
Medical Gas Piping Inspector Certification				

Section 3: Employment/Education

a. Formal Education	Date Graduated
Zane State (Associate) Electrical Eng.	2019
Wright State (Bachelor) Communications	2006

Francis | Ralph | 8759
Last Name | First Name | BBS Certification ID

b. Related Vocational or Technical Training	Years' Experience
c. U.S. Military construction experience (MOS or other designation):	Years' Experience
d. Place of Employment:	Years' Employed
City of Heath	3

SECTION 4: OBC/RCO BUILDING INSPECTION EXPERIENCE PERFORMED FOR A BBS CERTIFIED BUILDING DEPARTMENT

BBS Certified Building Department	BBS Certified Position/Title	Duties	Date of Service, Length of Time (MM/DD/YY)
N/A			

SECTION 5: EXPERIENCE *(DO NOT SUBSTITUTE WITH OTHER RESUMES).*

Refer to Experience Requirements Listed in O.A.C. 4101:7-3-01 and O.R.C. 3783

Below, list the specific projects you worked on, and the specific work you performed, your typical duties for each project, and dates of this work. You **must** demonstrate that you have the required number of months (years) of actual, practical experience for the certification requested (see matrix).

Provide letters from certified inspectors, employers, or contractors verifying your experience. Submit copies of any certificates, diplomas, or licenses. Remove all personal information.

List Each Construction Project AND Specific Type of Work Performed	Name of Employer, Contact, Address, Telephone Number	Project Time: From_ To _ (MM/YY)
Example: *Children's Hospital, Toledo* *Structural steel work on addition*	*Homer Steel and Trade* *125 Anytown Street* *My City, OH, 45454* *(419)555-1212*	*July 2013-May 2014* *(10 months)*
Total Experience on This Page (In Months):		

Francis — *Last Name*

Ralph — *First Name*

8759 — *BBS Certification ID*

SECTION 5 CONT.: EXPERIENCE

List Each Construction Project AND Specific Type of Work Performed	Name of Employer, Contact, Address, Telephone Number	Project Time: From_ To _ (MM/YY)
AEP 69KV & 138KV substations Asset Management of Conductors, circuit breakers, switches, relays, potential & current transformers. Drafted One-line Diagrams using Electric Assemblies.	Easi Engineering 8100 Walton Pkwy New Albany, OH 43054 614-741-8672	05/2018 - 04/2019 (11months)
	Total Experience on This Page (In Months):	11

Francis — *Last Name*

Ralph — *First Name*

8759 — *BBS Certification ID*

SECTION 6: PERSONAL HISTORY

1. Have you ever been convicted of any felony, or any crime involving moral turpitude? ☐ Yes ☑ No
   If you answered "Yes" please explain below:
2. Have you served in the U.S. armed services? (If No, skip question 3) ☐ Yes ☑ No
3. If YES, were you discharged under honorable conditions? ☐ Yes ☐ No
   If you answered "No" please explain below:

SECTION 7: CERTIFICATION

I certify the information contained in this application is true and complete, and I understand that providing false information may be grounds for not granting certification or for immediate termination of certification at any point in the future, if granted. I authorize the investigation of all statements contained herein and release all parties from all liability for any damage that may result from furnishing the same to Ohio Board of Building Standards. Falsification is a violation of section 2921.13 of the Ohio Revised Code and is punishable as a misdemeanor of the first degree.

Signature of Applicant: [signature]

Subscribed and duly sworn before me according to law, by the above named applicant this day 1st of April in the year 2022 at Heath, County of Licking and State of Ohio.

Notary Public: [signature]
DENISE M RUSH

Comm Expires: 5/12/2024

Board of Building Standards

Application for Trainee Certification, Building Department Personnel

Francis	Ralph	8759
Last Name	*First Name*	*BBS Certification ID*

SUPERVISOR CERTIFICATION OF TRAINEE

Please complete this certification and return it with the BBS Application for Trainee Certification.

Application for participation in a BBS trainee program is being made to the Board of Building Standards. I, Christopher T Wilson, trainee supervisor for the political subdivision of SafeBuilt, (Municipality, Township, County) hold certification as a CBO,RBO, BI, ESI Certification ID# 1643, effective until 06/2024, and hereby consent and agree to supervise the work of Ralph Francis (Applicant) as a Building Department Trainee pursuant to section 4101:7-3-01(F)(5)(b) of the Ohio Administrative Code.

Number of Trainees presently supervised (including this applicant):

X One _____ Two

Signature: Christopher T. Wilson Date: 04/07/2022

Francis — *Last Name*

Ralph — *First Name*

8759 — *BBS Certification ID*

BUILDING OFFICIAL CERTIFICATION OF TRAINEE AND SUPERVISOR

Please complete this certification and return it with the BBS Application for Trainee Certification

Application for participation in a BBS Trainee program is being made to the Board of Building Standards. I, Renee Snodgrass, Building Official for the political subdivision of Safebuilt (Municipality, Township, County) do hereby acknowledge that the applicant, Ralph Braden Francis, and the assigned supervisor, Chris Wilson are full-time employees of the above mentioned political subdivision.

Signature: Renee Snodgrass Date: 4-6-22

Last Name	First Name	BBS Certification ID

OPTIONAL ALTERNATIVE TRAINEE PROGRAM PLAN FORM

Building Official, Supervisor and Applicant shall complete and submit this form with BBS Application for Trainee Certification only if Trainee Sponsor is proposing an alternative trainee program in lieu of the requirements of the traditional trainee program specified in OAC 4101:7-3-01(F)(5)(e). No Alternative Trainee Program may propose to waive examination requirements or attendance at the OBCA.

PROPOSED ALTERNATIVE PROGRAM PLAN DESCRIPTION

Attach additional pages if necessary and/or a letter describing the proposed program conditions.

Proposed Alternative Program Length: _____

Proposed Alternative Program Education Requirements: _____

Proposed Alternative Program Training & Supervision Requirements: _____

Explanation of how the Proposed Alternative Program provides equivalent level of training and education based on the Applicant's experience documented in the application: _____

Applicant Signature: _____ Date: _____

Supervisor Signature: Christopher T. Wilson Date: 04/07/2022

Building Official Signature: _____ Date: _____

OBC TRAINEE REQUIREMENTS FOR NON-RESIDENTIAL BUILDING DEPARTMENT PERSONNEL

(4101:7-3-01 Ohio Administrative Code)

TRAINEE CERTIFICATIONS	TRAINEE EXPERIENCE REQUIREMENTS 4101:7-3-01(F)(5)	EXAM MODULE REQUIREMENTS NCPCCI or ICC	PROFESSIONAL LICENSE REQ.
MASTER PLANS EXAMINER TRAINEE	Graduate Architect or Engineer from an NAAB, EAC-ABET, or similarly accredited university. Submit copy of degree.	Examination and Ohio Code Academy requirements for the related certification to be completed within the allotted time of the trainee program.	Ohio registration within the allotted time of the trainee program
BUILDING PLANS EXAMINER TRAINEE ELECTRICAL PLANS EXAMINER TRAINEE FIRE PROTECTION PLANS EXAMAINER TRAINEE MECHANICAL PLANS EXAMINER TRAINEE PLUMBING PLANS EXAMINER TRAINEE	1. Trainee applicants shall: (a) Be a graduate Architect or Engineer from an NAAB, EAC-ABET, or similarly accredited university. Submit copy of degree, or (b) Have at least one year of experience as: (i) A full-time building inspector, fire protection inspector, plumbing inspector, electrical safety inspector, or mechanical inspector in a certified non-residential building department, of the division of industrial compliance in the Ohio department of commerce, or of county boards of health; or (ii) A full-time residential building official, residential plans examiner, residential building inspector, or residential mechanical inspector in a certified residential building department; or (iii) A full-time designer working under the direct supervision of a design professional preparing construction documents of any discipline directly related to buildings or structures within the scope of groups regulated by the Ohio building codes. (c) Submit evidence of eligibility to receive the education credit pursuant to paragraph (F)(6) of 4101:7-3-01.	Examination and Ohio Code Academy requirements for the related certification to be completed within the allotted time of the trainee program.	None Required
BUILDING INSPECTOR TRAINEE MECHANICAL INSPECTOR TRAINEE	1. One year of experience as a skilled tradesman for work subject to inspection under a building code adopted for non-residential buildings within the scope of groups regulated by the rules of the Board 2. Submit evidence of eligibility to receive the education credit pursuant to paragraph (F)(6) of 4101:7-3-01.	Examination and Ohio Code Academy requirements for the related certification to be completed within the allotted time of the trainee program.	None Required
ELECTRICAL SAFETY INSPECTOR TRAINEE	1. Two years of experience in the installation of electrical systems subject to inspection under a building code adopted for buildings within the scope of groups regulated by the rules of the Board 2. Submit evidence of eligibility to receive the education credit pursuant to paragraph (F)(6) of 4101:7-3-01.	Examination and Ohio Code Academy requirements for the related certification to be completed within the allotted time of the trainee program.	None Required
PLUMBING INSPECTOR TRAINEE	1. Three years of experience in the installation of plumbing systems subject to inspection under a building code adopted for buildings within the scope of groups regulated by the rules of the Board 2. Submit evidence of eligibility to receive the education credit pursuant to paragraph (F)(6) of 4101:7-3-01.	Examination and Ohio Code Academy requirements for the related certification to be completed within the allotted time of the trainee program.	None Required

NOTE 1. Only experience directly related to buildings or structures within the scope of groups regulated by the Ohio Building Code is acceptable for any class certification. THIS DOES NOT INCLUDE ONE-, TWO-, OR THREE-FAMILY STRUCTURES.

NOTE 2. Trainee applicants may obtain credit for one year of the required experience through education pursuant to 4101:7-3-01(F)(6) OAC. documentation must be submitted with the application.

NOTE 3. Trainee applicants must be under the direct supervision of a person certified in the trainee's respective field. Sponsor and Supervisor forms must be signed by the Building Official and the certified supervisor, respectively. Submit with application.

NOTE 4. Enforcement, inspection, or plans examination experience must be performed (a) prior to 1984, for a non-residential building department certified by the board of building standards to exercise enforcement authority for buildings or structures within the scope of groups regulated by the rules of the board; (b) in an agency or jurisdiction outside the state of Ohio enforcing a model non-residential building code of a national model code organization or a code adopted for the respective buildings or structures of the types regulated by the rules of the board; or (c) certification by the department of commerce, division of industrial compliance, as a plumbing inspector when application is made for board certification as a plumbing inspector. **THIS DOES NOT INCLUDE ONE-, TWO-, OR THREE-FAMILY STRUCTURES.**

OBC TRAINEE REQUIREMENTS FOR NON-RESIDENTIAL BUILDING DEPARTMENT PERSONNEL

(4101:7-3-01 Ohio Administrative Code)

NOTE 5. Trainee applicants must complete the Ohio Building Code Academy during their initial trainee certification period.

Exceptions:

(a) Medical gas piping inspectors pursuant to paragraph (E)(20) of 4101:7-3-01.

(b) Industrialized unit inspectors.

(c) Plumbing inspectors certified pursuant to Chapter 3703. of the Revised Code with five years of experience as full-time employees of the Division of Industrial Compliance in the Ohio Dept. of Commerce or of county boards of health who are seeking plumbing inspector certification.

(d) Individuals who have completed the Ohio Building Code Academy within thirty-six months immediately preceding the date of receipt of initial certification may attend "Code Administration and Skills Training" provided by the Board in lieu of the Ohio Building Code Academy.

NOTE 6. For scheduling examinations, applicants may contact either: Prometric, 1360 Energy Lane, St. Paul MN 55108, (800) 864-5309, www.prometric.com for NCPCCI exams or, International Code Council, National Certification Services, 900 Montclair Road, Birmingham, AL 35213, (888) 422-7233, www.iccsafe.org.

NOTE 7. Module description:

NCPCCI	ICC	
1A – Building 1-, 2 -Family Dwelling	MM – Management	M1 – Residential Mechanical Inspector
1B – Building General	MG – Legal	M2 – Commercial Mechanical Inspector
1C – Building Plan Review	BC – Building Codes and Standards	M3 – Mechanical Plan Examiner
2A – Electrical 1-, 2-Family Dwelling	CA – Commercial Fire Alarm Inspector	P1 – Residential Plumbing Inspector
2B – Electrical General	CF – Commercial Sprinkler Inspector	P2 – Commercial Plumbing Inspector
2C – Electrical Plan Review	CP – Commercial Fire Sprinkler Plans Examiner	P3 – Plumbing Plan Examiner
3B – Fire Protection General	B1 – Residential Building Inspector	
3C – Fire Protection Plan Review	B2 – Commercial Building Inspector	
4A – Mechanical 1-, 2-Family Dwelling	B3 – Building Plan Examiner	
4B – Mechanical General	E1 – Residential Electrical Inspector	
4C – Mechanical Plan Review	E2 – Commercial Electrical Inspector	
5A – Plumbing 1-, 2-Family Dwelling	E3 – Electrical Plan Examiner	
5B – Plumbing General		
5C – Plumbing Plan Review		

RCO TRAINEE REQUIREMENTS FOR RESIDENTIAL BUILDING DEPARTMENT PERSONNEL

(4101:7-3-01 Ohio Administrative Code)

TRAINEE CERTIFICATIONS	TRAINEE EXPERIENCE REQUIREMENTS. 4101:7-3-01(F)(5)	EXAM MODULE REQUIREMENTS NCPCCI or ICC	PROFESSIONAL LICENSE REQ.
RESIDENTIAL PLANS EXAMINER TRAINEE	1. One year of experience as a full-time designer working under the direct supervision of a design professional preparing construction documents; 2. One year of experience as a skilled tradesman for work subject to inspection under a residential or nonresidential code adopted for buildings or structures regulated by the rules of the Board.	Examination and Ohio Code Academy requirements for the related certification must be completed within the allotted time of the trainee program.	None Required
BUILDING OR MECHANICAL INSPECTOR TRAINEE	1. One year of experience as a skilled tradesman for work subject to inspection under a residential or nonresidential code adopted for buildings or structures regulated by the rules of the Board.	Examination and Ohio Code Academy requirements for the related certification must be completed within the allotted time of the trainee program.	None Required

NOTE 1. Only experience directly related to buildings or structures regulated by the rules of the Board shall be acceptable for any class certification.

NOTE 2. Trainee applicants for certification may obtain credit for one year of the required experience through education pursuant to Section 4101:7-3-01(F)(6) of the Ohio Administrative Code. Documentation must be submitted with the application.

NOTE 3. Trainee applicants must be under the direct supervision of a person certified in the trainee's respective field. Sponsor and Supervisor forms must be signed by the Building Official and the certified supervisor, respectively. Submit with application.

NOTE 4. Enforcement, inspection, or plans examination experience must be performed (a) prior to May 27th, 2006, for a residential building department exercising enforcement authority for buildings or structures regulated by an adopted model residential code , (b) for an agency or jurisdiction outside the state of Ohio enforcing a model residential code of a national model code organization for buildings or structures regulated by the Residential Code of Ohio, or (c) by an employee of a certified building department who is the holder of a BBS certification other than that for which application is being made.

NOTE 5. Trainee applicants must complete the Ohio Building Code Academy during their initial trainee certification period.

Exceptions:

(a) Medical gas piping inspectors pursuant to paragraph (E)(20) of 4101:7-3-01.
(b) Residential industrialized unit inspectors.
(c) Plumbing inspectors certified pursuant to Chapter 3703. of the Revised Code with five years of experience as full-time employees of the Division of Industrial Compliance in the Ohio Dept. of Commerce or of county boards of health who are seeking plumbing inspector certification.
(d) Individuals who have completed the Ohio Building Code Academy within thirty-six months immediately preceding the date of receipt of initial certification may attend "Code Administration and Skills Training" provided by the Board in lieu of the Ohio Building Code Academy.

NOTE 6. For scheduling examinations, applicants may contact either: Prometric, 1360 Energy Lane, St. Paul MN 55108, (800) 864-5309, www.prometric.com for NCPCCI exams or, International Code Council, National Certification Services, 900 Montclair Road, Birmingham, AL 35213, (888) 422-7233, www.iccsafe.org.

NOTE 7. Module description:

NCPCCI:	ICC:
1A – Building 1-, 2 -Family Dwelling	**B1 – Residential Building Inspector**
2A – Electrical 1-, 2-Family Dwelling	**E1 – Residential Electrical Inspector**
4A – Mechanical 1-, 2-Family Dwelling	**M1 – Residential Mechanical Inspector**
5A – Plumbing 1-, 2-Family Dwelling	**P1 – Residential Plumbing Inspector**

Ohio Board of Building Standards
6606 Tussing Road
Reynoldsburg, OH 43068-9009
Date Updated 6/10/2021

Timothy Galvin, Chairman

An Equal Opportunity Employer and Service Provider

614-644-2613
Fax 614 -644-3147
TTY/TDD 800-750-0750
com.ohio.gov/dico/bbs
Form Number 154

Zane State College

The Board of Trustees on the recommendation of the Faculty hereby confer upon

Ralph Brandon Francis

this diploma in testimony that the prescribed course of study for this degree has been completed and that the recipient has been awarded the degree of

Associate of Applied Science

Electrical/Electronics Engineering Technology

Cum Laude

with all the rights and privileges thereunto appertaining, in confirmation of which our signatures and the seal of the College are hereunto affixed. Given under the seal of Zane State College, Zanesville, Ohio, this ninth day of May, two thousand nineteen.

President

Chair of the Board of Trustees

Provost

Registrar

File Attachments for Item:

P-3 Kizer, Joshua ESI, EPE

Certification ID# 8810

Current Certifications: none

Staff Notes: OCILB Electrical Contractor, recommend approval.

ESIAC Recommendations:

Committee Recommendation:

Board of Building Standards Application for Interim Certification, Building Department Personnel

KIZER — *Last Name*

JOSHUA — *First Name*

BBS Certification ID

SECTION 1: CHECK INTERIM CERTIFICATION(S) BEING REQUESTED

☐ Building Official	☐ Master Plans Examiner	☐ Building Inspector	☑ Electrical Safety Inspector	☐ Fire Protection Inspector
☐ Building Plans Examiner	☐ Plumbing Plans Examiner	☐ Mechanical Plans Examiner	☑ Electrical Plans Examiner	☐ Fire Protection Plans Examiner
	☐ Plumbing Inspector	☐ Mechanical Inspector	☐ Non-Residential Industrial Unit Inspector	

SECTION 2: LIST ANY OHIO LICENSE, CERTIFICATE, OR REGISTRATION HELD

(Mark "T" If Trainee)

Description			Certificate Number	Date Received
Architectural Registration				
P.E. Registration				
Res	Non-Res			
☐	☐	Building Official Certification		
☐	☐	Plans Examiner Certification		
☐	☐	Building Inspector Certification		
☐	☐	Mechanical Inspector Certification		
Building Plans Examiner Certification				
Mechanical Plans Examiner Certification				
Fire Protection Plans Examiner Certification				
Electrical Plans Examiner Certification				
Plumbing Plans Examiner Certification				
Fire Protection Inspector Certification				
Electrical Safety Inspector Certification				
Plumbing Inspector Certification				
Fire Safety Inspector Certification				
Fire Protection System Designer Certification				
Medical Gas Piping Inspector Certification				

KIZER	JOSHUA	
Last Name	*First Name*	*BBS Certification ID*

SECTION 3: EMPLOYMENT/EDUCATION

Formal Education	Date Graduated
AA Electrical Mech Tech	7-07-07
AS Electrical Engineering Tech	8-15-12
Related Vocational or Technical Training	**Years' Experience**
IBEW App ship	5
OCILB Electrical Contractor	Lic# 47956
U.S. Military construction experience (MOS or other designation):	**Years' Experience**
NAVY Construction Electrician	6
Place of Employment:	**Years' Employed**
KTH Electrician	9
Kizer Electric	6

SECTION 4: APPLICANTS REQUESTING MEDICAL GAS INSPECTOR CERTIFICATION

Attach proof *of certification by an ASSE recognized third-party certifier in accordance with ASSE standard 6020.*

SECTION 5: OBC BUILDING INSPECTION EXPERIENCE PERFORMED FOR A BBS CERTIFIED BUILDING DEPARTMENT

BBS Certified Building Department	BBS Certified Position/Title	Duties	Date of Service, Length of Time (MM/DD/YY)

KIZER — *Last Name*
JOSHUA — *First Name*
BBS Certification ID

SECTION 6: ELECTRICAL SAFETY INSPECTOR (ESI) - SPECIFIC EXPERIENCE QUALIFICATIONS
Applicants for Electrical Safety Inspector Only Must Complete This Item
Section 3783 of the Ohio Revised Code specifies that an applicant for a Certificate of Competency as an Electrical Safety Inspector must meet on of the following to qualify to take required examination. Please check the qualification that applies:

1. ☒ Have been a journeyman electrician or equivalent for four years, two of which were as an electrician foreman, and have had two years' experience as a building department electrical inspector trainee;
2. ☐ Have been a journeyman electrician or equivalent for four years and have had three years' experience as a building department electrical inspector trainee;
3. ☐ Have had for four years' experience as a building department electrical inspector trainee;
4. ☒ Have been a journeyman electrician or equivalent for six years;
5. ☐ Am a graduate electrical engineer and registered in the State of Ohio. Registration number: _____
6. ☒ Applicant authorizes all testing organizations including ICC to provide test results to the BBS.

SECTION 7: EXPERIENCE *(DO NOT SUBSTITUTE WITH OTHER RESUMES).*
Refer to Experience Requirements Listed in O.A.C. 4101:7-3-01 and O.R.C. 3783
Below, list the specific projects you worked on, and the specific work you performed, your typical duties for each project, and dates of this work. You **must** demonstrate that you have the required number of months (years) of actual, practical experience for the certification requested (see matrix).
Provide letters from certified inspectors, employers, or contractors verifying your experience. Submit copies of any certificates, diplomas, or licenses. Remove all personal information.

SECTION 7 CONT.: EXPERIENCE

List Each Construction Project AND Specific Type of Work Performed	Name of Employer, Contact, Address, Telephone Number	Project Time: From_ To _ (MM/YY)
Example: *Children's Hospital, Toledo* *Structural steel work on addition*	*Homer Steel and Trade* *125 Anytown Street* *My City, OH, 45454* *(419)555-1212*	*July 2013-May 2014* *(10 months)*
KTH Electrician Industrial Electric	KTH 1111 OH-235 St Paris OH 43072	July 2013 – Present 9 years
Kizer Electric Owner Resident/Comm/Industrial Electric	Kizer Electric 2781 Concord Pk Urbana OH 43078	FEB 2016 – Present 6 years
Total Experience on This Page (In Months): 180		

Kizer — *Last Name*

Joshua — *First Name*

_____ — *BBS Certification ID*

List Each Construction Project AND Specific Type of Work Performed	Name of Employer, Contact, Address, Telephone Number	Project Time: From_ To _ (MM/YY)
Kone Cranes Industrial Cranes	Kone Cranes 4401 Gateway Blvd Springfield OH 45502	JAN 12 / July-13 30 months
IBEW Electrian	Fisk Electric 821 S. Broad ST New Orleans LA 70114	July 09 / JAN 12 30 months
NAVY Construction Electrician	NIA US NAVY	July 03 / July 09 72 months
	Total Experience on This Page (In Months):	132

KIZER — *Last Name*

JOSHUA — *First Name*

BBS Certification ID

SECTION 8: PERSONAL HISTORY

1. Have you ever been convicted of any felony, or any crime involving moral turpitude? ☐ Yes ☒ No

   If you answered "Yes" please explain below:

2. Have you served in the U.S. armed services? (If No, skip question 3) ☒ Yes ☐ No
3. If YES, were you discharged under honorable conditions? ☒ Yes ☐ No

   If you answered "No" please explain below:

SECTION 9: CERTIFICATION

I certify the information contained in this application is true and complete, and I understand that providing false information may be grounds for not granting certification or for immediate termination of certification at any point in the future, if granted. I authorize the investigation of all statements contained herein and release all parties from all liability for any damage that may result from furnishing the same to Ohio Board of Building Standards. Falsification is a violation of section 2921.13 of the Ohio Revised Code and is punishable as a misdemeanor of the first degree.

Signature of Applicant: [signature]

Subscribed and duly sworn before me according to law, by the above named applicant this day 31st of MARCH in the year 2022 at ~~CHAMPA~~ URBANA 11:21 AM, County of CHAMPAIGN and State of OHIO.

Notary Public: Beverly Fry

SEAL

BEVERLY FRY
NOTARY PUBLIC, STATE OF OHIO
My Commission Expires 6/16/2024

File Attachments for Item:

P-4 Zinn Sr., Randall - ESI, PI, MI

Certification ID: 8801

Current Certifications: none

Staff Notes: Holds OCILB license in HVAC and refrigeration. Per application, has been installing all components of refrigeration and mechanical systems for 24 years. Recommend approval.

ESIAC Recommendation:

Committee Recommendation:

Board of Building Standards Application for Interim Certification, Building Department Personnel

Last Name	First Name	BBS Certification ID
Zinn Sr.	Randall	

SECTION 1: CHECK INTERIM CERTIFICATION(S) BEING REQUESTED

☐ Building Official	☐ Master Plans Examiner	☐ Building Inspector	☒ Electrical Safety Inspector	☐ Fire Protection Inspector
☐ Building Plans Examiner	☐ Plumbing Plans Examiner	☐ Mechanical Plans Examiner	☐ Electrical Plans Examiner	☐ Fire Protection Plans Examiner
	☒ Plumbing Inspector	☒ Mechanical Inspector	☐ Non-Residential Industrial Unit Inspector	

SECTION 2: LIST ANY OHIO LICENSE, CERTIFICATE, OR REGISTRATION HELD
(Mark "T" If Trainee)

Description			Certificate Number	Date Received
Architectural Registration				
P.E. Registration				
Res	Non-Res			
☐	☐	Building Official Certification		
☐	☐	Plans Examiner Certification		
☐	☐	Building Inspector Certification		
☐	☐	Mechanical Inspector Certification		
Building Plans Examiner Certification				
Mechanical Plans Examiner Certification				
Fire Protection Plans Examiner Certification				
Electrical Plans Examiner Certification				
Plumbing Plans Examiner Certification				
Fire Protection Inspector Certification				
Electrical Safety Inspector Certification				
Plumbing Inspector Certification				
Fire Safety Inspector Certification				
Fire Protection System Designer Certification				
Medical Gas Piping Inspector Certification				

ZINN — *Last Name*

Randall — *First Name*

BBS Certification ID

SECTION 3: EMPLOYMENT/EDUCATION

Formal Education	Date Graduated
Related Vocational or Technical Training	**Years' Experience**
HVAC-R, Electrical, Plumbing	24
U.S. Military construction experience (MOS or other designation):	**Years' Experience**
Place of Employment:	**Years' Employed**
ZINN Mechanical	18
ZINN Refrigeration	6

SECTION 4: APPLICANTS REQUESTING MEDICAL GAS INSPECTOR CERTIFICATION

***Attach proof** of certification by an ASSE recognized third-party certifier in accordance with ASSE standard 6020.*

SECTION 5: OBC BUILDING INSPECTION EXPERIENCE PERFORMED FOR A BBS CERTIFIED BUILDING DEPARTMENT

BBS Certified Building Department	BBS Certified Position/Title	Duties	Date of Service, Length of Time (MM/DD/YY)

ZINN Randall

Last Name *First Name* *BBS Certification ID*

SECTION 6: ELECTRICAL SAFETY INSPECTOR (ESI) - SPECIFIC EXPERIENCE QUALIFICATIONS

Applicants for Electrical Safety Inspector Only Must Complete This Item

Section 3783 of the Ohio Revised Code specifies that an applicant for a Certificate of Competency as an Electrical Safety Inspector must meet on of the following to qualify to take required examination. Please check the qualification that applies:

1. ☐ Have been a journeyman electrician or equivalent for four years, two of which were as an electrician foreman, and have had two years' experience as a building department electrical inspector trainee;
2. ☐ Have been a journeyman electrician or equivalent for four years and have had three years' experience as a building department electrical inspector trainee;
3. ☐ Have had for four years' experience as a building department electrical inspector trainee;
4. ☒ Have been a journeyman electrician or equivalent for six years;
5. ☐ Am a graduate electrical engineer and registered in the State of Ohio. Registration number: _____
6. ☐ Applicant authorizes all testing organizations including ICC to provide test results to the BBS.

SECTION 7: EXPERIENCE *(DO NOT SUBSTITUTE WITH OTHER RESUMES).*

Refer to Experience Requirements Listed in O.A.C. 4101:7-3-01 and O.R.C. 3783

Below, list the specific projects you worked on, and the specific work you performed, your typical duties for each project, and dates of this work. You **must** demonstrate that you have the required number of months (years) of actual, practical experience for the certification requested (see matrix).

Provide letters from certified inspectors, employers, or contractors verifying your experience. Submit copies of any certificates, diplomas, or licenses. Remove all personal information.

SECTION 7 CONT.: EXPERIENCE

List Each Construction Project AND Specific Type of Work Performed	Name of Employer, Contact, Address, Telephone Number	Project Time: From_ To _ (MM/YY)
Example: *Children's Hospital, Toledo* *Structural steel work on addition*	*Homer Steel and Trade* *125 Anytown Street* *My City, OH, 45454* *(419)555-1212*	*July 2013-May 2014* *(10 months)*
Total Experience on This Page (In Months):		

Board of Building Standards Application for Interim Certification, Building Department Personnel

Zinn, Sr. | Randall | _____ (BBS Certification ID)

Last Name | *First Name*

Line 4 & 5

	List Each Construction Project AND Specific Type of Work Performed	Name of Employer, Contact, Address, Telephone Number	Project Time: From _ To _ (MM/YY)
①	Burntwood Tavern, Brecksville OH Remodel: 2-15T Air Handlers + Condensers, High+Low Voltage wiring, ductwork, Refrigerant linesets and drain line	Zinn Mechanical 1486 Medina Rd. Medina OH 44256 Randall Zinn, Sr. 330-461-2267	10/12 - 11/12
②	Southwest Cargo, Cleveland Hopkins Airport Install: Walk in Cooler, high and low voltage wiring, lineset and drain line.		10/14 - 11/14
③	Packaging Specialties Inc, Medina OH Install: 2-20T Air Handlers + Condensers. High + Low Voltage Wiring, Line sets, Drain Lines		4/15 - 5/15
④	Spring Grove Cemetery, Medina OH Install: 2-Furnaces, 2 condensers, Ductwork, High+Low Voltage Wiring, Line Sets, Drain Lines, Gas Lines		11/15 - 12/15
⑤	Wesley House, Hunting Valley, OH Install: 14 Furnaces + Condensers, wine cooler, Ductwork, Linesets, High+Low Voltage Wiring, Drain Lines, Gas Lines		10/15 - 01/19
⑥	Western Reserve Distillery, Lakewood, OH Install: 3 RTU's, Ventilation System, High Pressure Steam Boiler, 30 T Chiller High+Low Voltage Wiring, Refrigerant Line Sets, Gas Lines.		12/17 - 11/18
⑦	Yours Truly Restaurant, Hudson, OH Install: Make up Air Unit, Ductwork High+Low Voltage Wiring + Controls		1/19 - 1/19
⑧	Begg Home, Chagrin Falls New Addition Install: Furnace, Condenser, Ductwork, High+Low Voltage Wiring, Gas + Drain Line		6/18 - 2/20
⑨	Bandelow Home, Medina OH Install: 2 Ductless Split Systems 8-INDOOR UNITS, High+Low voltage Wiring, Linesets and Condensate pumps		4/20 - 5/20
⑩	Swamy Home, Moreland Hills OH INSTALL: 8 Furnaces + Condensers, Ductwork, Wine Cooler, Snowmelt System, 3 Boilers, High+Low Voltage Wiring, Gas + Drain Lines		11/14 - 12/14
⑪	First Baptist Church, Bedford OH INSTALL: Hydronic Boiler, 560,000 BTU, Water Lines, Gasline, High and Low Voltage Wiring		11/21 - 12/21
		Total Experience on This Page (In Months):	

Lookup Detail View

Name and Address

Name	Mail Address	Public Address
RANDALL P ZINN	4168 Sequoia Dr Medina, OH 44256-9044	4168 Sequoia Dr Medina, OH 44256-9044

Registration Information

Credential	License Type	Issue Date	Expiration Date	Status	Reason	Company
HV.44990	HVAC	07/04/2021	07/03/2022	ACTIVE	ACTIVE	ZINN MECHANICAL LLC
RE.44990	Refrigeration	07/04/2021	07/03/2022	ACTIVE	ACTIVE	ZINN MECHANICAL LLC

Continuing Education

Course Name	Course Type	Course Number	Course Hours	Course Date	Provider
GENERAC INSTALLATION & MAINTENANCE TRAINING	CODE	1530122	4.00	11/17/2021	WOLFF BROS SUPPLY INC

Renewal Requirements

Formatted Credential	Insurance Expiration Date	CE Requirements Completed	Estimated Amount Due
RE.44990	02/09/2017	No	$0.00

Generated on: 4/20/2022 12:31:59 PM

ZINN
Last Name

Randall
First Name

BBS Certification ID

SECTION 8: PERSONAL HISTORY

1. Have you ever been convicted of any felony, or any crime involving moral turpitude? ☐ Yes ☒ No

   If you answered "Yes" please explain below:
2. Have you served in the U.S. armed services? (If No, skip question 3) ☐ Yes ☒ No
3. If YES, were you discharged under honorable conditions? ☐ Yes ☐ No

   If you answered "No" please explain below:

SECTION 9: CERTIFICATION

I certify the information contained in this application is true and complete, and I understand that providing false information may be grounds for not granting certification or for immediate termination of certification at any point in the future, if granted. I authorize the investigation of all statements contained herein and release all parties from all liability for any damage that may result from furnishing the same to Ohio Board of Building Standards. Falsification is a violation of section 2921.13 of the Ohio Revised Code and is punishable as a misdemeanor of the first degree.

Signature of Applicant: _____

Subscribed and duly sworn before me according to law, by the above named applicant this day 21 of MARCH in the year 2022 at MEDINA County of MEDINA and State of OHIO.

Notary Public: _____

NOTARY PUBLIC STATE OF OHIO

NEAL WOZNIAK
Notary Public, State of Ohio
My Commission Expires
September 22, 2025
COMMISSION: 2015-RE-545898

File Attachments for Item:

ER-1 Grounding and Bonding, 2020 NEC (Dayton Area Electrical JATC)

EPE, ESI, RBO, EPE (two 6-hour sessions)

Staff Notes:

ESIAC Recommendation:

Committee Recommendation:

APPLICATION

FOR

Continuing Education Course Approval

Continuing education programs approved for education credit by the Ohio Board of Building Standards may be used for compliance with certification requirements related to code enforcement, plan review, and inspection responsibilities. The credit is to be used to renew the certifications issued by the Ohio Board of Building Standards pursuant to section 3781.10(E) ORC.

Board of Building Standards
6606 Tussing Road, P.O. Box 4009
Reynoldsburg, Ohio 43068-9009
(614) 644-2613 Fax: (614) 644-3147
dic.bbs@com.state.oh.us
www.com.state.oh.us/dic/dicbbs.htm

COURSE SUBMITTER:

Course Submitter: Anthony Henderson (Contact Name)
Organization: Dayton Ohio Area Electrical SATC (Organization/Company)
Address: 6550 Poe Ave (Include Room Number, Suite, etc.)
City: Dayton State: OH Zip: 45414
E-Mail: Ahenderson@IBEW82.org
Telephone: 937-264-2052 Fax: 937-264-2053
Course Sponsor: Dayton Ohio Area Electrical SATC

COURSE INFORMATION:

Course Title: Grounding and bonding Based on the 2020 NEC Part 1 & Part 2

New Course Submittal: ☑ Update Course: ☐ Prior Approval Number:

Purpose and Objective: To provide continuing education for CESI, Residential Plans Examiner and electrical plans examiner personel, Journeyman Electricians and Electrical Contractors. To Improve Knowledge by Discussion and lectures & better understanding of proper grounding & bonding.

Number of Instructional Contact Hours that can be obtained upon completion: 12

If Multi-Session, Number of Instructional Contact Hours Per Session: 6

Program Applicable for the Following Participants:

Building Official ☐	Master Plans Examiner ☐	Building Inspector ☐	Fire Protection Inspector ☐	Mechanical Inspector ☐	
	Building Plans Exam. ☐			Plumbing Inspector ☐	
	Plumbing Plans Exam. ☐			Non-Res IU Inspector ☐	
	Electrical Plans Exam. ☑				
	Mechanical Plans Exam. ☐				
	Fire Protect. Plans Exam. ☐				
Res Building Official ☑	Res Plans Examiner ☑	Res Building Inspector ☐	Res Mechanical Inspector ☐	Res IU Inspector ☐	
Electrical Safety Inspectors ☑					

Location of ESI Course: 6550 Poe Ave Dayton OH 45414 Date(s) of ESI Course(s): 7/9 & 7/16

SUBMITTAL CHECKLIST: **Make Sure** all of the Following Information is **Submitted**:		Check Off
Course Submitter:	Name of contact person and their certification numbers, organization, address, fax, phone	✓
	Organization sponsoring or requesting the program (if any)	
Course Title:	Name of course (related to content)	✓
Purpose/Objective:	Describe purpose and how course will improve competency of certification(s) listed	✓
Contact Hours:	Indicate instructional time and credit requested in hours (e.g.: 0.5 hr, 1 hr, 3.5 hrs)	✓
Participants:	Check off each certification for which credit is requested (for which course relates to certification)	✓
Content of Program:	Include collated agenda, time schedule, course outline; list specific sections of code, references, and topics covered	✓
Course Materials:	Collated workbooks, handouts, hard copy or electronic versions of program is available	✓
Instructor(s) Info.:	Resume of professional/educational qualifications & teaching/training experience/BBS certifications	✓
Test Materials:		
Completed Application:		✓

NOTE: The Board does NOT grant retroactive approval for courses presented prior to approval date.

RECEIVED
APR 13 2022
BOARD OF BUILDING STANDARDS

Form 1526

BBS 81028110

Grounding and Bonding based on the 2020 NEC – Part 1

Saturday 8:00 a.m. – 3:00 p.m.

8:00 a.m. – 9:30 a.m.

- Chapter 1 Introduction to Grounding
- Chapter 2 Circuit Basics and Overcurrent Protection

9:30 a.m. – 9:45 a.m.

- Break

9:45 a.m. – 11:30 a.m.

- Chapter 3 Code Arrangement and Application

11:30 – 12:00 p.m.

- Lunch

12:00 p.m. – 1:30 p.m.

- Chapter 4 Grounding Electrodes and the Grounding Electrode System

1:30 p.m. – 1:45 p.m.

- Break

1:45 p.m. – 3:00 p.m.

- Chapter 5 Requirements for service and grounded conductors

Grounding and Bonding based on the 2020 NEC – Part 2

Saturday 8:00 a.m. – 3:00 p.m.

8:00 a.m. – 9:30 p.m.

- Chapter 6 Grounding Electrode Conductors

9:30 a.m. – 9:45 a.m.

- Break

9:45 a.m. – 11:30 a.m.

- Chapter 7 Bonding Requirements

11:30 a.m. – 12:00 p.m.

- Lunch

12:00 p.m. – 1:30 p.m.

Chapter 8 Equipment Grounding Conductors

1:30 p.m. – 1:45 p.m.

- Break

1:45 p.m. – 3:00 p.m.

- Chapter 9 Grounding Electrical Equipment
- Chapter 10 Isolated Grounding Circuits and Receptacles

Instructor Qualifications

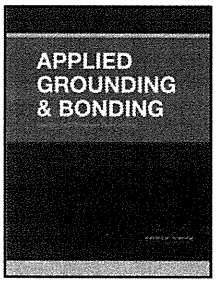
Edwin Lemaster

Ed has been in the electrical field since the mid 70's at which time he entered and completed a four-year apprenticeship with the IBEW Local 82. In 1992 he tested for and was subsequently certified by the State of Ohio as an Electrical Safety Inspector. Later, that same year he joined the International Association of Electrical Inspectors. In January of 1994, Ed began working for the City of Hamilton as an electrical inspector. Since that time he has tested for and received certificates as a Building Inspector Class III and Residential Building Official. In 1995 Ed joined Montgomery County as a Building and Electrical Inspector, where he is still currently employed. Ed continues to be an instructor for the National Electrical Contractors Association and the Dayton Electrical JATC.

Address
5426 Honeyleaf Way
Dayton, Ohio 45424
1-937-233-3613

Grounding and Bonding

Grounding Electrode Conductors



Grounding Electrode Conductors

Chapter 6

- Introduction
  - Where service equipment and other equipment and systems required to be grounded are installed on the premises, a path to the ground (Earth) must be established.
  - The grounding electrode conductor provides the conductive path to ground for grounded electrical systems and other equipment that must be grounded as required by the *NEC*.

Grounding Electrode Conductors

Chapter 6

- Introduction (continued)
  - There are specific installation requirements that apply to grounding electrode conductor installations.
  - These requirements relate to how this conductor must perform and how it must be protected from possible damage.

Grounding Electrode Conductors

Chapter 6

- Objectives
  - Understand the purpose of the grounding electrode conductor.
  - Determine the grounding electrode conductor connection locations at a service.
  - Recognize the materials permitted for a grounding electrode conductor.

Grounding Electrode Conductors

Chapter 6

- Objectives
  - Understand requirements for grounding electrode conductor installations and determine minimum sizes required for grounding electrode conductors.
  - Understand the requirements for grounding electrode conductor connections.
  - Understand the requirements for protecting grounding electrode conductors from physical damage and the effects of magnetic fields.

Grounding Electrode Conductors

Chapter 6

- The Path to Ground (Earth)
  - This conductive path is known as a grounding electrode conductor primarily because one end of this conductor is typically connected to a grounding electrode or other conductive object that completes a path to the Earth.
  - Grounding electrode conductors provide the connection to the Earth and the object or system conductor that is required to be connected to the ground.

Grounding Electrode Conductors

Chapter 6

- The Path to Ground (Earth)
  - These conductors are conductive bodies that extend the ground connections indicated in the definition of the term *grounded (grounding).*

Grounding Electrode Conductors

Chapter 6

- The Path to Ground (Earth)

Grounding Electrode Conductors

Chapter 6

- Article 100 Definition
  - Grounding Electrode Conductor. A conductor used to connect the system grounded conductor or the equipment to a grounding electrode or to a point on the grounding electrode system.

Grounding Electrode Conductors

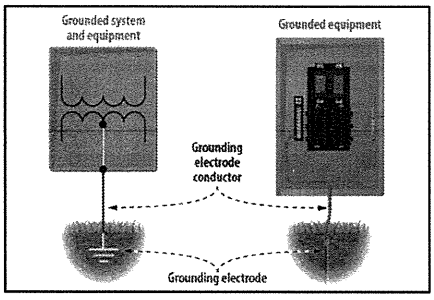
Chapter 6

- Purpose of Grounding Electrode Conductors
  - Grounding electrode conductors provide a conductive path to the ground (Earth) from systems and equipment that are required to be grounded or are otherwise grounded by choice.
  - This conductor serves to establish and maintain an equal potential between the Earth and the equipment or system conductor being grounded, or as close to the same potential as electrically possible.

Grounding Electrode Conductors

Chapter 6

- Connection to Earth



Grounding Electrode Conductors

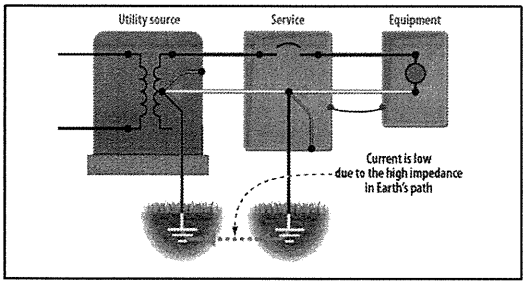
Chapter 6

- Current in Grounding Electrode Conductors
  - The ground (Earth) is part of electrical circuits or equipment that is grounded.
  - Current will be present in a circuit as long as the circuit is complete.
  - Current will also be present in all paths available between the source and point of use or ground-fault condition.
  - The amount of current present in each path is directly related to the amount of impedance in each path.

Grounding Electrode Conductors

Chapter 6

- Current in GEC



Grounding Electrode Conductors

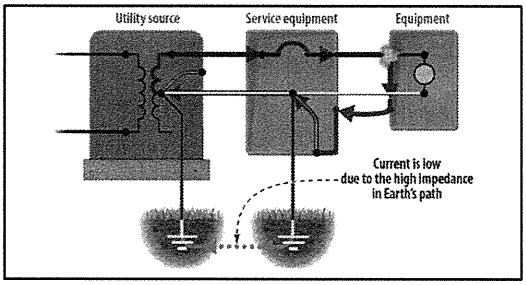
Chapter 6

- Current in Grounding Electrode Conductors
  - The amount of current the grounding electrode conductor carries during normal operation and under abnormal conditions such as ground faults is kept low because of the high impedance in that path through the Earth.

Grounding Electrode Conductors

Chapter 6

- Current in GEC



Grounding Electrode Conductors

Chapter 6

- Grounding Electrode Conductor Material
  - Grounding electrode conductors are required to be made of copper, copper-clad aluminum, or aluminum.
  - Copper-clad aluminum was used years ago in limited amounts as an effort to reduce electrical material costs during wartime periods but is less common in electrical installations today.
  - Copper-clad conductors are manufactured with a thin copper coating over an aluminum conductor core.

Grounding Electrode Conductors

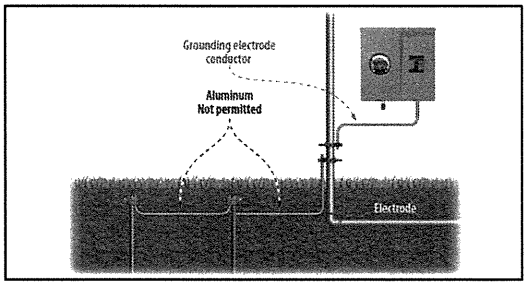
Chapter 6

- Aluminum Grounding Electrode Conductors
  - The *Code* includes installation and sizing requirements for aluminum and copper-clad aluminum grounding electrode conductors.
  - One such installation restriction is the prohibition of terminating aluminum grounding electrode conductors within 18 inches of the Earth outside.
  - Section 250.64(A)(2) relaxes the 18-inch restriction where an aluminum or copper-clad aluminum grounding electrode conductor is terminated within an enclosure that is suitable for the environment.

Grounding Electrode Conductors

Chapter 6

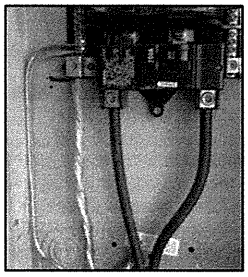
- Aluminum GEC Restrictions



Grounding Electrode Conductors

Chapter 6

- Sizing Grounding Electrode Conductors
  - Sizing grounding electrode conductors is covered in 250.66.
  - The size of a grounding electrode conductor for a service or separately derived system is based on the size of the largest ungrounded supply conductor.



Grounding Electrode Conductors

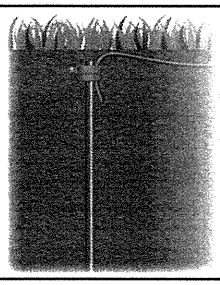
Chapter 6

- Sizing Grounded Electrode Conductors
  - The grounding electrode conductor is never sized based on an overcurrent protective device of a service or system.
  - Table 250.66 is generally used to size grounding electrode conductors for AC systems.
  - Section 250.166 is used for sizing grounding electrode conductors for DC systems.
  - Sections 250.66(A), (B), and (C) are sizing provisions that can be applied where the grounding electrode conductor connection is to rod or pipe type electrodes, concrete-encased electrodes, or to ground ring electrodes and does not extend to other types of electrodes that would require larger size GECs.

Grounding Electrode Conductors

Chapter 6

- Section 250.66(A) – Rod, Pipe, or Plate Electrodes

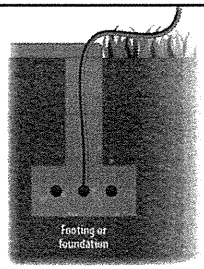


A grounding electrode conductor connected to a single rod, pipe, or plate electrode does not have to be larger than a 6 AWG copper conductor

Grounding Electrode Conductors

Chapter 6

- Section 250.66(B) – Concrete-Encased Electrodes

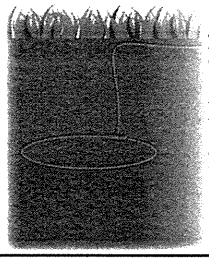


A grounding electrode conductor connected to a concrete-encased electrode, does not have to be larger than a 4 AWG copper conductor

Grounding Electrode Conductors

Chapter 6

- Section 250.66(C) – Ground Rings



A grounding electrode conductor connected to a ground ring(s) electrode does not have to be larger than the size of the ring

The ring has to completely circle the building or structure

A ground ring must be at least 2 AWG copper

Grounding Electrode Conductors

Chapter 6

- Using *NEC* Table 250.66
  - To use Table 250.66, first the size must be determined (in AWG or kcmil) of the largest ungrounded supply conductor or equivalent area for parallel conductors.
  - Then the range should be located of conductor sizes that the supply conductor falls within, in vertical columns 1 or 2 depending on whether they are copper or aluminum.
  - Last, vertical columns 3 or 4 should be looked at, depending on whether the conductor is copper or aluminum, to determine the grounding electrode conductor size.

Grounding Electrode Conductors

Chapter 6

Table 250.66 Grounding Electrode Conductor for Alternating-Current Systems (in part)

(1) Size of Largest Ungrounded Service-Entrance Conductor or Equivalent Area for Parallel Conductors (AWG/kcmil)		Size of Grounding Electrode Conductor (AWG/kcmil)	
Copper	Aluminum or Copper-Clad Aluminum	Copper	Aluminum or Copper-Clad Aluminum
2 or smaller	1/0 or smaller	8	6
1 or 1/0	2/0 or 3/0	6	4
2/0 or 3/0	4/0 or 250	4	2
Over 3/0 through 350	Over 250 through 500	2	1/0
Over 350 through 600	Over 500 through 900	1/0	3/0
(2) Over 600 through 1100	Over 900 through 1750	(3) 2/0	4/0
Over 1100	Over 1750	3/0	250

1. Determine the size of the largest ungrounded service-entrance conductor
2. Proceed down the column to the range where the size is included
3. Proceed left horizontally to the copper column to determine the minimum size grounding electrode conductor required

Grounding Electrode Conductors

Chapter 6

- Example Using Table 250.66
  - The size of the largest ungrounded AC service-entrance conductor is 900 kcmil copper [(3) parallel 300 kcmil conductors per phase].
  - What is the minimum size required for a copper grounding electrode conductor?
  - Note: The grounding electrode in this example is a metal in-ground support structure.

Grounding Electrode Conductors

Chapter 6

Table 250.66 Grounding Electrode Conductor for Alternating-Current Systems (in part without notes)

Size of Largest Ungrounded Service-Entrance Conductor or Equivalent Area for Parallel Conductors (AWG/kcmil)		Size of Grounding Electrode Conductor (AWG/kcmil)	
Copper	Aluminum or Copper-Clad Aluminum	Copper	Aluminum or Copper-Clad Aluminum
2 or smaller	1/0 or smaller	8	6
1 or 1/0	2/0 or 3/0	6	4
2/0 or 3/0	4/0 or 250	4	2
Over 3/0 through 350	Over 250 through 500	2	1/0
Over 350 through 600	Over 500 through 900	1/0	3/0
Over 600 through 1100	Over 900 through 1750	2/0	4/0
Over 1100	Over 1750	3/0	250

Grounding Electrode Conductors

Chapter 6

- DC System Grounding Electrode Conductors
  - The connection point of the grounding electrode conductor for a DC system is covered in Section 250.164.
  - If the DC source is not located on the premises, the grounding electrode conductor connection shall be made at one or more supply stations.
  - The grounding electrode conductor connection is not permitted to be made at individual services or at any point on the premises wiring if the source is not located on the premises. [*NEC* 250.164]

Grounding Electrode Conductors

Chapter 6

- DC System Grounding Electrode Conductors
  - If the DC system (source) is located on the premises, the grounding electrode conductor connection has to be made at one of the following locations:

    1. At the source
    2. At the first system disconnecting means or overcurrent protective device
    3. By other means that provides equivalent protection and utilizes listed and identified equipment

    [*NEC* 250.164(B)]

Grounding Electrode Conductors

Chapter 6

- DC System Grounding Electrode Conductors
  - The minimum-size grounding electrode conductor for a DC system is generally required to be not less than the sizes indicated in 250.166(A) and (B).
  - When the DC system consists of a three-wire balancer set or a balancer winding with overcurrent protection, the grounding electrode conductor must be no smaller than the neutral conductor and can never be smaller than 8 AWG copper or 6 AWG aluminum.

Grounding Electrode Conductors

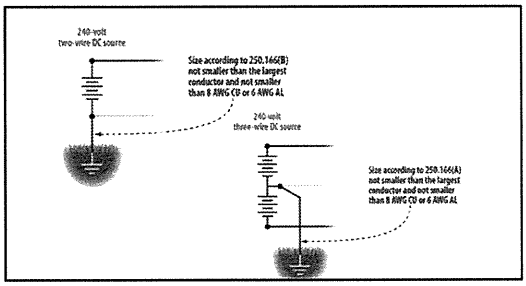
Chapter 6

- DC System Grounding Electrode Conductors
  - When the DC system is other than as described in 250.166(A), the grounding electrode conductor cannot be smaller than the largest conductor supplied by the system and can never be smaller than 8 AWG copper or 6 AWG aluminum.
  - DC grounding electrode conductors must meet the sizing requirements in 250.166 but do not have to be larger than the sizes in Table 250.66.
  - The provisions of 250.66(A),(B), or (C) can be applied where the grounding electrode conductor is a connection to the types of electrodes covered in those sections.

Grounding Electrode Conductors

Chapter 6

- DC Grounding Electrode Conductor Size



Grounding Electrode Conductors

Chapter 6

- Grounding Electrode Conductor Installation
  - Specific rules apply to installations of the grounding electrode conductor.
  - No identification requirement for grounding electrode conductors exists, but identifying using the color green is not prohibited.
  - They can be insulated covered or bare, but they are not required to be identified using the color green or green with yellow stripes as is required for the EGC.

Grounding Electrode Conductors

Chapter 6

- Grounding Electrode Conductor Installation
  - The installation requirements for grounding electrode conductors in the *NEC* deal with sizing requirements, connections, protection of the conductor from physical damage, and protection from the effects of magnetic fields.
  - Although not specifically required by the *NEC*, the grounding electrode conductors should be installed avoiding sharp bends when possible and connected directly to grounding electrodes.
  - This requirement is included in the *NEC* for grounding electrode conductors of communications systems in Chapters 7 and 8.

Grounding Electrode Conductors

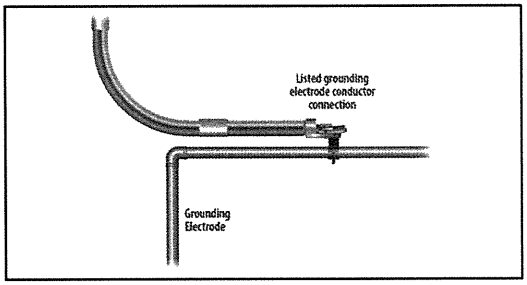
Chapter 6

- Securing and Protecting from Physical Damage
  - When grounding electrode conductors are installed exposed, they are required to be securely fastened to the surface on which they are placed.
  - If a grounding electrode conductor is installed in a conduit or other armor, the conduit or armor has to be secured to the surface.
  - Grounding electrode conductors in sizes 4 AWG or larger must be protected where installed in locations that expose them to physical damage.
  - Protection can be provided by installation in a raceway or armor.

Grounding Electrode Conductors

Chapter 6

- Protect GEC from Physical Damage



Grounding Electrode Conductors

Chapter 6

- Securing and Protecting from Physical Damage
  - The *Code* also recognizes that if grounding electrode conductors that are 6 AWG or larger are installed such that they are not exposed to potential physical damage, they can be run without being placed in a raceway or armor if they are securely fastened.
  - Grounding electrode conductors also can be installed on or run through wood or other framing members.
  - Physical protection in this case is usually inherently provided by this location within the construction framing.

Grounding Electrode Conductors

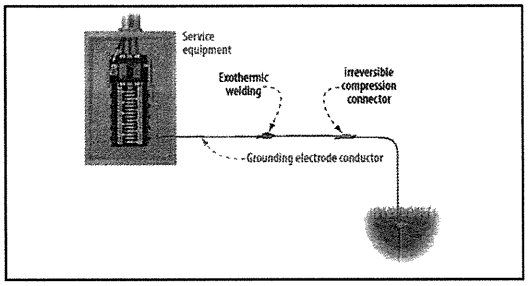
Chapter 6

- GEC in Continuous Lengths
  - Grounding electrode conductors are generally required to be installed in a continuous length without a splice or joint unless splices are made using irreversible compression connectors or the exothermic welding process.
  - The irreversible compression connectors have to be listed as grounding and bonding equipment.
  - Busbars are also permitted to be connected together in order to form grounding electrode conductors.

Grounding Electrode Conductors

Chapter 6

- No Splices Permitted (generally)



Grounding Electrode Conductors

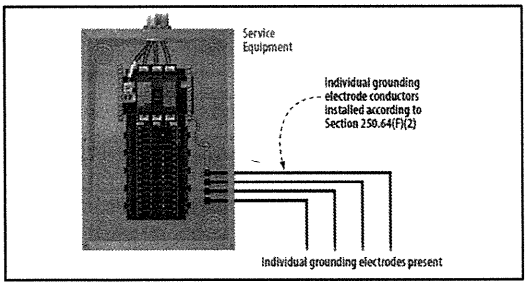
Chapter 6

- Methods of Installing Grounding Electrode Conductors
  - Individual grounding electrode conductors can be installed from each electrode to the service.
  - A grounding electrode conductor can also be run to one or more electrodes and bonding jumpers can interconnect the rest of the electrodes to form the grounding electrode system.

Grounding Electrode Conductors

Chapter 6

- GECs to Individual Electrodes



Grounding Electrode Conductors

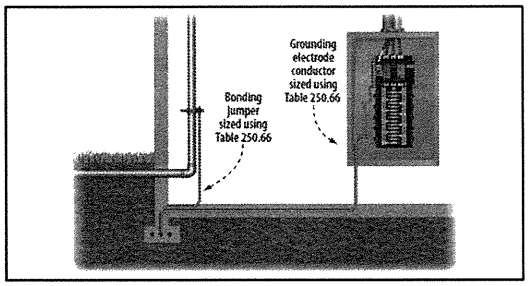
Chapter 6

- Methods of Installing Grounding Electrode Conductors
  - When multiple grounding electrodes form a system of electrodes, the size required for the grounding electrode conductor has to be for the largest grounding electrode conductor connected in the system.
  - For example, if a grounding electrode conductor is installed from a service to a concrete-encased electrode and a bonding jumper is installed from the concrete-encased electrode to a water pipe electrode, then both would have to be sized using Table 250.66 based on the requirement for connection to the water pipe.

Grounding Electrode Conductors

Chapter 6

- Size GEC Using Table 250.66



Grounding Electrode Conductors

Chapter 6

- Methods of Installing Grounding Electrode Conductors
  - Grounding electrode conductors are permitted to be run to any electrode in the grounding electrode system if the other grounding electrodes are connected using bonding jumpers as indicated in 250.64(F).
  - The bonding jumpers must be installed in accordance with 250.53(C), which indicates that sizing must be per 250.66 and the connections have to be made according to the requirements in 250.70.

Grounding Electrode Conductors

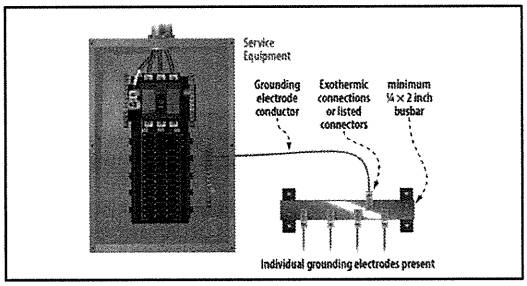
Chapter 6

- Methods of Installing Grounding Electrode Conductors
  - Another method of interconnecting grounding electrodes to form the grounding electrode system is to connect the grounding electrode conductor(s) and bonding jumper(s) from each electrode to a copper or aluminum busbar.
  - The busbar must be at least ¼ in. thick x 2 in. wide and be long enough for the number of conductors that must be connected.
  - The connections to the busbar must be listed and the busbar must be securely fastened to the structure in an accessible location.

Grounding Electrode Conductors

Chapter 6

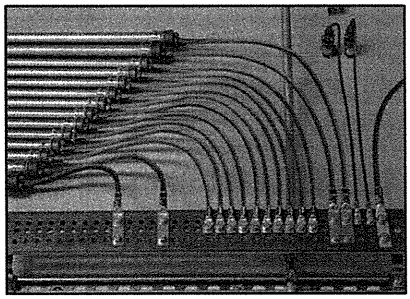
- Connection to a Common Busbar



Grounding Electrode Conductors

Chapter 6

- GEC Connections to Busbar



Grounding Electrode Conductors

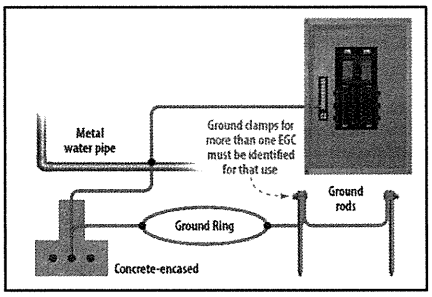
Chapter 6

- Connection Point for Grounding Electrode Conductors
  - A single grounding electrode conductor is permitted to be run to grounding electrode system. It is usually connected at the service equipment enclosure.
  - Typically, a specific termination means is provided in assemblies such as switchboards, panelboards, motor control centers, and other equipment that is suitable for use as service equipment.
  - This connection is permitted within the listed enclosure even though it is closer than 18 inches to the earth. See Section 250.64(A)(3).

Grounding Electrode Conductors

Chapter 6

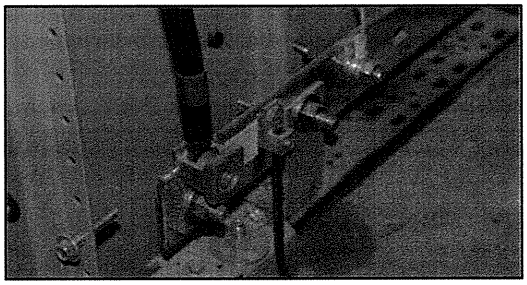
- Single GEC to Electrode System



Grounding Electrode Conductors

Chapter 6

- GEC Connected to Bus in Switchboard



Grounding Electrode Conductors

Chapter 6

- Methods of Connection at Service Disconnecting Means
  - A grounding electrode conductor can be connected to a single service disconnecting means enclosure.
  - Individual grounding electrode conductors can be connected to a service equipment enclosure containing up to six disconnects.
  - Individual grounding electrode conductors can be installed from separate service disconnects to the grounding electrode system.
  - A common grounding electrode conductor can be installed and taps to separate service disconnects can be installed.

Grounding Electrode Conductors

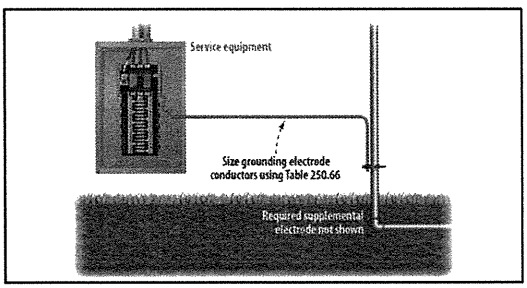
Chapter 6

- Single Disconnecting Means
  - A single grounding electrode conductor can be installed from the grounded conductor terminal bus in the equipment to the grounding electrode system.
  - This method can be used for a single service disconnect, or separate grounding electrode conductors can be installed from each service disconnect to the grounding electrode system.
  - Individual grounding electrode conductors can be installed to each electrode in the grounding electrode system.

Grounding Electrode Conductors

Chapter 6

- Size GEC Using Table 250.66



Grounding Electrode Conductors

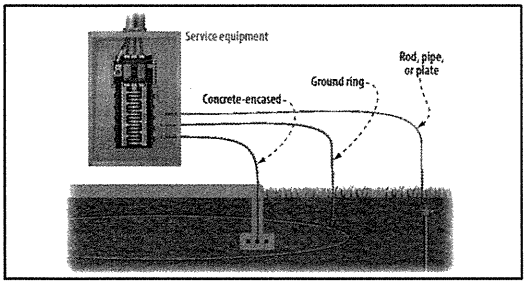
Chapter 6

- Single Disconnecting Means
  - The minimum size of the grounding electrode conductor is determined by using Table 250.66.
  - Sizing is based on the size of the largest ungrounded service conductor.
  - Remember that 250.66 permits smaller sizes to be used for certain types of electrodes.

Grounding Electrode Conductors

Chapter 6

- Connections to Electrodes



Grounding Electrode Conductors

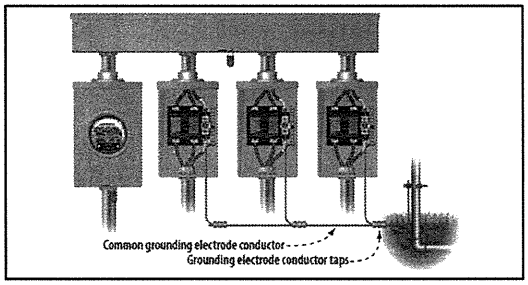
Chapter 6

- Service Disconnecting Means in Separate Enclosures
  - The common grounding electrode conductor is typically used where multiple service disconnecting means are installed in separate enclosures as permitted by 230.71(A).
  - In these types of installations, a single, large common grounding electrode conductor installed and has multiple grounding electrode conductor taps are connected to the common grounding electrode conductor.

Grounding Electrode Conductors

Chapter 6

- GEC Tap Conductors



Grounding Electrode Conductors

Chapter 6

- Service Disconnecting Means in Separate Enclosures
  - The term *common grounding electrode conductor* implies a GEC and is not permitted to have any splices or joints as described in the general rule in 250.64(D)(1).
  - The term *grounding electrode conductor tap* is not a defined term in the *NEC* and is therefore not subject to this same restriction.

Grounding Electrode Conductors

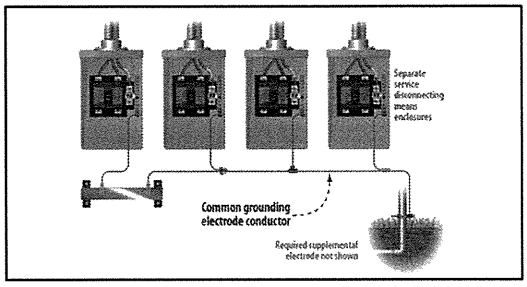
Chapter 6

- Service Disconnecting Means in Separate Enclosures
  - Grounding electrode conductor tap connections to a common grounding electrode conductor must be made by exothermic welding listed grounding and bonding connections.
  - A minimum ¼ in. wide x 2 in. thick aluminum or copper busbar may be used with exothermic or listed connections.

Grounding Electrode Conductors

Chapter 6

- Common GEC



Grounding Electrode Conductors

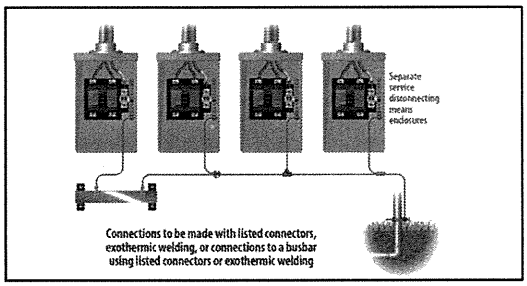
Chapter 6

- Connections to the Common GEC
  - The minimum size of the *common grounding electrode conductor* is based on the sum of the circular mil area of the largest ungrounded service-entrance conductor(s).
  - Grounding electrode conductor taps must be connected to a common grounding electrode conductor in a manner so that the common grounding electrode conductor remains without a splice.

Grounding Electrode Conductors

Chapter 6

- Size of Common GEC



Grounding Electrode Conductors

Chapter 6

- Sizing Grounding Electrode Conductor Taps
  - Grounding electrode tap conductors must be sized using Table 250.66.
  - Sizing is based on the size of the largest ungrounded service conductor serving each service disconnecting means enclosure.

Grounding Electrode Conductors

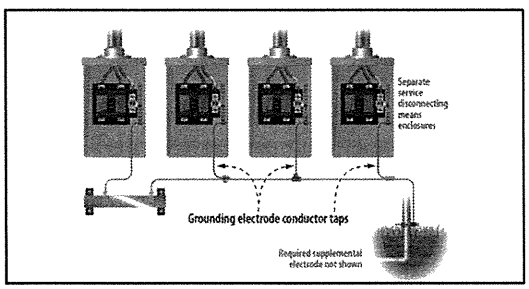
Chapter 6

- Sizing Grounding Electrode Conductor Taps
  - Example: Common grounding electrode conductor is 3/0 AWG copper and each service disconnect is supplied with 4/0 AWG copper service-entrance conductors.
  - The minimum size grounding electrode conductor tap to each disconnect is 2 AWG copper based on Table 250.66.

Grounding Electrode Conductors

Chapter 6

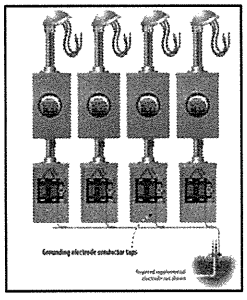
- Sizing GEC Tap Conductors



Grounding Electrode Conductors

Chapter 6

- Grounding Electrode Conductor Taps
  - Grounding electrode conductors for individual separate service disconnecting means enclosures.
  - Common grounding electrode conductor from the grounding electrode and connected using grounding electrode conductor taps.



Grounding Electrode Conductors

- Individual Grounding Electrode Conductors
  - The grounding electrode conductors can also be run individually from each grouped service disconnect to the grounding electrode system.
  - Each GEC size in this case is based on the size of the largest ungrounded service conductor serving each service disconnecting means enclosure.

Grounding Electrode Conductors

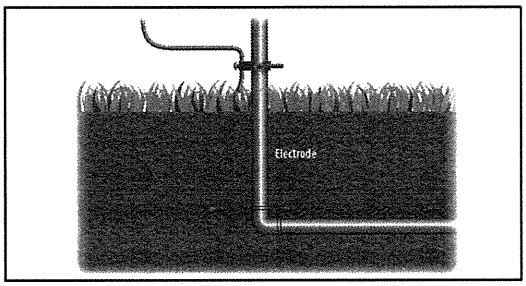
- Effectiveness of the Grounding Path
  - Section 250.68 generally requires that connections to a grounding electrode be accessible.
  - Exceptions to 250.68 that address conditions that relax this grounding electrode conductor connection accessibility requirement as follows:
    - Buried connections, such as those used for rods, pipes, or plate electrodes
    - Encased connections to concrete-encased electrodes

Grounding Electrode Conductors

- Effectiveness of the Grounding Path
  - Exothermic welding is used as the connection means or if the connections are made by irreversible compression connectors to fireproofed structural metal

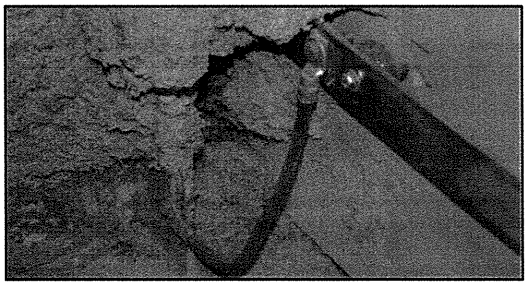
Grounding Electrode Conductors

- GEC Connections to be Accessible



Grounding Electrode Conductors

- Encapsulation in Fireproofing Permitted



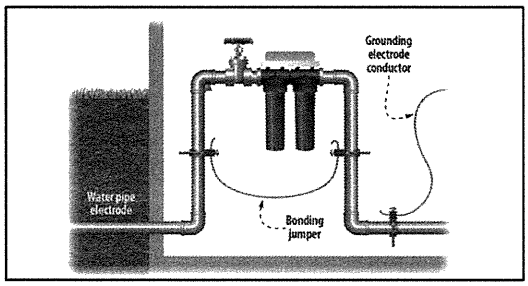
Grounding Electrode Conductors

- Integrity of Grounding Connection
  - To ensure the grounding path for a metal piping system grounding electrode, bonding must be provided around any insulated joints and around equipment that is likely to be disconnected or removed for repairs or replacement.
  - Bonding jumpers must be of sufficient length to permit removal of such equipment while retaining the integrity of the grounding path.
  - Size the bonding jumper using Table 250.66 (same size as the required grounding electrode conductor).

Grounding Electrode Conductors

Chapter 6

- Bonding Jumpers Required



Grounding Electrode Conductors

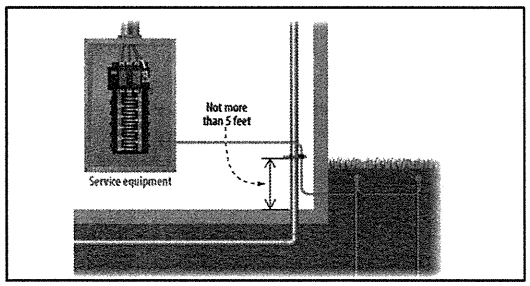
Chapter 6

- Grounding Electrode Conductor Connection Locations
  - The grounding electrode conductor connection to water pipe electrode must be made within 5 feet of the water pipe point of entry at the building or structure served.

Grounding Electrode Conductors

Chapter 6

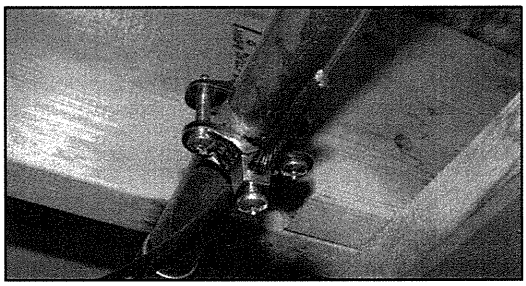
- GEC Connection Locations



Grounding Electrode Conductors

Chapter 6

- GEC Connection Locations



Grounding Electrode Conductors

Chapter 6

- Grounding Electrode Conductor Connection Locations
  - Section 250.68(C)(1) also prohibits the use of that portion of the interior metal water piping system that extends more than 5 feet beyond the point of entrance into the building to be used as a conductor to interconnect grounding electrodes.

Grounding Electrode Conductors

Chapter 6

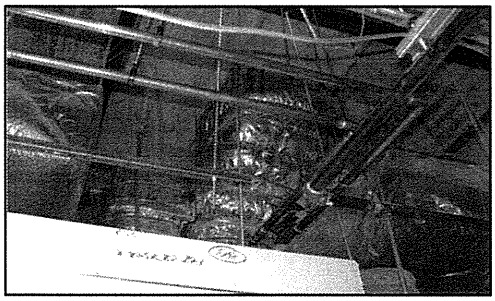
- Grounding Electrode Conductor Connection Locations
  - By exception, the grounding electrode conductor connection or connections of bonding jumpers of the grounding electrode system are permitted at locations farther than 5 feet from where the water piping enters the building or structure under the following specific conditions:

    1. Conditions of maintenance and supervision ensure that qualified persons service the installation.
    2. The entire length of the piping is exposed other than where it passes perpendicularly through walls or floors.

Grounding Electrode Conductors

Chapter 6

- GEC Connection Location Exception



Grounding Electrode Conductors

Chapter 6

- Conductive Paths to Electrodes
  - Section 250.68(C) includes provisions that recognize the conductive paths (building steel and metal water piping systems) that are ultimately connected to grounding electrodes but that are not electrodes by definition.
  - Interior metal water piping located not more than 5 feet from the point of entrance to the building or structure shall be permitted as a conductor to interconnect electrodes that are part of the grounding electrodes system.

Grounding Electrode Conductors

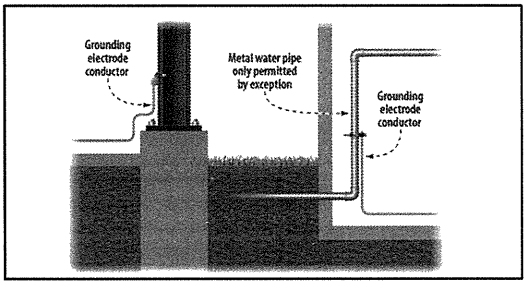
Chapter 6

- Conductive Paths to Electrodes
  - A structural metal building frame shall be permitted to be used as a conductor to interconnect electrodes that are part of the grounding electrode system.
  - A structural metal building frame shall also be permitted to be used as a grounding electrode conductor.

Grounding Electrode Conductors

Chapter 6

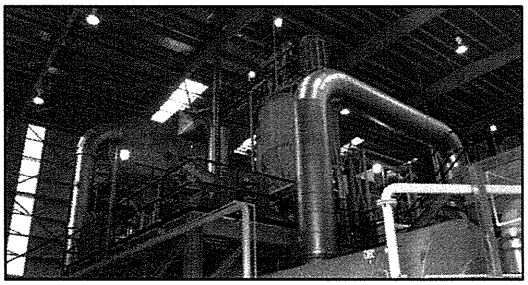
- Conductive Paths to Electrodes



Grounding Electrode Conductors

Chapter 6

- Structural Metal Building Frame



Grounding Electrode Conductors

Chapter 6

- Concrete-Encased CEC Connection
  - A concrete-encased electrode of the wire type or of the rebar type installed in accordance with 250.52(A)(3) shall be permitted to be extended to an accessible location above the concrete.
  - The rebar extension must not be in contact with the earth without corrosion protection. See Section 250.68(C)(3)(c)
  - Installing a length of rebar that turns up vertically and emerges above the concrete is common and provides an accessible connection means to concrete-encased electrodes.

Grounding Electrode Conductors

Chapter 6

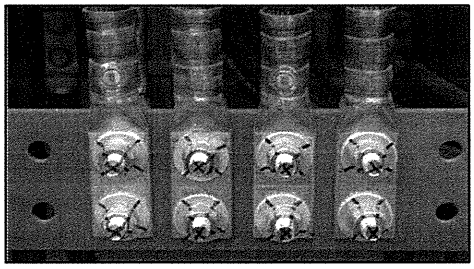
- GEC Connections
  - Section 250.70 indicates that grounding electrode conductors or bonding jumpers of the grounding electrode system can be made using one of the following methods:

    1. Listed lugs
    2. Exothermic welding processes
    3. Listed pressure connectors
    4. Listed clamps
    5. Or other listed means

Grounding Electrode Conductors

Chapter 6

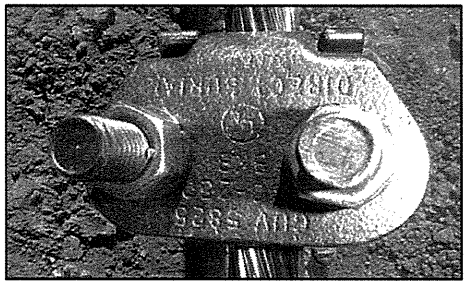
- GEC Connections



Grounding Electrode Conductors

Chapter 6

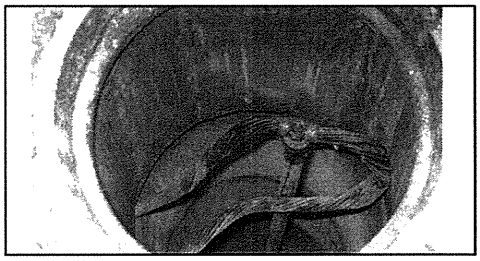
- GEC Connections



Grounding Electrode Conductors

Chapter 6

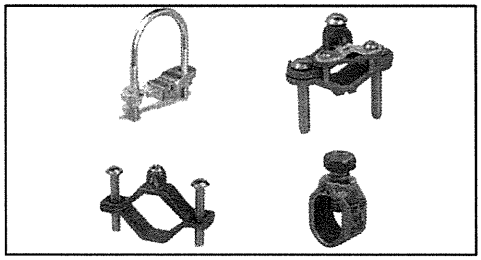
- GEC Connections



Grounding Electrode Conductors

Chapter 6

- Listed GEC Connections

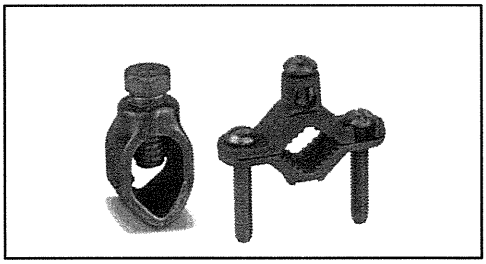


Courtesy of ABB

Grounding Electrode Conductors

Chapter 6

- Listed Direct Burial GEC Connections



Courtesy of ABB

Grounding Electrode Conductors

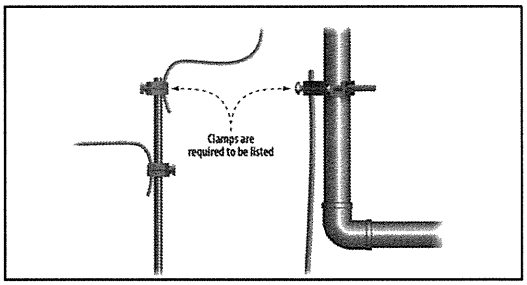
Chapter 6

- Grounded Electrode Conductor Connections
  - Grounding or bonding clamps must be listed as grounding and bonding equipment and are typically suitable for connecting only one conductor.
  - More than one grounding electrode conductor is permitted to be used with a single clamp where the clamp is identified for multiple conductors.

Grounding Electrode Conductors

Chapter 6

- One GEC Conductor Per Clamp



Grounding Electrode Conductors

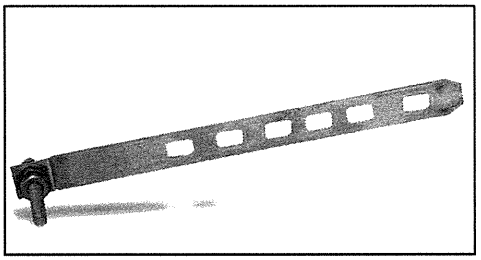
Chapter 6

- Communications Grounding Electrode Connections
  - Listed grounding clamps for grounding electrode conductors used with communications systems or other limited energy systems are available in a strap-type configuration for indoor use only.
  - These types of grounding electrode conductor connections are not permitted for use with power system grounding electrode conductors.
  - These clamps must be listed and must have a rigid metal base and strap that encircles the piping system and is not likely to stretch after installation.

Grounding Electrode Conductors

Chapter 6

- Ground Clamp for Communications Systems



Courtesy of ABB

Grounding Electrode Conductors

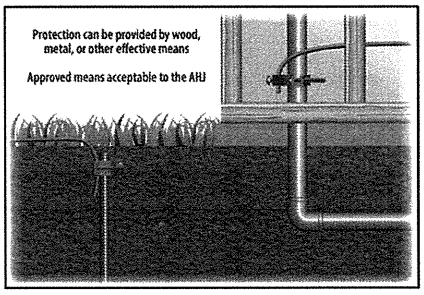
Chapter 6

- Protection of Ground Clamps
  - Grounding clamps are required to be protected from physical damage unless the fittings (clamps) are approved for use without additional protection.
  - Buried connections to ground rods provide sufficient protection.

Grounding Electrode Conductors

Chapter 6

- Protection of Ground Clamps



Grounding Electrode Conductors

Chapter 6

- Magnetic Field Concerns
  - Where a grounding electrode conductor is installed in a ferrous metal raceway, the raceway must be electrically continuous from the point of attachment to the cabinet or equipment to the grounding electrode and must be securely fastened to the ground clamp or fitting.
  - Ferrous metal conduits and tubing have a magnetic property that reacts to rising and falling magnetic fields present in AC systems.
  - During a ground fault event, the current in a grounding electrode conductor can be relatively high for the duration of the event.

Grounding Electrode Conductors

Chapter 6

- Magnetic Field Concerns
  - The strength of the magnetic field will increase in direct proportion to the amount of current in the conductor.
  - In many cases the magnetic lines of force in the conductor are induced into the conduit enclosing the grounding electrode conductor.
  - The magnetic lines of force can surpass the saturation point of the steel raceway.

Grounding Electrode Conductors

Chapter 6

- The Choke Effect
  - Where the grounding electrode conductor exits, the conduit, the magnetic lines of force generated by the fault current in the conductor will be induced on the end of the conduit creating a saturation point that exceeds the capacity of the conduit.
  - The steel conduit in this instance is acting like a steel core of a coil to concentrate the magnetic lines of force resulting in what the industry refers to as a *choke effect*.
  - Specific bonding requirements are necessary for ferrous metal raceways that contain grounding electrode conductors.

Grounding Electrode Conductors

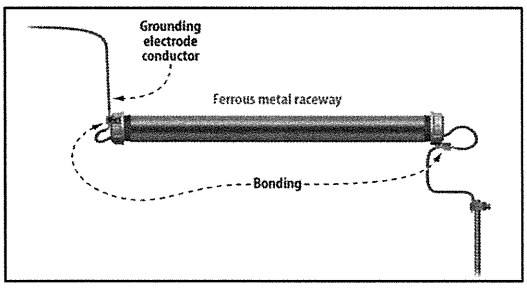
Chapter 6

- Enclosures for Grounding Electrode Conductors Bonding Ferrous Metal
  - Ferrous metal enclosures for grounding electrode conductors that are not physically continuous from cabinets or equipment to the grounding electrode must be made electrically continuous by bonding each end of the raceway to the contained grounding electrode conductor.
  - The method required for bonding each end of the raceway must be one of those provided in Sections 250.92(B)(2) through (B)(4).

Grounding Electrode Conductors

Chapter 6

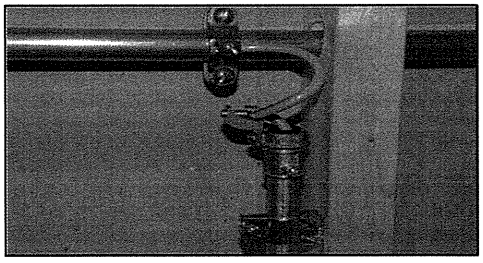
- Bonding GEC to Ferrous Metal Conduit



Grounding Electrode Conductors

Chapter 6

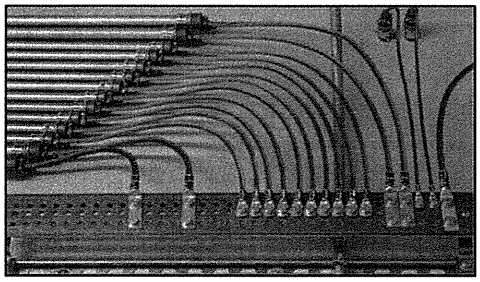
- Bonding GEC to Ferrous Metal Conduit



Grounding Electrode Conductors

Chapter 6

- Bonding GEC to Ferrous Metal Conduit



Grounding Electrode Conductors

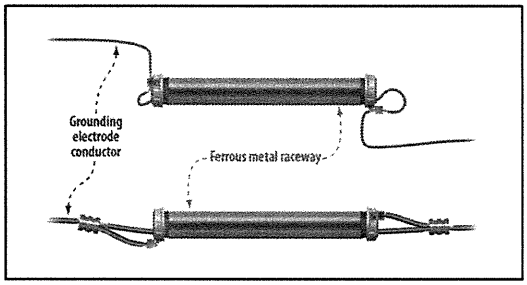
Chapter 6

- Enclosures for Grounding Electrode Conductors Bonding Ferrous Metal
  - One method is to use bonding bushings at each end of the raceway.
  - Another method is to use bonding fittings that are manufactured specifically for this purpose.
  - In this case the hub-type fitting is installed on the end(s) of the conduit or tubing, and it includes a conductor clamp for completing an effective bonding connection between the hub and the grounding electrode conductor.

Grounding Electrode Conductors

Chapter 6

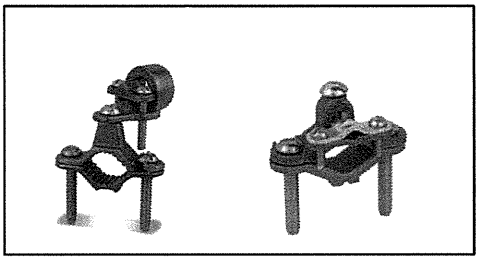
- Bonding GEC to Ferrous Metal Conduit



Grounding Electrode Conductors

Chapter 6

- Listed Clamps



Courtesy of ABB

Grounding Electrode Conductors

Chapter 6

- Conduit Fill for GEC
  - The conduit and tubing fill percentage restrictions in Table 1, Chapter 9 of the *NEC* apply to conductors installed in raceways.
  - If a single conductor (grounding electrode conductor in this case) is installed in conduit or tubing, the percentage of fill must not generally not exceed 53%.
  - Note 2 of the Chapter 9 Tables exempt raceways used to provide physical protection.

Grounding Electrode Conductors

Chapter 6

- Single GEC in Conduit or Tubing

Table 1 Percentage of Cross Section of Conduit and Tubing for Conductors

Number of Conductors	All Conductor Types
1	53
2	31
Over 2	40

53% 31% 40%

Reproduction of Table 1, Chapter 9 (without notes to tables)

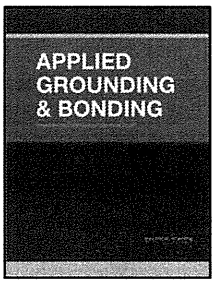
Grounding Electrode Conductors

Chapter 8

- Summary
  - This conductor performs grounding function and maintains the connection to the Earth for systems and equipment.
  - The grounding electrode conductor does not perform as an effective ground-fault current path.
  - Grounding electrode conductors are generally sized using Table 250.66.
  - Grounding electrode conductors can be copper, aluminum, or copper-clad aluminum.
  - Grounding electrode conductor connections are generally required to be accessible.

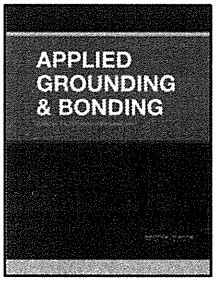
Grounding and Bonding

Grounding Electrode Conductors



Grounding and Bonding

Bonding Requirements



Bonding Requirements

Chapter 7

- Introduction
  - Bonding is the process of connecting conductive parts or equipment together.
  - Section 250.4 contains important performance criteria that clearly describes what electrical bonding is intended to accomplish.
  - Bonding methods and sizing of equipment bonding jumpers are covered in Part V of Article 250 along with requirements for bonding piping systems, structural metal building frames, and other conductive parts within or attached to buildings or structures.
  - Electrical bonding requires connections that must be effective to ensure that optimal performance is achieved at any point in the electrical system.

Bonding Requirements

Chapter 7

- Objectives
  - Understand the *NEC* definitions related to electrical bonding requirements.
  - Understand the requirements for bonding on the supply side of the service disconnecting means.
  - Determine where equipment bonding jumpers are required.

Bonding Requirements

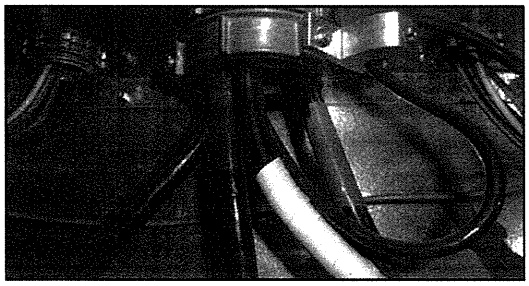
Chapter 7

- Objectives (continued)
  - Understand the difference between supply-side and load-side bonding requirements and establish appropriate sizes for supply-side bonding jumpers and load-side bonding jumpers.
  - Understand the importance of bonding in the effective ground-fault current path.
  - Determine the requirements for bonding metal piping systems and structural metal building framing.

Bonding Requirements

Chapter 7

- Bonding for Continuity and Conductivity



Bonding Requirements

Chapter 7

- Article 100 Definitions
  - Bonded (Bonding). Connected to establish electrical continuity and conductivity.
  - Bonding Conductor or Jumper. A reliable conductor to ensure the required electrical conductivity between metal parts required to be electrically connected.
  - Bonding Jumper, Equipment. The connection between two or more portions of the equipment grounding conductor.

Bonding Requirements

Chapter 7

- Article 100 Definitions
  - Bonding Jumper, Main. The connection between the grounded circuit conductor and the equipment grounding conductor, or the supply-side bonding jumper, or both, at the service.
  - Bonding Jumper, Supply-Side. A conductor installed on the supply side of a service or within a service equipment enclosure(s), or for a separately derived system, that ensures the required electrical conductivity between metal parts required to be electrically connected.

Bonding Requirements

Chapter 7

- Article 100 Definitions
  - Bonding Jumper, System. The connection between the grounded circuit conductor and the supply-side bonding jumper, or the equipment grounding conductor, or both, at a separately derived system.
  - Service Point. The point of connection between the facilities of the serving utility and the premises wiring.

Bonding Requirements

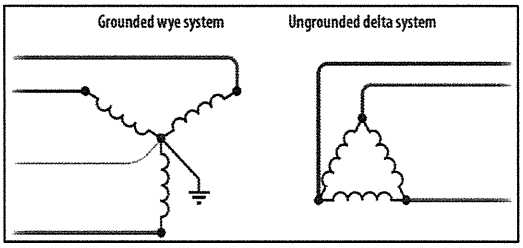
Chapter 7

- Bonding Performance Criteria
  - Section 250.4 consists of subdivisions (A) and (B).
  - Section 250.4(A) provides grounding and bonding performance criteria for grounded systems and associated equipment.
  - Section 250.4(B) provides grounding and bonding performance criteria for ungrounded systems and associated equipment.

Bonding Requirements

Chapter 7

- Grounded and Ungrounded Systems



Bonding Requirements

Chapter 7

- Bonding Performance Criteria (continued)
  - The goals of bonding are the same for grounded systems as for ungrounded systems.
  - Bonding must be effective and perform properly during ground-fault conditions.
  - Each fitting, bushing, connector, coupling, and so forth must be made up tight to keep impedance low.
  - Loose fittings and poorly installed wiring methods that are not supported properly can impair bonding connections.

Bonding Requirements

Chapter 7

- Electrical Workmanship
  - The effectiveness of all bonding connections is directly related to workmanship.
  - Good workmanship is essential in electrical construction.
  - Loose fittings and poorly installed wiring methods that are not supported properly can impair bonding connections in metallic wiring methods installed for services, feeders, and branch circuits.
  - See NECA 1 *Standard for Good Workmanship in Electrical Construction*.

Bonding Requirements

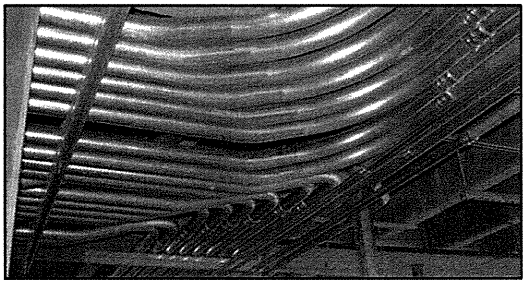
Chapter 7

- Tighten Locknuts and Fittings

Bonding Requirements

Chapter 7

- Tighten Locknuts and Fittings



Bonding Requirements

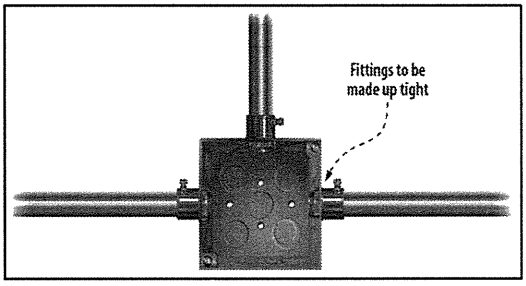
Chapter 7

- Maintaining Continuity
  - The primary objective of bonding is to make two conductive objects become one electrically.
  - Conductive parts of an electrical system together puts the parts at the same or nearly the same potential.
  - Section 250.90 provides a general requirement to bond where necessary to ensure electrical continuity and the capacity to conduct safely any imposed fault current.

Bonding Requirements

Chapter 7

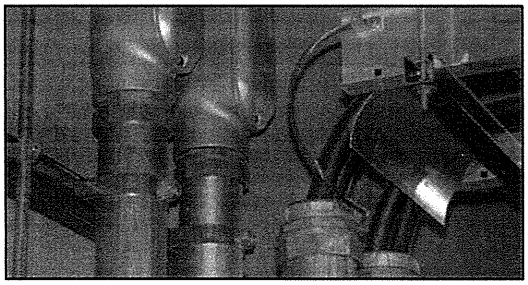
- Tighten Locknuts and Fittings



Bonding Requirements

Chapter 7

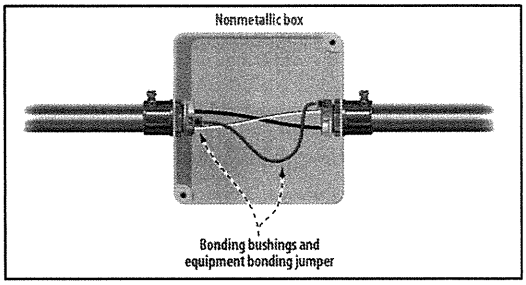
- Bonding Jumper Installation



Bonding Requirements

Chapter 7

- Bonding Jumpers



Bonding Requirements

Chapter 7

- Bonding Connections (Wire-Type Conductors)
  - For equipment grounding conductors, bonding conductors, and jumpers to perform effectively, thorough, tight connections must be made.
  - Section 250.8 provides the acceptable methods of making grounding and bonding connections and applies generally to connections for wire-type conductors.
  - Any loose or improper bonding connections in the effective ground-fault current path can compromise the performance of the electrical safety system (the grounding and bonding circuits).

Bonding Requirements

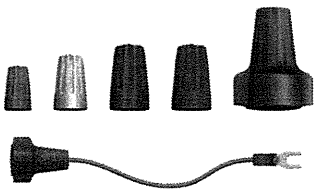
Chapter 7

- Methods of Bonding Connections
  - Several methods and various devices provide many choices for grounding and bonding connections.
  - The type of connection made is usually determined based on the equipment type and location in the system.

Bonding Requirements

Chapter 7

- Listed Pressure Connectors

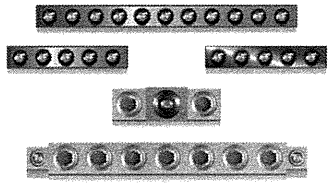


Listed wire pressure connectors are suitable for grounding and bonding connections.

Bonding Requirements

Chapter 7

- Equipment Grounding Terminal Bars

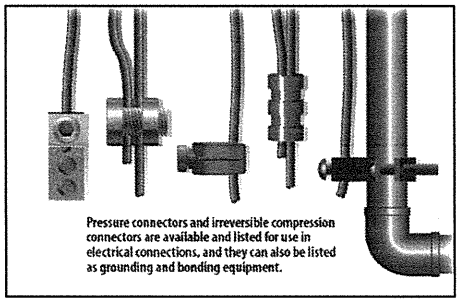


Available separately or as accessories for switchboards, panelboards, and other equipment
Equipment grounding terminal bars are often installed in panelboards and switchboards.

Bonding Requirements

Chapter 7

- Listed Pressure Connectors

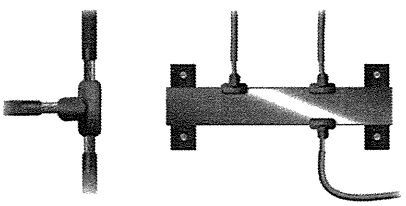


Pressure connectors and irreversible compression connectors are available and listed for use in electrical connections, and they can also be listed as grounding and bonding equipment.

Bonding Requirements

Chapter 7

- Exothermic Welding



Exothermic welding processes are suitable for grounding and bonding connections. They are not required to be listed, but the manufacturer's instructions must be followed.

Bonding Requirements

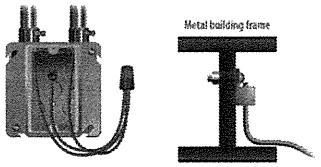
Chapter 7

- Cleaning Coated Surfaces
  - For effective electrical connections, the joint or termination must offer little to no opposition in the electrical circuit.
  - Section 250.12 of the *NEC* addresses cleaning of surfaces.
  - Coated electrical products such as painted enclosures and coated raceways can introduce additional impedance in the grounding and bonding system.
  - Coated or painted surfaces must be cleaned to remove coatings such as paint, lacquer, and enamel from threads and contact surfaces.

Bonding Requirements

Chapter 7

- Grounding Screws and Terminals



Machine screw fasteners can be used to connect (such as grounding screws) as long as no fewer than two full threads are engaged. Machine screws that are secured with a nut are also suitable for grounding and bonding connections.

Bonding Requirements

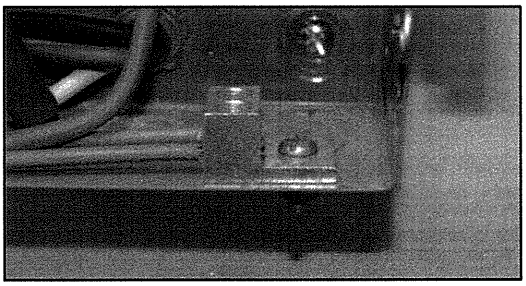
Chapter 7

- Bonding Jumper and Bonding Conductor Length
  - The defined term *bonding conductor or jumper* addresses two concepts that accomplish the same purpose: to ensure electrical conductivity and continuity between metal parts.
  - Bonding jumpers are generally understood to be a relatively short bonding means while bonding conductors have generally been understood to be a conductor length exceeding that of a jumper.
  - No bonding jumper length is specified in the *NEC*.

Bonding Requirements

Chapter 7

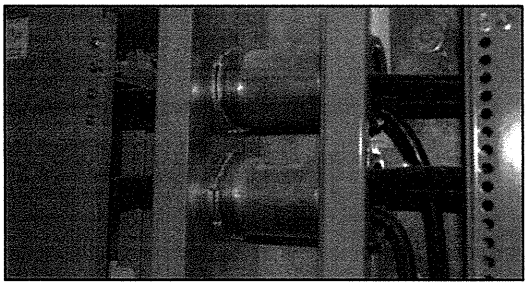
- Fastening Pressure Lugs to Enclosures



Bonding Requirements

Chapter 7

- Fastening Conduit to Enclosures



Bonding Requirements

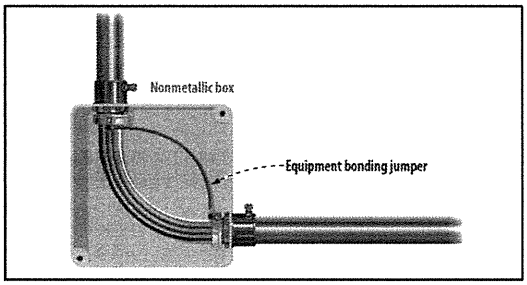
Chapter 7

- Equipment Bonding Jumpers (Function and Purpose)
  - Bonding jumpers are connections between two conductive objects that establish continuity and conductivity.
  - An example of an equipment bonding jumper installation is when it is used to connect two sections of EMT that are attached to a nonmetallic enclosure.
  - Another example of an equipment bonding jumper installation is the connection between a grounded metal outlet box and a grounding-type receptacle.

Bonding Requirements

Chapter 7

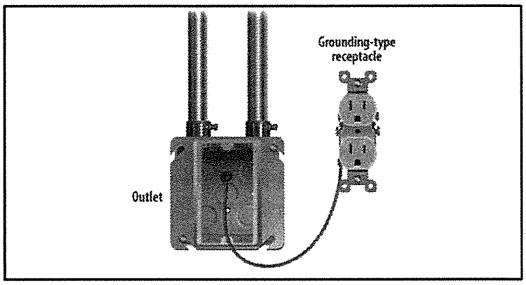
- Equipment Bonding Jumper



Bonding Requirements

Chapter 7

- Equipment Bonding Jumper



Bonding Requirements

Chapter 7

- Equipment Bonding Jumper

Bonding Requirements

Chapter 7

- Sizing Equipment Bonding Jumpers
  - The *Code* includes two general sizing requirements for equipment bonding jumpers in services.
    - Section 250.102(C) provides the minimum requirements for sizing supply-side bonding jumpers (those located on the supply side of an overcurrent device).
    - Section 250.102(D) provides the minimum requirements for sizing equipment bonding jumpers on the load side of an overcurrent device.

Bonding Requirements

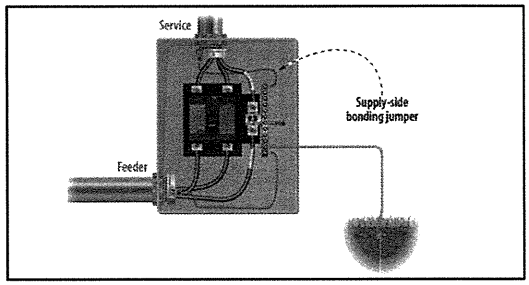
Chapter 7

- Service Bonding Rules (Supply Side)
  - The conductors from the service point to the service disconnect are usually not protected at their ampacity.
  - In this case, the supply-side bonding rules in 250.102(C) apply.
  - Sizing bonding jumpers on the supply side of the service overcurrent protective devices is accomplished using Table 250.102(C)(1) (or the 12.5% rule for larger services).
  - Sizing is based on the size of the largest ungrounded supply conductor(s) supplying the service disconnecting means.

Bonding Requirements

Chapter 7

- Supply-Side Bonding Jumper



Bonding Requirements

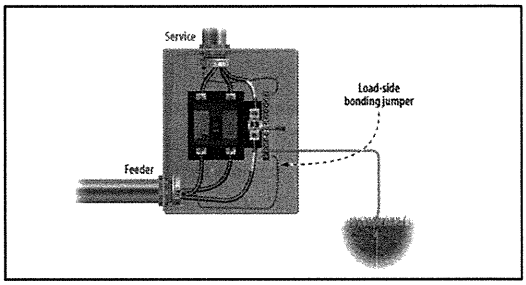
Chapter 7

- Bonding Rules (Load-Side)
  - Equipment bonding jumpers for a feeder supplying a panelboard from the service disconnecting means enclosure are on the load-side of an overcurrent protective device.
  - In this case the (load-side) equipment bonding jumper is sized in accordance with 250.102(D) using Table 250.122 based on the rating of the overcurrent protective device for the feeder circuit.

Bonding Requirements

Chapter 7

- Load-Side Bonding Jumper



Bonding Requirements

Chapter 7

- Service Bonding Rules
  - Section 250.92 provides rules related to bonding methods for enclosures, raceways, and other normally non–current-carrying metal parts at the service and on the supply side of the service disconnecting means and overcurrent protective device.
  - During ground-fault conditions, these metal enclosures and raceways carry high levels of fault current for the duration of time it takes for the overcurrent protective device on the primary side of the utility transformer to open the circuit.
  - Bonding connections must be effective and comply with Sections 250.92(A) and (B).

Bonding Requirements

Chapter 7

- Parts Required to be Bonded
  - The following metal parts of equipment containing service conductors are required to be bonded together:
    1. Raceways
    2. Cable tray
    3. Cable bus frames
    4. Auxiliary gutters
    5. Service cable armor or sheath
  - Enclosures such as meter enclosures, panelboards, switchboards, boxes, and so forth, interposed in the service raceway installation and must be bonded together.

Bonding Requirements

Chapter 7

- Service Bonding Rules
  - Bonding requirements for metallic parts on the supply side of the service disconnect are more restrictive and result in more robust or strengthened bonding installations.
  - The methods for bonding at the service equipment are outlined in Section 250.92(B)(1) through (4).
  - Section 250.92(B)(1) recognizes the grounded conductor for a bonding means.

Bonding Requirements

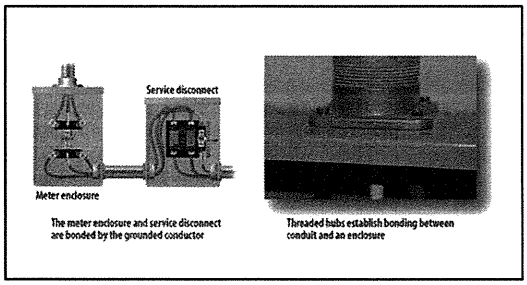
Chapter 7

- Service Bonding Methods
  - Use of the grounded conductor for bonding enclosures together.
  - Connections using threaded couplings or listed threaded hubs on enclosures if made up tight.
  - Threadless couplings or connectors for metal raceways and metal-clad cables (where made up tight).
  - Other listed devices such as bonding-type locknuts or bonding bushings.

Bonding Requirements

Chapter 7

- 250.92(B)(1) through (4)



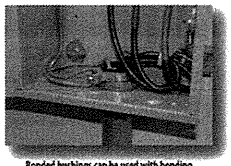
The meter enclosure and service disconnect are bonded by the grounded conductor

Threaded hubs establish bonding between conduit and an enclosure

Bonding Requirements

Chapter 7

- 250.92(B)(1) through (4)



Bonded bushings can be used with bonding jumpers on the supply side or load side of the service disconnect means

A bonding wedge can be used for establishing a bonding connection between the conduit and an enclosure

Courtesy of ABB

Bonding Requirements

Chapter 7

- Service Bonding Concerns
  - It is important to bond around any compromised entries to enclosures, such as reducing washers and oversized, concentric, or eccentric knockouts.
  - Standard locknuts, on both sides of the enclosure, are acceptable for making the mechanical connection of the service raceway to the enclosure, but they are not suitable for the heavier bonding prescribed in Section 250.92.
  - Section 250.12 provides a general requirement to remove coatings such as paint that could impair the bonding connection.

Bonding Requirements

Chapter 7

- Bonding for Circuits Over 250 Volts
  - Where concentric, eccentric, or oversized knockouts are encountered in the installation, the bonding requirements in 250.97 apply, if the circuit voltage exceeds 250 volts phase-to-ground.
  -
  - The exception to Section 250.97 relaxes this bonding requirement for installations where oversized, concentric, or eccentric knockouts are not encountered or where a box or enclosure with concentric or eccentric knockouts is listed and provides a reliable bonding connection.

Bonding Requirements

Chapter 7

- Bonding for Circuits Over 250 Volts
  - If additional bonding is required, one of the following methods can be used to establish an effective bonding connection:

    1. Threadless couplings and connectors for cables with metal sheaths
    2. Two locknuts, on RMC or intermediate metal conduit—one inside and one outside of boxes and cabinets
    3. Fittings with shoulders that seat firmly against the box or cabinet, such as EMT connectors, flexible metal conduit connectors, and cable connectors, with one locknut on the inside of boxes and cabinets
    4. Listed fittings

Bonding Requirements

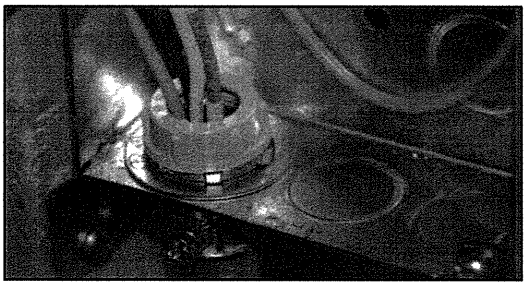
Chapter 7

- Reducing Washers for Bonding
  - Listed reducing washers are suitable for bonding when they meet listing requirements.
  - Listed metal reducing washers are considered suitable for grounding in circuits over and under 250 volts when installed according to the *NEC*.
  - Generally, all concentric or eccentric rings must be removed and painted, or coatings must be removed so metal-to-metal contact is achieved when using reducing washers for bonding purposes.
  - See UL Product IQ Category (QCRV) for additional information.

Bonding Requirements

Chapter 7

- Reducing Washers



Bonding Requirements

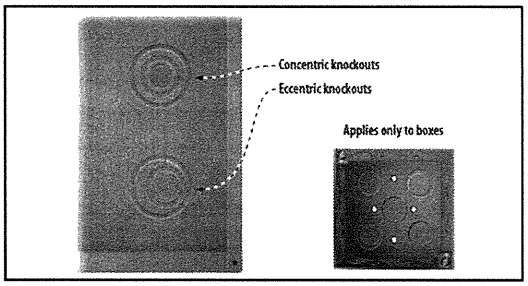
Chapter 7

- Boxes with Concentric or Eccentric Knockouts
  - Bonding around punched concentric or eccentric knockouts is not required in all cases if the box or enclosure containing the pre-punched concentric or eccentric knockouts has been tested and is listed as suitable for bonding.
  - Listed metal outlet boxes are suitable for bonding in circuits above or below 250 volts to ground without the use of additional bonding equipment.
  - Be sure that metal-to-metal contact is made according to *NEC* Section 250.12

Bonding Requirements

Chapter 7

- Concentric and Eccentric Knockouts



Bonding Requirements

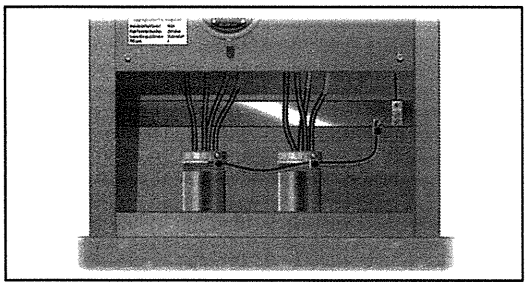
Chapter 7

- Supply-Side Bonding Jumpers (Wire Types)
  - Wire-type bonding jumpers are installed on the supply-side of the service disconnecting means and must be sized according to 250.102(C)(1).
  - Use Table 250.102(C)(1) or the 12.5% rule for larger services.
  - Wire-type bonding jumpers can be installed from conduits individually or in a series loop (daisy chain) connecting multiple conduits using a single supply-side bonding jumper.

Bonding Requirements

Chapter 7

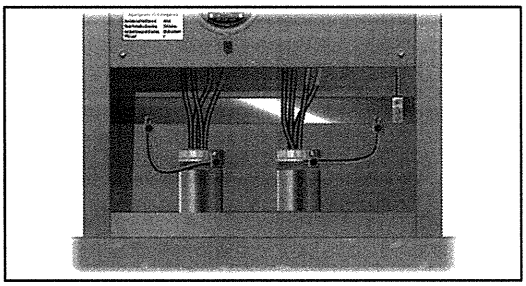
- Supply-Side Bonding Jumpers



Bonding Requirements

Chapter 7

- Supply-Side Bonding Jumpers



Bonding Requirements

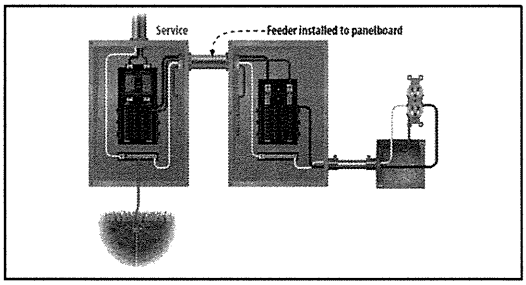
Chapter 7

- General Equipment Bonding (Load Side)
  - Electrical bonding is also required on the load side of the service disconnect.
  - Bonding functions occur from the point of delivery at the service equipment to the final outlets in the branch circuits.
  - The feeder and branch circuit equipment grounding conductor(s), either a wire type or raceway, perform both bonding and grounding functions.

Bonding Requirements

Chapter 7

- EGC Performs Bonding



Bonding Requirements

Chapter 7

- Installing Bonding Jumpers (Load Side)
  - Equipment bonding jumpers must be copper or other corrosion-resistant material.
  - Bonding jumpers can be a bus, wire, or other suitable conductor.
  - Bonding jumper connections must meet the provisions in Section 250.8.
  - Feeder and branch circuit equipment bonding jumper sizes are established using Table 250.122.

Bonding Requirements

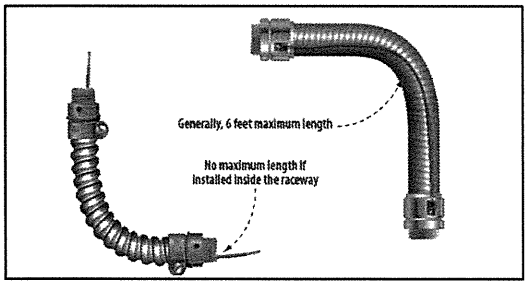
Chapter 7

- Bonding Jumper Installation

Bonding Requirements

Chapter 7

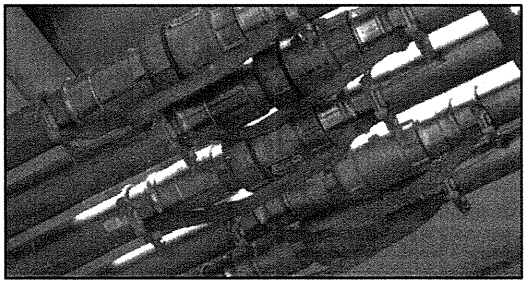
- Bonding Jumper Installation



Bonding Requirements

Chapter 7

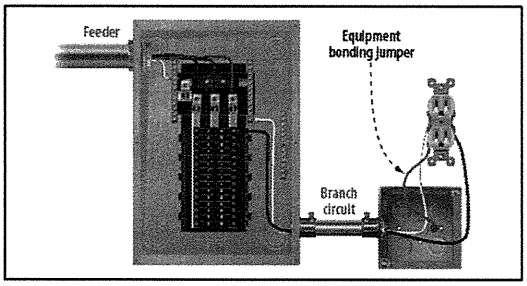
- Bonding Jumper Installation



Bonding Requirements

Chapter 7

- Equipment Bonding Jumper Installation



Bonding Requirements

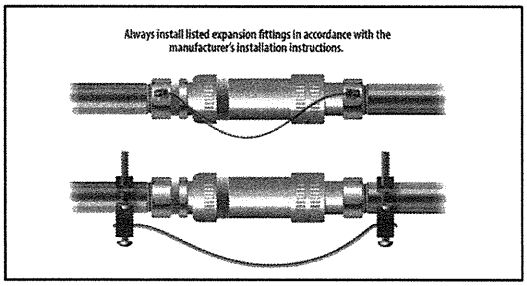
Chapter 7

- Expansion, Expansion-Deflection, Deflection Fittings and Loose Joined Metal Fittings
  - Equipment bonding jumpers are often installed around expansion, expansion-deflection, deflection fittings and loose joined metal fittings conduit fittings to maintain required continuity.
  - Follow the manufacturer's installation instructions.
  - If flexible metal conduit or liquidtight flexible metal conduit is installed around building expansion joints, equipment bonding jumpers must be installed.

Bonding Requirements

Chapter 7

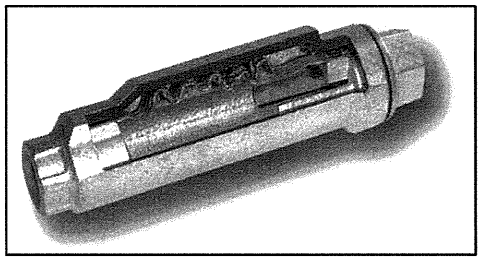
- Bond Around Expansion Fittings



Bonding Requirements

Chapter 7

- Listed Expansion Fitting With Jumper



Courtesy of ABB

Bonding Requirements

Chapter 7

- Bonding Metal Piping Systems
  - Section 250.104 provides requirements for bonding metal piping systems.
  - Section 250.104(A) addresses bonding metal water piping systems.
  - Section 250.104(A) applies to potable water piping systems, sprinkler system piping, and chilled water system piping.
  - Section 250.104(B) addresses bonding other metal piping systems such as air piping, gas piping, and others.
  - Bonding connections are generally required to be accessible.

Bonding Requirements

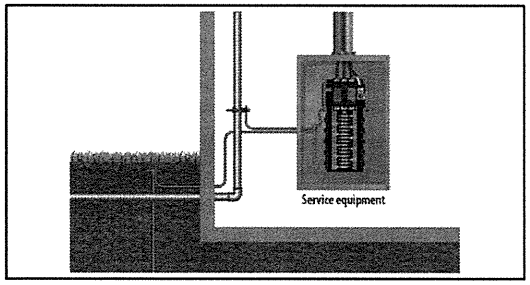
Chapter 7

- Metal Water Piping System

Bonding Requirements

Chapter 7

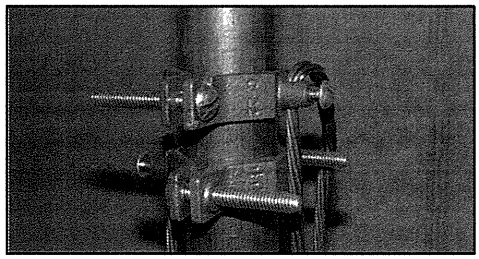
- Bonding Metal Water Piping Systems



Bonding Requirements

Chapter 7

- Metal Water Piping System



Bonding Requirements

Chapter 7

- Bonding Connection Location and Sizing
  - The *NEC* requires metallic water piping systems to be bonded to one of the following:
    - The service equipment enclosure
    - The grounded conductor at the service
    - The grounding electrode conductor where it is of sufficient size
    - One or more of the grounding electrodes of the building grounding electrode system
  - The bonding jumper must not be smaller than the values listed in Table 250.102(C)(1) except that it does not have to be larger than 3/0 copper or 250 kcmil aluminum or copper clad aluminum.

Bonding Requirements

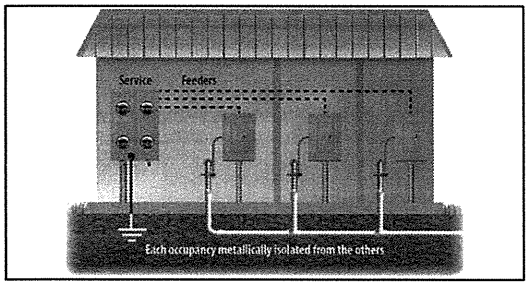
Chapter 7

- Bonding Metal Piping in Multiple Occupancy Buildings
  - In multiple occupancy buildings, if the metal piping system for each individual occupancy is metallically isolated from all other occupancies by use of nonmetallic water piping, the metal water piping system or systems for each occupancy are permitted to be bonded to the equipment grounding terminal bus of the panelboard or switchboard enclosure that supplies the individual occupancy.
  - The bonding jumper is permitted to be sized using Table 250.122 based on the rating of the overcurrent device for the feeder supplying each individual occupancy.

Bonding Requirements

Chapter 7

- 250.104(A)(2) Multiple Occupancies



Bonding Requirements

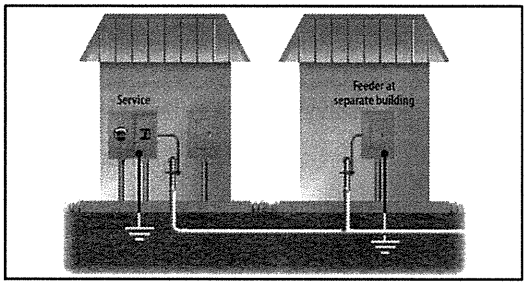
Chapter 7

- Multiple Buildings or Structures Supplied by a Feeder or Branch Circuit
  - The bonding jumpers shall be sized in accordance with Table 250.102(1), using the size of the feeder or branch circuit conductors that supply the building.
  - The bonding jumper is not required to be larger than the largest ungrounded feeder or branch circuit conductor supplying the building or structure.

Bonding Requirements

Chapter 7

- Size Bonding Jumper Per Table 250.102(C)(1)



Bonding Requirements

Chapter 7

- Bonding Other Metal Piping Systems
  - The requirements for bonding metal piping systems other than metal water piping systems are provided in Section 250.104(B).
  - The *Code* requires bonding only if these other metal piping systems are *likely to become energized.*
  - Likely to become energized is described in the *NEC Style Manual* as the failure of insulation on.

Bonding Requirements

Chapter 7

- Bonding Other Metal Piping Systems
  - The bonding jumper is required to be installed and connected to one of the following:
    - The equipment grounding conductor that is likely to energize the piping system
    - The service equipment enclosure
    - The grounded conductor at the service
    - The grounding electrode conductor if large enough
    - Any grounding electrode in the grounding electrode system

Bonding Requirements

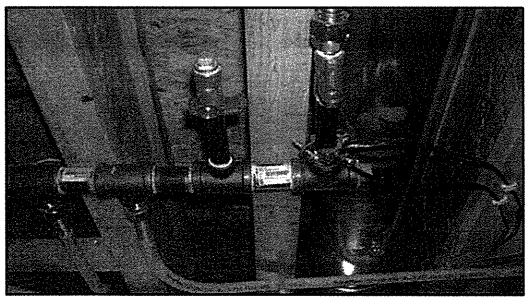
Chapter 7

- Bonding Other Metal Piping Systems
  - At a minimum, other metal piping systems, including metal gas piping systems, are required to be bonded using a branch circuit equipment grounding conductor sized in accordance with Table 250.122 if they are likely to become energized.

Bonding Requirements

Chapter 7

- Bonding Metal Gas Piping Systems



Bonding Requirements

Chapter 7

- Bonding Other Metal Piping Systems
  - Example:
    - If the branch circuit supplying a gas-fired furnace is protected by a 30- ampere overcurrent protective device, then the 10 AWG equipment grounding conductor of the 30-ampere branch circuit can serve as the bonding means.
    - In these cases the branch circuit supplying the appliance is viewed as the circuit *likely to energize* the piping system.

Bonding Requirements

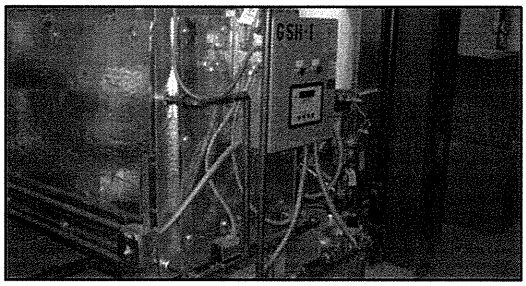
Chapter 7

- Bonding Other Metal Piping Systems
  - The National Fuel Gas Code (NFPA 54) includes additional requirements for bonding metal gas piping systems.
  - Manufacturers of corrugated stainless-steel tubing (CSST) gas piping provide instructions for more restrictive bonding requirements than those contained in the *NEC*.

Bonding Requirements

Chapter 7

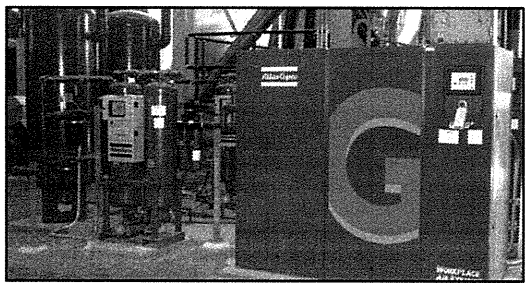
- Gas Piping for Furnace



Bonding Requirements

Chapter 7

- Gas Piping for Furnace



Bonding Requirements

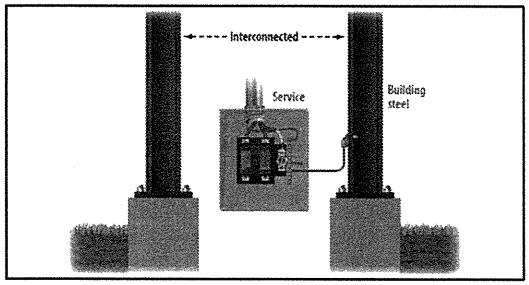
Chapter 7

- Bonding Structural Metal Building Frames
  - Exposed structural metal that does not qualify as an electrode, is interconnected to form a building frame, and is not already intentionally grounded or bonded is required to be bonded to the electrical supply service of the building or structure.
  - This requirement also applies only when the structural metal building framing is *likely to become energized*.
  - Size the bonding jumper(s) using Table 250.102(C)(1) except it does not have to be larger than 3/0 copper or 250 kcmil aluminum or copper clad aluminum.

Bonding Requirements

Chapter 7

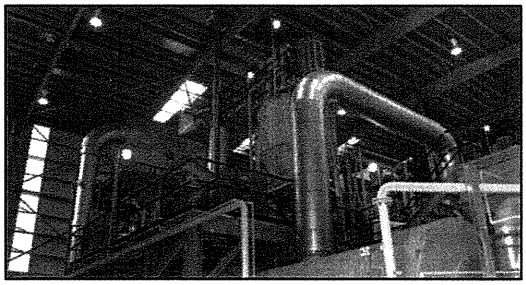
- Bonding Metal Building Frames



Bonding Requirements

Chapter 7

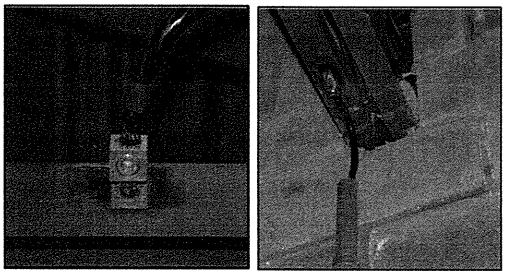
- Interconnected Metal Building Frame



Bonding Requirements

Chapter 7

- Bonding Jumper Connection



Bonding Requirements

Chapter 7

- Bonding Lightning Protection Systems
  - Section 250.106 of the *NEC* requires that the ground terminals of a lightning protection system be bonded to the building or structure grounding electrode system.
  - This ensures that any rise or fall of potential on conductive objects in or on the building or structure will occur at the same potential and reduce flashover possibilities.

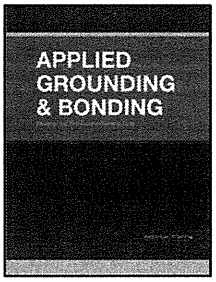
Bonding Requirements

Chapter 7

- Summary
  - Bonding is the process of connecting conductive parts or equipment together to establish electrical continuity and conductivity.
  - Effective bonding results in conductive parts being connected together in a manner that functions electrically to provide safety for the overall electrical system.
  - There are strengthened bonding requirement for the supply side of the service disconnecting means.
  - There are specific sizing rules for wire-type bonding jumpers on the supply-side of the service and the load side of the service.

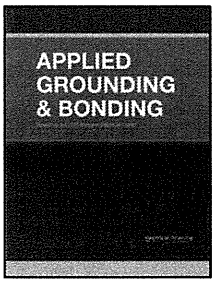
Grounding and Bonding

Bonding Requirements



Grounding and Bonding

Equipment Grounding Conductors



Equipment Grounding Conductors

Chapter 8

- Introduction
  - The equipment grounding conductor (EGC) is another important component in the grounding and bonding system.
  - EGCs are typically installed with feeders and branch circuits of electrical systems.
  - They perform grounding, bonding, and serve as effective ground-fault current paths.

Equipment Grounding Conductors

Chapter 8

- Introduction (continued)
  - EGCs are electrically conductive paths that extend the ground (Earth) connection to equipment that is required to be grounded.
  - The performance of EGCs is directly related to the integrity of this conductive path that is ensured through good workmanship.

Equipment Grounding Conductors

Chapter 8

- Objectives
  - Understand the definition of the term *equipment grounding conductor (EGC).*
  - Identify the types of equipment grounding conductors recognized by the *NEC.*
  - Understand the purpose and performance of the equipment grounding conductor in the electrical system.
  - Determine the requirements for identification and connections of equipment grounding conductors.
  - Understand installation requirements and determine minimum sizes for wire-type equipment grounding conductors.

Equipment Grounding Conductors

Chapter 8

- Article 100 Definition
  - Grounding Conductor, Equipment (EGC). The conductive path(s) that provides an effective ground-fault current path and connects normally non–current-carrying metal parts of equipment together and to the system grounded conductor or to the grounding electrode conductor, or both.
    - Informational Note No. 1: It is recognized that the equipment grounding conductor also performs bonding.
    - Informational Note No. 2: See 250.118 for a list of acceptable equipment grounding conductors.

Equipment Grounding Conductors

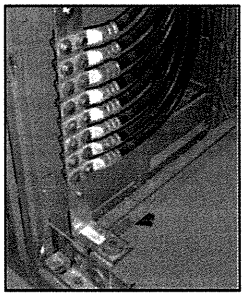
Chapter 8

- Article 100 Definitions
  - Grounded (Grounding). Connected (connecting) to ground or to a conductive body that extends the ground connection.
  - Effective Ground-Fault Current Path. An intentionally constructed, low impedance electrically conductive path designed and intended to carry current under ground-fault conditions from the point of a ground fault on a wiring system to the electrical supply source and that facilitates the operation of the overcurrent protective device or ground-fault detectors on high-impedance grounded systems.

Equipment Grounding Conductors

Chapter 8

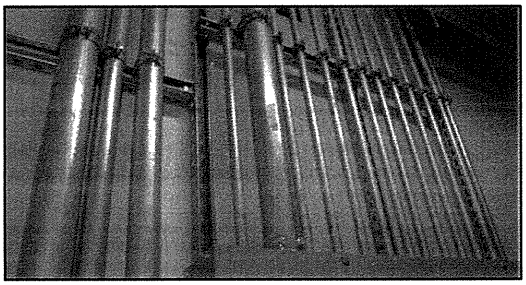
- Part VI of Article 250
  - The general requirements for equipment grounding conductors are provided in Part VI of *NEC* Article 250.
  - These rules cover types, identification, installation, and sizing of EGCs.
  - EGCs can be in the form of a wire-type conductor or other types as provided in 250.118.



Equipment Grounding Conductors

Chapter 8

- Types of EGCs



Equipment Grounding Conductors

Chapter 8

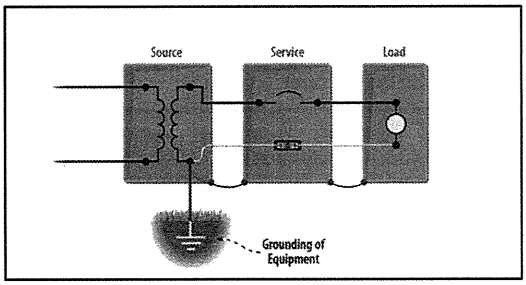
- Performance of Equipment Grounding Conductors
  - The EGC performs three important functions in the electrical safety system.

1. EGCs are intended to provide a path that connects equipment to ground (the Earth), thereby performing grounding functions.
2. EGCs perform bonding functions by connecting equipment together and to ground.
3. EGCs perform as effective ground-fault current paths to facilitate overcurrent device operation during ground fault conditions.

Equipment Grounding Conductors

Chapter 8

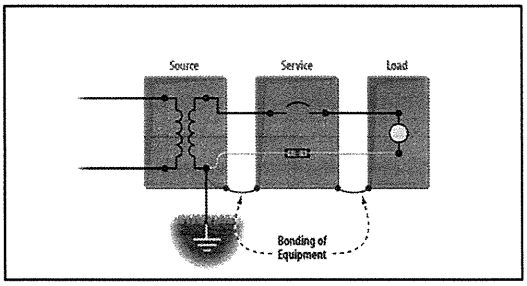
- EGC Performs Grounding



Equipment Grounding Conductors

Chapter 8

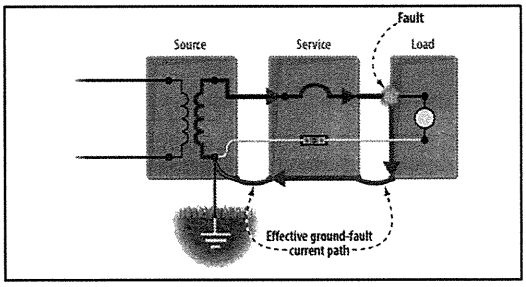
- EGC Performs Bonding



Equipment Grounding Conductors

Chapter 8

- EGC Provides a Fault Current Path



Equipment Grounding Conductors

Chapter 8

- Equipment Grounding Conductor Material
  - Section 250.118 indicates EGCs can be made of copper, aluminum, or copper-clad aluminum material.
  - These conductor materials can be in the form of a wire (stranded or solid) or busbar of any shape, and they can be insulated, covered, or bare.
  - An equipment grounding conductor can be a wire type or can be the wiring method, such as a metal rigid conduit or the armor of Type AC cable.

Equipment Grounding Conductors

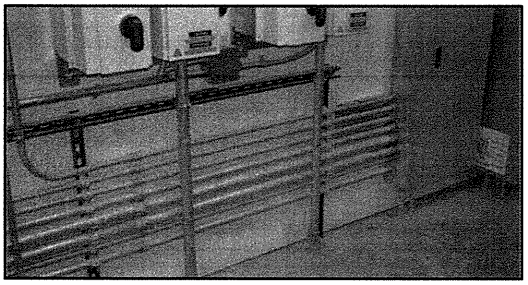
Chapter 8

- Types of Equipment Grounding Conductors
  - Section 250.118 provides a list of acceptable equipment grounding conductors.
    - A copper, aluminum, or copper-clad aluminum conductor (wire)
    - Rigid metal conduit (RMC) or Intermediate metal conduit (IMC)
    - Electrical metallic tubing (EMT)
    - Armor of Type AC cable, as provided in Section 320.108
    - Metal-clad cable (Type MC) as provided in 250.118(10)

Equipment Grounding Conductors

Chapter 8

- EMT as EGC Proper Supports



Equipment Grounding Conductors

Chapter 8

- Types of Equipment Grounding Conductors
  - Section 250.118 provides a list of acceptable equipment grounding conductors (continued)
    - The copper sheath of mineral-insulated, metal-sheathed cable Type MI
    - Cable trays, as permitted 392.10 and 392.60
    - Cable bus framework, as permitted in 370.3
    - Other listed electrically continuous metal raceways and listed auxiliary gutters
    - Surface metal raceways listed for grounding

Equipment Grounding Conductors

Chapter 8

- Types of Equipment Grounding Conductors
  - Section 250.118 provides a list of acceptable equipment grounding conductors (continued)
    - Flexible metallic tubing is recognized as an equipment grounding conductor in accordance with the conditions of 250.118(7).
    - Listed flexible metal conduit is recognized as an equipment grounding conductor if it meets all of the conditions in 250.118(5).
    - Listed liquidtight flexible metal conduit is recognized as an equipment grounding conductor if it meets all of the conditions in 250.118(6).

Equipment Grounding Conductors

Chapter 8

- Listed Flexible Metal Conduit
  - Listed FMC permitted as an EGC if all the following are met:
    - Listed fittings are installed
    - The size does not exceed 1-¼ inch trade size
    - 20-A maximum OCPD protecting the contained circuit
    - The combined length of FMC, LFMC, and FMT in the same ground-fault current path does not exceed 6 feet

Equipment Grounding Conductors

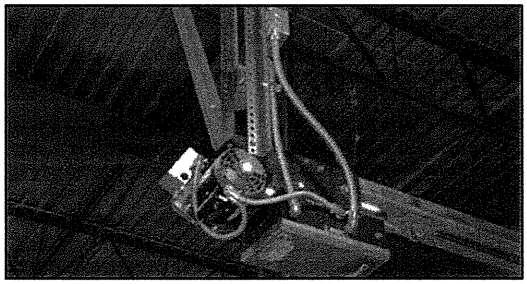
Chapter 8

- Listed Flexible Metal Conduit (continued)
  - If used to connect equipment in which flexibility is necessary to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation, an EGC must be installed.

Equipment Grounding Conductors

Chapter 8

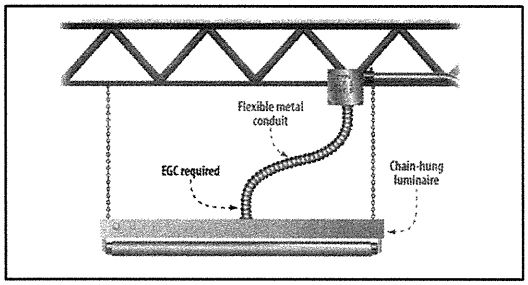
- Listed Flexible Metal Conduit



Equipment Grounding Conductors

Chapter 8

- Wire-Type EGC Required



Equipment Grounding Conductors

Chapter 8

- Listed Liquidtight Flexible Metal Conduit
  - Listed LFMC permitted as an EGC if all the following are met:
    - Listed fittings are installed
    - For ⅜ in. through ½ in. sizes, a 20-A maximum OCPD protects the contained circuit conductors
    - For ¾ in. through 1¼ in. sizes, a 60-A maximum OCPD protects the contained circuit conductors
    - The combined length of FMC, LFMC, and FMT in the same ground-fault current path does not exceed 6 feet

Equipment Grounding Conductors

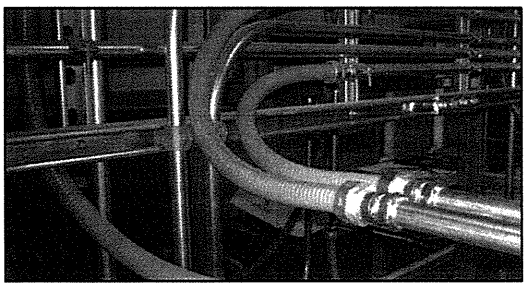
Chapter 8

- Listed Liquidtight Flexible Metal Conduit (continued)
  - If used to connect equipment in which flexibility is necessary to minimize the transmission of vibration from equipment or to provide flexibility for equipment that requires movement after installation, an EGC must be installed.

Equipment Grounding Conductors

Chapter 8

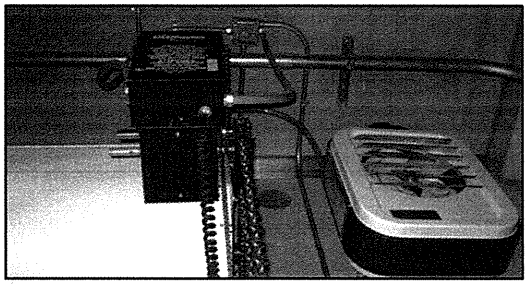
- Listed LFMC Secured



Equipment Grounding Conductors

Chapter 8

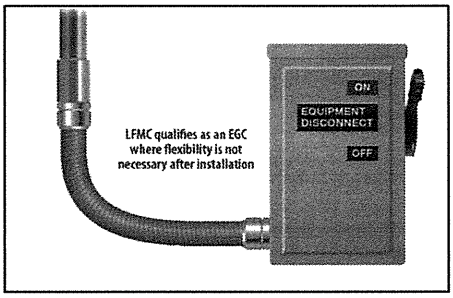
- Listed LFMC Movement Anticipated



Equipment Grounding Conductors

Chapter 8

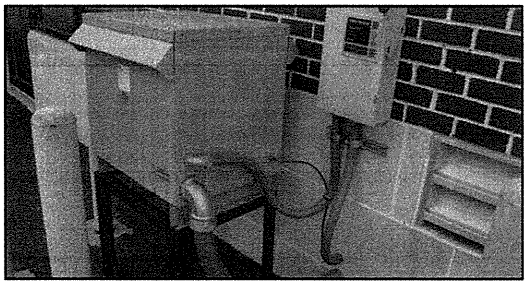
- Listed LFMC Standard



Equipment Grounding Conductors

Chapter 8

- Listed LFMC Requires EGC due to vibration



Equipment Grounding Conductors

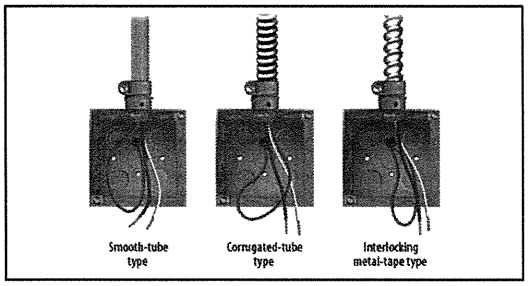
Chapter 8

- Metal-Clad Cable – Type MC
  - Type MC is suitable as an EGC in accordance with any of the following:
    - It contains an insulated or uninsulated EGC in compliance with 250.118(1)
    - The combined metallic sheath and uninsulated equipment grounding/bonding conductor of interlocked metal-tape–type MC cable that is listed and identified as an EGC
    - The metallic sheath or the combined metallic sheath and EGCs of the smooth or corrugated-tube–type MC cable that is listed and identified as an EGC

Equipment Grounding Conductors

Chapter 8

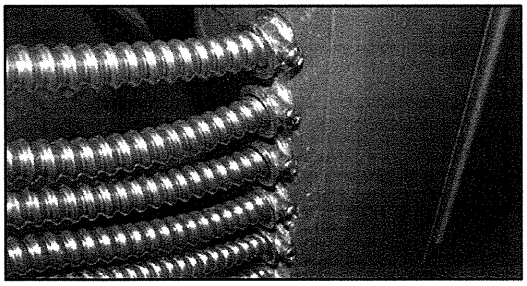
- Types of MC Cable



Equipment Grounding Conductors

Chapter 8

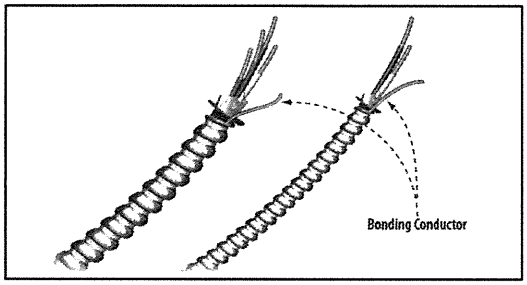
- Interlocking Metal Tape-Type MC Cable



Equipment Grounding Conductors

Chapter 8

- MC Cable Sheath as Suitable EGC



Equipment Grounding Conductors

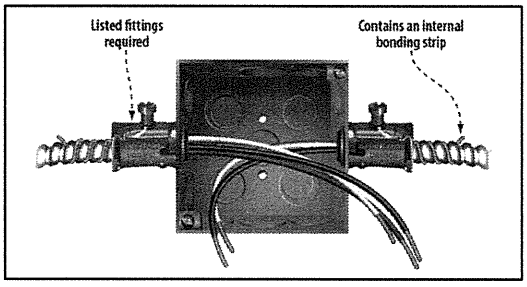
Chapter 8

- Armored-Clad Cable – Type AC
  - Section 250.118(8) recognizes the armor sheath of armored-clad (Type AC) cables as an EGC.
    - The cable armor qualifies as an EGC because of the bare internal bonding strip that is in intimate contact with the armor from fitting to fitting.
    - The combination of the internal bonding strip in the assembly, together with the interlocking metal-tape–type armor, are suitable as an effective ground-fault current path.

Equipment Grounding Conductors

Chapter 8

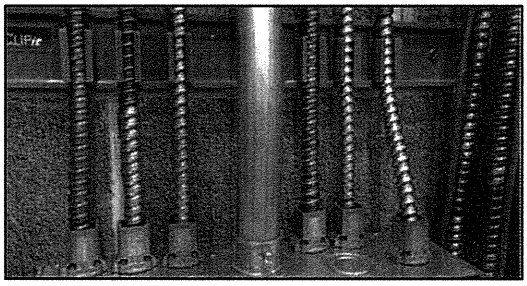
- AC Cable Suitable as EGC



Equipment Grounding Conductors

Chapter 8

- AC Cables as EGC



Equipment Grounding Conductors

Chapter 8

- Equipment Grounding Conductor Installation
  - Section 250.120 provides installation requirements for EGCs of all types.
    - The fittings and terminations used with the wiring method chosen have to be suitable for use with the type of wiring method installed.
    - For example, fittings (connectors, couplings, and locknuts, for example) used with EMT have to be listed for use with EMT, as required by 358.6.

Equipment Grounding Conductors

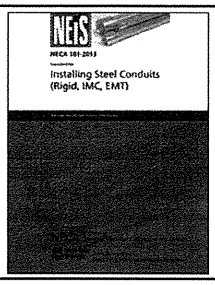
Chapter 8

- Workmanship is Important
  - All connections have to be made tight using suitable tools.
    - This requirement relates to the workmanship requirement in 110.12.
    - It is important to tighten fittings because of the functions they are expected to perform both in normal operation and during abnormal conditions such as ground faults.
    - Loose fittings such as set-screw couplings, connectors, and locknuts introduce impedance into the ground-fault current path and could affect quick operation of overcurrent devices.

Equipment Grounding Conductors

Chapter 8

- National Electrical Installation Standards (NEIS)



ANSI-NECA-101

National Electrical Installation Standard (NEIS)

Developed by National Electrical Contractors Association (NECA)

Standard for Installing Steel Conduit (Rigid, IMC, EMT)

Defines good workmanship as required by *NEC* Section 110.12

Equipment Grounding Conductors

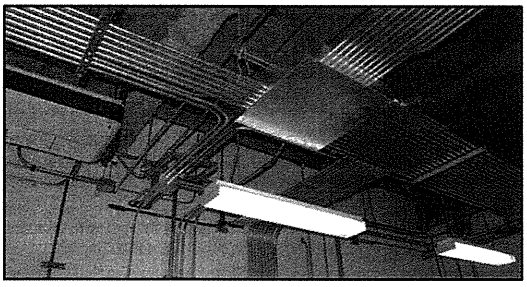
Chapter 8

- Securing and Supporting Wiring Methods
  - Chapter 3 of the *Code* includes requirements for securing and supporting conduit and other raceways that are included in 250.118 as EGCs.
  - The integrity of the effective ground-fault current path established by the wiring method itself depends on effective, *code*-compliant support and securing of the raceway or cable system.
  - Workmanship is important for many reasons.

Equipment Grounding Conductors

Chapter 8

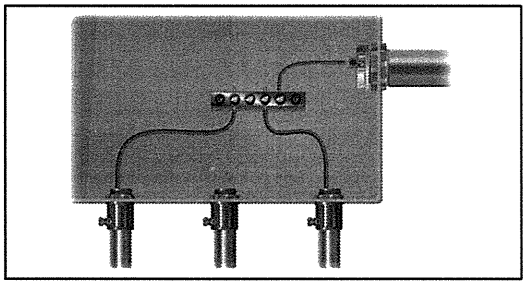
- Secured EMT as EGC



Equipment Grounding Conductors

Chapter 8

- Tighten Fittings and Locknuts



Equipment Grounding Conductors

Chapter 8

- Protection from Physical Damage
  - Aluminum or copper-clad aluminum EGCs are not permitted to be terminated within 18 inches of the Earth.
  - These conductor types are more vulnerable to the effects of corrosion and deterioration than copper conductors.
  - Section 250.120(C) indicates that EGCs smaller than 6 AWG are required to be protected from physical damage by a raceway or cable armor.
  - This damage protection rule is relaxed for EGCs installed in hollow spaces of walls or partitions that protect them from physical damage.

Equipment Grounding Conductors

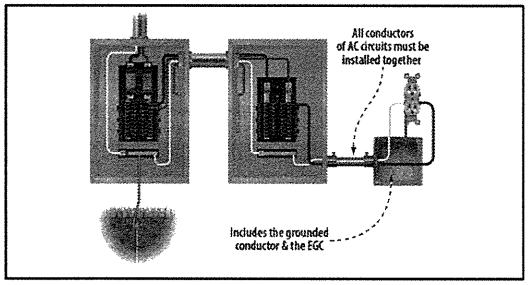
Chapter 8

- Installation with Circuit Conductors
  - Sections 300.3(B) and 250.134(2) provide important information about installing EGCs with AC circuits.
  - One of the most important requirements is to keep the EGC as close as possible to its associated circuit conductors.
  - This keeps the impedance values as low as possible during normal operation and during ground fault conditions.

Equipment Grounding Conductors

Chapter 8

- Install EGC with Circuit Conductors



Equipment Grounding Conductors

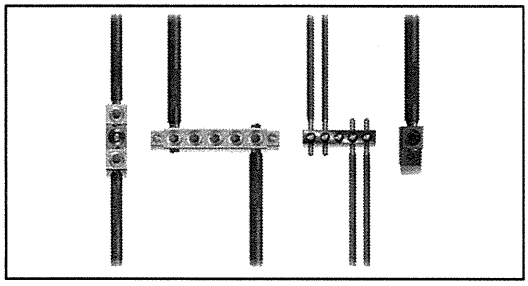
Chapter 8

- EGC Connections
  - Connections of grounding and bonding conductors are covered in 250.8.
  - The list of connection means is provided to clarify how EGCs must be terminated.
  - The connections must be tight, and if the EGC is of the wire type, installers must torque connections at terminal lugs to manufacturer specifications. [*NEC* 110.14(D)]

Equipment Grounding Conductors

Chapter 8

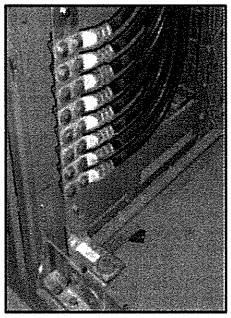
- EGC Connections



Equipment Grounding Conductors

Chapter 8

- Irreversible Compression Lugs
  - Compression lug connectors are required to be installed using the tool and die as specified by the manufacturer.
  - The lugs must be connected to the equipment grounding terminal bar and tightened to manufacturer specifications.



Equipment Grounding Conductors

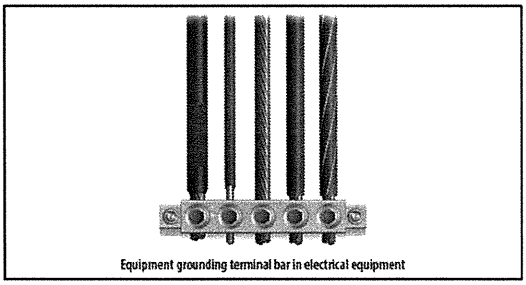
Chapter 8

- EGC Identification
  - The *Code* provides specific identification requirements for EGCs of the wire type.
  - EGCs can be insulated, covered, or bare.
  - Identification requirements for EGCs are provided in Section 250.119.
  - If a wire-type EGC is insulated or covered, the insulation or covering is required to have a continuous outer finish that is either green or green with one or more yellow stripes.

Equipment Grounding Conductors

Chapter 8

- EGC Identification



Equipment Grounding Conductors

Chapter 8

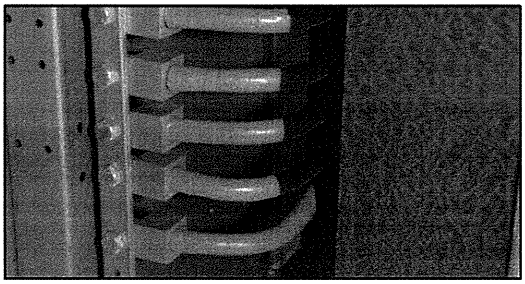
- EGC Identification
  - The identification for sizes 4 AWG and larger must encircle the conductor and is required to be accomplished by one of the following:

    1. Stripping the insulation or covering from the entire exposed length
    2. Coloring the insulation or covering green at the termination
    3. Marking the insulation with green tape or green adhesive labels at terminations

Equipment Grounding Conductors

Chapter 8

- EGC Identification Sizes 4 AWG and Larger



Equipment Grounding Conductors

Chapter 8

- Multi-Conductor Cables
  - Section 250.119 recognizes a bare conductor as an EGC.
  - An example is the bare EGC often included in nonmetallic sheathed cable or Type SE cable assemblies.
  - If the conductor is insulated or covered, the insulation or covering is required to have a continuous outer finish that is either green or green with one or more yellow stripes.

Equipment Grounding Conductors

Chapter 8

- Exception for Multi-Conductor Cables
  - One or more insulated conductors in a multi-conductor cable, at the time of installation, are permitted to be identified as EGCs at each end and at every point where the conductors are accessible by any one of the following methods:

    1. Stripping the insulation from the entire exposed length
    2. Coloring the exposed insulation green
    3. Marking the exposed insulation with green tape or green adhesive labels

Equipment Grounding Conductors

Chapter 8

- EGC Sizing Criteria
  - Sizing requirements for EGCs of the wire type are found in 250.122 and Table 250.122 of the *NEC*.
  - The minimum sizes are provided in Table 250.122.
  - An important note follows Table 250.122 and provides an appropriate reference to 250.4.
  - The I^2T values (short-time rating or withstand rating) of the EGC sizes are between 13 and 28 times their nominal continuous rating based on 1 ampere for every 42.25 circular mils of conductor. [Insulated Cable Engineers Association (ICEA)]

Equipment Grounding Conductors

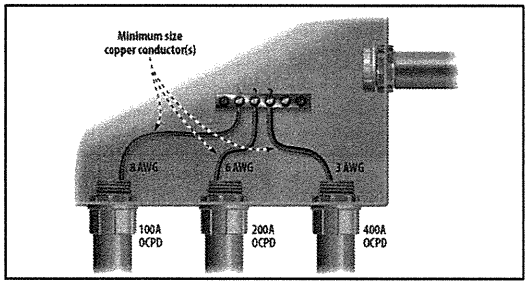
Chapter 8

- Equipment Grounding Conductor Sizing
  - In addition to the engineering basics of the effective ground-fault current path, the minimum sizing rules in the *NEC* for EGCs are also important.
  - The driving text of 250.122 indicates that the minimum size required for wire-type EGCs is not to be less than the values in Table 250.122.
  -
  - The equipment grounding conductor is not required to be larger than circuit conductors supplying the equipment.

Equipment Grounding Conductors

Chapter 8

- Sizing for Wire-Type EGCs



Equipment Grounding Conductors

Chapter 8

- Using Table 250.122
  - Using Table 250.122 requires knowing the rating of the overcurrent device protecting the branch circuit or feeder.
  - Once this value is known, the rating or a rating that does not exceed the value in the left column of the table should be found.
  - Follow across the table horizontally from left to right to determine the minimum size EGC expressed in AWG or circular mils.
  - The appropriate column for aluminum as compared with copper EGCs should be used.

Equipment Grounding Conductors

Chapter 8

- Using Table 250.122

Table 250.122 Minimum Size Equipment Grounding Conductors for Grounding Raceway and Equipment (in part)

Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Conduit, etc., Not Exceeding (Amperes)	Size (AWG or kcmil)	
	Copper	Aluminum or Copper-Clad Aluminum*
15	14	12
20	12	10
30	10	8
40	8	6
200	6	4
300	4	2
400	3	1

Notes: Where necessary to comply with 250.4(A)(5) or 250.4(B)(4), the equipment grounding conductor shall be sized larger than given in this table.

* See installation restrictions in 250.120.

Equipment Grounding Conductors

Chapter 8

- Examples Using Table 250.122

Size of OCPD	Copper EGC	Aluminum EGC
20	12	10
45	10	8
60	10	8
90	8	6
110	6	4
225	4	2
350	3	1
450	2	1/0

Equipment Grounding Conductors

Chapter 8

- Increases in Size of Wire-Type EGC
  - EGCs are required to be increased in size proportionate to any increase of associated ungrounded conductors from the minimum size that has sufficient ampacity for the intended installation.
  - If the ungrounded circuit conductors are increased in size for any reason other than as required in 310.15(B) or (C) the wire-type EGCs must be increased proportionately.
  - Use *NEC* Table 8 in Chapter 9 to calculate proportionate increases in sizes of equipment grounding conductors.

Equipment Grounding Conductors

Chapter 8

- Increases in Size of Wire-Type EGC

Equipment Grounding Conductors

Chapter 8

- Example of Proportionate Size Adjustment
  - The 400-ampere feeder (420 allowable ampacity) is generally installed using 600 kcmil copper circuit conductors and a 3 AWG copper EGC.
  - For voltage drop reasons, the 600 kcmil conductor has to be increased in size from 600 kcmil to two paralleled 400 kcmil copper conductors for each ungrounded phase conductor and the neutral conductor.
  - The equipment grounding conductor (if of the wire type) must be increased in size in proportion to the increase of the size of ungrounded conductors for the circuit.

Equipment Grounding Conductors

Chapter 8

- Proportionate Size Adjustment Example
  - The adjusted size (800 kcmil) is divided by the originally required size (600 kcmil) to determine a multiplier.

800 ÷ 600 = 1.3 (multiplier)

  - The circular mil value of a 3 AWG conductor is 52620 as provided in *NEC* Table 8, Chapter 9.
  - Take the value 52620 cm and multiply by 1.3 to come up with 68406 circular mils.

52620 x 1.3 = 68406 circular mils

Equipment Grounding Conductors

Chapter 8

- Example of Proportionate Size Adjustment
  - The next higher circular mil value in *NEC* Table 8 is 83690.
  - The new minimum size required for this EGC is a 1 AWG copper based on the proportionate adjustment.
  - It is always best to perform this simple calculation to verify that the adjusted size of the EGC meets or exceeds the minimum requirements.

Equipment Grounding Conductors

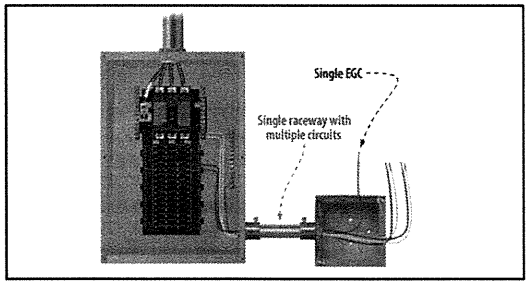
Chapter 8

- Multiple Circuits in Raceway or Cable Tray
  - When multiple circuits are installed in a single raceway, cable, or cable tray, a single EGC is permitted.
  - The sizing requirement is based on the rating of the largest overcurrent protective device ahead of any circuit in the raceway, cable, or cable tray.
  - When EGCs are installed in cable tray, they have to meet the requirements in 250.122 and 392.10(B)(1)(c).

Equipment Grounding Conductors

Chapter 8

- Multiple Circuits in Raceway



Equipment Grounding Conductors

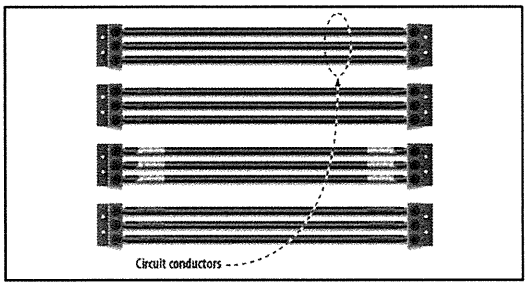
Chapter 8

- EGCs for Parallel Runs
  - Installing feeders or circuits in parallel requires compliance with 310.10(G), which means the conductors must be the same length, same material, and same size; have the same insulation; and be terminated in the same manner.
  - When the entire parallel arrangement of conductors is installed in a single raceway, cable, or cable tray, a single EGC is permitted to be installed.
  - The metallic raceway or cable tray could also qualify as an EGC in accordance with 250.118.

Equipment Grounding Conductors

Chapter 8

- EGCs for Parallel Runs



Equipment Grounding Conductors

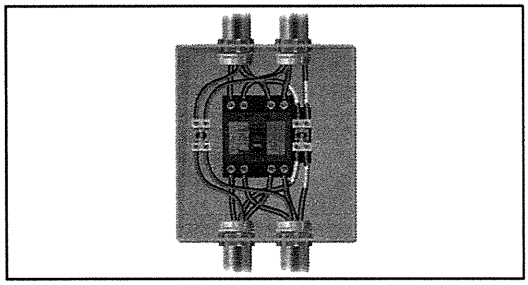
Chapter 8

- EGCs for Parallel Runs
  - Section 250.122(F) indicates where conductors are run in parallel, in separate raceways or cables, any wire-type EGCs are also required to be run in parallel in each respective raceway or cable.
  - In this type of installation, each EGC installed in parallel is required to be sized using Table 250.122 based on the rating of the fuse or circuit breaker protecting the entire parallel set.

Equipment Grounding Conductors

Chapter 8

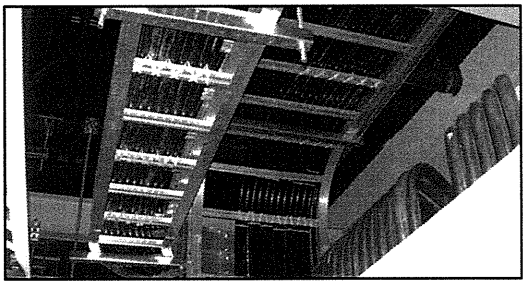
- EGCs for Parallel Runs



Equipment Grounding Conductors

Chapter 8

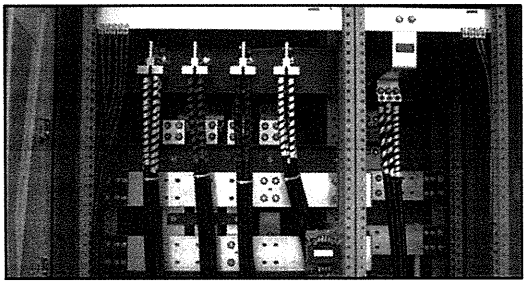
- EGC in Cable Tray



Equipment Grounding Conductors

Chapter 8

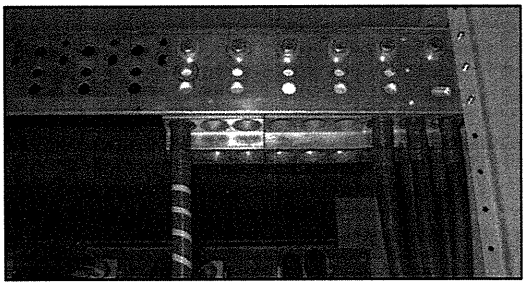
- EGCs for Parallel Runs



Equipment Grounding Conductors

Chapter 8

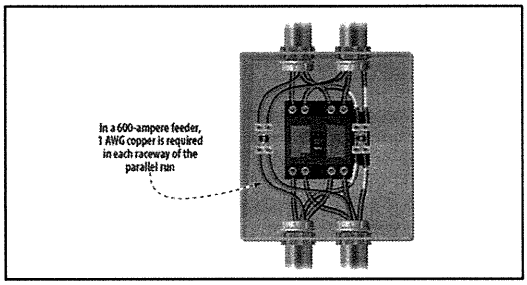
- EGCs for Parallel Runs



Equipment Grounding Conductors

Chapter 8

- Example Sizing EGCs for Parallel Run



Equipment Grounding Conductors

Chapter 8

- Sizing Example for Parallel Installations
  - Example 1: A 4,000-ampere feeder is installed in 10 PVC conduits in a parallel arrangement, each containing four 750 copper conductors. What is the minimum size copper EGC required in each conduit?
  - Answer: A 500 kcmil copper EGC is required in each raceway based on the 4,000-ampere overcurrent device in accordance with Table 250.122.

Equipment Grounding Conductors

Chapter 8

- Sizing Example for Parallel Installations
  - Example 2: If an 800-ampere feeder is installed in two raceways in a parallel arrangement, each containing four 750 copper conductors, what is the minimum size wire-type EGC for this circuit?
  - Answer: A 1/0 AWG copper EGC is required in each raceway.

Equipment Grounding Conductors

Chapter 8

- Cable Assemblies in Parallel
  - If cable assemblies are installed in large-capacity parallel circuits, it is necessary to verify that the EGC in each of the individual cables of the parallel set is sized as required by Table 250.122, based on the size of the fuse or circuit breaker protecting the entire parallel circuit.
  - Installing cable assemblies in parallel arrangements may necessitate a special order that includes sizing the EGC within the cable assembly.
  - Each EGC of the wire type in parallel runs must be full size (based on Table 250.122) in each raceway or cable.

Equipment Grounding Conductors

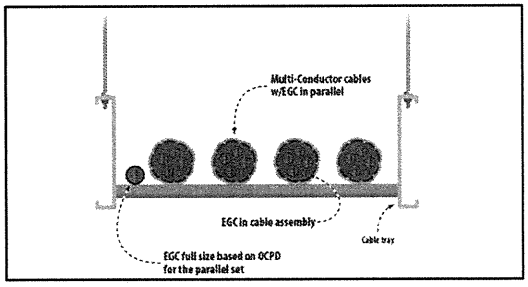
Chapter 8

- Cable Assemblies in Parallel (continued)
- Section 250.122(F)(2)(2) in the 2017 *NEC* is recognition of multiple MC cables installed in parallel with standard size EGCs in each.
- This alternative recognizes that a single standard size EGC in each cable can be connected in parallel at each end and connected to a full-size EGC sized based on the OPCD for the entire circuit.
- The single full size EGC shall be sized in accordance with 250.122.

Equipment Grounding Conductors

Chapter 8

- Cable Assemblies in Parallel



Equipment Grounding Conductors

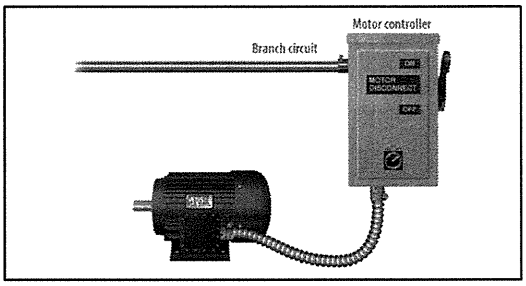
Chapter 8

- EGCs for Motor Circuits
  - Sizing requirements for EGCs in motor circuits are provided in 250.122(D).
  - The basic requirement is that the EGC (wire-type) be sized not smaller than determined by 250.122(A) based on the rating of the branch-circuit short circuit and ground-fault protective device of the motor circuit.
  - The branch-circuit short-circuit ground fault protective device is usually sized larger to carry the starting current of the motor, which affects the size of a wire-type EGC.

Equipment Grounding Conductors

Chapter 8

- EGC for Motor Circuits



Equipment Grounding Conductors

Chapter 8

- EGCs for Motor Circuits
  - When an instantaneous trip circuit breaker or motor short circuit protector is selected as the overcurrent protective device for a motor circuit, a wire-type EGC is required to be sized no smaller than provided in 250.122(A) using the maximum rating of a dual element time-delay fuse selected for branch-circuit short-circuit and ground-fault protection in accordance with 430.52(C)(1) Exception No.1.

Equipment Grounding Conductors

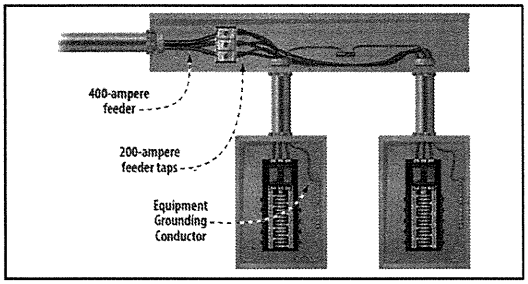
Chapter 8

- EGCs with Feeder Taps
  - The minimum size EGC with feeder tap conductors must not be smaller than the size required based on the rating of the overcurrent protection for the feeder to which the tap is connected.
  - For example, a 400-ampere feeder that is tapped by two 200-ampere feeders would require a 3 AWG copper EGC in each of the feeder tap raceways.
  - Metallic raceways that are suitable equipment grounding conductors according to 250.118, are not required to contain a wire-type equipment grounding conductor.

Equipment Grounding Conductors

Chapter 8

- EGCs with Feeder Taps



Equipment Grounding Conductors

Chapter 8

- Current in Equipment Grounding Conductors
  - In normal operation, no current should be present in the EGC.
  - Equipment grounding conductors should only carry current during abnormal events like a ground fault.
  - Equipment grounding conductors, with the exception of wire-type EGCs, are generally prohibited from being used as grounding electrode conductors. [See *NEC* 250.121 and Exception]
  - Installation rules and sizing requirements for grounding electrode conductors are different than those for equipment grounding conductors.

Equipment Grounding Conductors

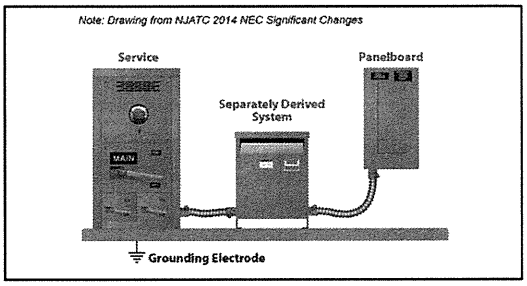
Chapter 8

- 250.121 Restricted Use of EGC
  - An EGC is restricted from use as both the equipment grounding conductor and the grounding electrode conductor simultaneously unless it meets the following conditions:
    - The EGC complies with the applicable requirements in Parts II, III, and VI of Article 250 including sizing and all installation requirements.
    - The EGC is installed to comply with 250.6(A), which addresses objectionable current.

Equipment Grounding Conductors

Chapter 8

- 250.121 Exception



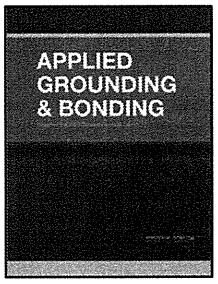
Equipment Grounding Conductors

Chapter 8

- Summary
  - Equipment grounding conductors perform grounding, bonding, and they facilitate overcurrent device operation while performing as an effective ground-fault current path.
  - The types of acceptable equipment grounding conductors are provided in 250.118.
  - Equipment grounding conductors must be installed in accordance with 250.120 and sized according to Section 250.122.

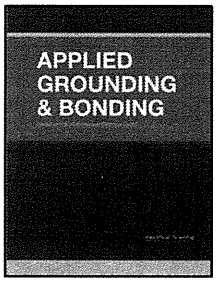
Grounding and Bonding

Equipment Grounding Conductors



Grounding and Bonding

Grounding Electrical Equipment



Grounding Electrical Equipment

Chapter 9

- Introduction
  - Grounding of equipment is accomplished by a direct connection to ground (Earth), or by connection to a conducting body that extends the grounding connection, or both.
  - Specific *NEC* rules apply to fixed equipment that must be grounded with very few exceptions.

Grounding Electrical Equipment

Chapter 9

- Introduction (continued)
  - Auxiliary grounding electrodes are addressed in the *NEC* as optional, but where installed, they must meet specific requirements but are not permitted as the only grounding means for equipment.
  - Grounded conductors are permitted for grounding equipment such as appliances but only in existing installations.

Grounding Electrical Equipment

Chapter 9

- Objectives
  - Understand the reasons for grounding electrical equipment.
  - Identify the methods of equipment grounding for feeders and branch circuits and specific conditions that provide exemptions from grounding equipment.
  - Understand the methods for installing equipment grounding conductors for devices such as receptacles and switches.
  - Understand the requirements to isolate neutrals from ground and grounded metal parts.
  - Determine the requirements for auxiliary grounding electrodes installed for equipment.

Grounding Electrical Equipment

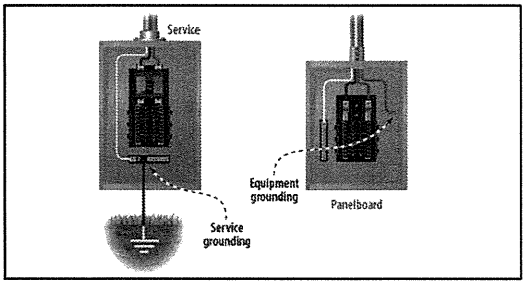
Chapter 9

- Purpose of Grounding Equipment
  - Grounding is necessary to establish an Earth reference (connection) for connected systems and equipment.
  - Grounding equipment places it as close to Earth as possible, thereby minimizing shock hazard possibilities.
  - Grounding also limits the voltage to ground during line surge events, lightning events, and unintentional contact with higher-voltage lines.

Grounding Electrical Equipment

Chapter 9

- Equipment Grounding



Grounding Electrical Equipment

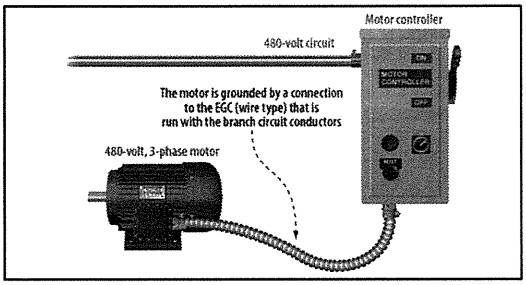
Chapter 9

- General Grounding Rules for Equipment
  - Part VI of *NEC* Article 250 provides requirements for grounding equipment that is fastened in place or connected by permanent wiring methods (fixed).
  - There are a few alternatives to grounding addressed in 250.1(6) such as isolation, insulation, and guards.
  - If the equipment operates at more than 150 volts to ground, it is generally required to be grounded by connection to an equipment grounding conductor (EGC).

Grounding Electrical Equipment

Chapter 9

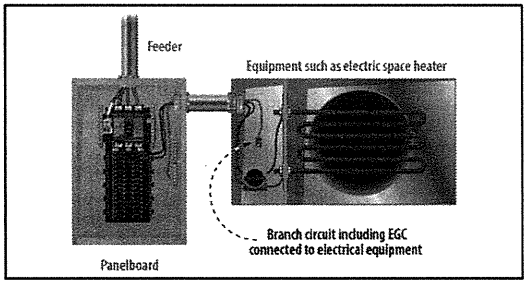
- Equipment Grounding (Motor)



Grounding Electrical Equipment

Chapter 9

- Equipment Grounding (Heater)



Grounding Electrical Equipment

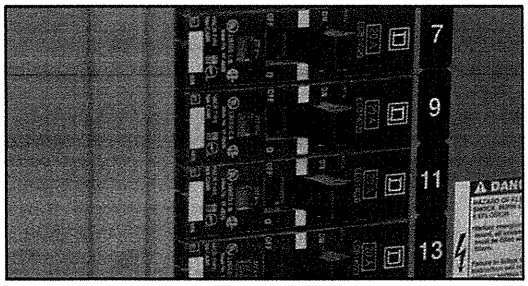
Chapter 9

- Wire-Type EGC Size
  - The minimum sizes for wire-type equipment grounding conductors are provided in Table 250.122.
  - This sizing method requires using the rating of the overcurrent protective device (fuse or circuit breaker) for the circuit supplying the equipment.

Grounding Electrical Equipment

Chapter 9

- Size EGC Based on Table 250.122



Grounding Electrical Equipment

Chapter 9

- General Rules for Grounding Equipment
  - If the equipment is within 8 feet vertically or 5 feet horizontally of ground or grounded metal objects that are subject to contact by people, it must be grounded.
  - There is a condition that relaxes the grounding requirement by isolation or elevation.
  - If the equipment is 10 feet above the ground and not subject to contact by people, grounding is optional if the location is not wet or damp.

Grounding Electrical Equipment

Chapter 9

- General Rules for Grounding Equipment
  - When the equipment is in a wet or damp location and is not isolated, the equipment generally has to be grounded.
  - When electrical equipment is in a hazardous (classified) location, it is required to be grounded as covered in Articles 500 through 517.
  - When equipment is supplied by metal raceways, metal-sheathed or metal-clad cables, or another wiring method that provides an EGC, the equipment has to be grounded by connection to the EGC.

Grounding Electrical Equipment

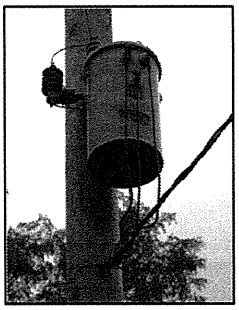
Chapter 9

- General Rules for Grounding Equipment
  - Three exceptions follow the grounding requirements provided in 250.110.
  - One exception relaxes the grounding requirement for frames of electrically heated appliances that are permanently and effectively insulated from ground.
  - This is a case in which insulation is used as a substitute for grounding and offers equal and effective safety, such as double-insulated tools.

Grounding Electrical Equipment

Chapter 9

- Exception by Elevation
  - Another exception from the grounding requirement is for distribution apparatuses such as transformers and capacitor enclosure cases mounted on wood poles and elevated to a height that exceeds 8 feet above ground.
  - A pole-mounted transformer is shown in the photo to the right.



Grounding Electrical Equipment

Chapter 9

- General Rules for Grounding Equipment
  - Section 250.112 provides a list of specific equipment that is connected by permanent wiring and is required to be grounded by connection to an EGC.
    - Switchgear and switchboard frames and structures
    - Enclosures for motor controllers
    - Electric signs
    - Luminaires (lighting fixtures)

Grounding Electrical Equipment

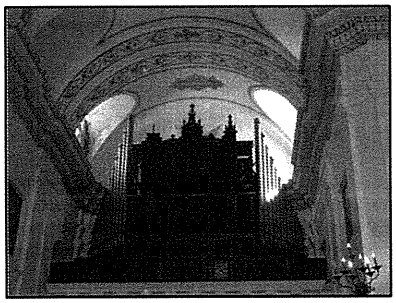
Chapter 9

- General Rules for Grounding Equipment (continued)
  - Section 250.112 provides a list of specific equipment that is connected by permanent wiring and is required to be grounded by connection to an EGC.
    - Elevators and cranes
    - Motion picture projection equipment
    - Skid-mounted equipment
    - Pipe organs
    - Motor frames

Grounding Electrical Equipment

Chapter 9

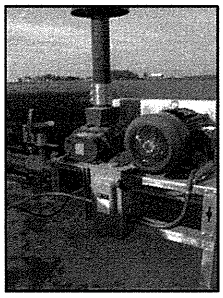
- Pipe Organ



Grounding Electrical Equipment

Chapter 9

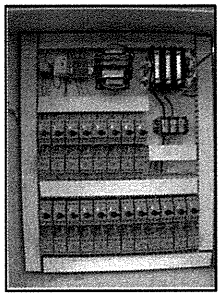
- Motor Frames
  - Section 430.242 requires motor frames to be grounded by connection to an EGC.
  - The equipment grounding conductor connection can be inside the motor terminal housing or on the outside as indicated in 430.12(E).



Grounding Electrical Equipment

Chapter 9

- Motor Controllers
  - Enclosures for motor controllers must be grounded unless attached to ungrounded portable equipment.
  - Note the provisions for connecting equipment grounding conductors are an integral part of this control enclosure. [*NEC* 409.60]



Grounding Electrical Equipment

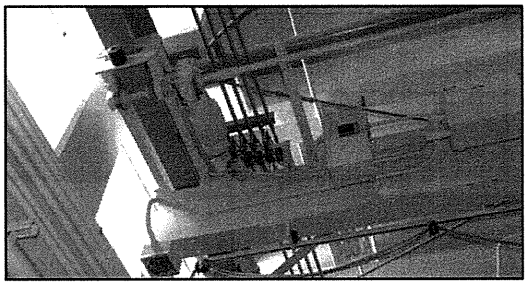
Chapter 9

- Elevators and Cranes
  - Electrical equipment for elevators and cranes is required to be grounded by connection to the EGC of the supply circuit.
  - Section 610.60 provides the equipment grounding requirements for cranes and hoists.
  - Part IX of Article 620 provides the equipment grounding and bonding requirements for elevators and similar equipment.

Grounding Electrical Equipment

Chapter 9

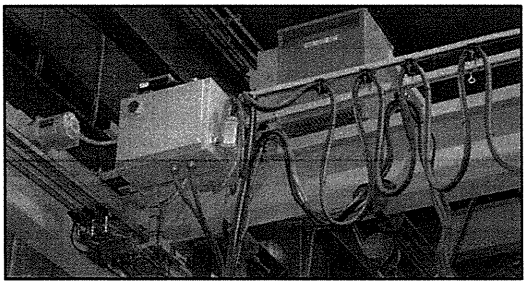
- Elevators and Cranes



Grounding Electrical Equipment

Chapter 9

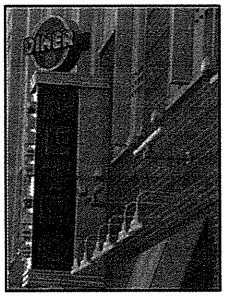
- Elevators and Cranes



Grounding Electrical Equipment

Chapter 9

- Electric Signs and Outline Lighting
  - Electric signs, outline lighting, and associated equipment are all required to be grounded by connection to an EGC as provided in 600.7.
  - See the specific requirements in 600.7(B) for bonding metal parts associated with high voltage secondary circuits of neon lighting systems.



Grounding Electrical Equipment

Chapter 9

- General Rules for Grounding Equipment
  - Equipment supplied by Class 1 circuits shall be grounded unless the equipment operates at less than 50 volts.
  - Equipment supplied by Class 1 power-limited circuits, by Class 2 and Class 3 remote-control and signaling circuits, and by fire alarm circuits must be grounded only when system grounding is required by Part II or Part VIII of Article 250.
  - In other words, if the supply system is grounded, the equipment it supplies has to be grounded.

Grounding Electrical Equipment

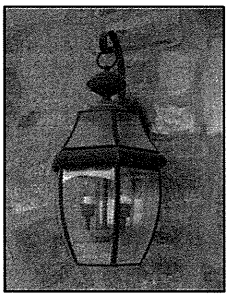
Chapter 9

- General Rules for Grounding Equipment
  - Section 250.112 provides a list of specific equipment that is connected by permanent wiring and is required to be grounded by connection to an EGC.
    - Motor frames
    - Garages, theaters, and motion picture studios
    - Remote-control, signaling, and fire alarm circuits
    - Motor-operated water pumps and metal well casings

Grounding Electrical Equipment

Chapter 9

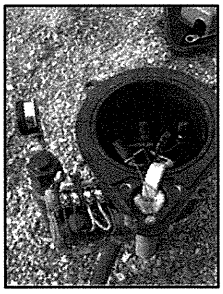
- Grounding Luminaires
  - Luminaires (lighting fixtures) are required to be grounded as provided in Part V of Article 410.
  - Luminaires are generally equipped with provisions to connect an equipment grounding conductor as required in product standards.



Grounding Electrical Equipment

Chapter 9

- Motor-Operated Water Pumps
  - Motor-operated water pumps, including the submersible type, are required to be grounded by connection to an EGC.
  - When a submersible pump is used in a metal well casing, the well casing must be connected to the pump circuit EGC.



Grounding Electrical Equipment

Chapter 9

- Conductor Enclosure and Raceway Grounding
  - Section 250.86 provides grounding requirements for metal raceways and enclosures other than those for service conductors.
  - The general requirement in 250.86 is that these metal enclosures be grounded by connecting them to an EGC.
  - There are three exceptions to these general grounding requirements.

Grounding Electrical Equipment

Chapter 9

- Exception for Knob-and-Tube Extensions
  - The first exception is for metal enclosures and raceways used for conductors that extend existing installations of old knob-and-tube systems and nonmetallic sheathed cable systems installations.
  - Four conditions must be met to qualify for the exemption from grounding metal enclosures and raceways with these extensions. [*NEC* 250.86 Exception 1(1) through (4)]

Grounding Electrical Equipment

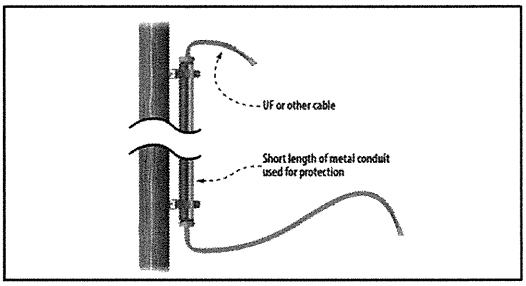
Chapter 9

- Short Sections of Metal Raceways
  - Another exception is for short sections of metal raceway or metal enclosures used for support or to provide protection from physical damage for cable assemblies.
  - An example of a short section of metal not required to be grounded would be a length of conduit used to provide physical protection for UF cable emerging from the ground at a pole.

Grounding Electrical Equipment

Chapter 9

- Short Sections of Metal Raceways



Grounding Electrical Equipment

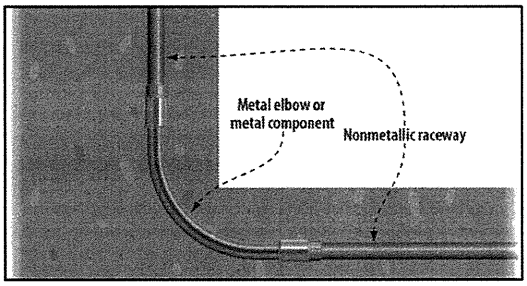
Chapter 9

- Concrete-Encased Metal Components
  - There is an exception for metal components such as metal elbows that are isolated from public contact by a minimum of not less than 18 inches when buried or encased in not less than two inches of concrete are not required to be grounded.

Grounding Electrical Equipment

Chapter 9

- Concrete-Encased Metal Components Such as Metal Elbows



Grounding Electrical Equipment

Chapter 9

- Methods of Grounding Equipment (Part VII of Article 250)
  - As the feeder and branch circuit wiring is installed on the job site, EGCs are being installed as required.
  - Section 215.6 requires EGCs to be provided with feeder conductors if they supply branch circuits that require EGCs.
  - Because most equipment is required to be grounded, as required by 250.110 and 250.112, nearly all feeders and branch circuits have an EGC installed with the circuit conductors.

Grounding Electrical Equipment

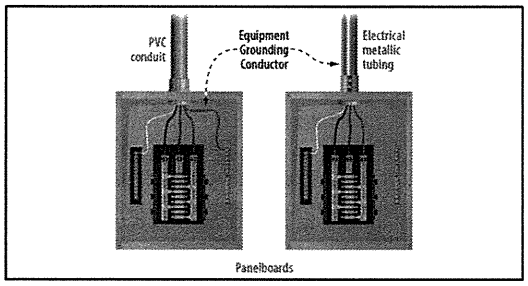
Chapter 9

- Feeders and Branch Circuits
  - The requirements of 250.134 indicate that if equipment such as raceways and other enclosures are required to be grounded, then a method in 250.134(1) or (2) must be used.
  - Equipment grounding can be accomplished by connection to any EGC type, which could be a wire, raceway, or other type mentioned in the listed items contained in 250.118.

Grounding Electrical Equipment

Chapter 9

- 215.6 EGC Required (Generally)



Grounding Electrical Equipment

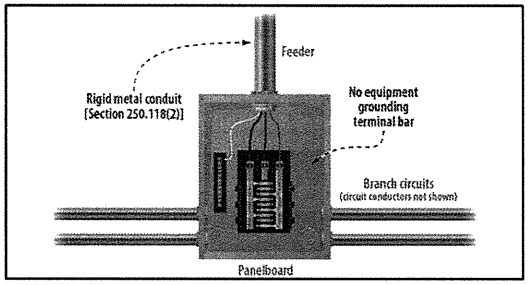
Chapter 9

- EGC with Feeders and Branch Circuits
  - If the feeder and branch circuits connected at a panelboard enclosure are all installed using rigid metal conduit (RMC) or intermediate metal conduit (IMC), wire-type EGCs are not required.
  - In this case, the connection between the feeder EGC and the EGCs of the branch circuits is accomplished through the metal panelboard enclosure.

Grounding Electrical Equipment

Chapter 9

- No Wire-Type EGCs Installed



Grounding Electrical Equipment

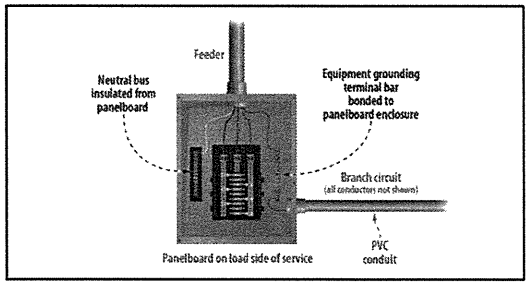
Chapter 9

- Equipment Grounding Terminal Bars
  - Section 408.40 requires an equipment grounding terminal bar in panelboards if nonmetallic raceways or cables are used, or where separate EGCs of the wire type are installed.
  - The equipment grounding terminal bar is typically an accessory feature provided by the panelboard manufacturer.
  - This terminal bar may be installed on the panelboard or its enclosure.
  - A terminal bar assembly kit must include instructions for installation and panelboard or enclosure markings.

Grounding Electrical Equipment

Chapter 9

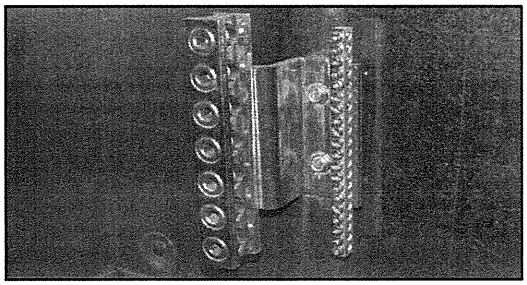
- Equipment Grounding Terminal Bars



Grounding Electrical Equipment

Chapter 9

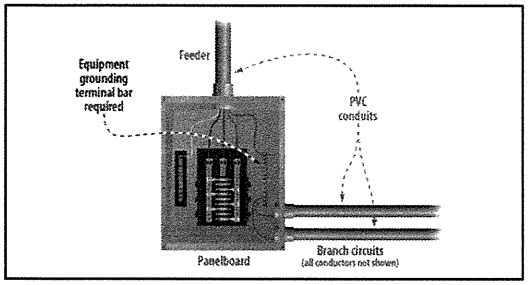
- Equipment Grounding Terminal Bar



Grounding Electrical Equipment

Chapter 9

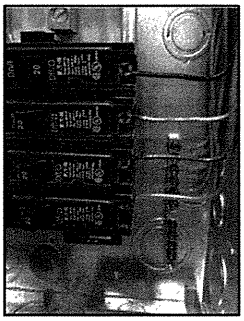
- IG Terminal Bar Required



Grounding Electrical Equipment

Chapter 9

- Panelboard Grounding Terminal Bar
  - The installation and use of an equipment grounding terminal bar for EGCs is driven by panelboards used with nonmetallic raceway or cable or when separate EGCs (wire types) are installed with the circuits.
  - The terminal bar may be installed on the panelboard or its enclosure.



Grounding Electrical Equipment

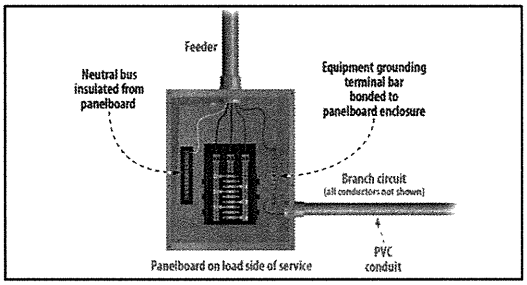
Chapter 9

- Isolate Grounded Conductor from Ground
  - Sections 250.24(A)(5) and 250.142(B) provide clear direction on the requirement to isolate and separate the grounded conductors (neutrals) from equipment grounding conductors and other ground connections.
  - The exceptions to this general restriction are for meter enclosures and the frames of existing ranges or dryers in which the grounded conductor can be used for grounding the equipment. [*NEC* 250.140]

Grounding Electrical Equipment

Chapter 9

- Isolate Grounded Conductor from Ground



Grounding Electrical Equipment

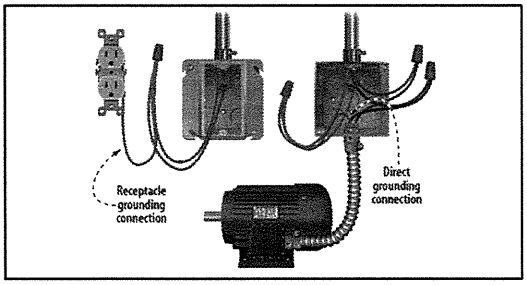
Chapter 9

- EGC Connections
  - Section 250.120 provides the general requirements for equipment grounding conductor connections.
  - Sections 250.146 and 250.148 provide the requirements for attachment of EGCs at outlets and other boxes.
  - Equipment grounding conductor connections can be accomplished through a receptacle or by a direct (hard-wired) connection.

Grounding Electrical Equipment

Chapter 9

- EGC Connections



Grounding Electrical Equipment

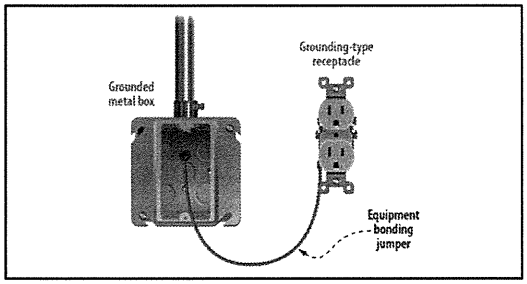
Chapter 9

- Receptacle Grounding Connections
  - Section 406.4(C) requires that branch circuit wiring methods provide an EGC to which the EGC terminal of receptacles is to be connected.
  - Section 250.146 generally requires an equipment bonding jumper to be installed from a grounded metal box to the grounding terminal on a grounding-type receptacle.
  - The equipment bonding jumper must be sized from Table 250.122 based on the rating of the fuse or circuit breaker protecting the branch circuit.

Grounding Electrical Equipment

Chapter 9

- Receptacle Grounding Connections



Grounding Electrical Equipment

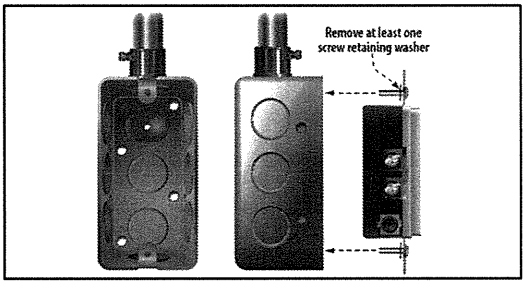
Chapter 9

- Receptacle Grounding Connections
  - Section 250.146(A) through (D) offers alternatives to this general requirement.
  - Section 250.146(A) addresses surface metal boxes only.
  - If the grounded metal box is mounted on the surface and there is direct metal-to-metal contact between the mounting strap of the device and the grounding metal box, the equipment bonding jumper is not required.
  - The requirement includes removal of at least one of the 6-32 insulated screw retaining washers.

Grounding Electrical Equipment

Chapter 9

- Receptacle Grounding Connections



Grounding Electrical Equipment

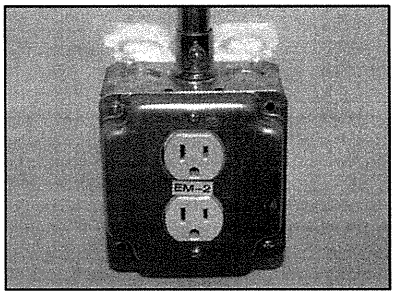
Chapter 9

- Receptacle Grounding Connections
  - An equipment bonding jumper is not required for surface box and cover combinations in which the receptacle cover has provisions to securely fasten the receptacle with rivets, thread locking screws, or a screw and nut combination and the cover has a flat, non-raised portion that seats firmly against the grounded metal box.
  - This receptacle grounding connection alternative applies only to surface mounted boxes.

Grounding Electrical Equipment

Chapter 9

- Surface Box Receptacle Covers



Grounding Electrical Equipment

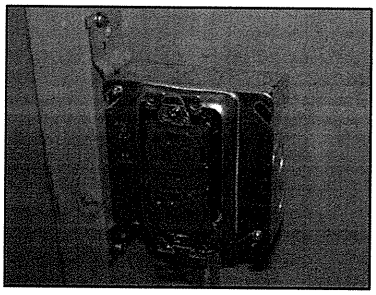
Chapter 9

- Self-Grounding Receptacles
  - Another alternative to installing an equipment bonding jumper from the receptacle to the grounded metal box is when self-grounding receptacles are installed.
  - These types of receptacles have a spring tension device that maintains an effective bonding connection between the 6-32 device mounting screw and the grounded metal box.

Grounding Electrical Equipment

Chapter 9

- Self-Grounding Receptacles



Grounding Electrical Equipment

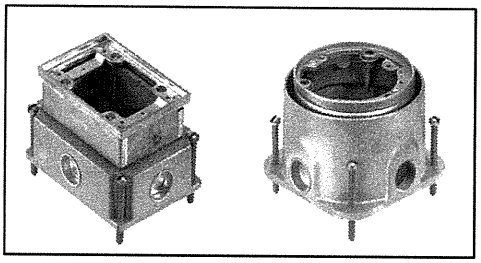
Chapter 9

- Listed Floor Boxes
  - Listed floor boxes that provide satisfactory grounding continuity between the grounding-type receptacle and the grounded metal portion of the assembly do not require an equipment bonding jumper for the receptacle grounding connection. [*NEC* 250.146(C)]

Grounding Electrical Equipment

Chapter 9

- Listed Floor Boxes



Courtesy of ABB

Grounding Electrical Equipment

Chapter 9

- Isolated Ground Receptacles
  - Section 250.146(D) relaxes the equipment bonding jumper requirement where an insulated EGC is connected to a receptacle that is designed specifically to isolate the grounding terminal and mounting strap from the grounding metal box.
  - These receptacles are referred to in the *NEC* as *isolated ground receptacles*.

Grounding Electrical Equipment

Chapter 9

- Isolated Ground Receptacles
  - In these types of installations, the insulated EGC is run with the circuit conductors but does not connect to the metal box where the receptacle is installed.
  - Another EGC or the metal raceway (often referred to as the dirty ground) is connected to the box to accomplish the grounding required for the metal box and plate.
  - Installing an IG circuit and IG receptacle does not relieve the requirement for grounding metal boxes and or metallic portions of the branch circuit supplying the IG receptacle.

Grounding Electrical Equipment

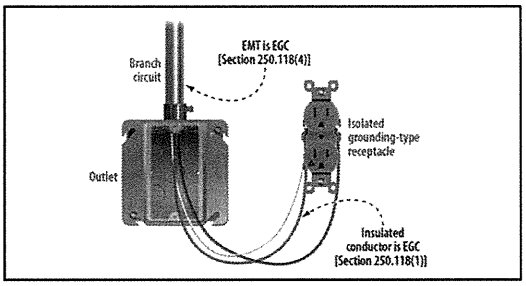
Chapter 9

- Isolated Ground Receptacles
  - The isolated (insulated) EGC used with isolated grounding (IG) receptacles is permitted to pass through boxes, wireways, panelboards, and other enclosures so as to terminate at the grounding point for the applicable service or separately derived system.
  - The rule is permissive, meaning the isolated/insulated EGC is permitted to pass through these enclosures to connect to the applicable source or service grounding point.

Grounding Electrical Equipment

Chapter 9

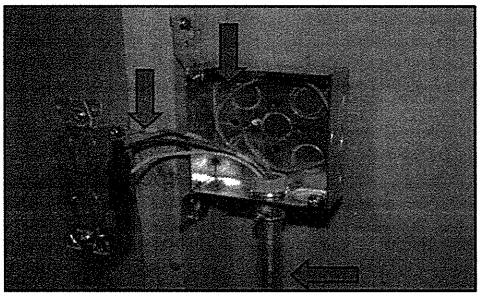
- Isolated Ground Receptacles



Grounding Electrical Equipment

Chapter 9

- Isolated Ground Receptacles



Grounding Electrical Equipment

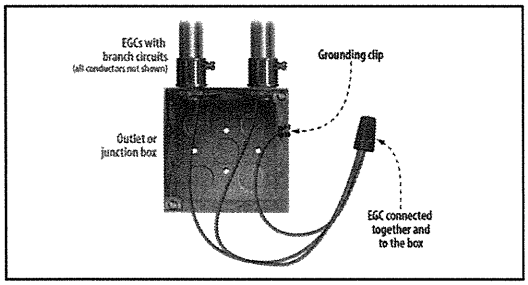
Chapter 9

- EGC Continuity
  - When EGCs are spliced within a box or connected to equipment such as devices that are secured to the box, all EGCs associated with any of the circuit conductors are required to be connected to the box or within the box with suitable devices such as a grounding screw, listed grounding clip, or other equipment listed for accomplishing this grounding connection.
  - EGC connections in outlet boxes must be made such that the removal of a device such as a receptacle, switch, or luminaire does not interfere with the grounding connection or continuity. [*NEC* 250.148(B)]

Grounding Electrical Equipment

Chapter 9

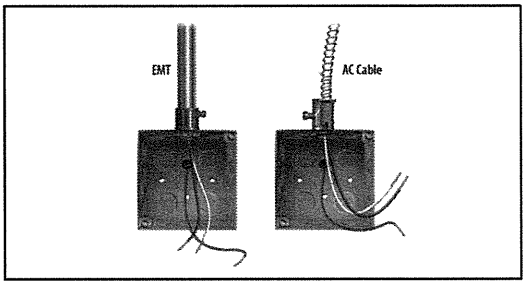
- EGC Continuity



Grounding Electrical Equipment

Chapter 9

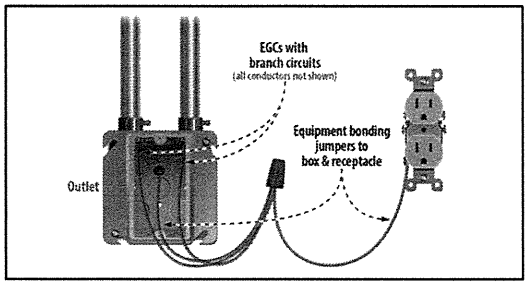
- EGC Continuity



Grounding Electrical Equipment

Chapter 9

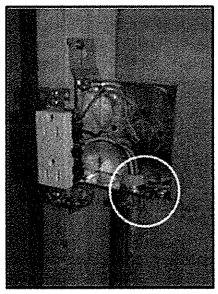
- EGC Continuity



Grounding Electrical Equipment

Chapter 9

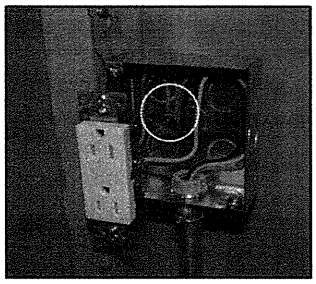
- EGC Continuity
  - When EGCs are spliced together in a box, the connections or splices have to meet the requirements in 110.14(B), except insulation of the splice is not required.
  - Connection to the box can be accomplished using a suitable device such as a listed ground clip or grounding screw.



Grounding Electrical Equipment

Chapter 9

- EGC Continuity



Grounding Electrical Equipment

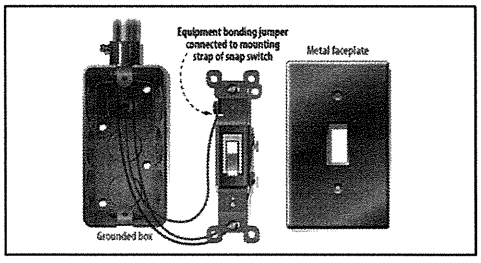
Chapter 9

- Grounding Snap Switches
  - Section 404.9(B) provides specific grounding requirements for snap switches.
  - The grounding rules for switches are similar to those for receptacles because both of these types of equipment (devices) have a mounting strap or yoke.
  - An EGC must be connected to the switch mounting strap so that the grounding is extended to a metal faceplate even if a nonmetallic faceplate is initially installed.

Grounding Electrical Equipment

Chapter 9

- Grounding Snap Switches



Grounding Electrical Equipment

Chapter 9

- Grounding Snap Switches
  - The mounting yoke of a snap switch can serve as an effective ground-fault current path under the following conditions:

    1. The switch is mounted with metal screws to a metal box or metal cover that is connected to an EGC or to a nonmetallic box with integral means for connecting to an EGC.
    2. An EGC or equipment bonding jumper is connected to an equipment grounding termination of the snap switch.

Grounding Electrical Equipment

Chapter 9

- Wiring Device Terminal Identification
  - The grounding terminal connection on devices must be identified by one of the following methods:

    1. A green screw with a hexagon head that is not easily removed from the device
    2. A green hexagonal nut that is not easily removed
    3. A green pressure wire connector
    4. If the connection point for the EGC to the device is not visible, then the EGC entrance hole has to be marked with the words *green or ground, the letters G or* GR, a grounding symbol, or otherwise identified by a distinctive green color.

Grounding Electrical Equipment

Chapter 9

- Wiring Device Terminal Identification (continued)
  - The installer does not have to provide this identification on devices because it is provided by the manufacturer.

Grounding Electrical Equipment

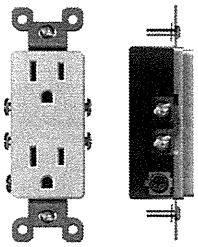
Chapter 9

- Wiring Device Terminal Identification

If connection point for the EGC is not visible, mark with one of the following:

- A distinctive green color
- A grounding symbol, such as

- The letters *G* or *GR*
- The words *Green* or *Ground*



Grounding Electrical Equipment

Chapter 9

- Attachment Plug and Receptacle Continuity
  - EGC continuity is established through receptacles and attachment plugs.
  - These are referred to in the *NEC* as *separable connections.*
  - Section 250.124 requires separable connections to provide for a "first-make, last-break" connection of the equipment grounding conductor.

Grounding Electrical Equipment

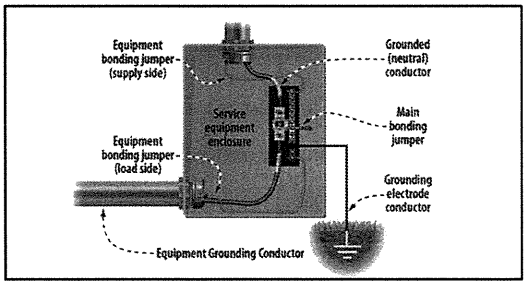
Chapter 9

- EGC Connections at Services
  - Section 250.130(A) addresses premises wiring that is supplied by grounded systems.
  - This rule requires that the EGCs be connected to the grounded conductor and the grounding electrode conductor at the service.
  - When the wiring system is supplied by a service that is ungrounded, the connection of the EGCs has to be made to the enclosure and grounding electrode conductor at the service.

Grounding Electrical Equipment

Chapter 9

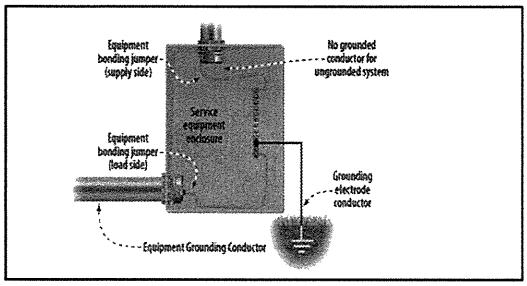
- Service Supplied by Grounded System



Grounding Electrical Equipment

Chapter 9

- Service Supplied by Ungrounded System



Grounding Electrical Equipment

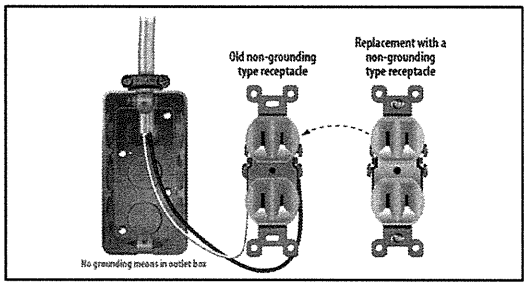
Chapter 9

- Receptacle Replacements
  - Section 406.4(D)(1) indicates that grounding-type receptacles are required to be replaced only with grounding-type receptacles.
  - A non-grounding-type receptacle can be replaced with another non-grounding-type receptacle.
  - Non-grounding-types are not permitted as replacements when the outlet provides an equipment grounding conductor.

Grounding Electrical Equipment

Chapter 9

- Non-Grounding Receptacle Replacements



Grounding Electrical Equipment

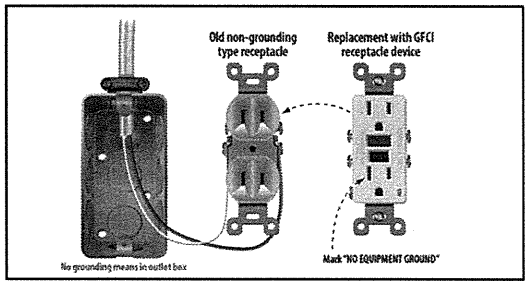
Chapter 9

- Replacing Non-Grounding-Type Receptacles
  - The second alternative allows a ground-fault circuit-interrupter (GFCI) receptacle device to replace a non-grounding-type receptacle.
  - If this alternative is chosen, the GFCI device has to be marked "No Equipment Ground."
  - Using this alternative, an EGC is not permitted to be installed from the GFCI receptacle device to any outlet downstream supplied by the GFCI replacement.

Grounding Electrical Equipment

Chapter 9

- Replacing Non-Grounding-Type Receptacles



Grounding Electrical Equipment

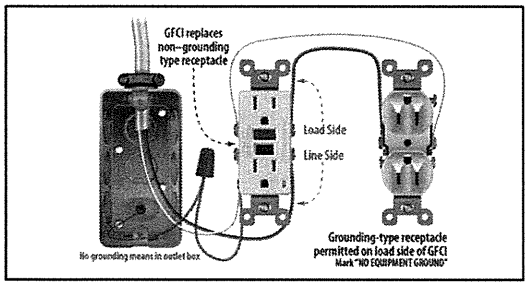
Chapter 9

- Replacing Non-Grounding-Type Receptacles
  - The third alternative allows grounding-type receptacles to be installed as replacements for non-grounding-types on the load side of the GFCI replacement in the circuit, provided each grounding-type receptacle on the load side of the GFCI device is marked "No Equipment Ground."
  - An EGC is not permitted to be connected between the GFCI replacement and the grounding-type receptacles installed on the load side of the GFCI downstream.

Grounding Electrical Equipment

Chapter 9

- Replacing Non-Grounding-Type Receptacles



Grounding Electrical Equipment

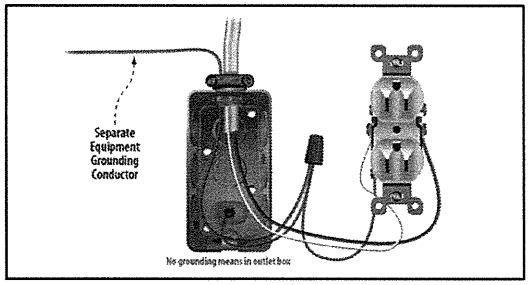
Chapter 9

- Installing a Separate EGC
  - Section 250.130(C) includes some criteria that can be applied for replacements using grounding-type receptacles if an EGC does not exist at the outlet.
  - An EGC is permitted to be installed separately from the existing branch circuit wiring already in place within the building walls, ceilings, or other inaccessible locations.

Grounding Electrical Equipment

Chapter 9

- Installing a Separate EGC



Grounding Electrical Equipment

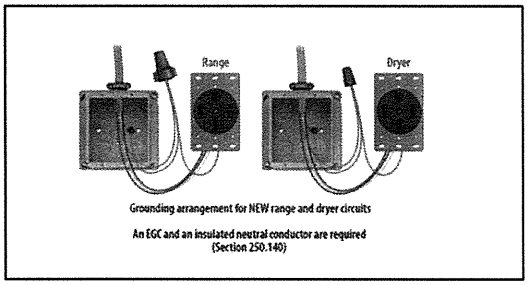
Chapter 9

- Grounding Appliances with EGC
  - The frames of wall-mounted ovens, counter-mounted cooking units, ranges, dryers, and associated outlet or junction boxes are required to be connected to an EGC and must include an insulated grounded circuit conductor if it is needed for the load, according to Sections 250.140 and 250.142.

Grounding Electrical Equipment

Chapter 9

- Grounding Appliances with EGC



Grounding Electrical Equipment

Chapter 9

- Existing Installations
  - The grounded conductor to be used for grounding in existing three-wire circuits supplying this type of equipment, but only under the following (4) conditions:

    1. The supply circuit is 120/240-volt, single-phase, 3-wire; or 208Y/120-volt derived from a 3-phase, 4-wire, wye-connected system.
    2. The grounded conductor is not smaller than 10 AWG copper or 8 AWG aluminum.

Grounding Electrical Equipment

Chapter 9

- Existing Installations (continued)

  3. The grounded conductor is insulated, or the grounded conductor is uninsulated and part of a Type SE service entrance cable and the branch circuit originates at the service equipment.

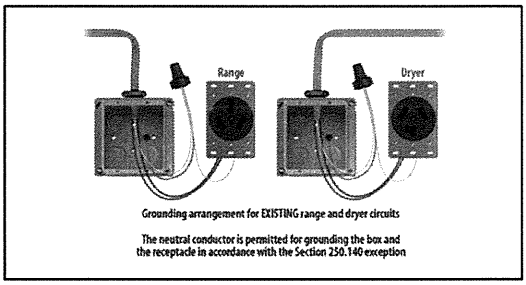
  4. Grounding contacts of receptacles furnished as part of the equipment are bonded to the equipment. [*NEC* 250.140 Exception]

  - Branch circuits installed for new appliance installations are required to provide an EGC sized in accordance with Table 250.122 for grounding the non-current-carrying metal parts.

Grounding Electrical Equipment

Chapter 9

- 250.140 Exception



Grounding Electrical Equipment

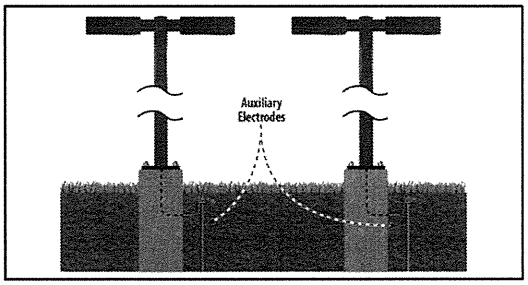
Chapter 9

- Auxiliary Grounded Electrodes
  - Section 250.54 indicates that it is permissible to connect one or more grounding electrodes to the EGCs specified in 250.118.
  - Auxiliary grounding electrodes should never be used as the only equipment grounding means.
  - Auxiliary grounding electrodes for equipment must meet the provisions in 250.54 and satisfy the provisions in 250.4(A)(5) or 250.4(B)(4).
  - The Earth is never permitted as an effective path for ground-fault current.

Grounding Electrical Equipment

Chapter 9

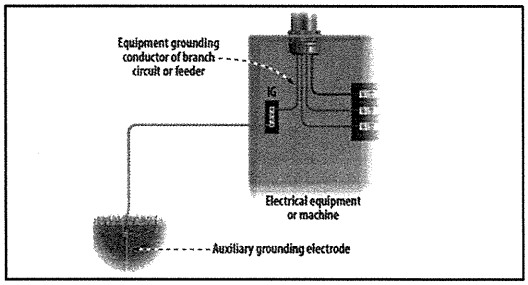
- Auxiliary Grounding Electrodes



Grounding Electrical Equipment

Chapter 9

- Auxiliary Grounding Electrodes



Grounding Electrical Equipment

Chapter 9

- Grounding Non-Electrical Equipment
  - The metal parts of some non-electrical equipment are required to be connected to an EGC.
  - For example, the frames and tracks of electrically operated cranes and hoists must be grounded by connection to an EGC installed with the circuit supplying the equipment.

Grounding Electrical Equipment

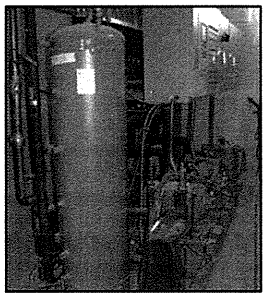
Chapter 9

- Equipment Grounded by Secure Metal Supports
  - There are installations in which a support frame can provide the equipment grounding required by the *NEC*.
  - The EGC, if of the wire type, must be sized based on the requirements in Table 250.122.
  - Section 250.136 recognizes these types of installations as meeting the minimum requirements for grounding equipment.

Grounding Electrical Equipment

Chapter 9

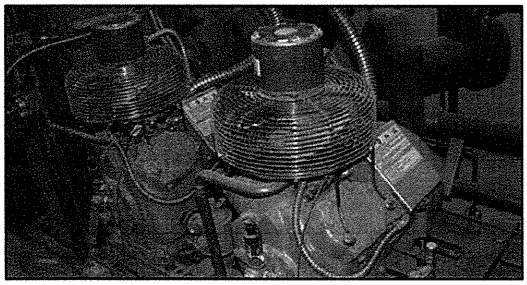
- Equipment Considered Grounded
  - A common frame that supports multiple motors can be grounded by a single EGC that grounds all the motors mounted to the common metal frame or rack.



Grounding Electrical Equipment

Chapter 9

- Equipment Considered Grounded



Grounding Electrical Equipment

Chapter 9

- Use of Grounded Conductor for Grounding
  - The grounded conductor is generally not permitted to be connected to ground on the load side of the service grounding point or the load side of the grounding point of a separately derived system. [*NEC* 250.24(A)(5) and 250.30(A)]
  - Section 250.142 includes a few conditions in which the grounded conductor is permitted to be used for grounding equipment, but these are restrictive conditions.

Grounding Electrical Equipment

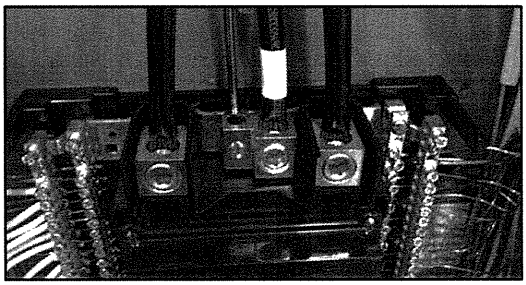
Chapter 9

- Use of Grounded Conductor for Grounding
  - On the supply side or within the enclosure of the service, a grounded (usually the neutral) conductor can be used for grounding non–current–carrying metal parts of equipment, raceways, and other enclosures.
  - The grounded conductor can be used for grounding equipment at locations on the supply side or within the enclosure of the main disconnecting means for separate buildings, as provided in 250.32(B)(1) Exception No. 1, and at locations on the supply side or within the enclosure of the main disconnecting means or overcurrent devices of a separately derived system, as permitted by 250.30(A)(1). [*NEC* 250.142(A)]

Grounding Electrical Equipment

Chapter 9

- Grounding Equipment (Supply Side)



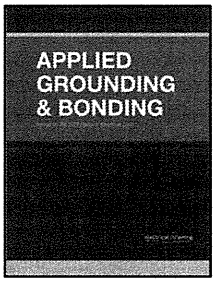
Grounding Electrical Equipment

Chapter 9

- Summary
  - Parts VI and VII of Article 250 include the general requirements for equipment grounding and there are a few substitutes for grounding such as isolation, insulation, or guarding.
  - Equipment grounding conductor installations must meet the requirements in 250.120.
  - Connecting equipment to ground can be accomplished using an auxiliary electrode in addition to the required EGC.
  - Load-side grounding connections are generally not permitted for the grounded conductor (usually a neutral) as specified in 250.24(A)(5) and 250.30(A).

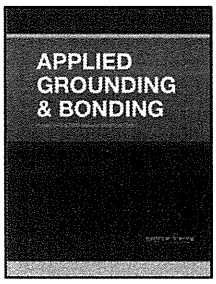
Grounding and Bonding

Grounding Electrical Equipment



Grounding and Bonding

Isolated/Insulated Grounding Circuits and Receptacles



Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- Introduction
  - Clean power is the key objective when designing and installing electrical systems for electronic equipment.
  - The term *clean power* is not defined in the *Code*; neither are the terms *isolated ground* or *quiet ground.*
  - There are wiring techniques that can be used to achieve optimal performance in equipment grounding circuits for electronic equipment while maintaining compliance with the *NEC* safety regulations.
  - Wiring isolated grounding circuits and receptacles for information technology equipment must never compromise safety in the grounding and bonding system.

Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- Objectives
  - Identify provisions in the *NEC* that address *objectionable current* in the grounding and bonding system.
  - Understand sources of electromagnetic interference (EMI) that can affect normal operation of electronic equipment.
  - Understand various alternatives for reducing objectionable current and noise (EMI) in the grounding circuits and review use of surge protective devices (SPDs).

Isolated/Insulated Grounding Circuits and Receptacles

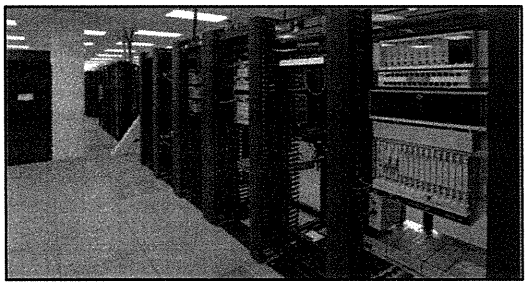
Chapter 10

- Objectives
  - Understand installation requirements for isolated equipment grounding conductors and isolated grounding receptacles.
  - Determine specific grounding requirements that apply to information technology equipment and rooms and understand the purpose of signal reference structures (grids).

Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- Information Technology Equipment



Isolated/Insulated Grounding Circuits and Receptacles

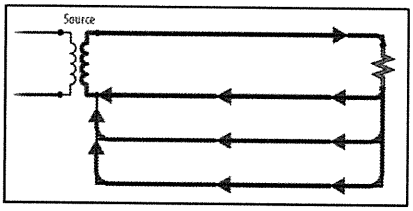
Chapter 10

- Electromagnetic Interference (EMI) in Grounding Circuits
  - Electronic equipment can react negatively to electromagnetic interference (EMI) in the grounding circuit.
  - The term *sensitive electronics* refers to equipment that is vulnerable EMI or circulating currents, typically at low current levels.
  - *Objectionable current* and *ground loops* are not defined in the *Code,* but in the IT world, these terms refer to circulating currents through various grounding paths.
  - The current in these paths is thought to be moving in circular fashion or over multiple paths while returning to the source.
  - This circular movement of current is more commonly called a ground loop.

Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- Circulating Currents in Multiple Paths



Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

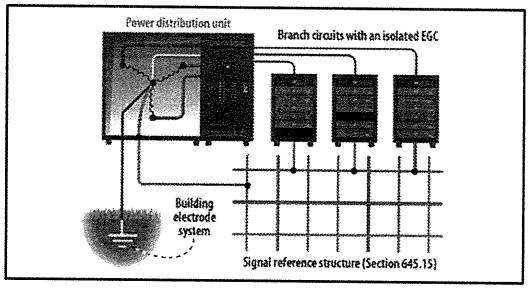
- Practical Solutions
  - Some practical solutions for dealing with EMI and circulating currents associated with information technology systems are as follows:

    1. Single point grounding and use of a single power supply system (PDU) and signal reference grids.
    2. Modems, which are normally used as interfaces with telephone circuits.
    3. Fiber optic transmission over completely non-conducting paths or optical isolators.
    4. Interface devices (surge arresters and surge protection devices).

Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- Power Distribution Units (PDUs)



Isolated/Insulated Grounding Circuits and Receptacles

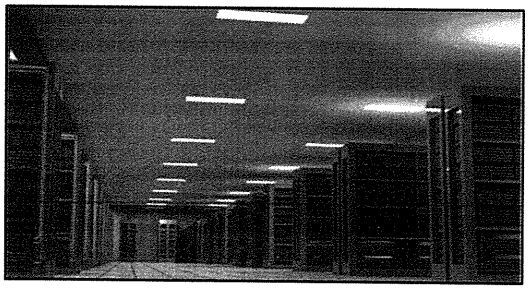
Chapter 10

- High Frequency Effects (Resonance)
  - Another challenge in IT room installations or with electronic equipment is the high-frequency effects in grounding circuits.
  - Resonance can occur when the length of a conductor and the frequency of alternating current are in tune.
  - Avoiding resonance at high frequency is important and more challenging for IT equipment because of the higher frequencies in today's digital signaling circuits.

Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- Power Distribution Units (PDUs) for IT Rooms



Isolated/Insulated Grounding Circuits and Receptacles

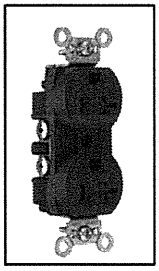
Chapter 10

- Purpose of Isolated Grounding Circuits and Receptacles
  - Isolated grounding circuits and receptacles are installed to reduce EMI that can interfere with data systems and equipment.
  - This type of circuit design can reduce or minimize electromagnetic interference (EMI) on the equipment grounding circuits by insulating the conductive paths and reducing the grounding circuit to a single insulated path that extends back to the source grounding point, usually at a service or separately derived system.

Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- Isolated Grounding Receptacles
  - Isolated grounding receptacles installed in a branch circuit include an isolated, insulated EGC installed in accordance with 250.146(D).
  - IG receptacles are required to be identified using an orange triangle on the face of the receptacle.
  - The receptacle grounding means is isolated from the mounting strap of the device.

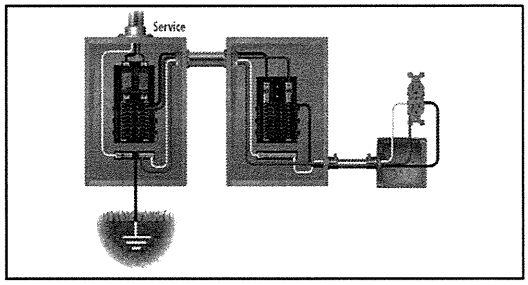


Courtesy of Pass and Seymour Legrand

Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

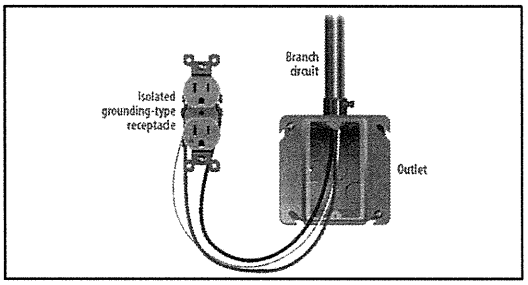
- Minimizing Electromagnetic Interference (EMI)



Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- Wiring IG Receptacles



Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- Objectionable Current
  - The *NEC* addresses *objectionable current* in 250.6 and provides some alternatives to reduce objectionable current.
  - Current that introduces electromagnetic interference or data errors in electronic equipment is not considered objectionable current, as addressed in 250.6.
  - Objectionable currents in grounding circuits are often a result of improper neutral-to-ground connections.

Isolated/Insulated Grounding Circuits and Receptacles

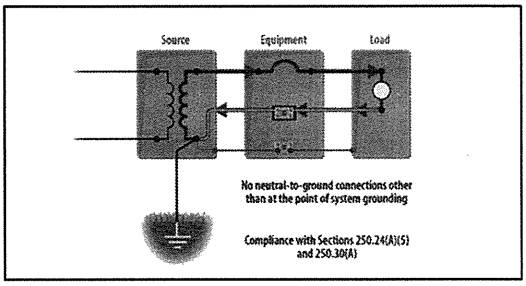
Chapter 10

- Objectionable Current (continued)
  - Remedial alternatives for eliminating or minimizing objectionable currents are addressed in 250.6(B).
  - The alternatives provided in 250.6 do not allow for the removal of safety equipment grounding in compliance with *NEC* minimums.

Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

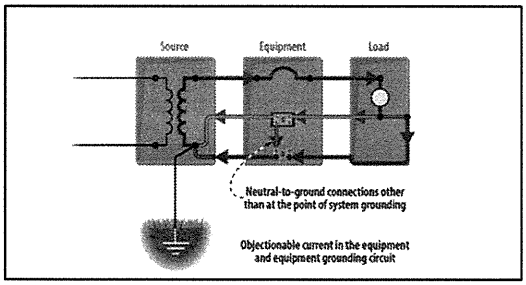
- Normal Current Path(s)



Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- Objectionable Current



Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- Remedial Solutions
  - Disconnection of one or more, but not all, grounding connections.
  - Change of the location of the grounding connections.
  - Interruption of the continuity of the conductor or conductive path causing objectionable current.
  - Other remedial action approved by the authority having jurisdiction (AHJ) [*NEC* 250.6(B)].

Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- Power Quality System Grounding Analysis
  - When a building power quality analysis is performed, it should always include a thorough analysis of the building grounding and bonding system.
  - Generally, there should be no neutral-to-ground connections on the load side of the service grounding point or on the load side of the grounding point for a separately derived system [250.24(A)(5) and 250.30(A)].
  - Load-side neutral-to-ground connections can cause current in the EGC circuit(s) and in other conductive paths connected to the source.

Isolated/Insulated Grounding Circuits and Receptacles

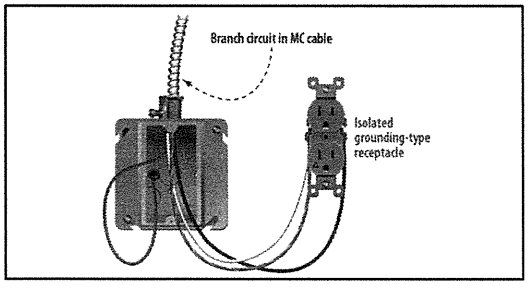
Chapter 10

- Isolated Grounding Circuits
  - When isolated/insulated EGCs are installed with the branch circuit, there are two EGC paths.
  - The first path is the required EGC for safety; the next path is the desired isolated/insulated EGC for performance.
  - The first path can be metallic conduit, tubing, cable armor, and so forth as recognized in 250.118.
  - However, the second path must always be an insulated conductor of the wire type identified by the color green or green with one or more yellow stripes.

Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- Isolated Equipment Grounding Conductors



Isolated/Insulated Grounding Circuits and Receptacles

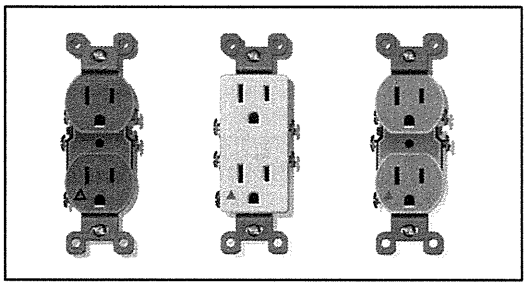
Chapter 10

- Isolated Ground Receptacle Wiring
  - Isolated ground receptacles are manufactured with a grounding terminal that is deliberately isolated from the mounting strap of the device.
  - Isolated grounding-type receptacles must be marked with an orange triangle on the face of the receptacle.

Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- IG Receptacle Identification



Isolated/Insulated Grounding Circuits and Receptacles

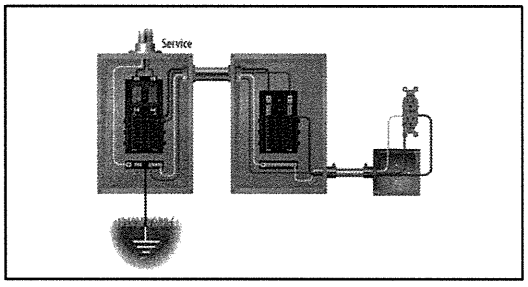
Chapter 10

- Isolated Ground Receptacle Wiring Rules
  - Section 250.146(D) includes the permissive text that allows an insulated EGC to pass through panelboards and other enclosures without connecting to them, as long as they are terminated at the point of grounding of the circuit.
  - The point of grounding is either usually at the service equipment or at a source of a separately derived system, which could be a transformer or PDU in an IT room.
  - In the completed wiring installation, two separate EGC paths are present from the outlet to the source grounding point.

Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

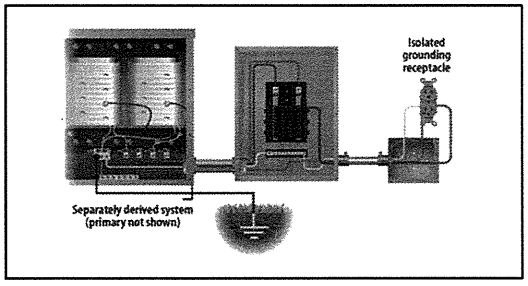
- Routing of IG Conductor



Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- Routing of IG Conductor



Isolated/Insulated Grounding Circuits and Receptacles

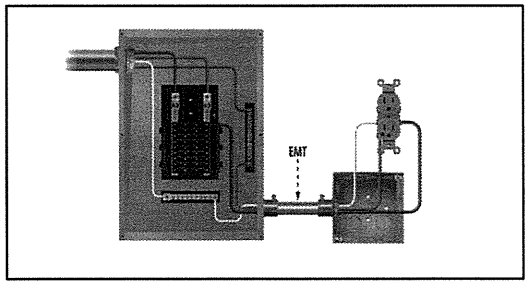
Chapter 10

- Panelboards and Isolated Grounding Circuits
  - In some designs, an isolated grounding terminal bar is installed in the panelboard for connecting all isolated/insulated EGCs from IG branch circuits.
  - In such designs, typically two separate EGCs are run with the feeder to the panelboard.
  - One EGC serves as the normal EGC and connects directly to the enclosure; the other serves as the isolated/insulated EGC and is isolated from the panelboard enclosure.

Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

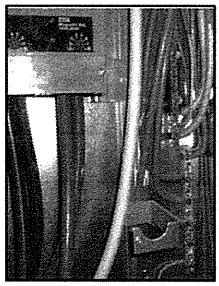
- IG Terminal Bar in Panelboard



Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

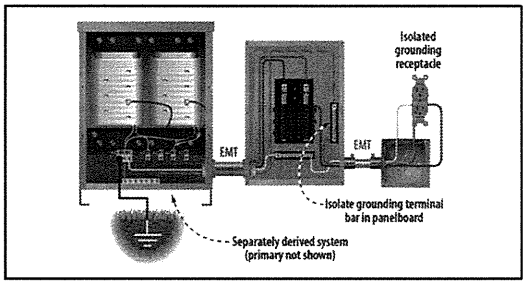
- Isolated Equipment Grounding Conductors
  - IG conductors are often terminated in equipment that has an insulated EG terminal bar for this purpose.
  - Normal wire-type equipment grounding conductors are generally identified as green.
  - IG conductors are generally identified as green with one or more yellow stripes. [*NEC* 250.119]



Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

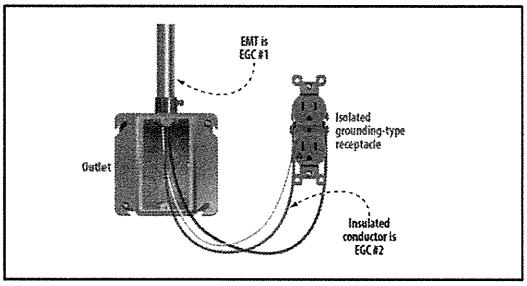
- IG Routed to Transformer



Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- Two EG Paths to Source



Isolated/Insulated Grounding Circuits and Receptacles

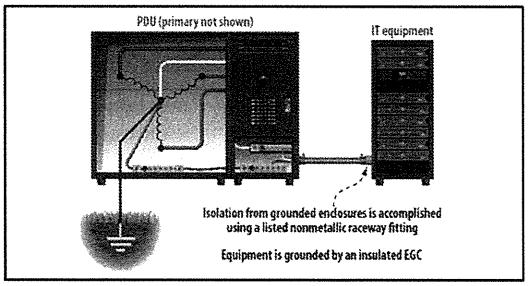
Chapter 10

- Isolated Grounding Circuits for Equipment
  - Section 250.96(B) indicates that when a reduction of electrical noise on grounding circuits is desired, an equipment (typically IT equipment) enclosure is permitted to be supplied by a branch circuit containing an insulated EGC that is isolated from metal raceways by using a listed nonmetallic raceway fittings (PVC fittings).
  - The fitting removes the connection of a metallic raceway that may carry electromagnetic interference.

Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- 250.96 IG Conductor



Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- IG Circuits in Health Care Facilities
  - Branch circuits serving patient care spaces must meet the equipment grounding requirements in 517.13(A) and (B).
  - Isolated ground receptacles and equipment grounding may be required or installed in other than a patient care vicinity of health care facilities.
  - The isolated EGC cannot be counted as one of the two grounding paths required by 517.13 because this path does not provide a functional benefit of being in parallel with the metal raceway or cable system for the branch circuit.

Isolated/Insulated Grounding Circuits and Receptacles

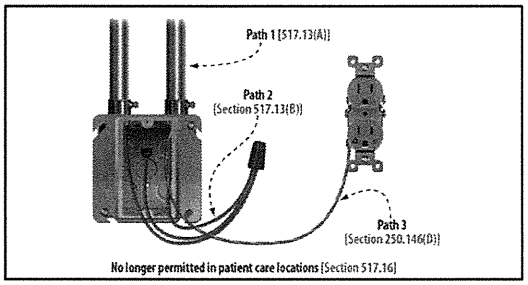
Chapter 10

- IG Circuits in Health Care Facilities
  - The *NEC* no longer permits the installation of IG circuits and receptacles in patient care vicinities of health care facilities as restricted by 517.16(A).
  - NFPA 99 *Standard for Health Care Facilities* and the *NEC* still address installations of isolated grounding circuits and receptacles.
  - NFPA 99 also requires periodic testing of grounding systems, which includes installations of isolated grounding receptacles and circuits in health care facilities.

Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- IG Circuits in Health Care Facilities



Isolated/Insulated Grounding Circuits and Receptacles

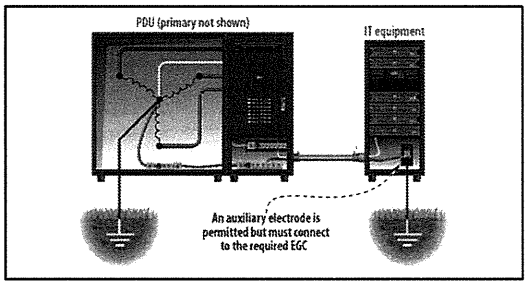
Chapter 10

- Auxiliary Grounding Electrodes
  - When isolated/insulated circuits are installed, there is often a desire to install a separate supplemental connection to the Earth at the equipment location.
  - Installation of auxiliary grounding electrodes does not relieve the requirement for connection of an EGC.
  - It is installed in addition to the required EGC for the branch circuit.
  - When an auxiliary grounding electrode is installed, both the EGC and the grounding electrode conductor to the electrode must be connected to the equipment.

Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- Auxiliary Grounding Electrodes



Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- Grounding and Bonding in Information Technology Centers
  - Section 645.15 includes specific grounding requirements for equipment in an information technology room.
  - The primary requirement is that all non-current-carrying metal parts of such equipment be connected to the EGC of the supply branch circuit or feeder in accordance with Article 250.
  - There is an exemption from the grounding requirement, but only where the IT equipment is double-insulated.

Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- Grounding and Bonding in Information Technology Centers
  - To minimize possible differences in potential in the grounding systems for power circuits supplying IT equipment, it is common for these centers to be equipped with a single PDU or multiple PDUs.

Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- Power Distribution Units (PDUs)
  - The PDUs that are used for IT equipment are permitted to include multiple panelboards within a single cabinet, provided that the PDU is utilization equipment listed for IT application.
  - A PDU typically is equipped with a separately derived system to supply the IT equipment.

Isolated/Insulated Grounding Circuits and Receptacles

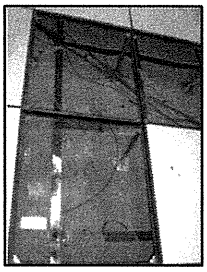
Chapter 10

- Signal Reference Structures (Grids)
  - The IT term *signal reference grid* refers to a common conductive structure such as a computer floor, copper interconnected sheet strips, or a copper mesh grid installed under the raised IT room floor.
  - This grid provides an effective equipotential bonding structure to which all equipment can be connected.
  - All equipment in the room, including equipment that is mounted to the wall, should be connected to the grid.
  - The signal reference structure must be connected to the EGC in the supply branch circuit for the IT equipment.

Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- Signal Reference Grids
  - IT equipment is connected to the signal reference grid to equalize the potential between components.
  - In some designs, the floor panels and frame are an integral part of the signal reference structure.
  - These grids minimize differences of potential in IT room installations.

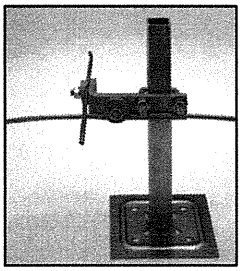


Courtesy of Hargar Lightning and Grounding

Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- Signal Reference Grids
  - Sometimes support structures for the raised floor are part of the signal reference structure.
  - Listed products are available for constructing a signal reference grid in an IT room.

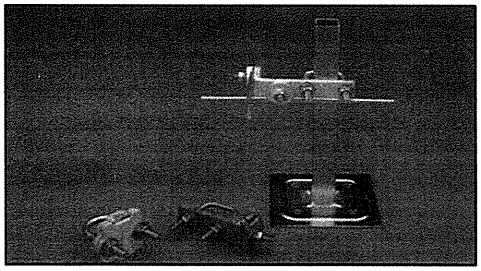


Courtesy of Hargar Lightning and Grounding

Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- Signal Reference Grid Components



Courtesy of Hargar Lightning and Grounding

Isolated/Insulated Grounding Circuits and Receptacles

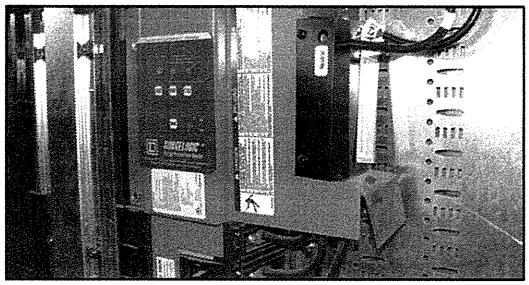
Chapter 10

- Surge Protection (SPDs)
  - Surge protection is often desired for IT equipment installations for providing a greater degree of protection against line surges.
  - Installations of surge protective devices (SPDs) are covered by the *NEC* but are not required by the *NEC*.
  - If surge protection is installed, it has to comply with the applicable provisions in Article 242.
  - Specific equipment grounding requirements are often provided by the SPD manufacturer.

Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

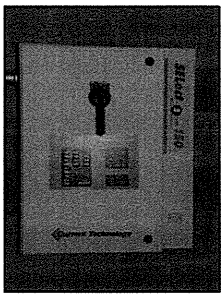
- Surge Protection (SPDs)



Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

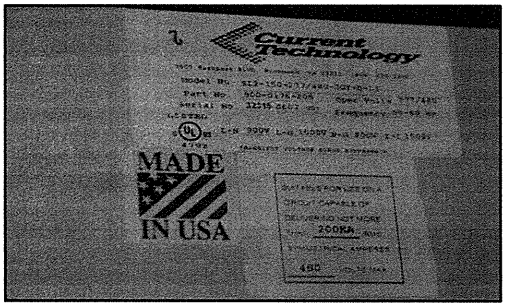
- Grounding SPDs
  - Grounding conductor connections to surge protection devices must meet the requirements in Part III of Article 250.
  - When the grounding conductor is installed in a ferrous metal raceway, it must comply with 250.64(E).
  - Follow the instructions provided by the manufacturer.



Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

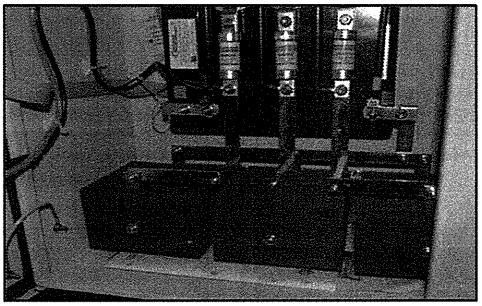
- Listing and Markings on SPDs



Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

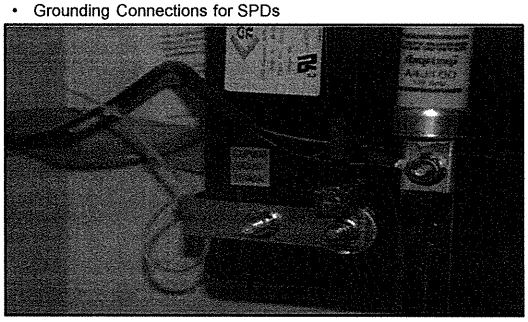
- Grounding SPDs



Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- Grounding Connections for SPDs



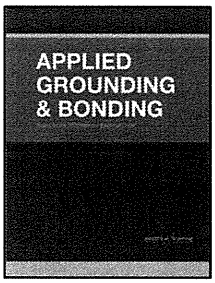
Isolated/Insulated Grounding Circuits and Receptacles

Chapter 10

- Summary
  - The minimum requirements for installing isolated grounding circuits and receptacles are covered by the *NEC*.
  - The *NEC* includes some alternative equipment grounding techniques that are often applied in IT system designs to address concerns related to normal operation of electronic equipment.
  - Various common techniques are applied to achieve optimal performance in the IT grounding system while meeting minimum safety requirements of the *NEC*, simultaneously.

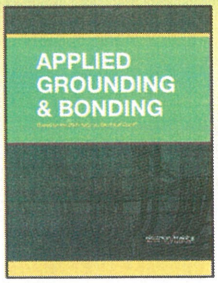
Grounding and Bonding

Isolated/Insulated Grounding Circuits and Receptacles



Grounding and Bonding

Introduction to Grounding



Introduction

Chapter 1

- Basic grounding and bonding concepts and the related performance provisions contained in the *National Electrical Code® (NEC®)* are knowledge areas Electrical Workers must be familiar with.
- Grounding and bonding are essential for safe electrical installations and systems.
- Mastering the subject of grounding and bonding requires understanding of what is intended to be accomplished by electrical grounding and bonding.
- This chapter reviews basic grounding and bonding concepts.

Introduction

Chapter 1

- Objectives
  - Recognize and understand key grounding and bonding terms.
  - Understand the role of the Earth in the electrical grounding system.
  - Understand the purpose of electrical grounding and bonding, and define fundamental grounding concepts for systems and equipment.

Introduction

Chapter 1

- Objectives (continued)
  - Understand fundamentals related to bonding and connecting conductive parts and equipment to establish electrical continuity and conductivity.
  - Understand grounding and bonding concepts that perform simultaneously in electrical wiring systems.
  - Understand performance requirements for electrical grounding and bonding and application of the *NEC* rules.
  - Recognize that if there is no connection to ground (the Earth), there is no grounding.

Introduction

Chapter 1

- Grounding and Bonding for Safety
  - The *NEC* provides minimum safety requirements that are intended to protect persons and property from hazards associated with the use of electricity.
  - Grounding and bonding are necessary for safe electrical installations.
  - One function compliments and supports the other simultaneously.
  - When non-current-carrying parts of equipment are bonded together and connected to ground, bonding and grounding are accomplished, enhancing safety in electrical systems.

Introduction

Chapter 1

- Earth In The Circuit
  - Grounding electrical equipment is the most popular and effective method of building safety into electrical systems, at least in the United States.
  - When an electrical system or electrical equipment is grounded, the earth is included in the electrical circuit.

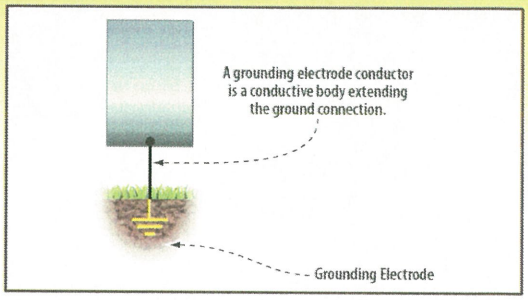
Introduction

Chapter 1

- Earth In The Circuit (continued)
  - Grounded electrical systems and equipment offer the advantage of circuit protection by causing fuses or circuit breakers to operate in a phase-to-ground fault condition.
  - Equipment and systems that are grounded are connected to the earth through a grounding electrode.

Introduction

Chapter 1



Introduction

Chapter 1

The term *ground* is defined as "the Earth."

The Earth is a conductor, but it is a very poor current-carrying conductor.

The Earth is included in an electrical grounding circuit.

Introduction

Chapter 1

- Article 100 Definition(s)
  - Grounding and Bonding terms are all defined in Article 100 of the *NEC*.
  - The term *Ground* is simply defined in the *NEC* as "The earth."
  - The term *Grounded* (Grounding) is defined in the *NEC* as "Connected (connecting) to ground or to a conductive body that extends the ground connection.
  - Examples of conductive bodies that extend the ground connection are equipment grounding conductors and grounding electrode conductors.

Introduction

Chapter 1

- Grounding Concepts
  - The function of grounding involves a connection to this planet – Earth.
  - Buildings are required to be constructed on a solid foundation that supports the weight of the building or structure.

Introduction

Chapter 1

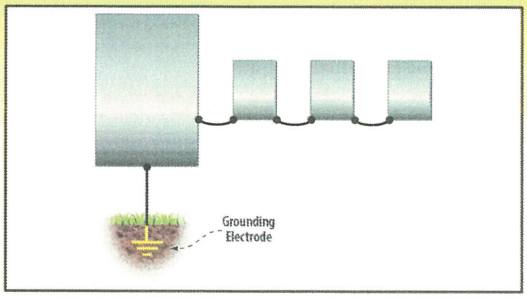
- Grounding Concepts (continued)
  - Electrical systems that are grounded are also connected to the Earth usually through a system of grounding electrodes.
  - The grounding electrode system is the foundation of the electrical system and grounded equipment.
  - Without a connection to the Earth, there is no grounding.

Introduction

Chapter 1

Introduction

Chapter 1



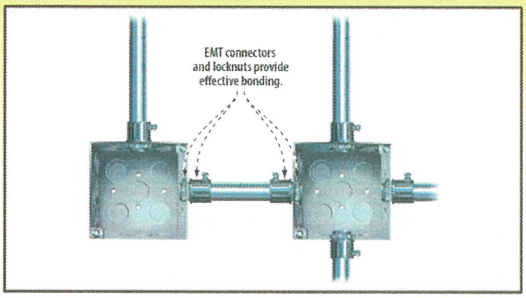
Introduction

Chapter 1

- Bonding Concepts
  - When two conductive objects such as metal boxes or other enclosures are connected by metal conduit, bonding is accomplished.
  - Bonding can also be accomplished by connecting metal parts together using wire-type bonding jumpers.
  - When bonding is accomplished in power system installations, electrical continuity and conductivity is created between conductive materials and equipment.

Introduction

Chapter 1



Introduction

Chapter 1

- Article 100 Definition
  - Bonded (Bonding). Connected to establish electrical continuity and conductivity.
  - Note: The definition uses the word connected indicating that connections are an integral function of bonding.

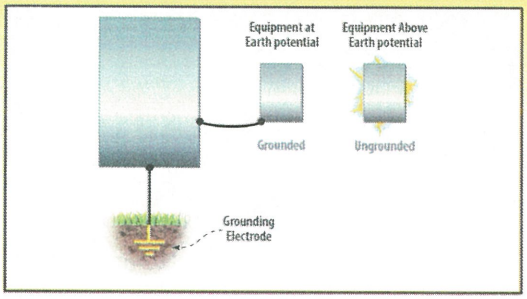
Introduction

Chapter 1

- Minimizing Shock Hazards
  - Grounding and bonding reduces potential differences between conductive parts and the Earth.
  - The grounding and bonding process thereby reduce potential shock hazards.
  - The *NEC* places significant emphasis on establishing an effective ground-fault current path.
  - The purpose of this path is to facilitate overcurrent device operation and quickly remove faulted conditions from the system.

Introduction

Chapter 1



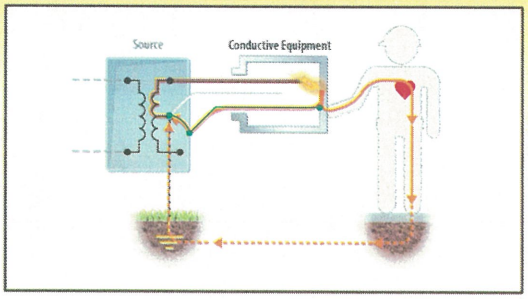
Introduction

Chapter 1

- Minimizing Shock Hazards (continued)
  - Ground fault current returns to the source through multiple conductive paths such as:
    1. through the equipment grounding conductor (EGC);
    2. through conductive material other than the electrical system ground (metal, water pipes, and so forth);
    3. through a person; or
    4. through a combination of these ground return paths.

Introduction

Chapter 1



Introduction

Chapter 1

- Path for Current through the Body
  - Current can travel in a series circuit through the human body.
  - Current can travel in a parallel circuit through the human body.

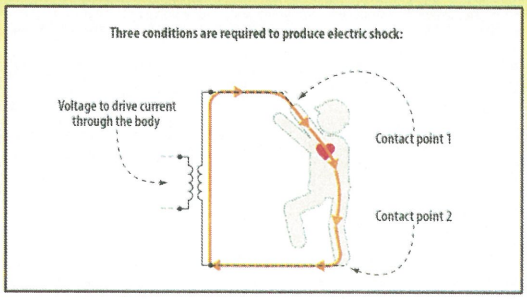
Introduction

Chapter 1

- Path for Current through the Body
  - Three conditions are required to result in an electrical shock:
    1. There must be a contact point on the body for entry of the circuit current.
    2. The current must exit through a second contact point.
    3. There must be a voltage to force the current across the human body.
  - The body can take on the same voltage potential as an electrical circuit if isolated from other current return paths.

Introduction

Chapter 1



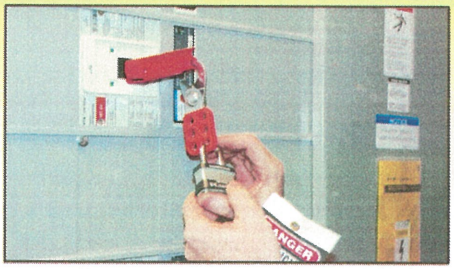
Introduction

Chapter 1

- Safe Work Practices and Shock Protection
  - Protection from shock and other electrical hazards is achieved by establishing an electrically safe work conditioning in accordance with NFPA 70E® *Standard for Electrical Safety in the Workplace*.
  - Requirements for lockout/tagout are provided in Article 120 of NFPA 70E.

Introduction

Chapter 1



Introduction

Chapter 1

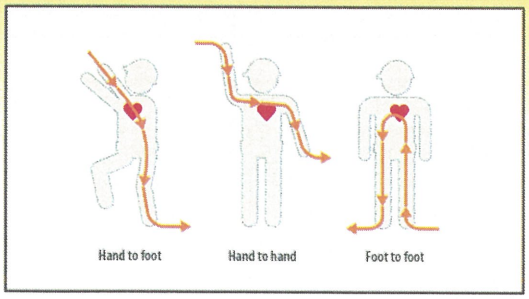
Introduction

Chapter 1

- Severity of Electric Shock
  - How serious the electrical shock injury generally depends on the:
    1. amount of current (amperes);
    2. duration (time) the current is present; and
    3. path the current takes through the body.
  - The circuit frequency can also affect the severity of shock a person receives.
  - The amount of damage is influenced by factors such as moisture levels, temperatures, and where on the body there is contact with the circuit.

Introduction

Chapter 1

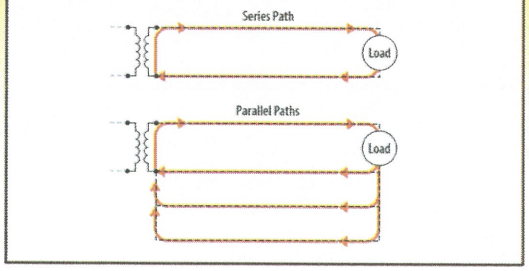


Introduction

Chapter 1

- Current Takes all Paths Available
  - For current to be present in a circuit, the circuit must be complete.
  - In series contact, the person is the only current path and the equipment grounding conductor (EGC) is not involved in the circuit.
  - Current will take any/all paths available to return to its source.
  - Electrical shock can occur when the human body is in series with electrical current or when it is in parallel with the current returning to the source.

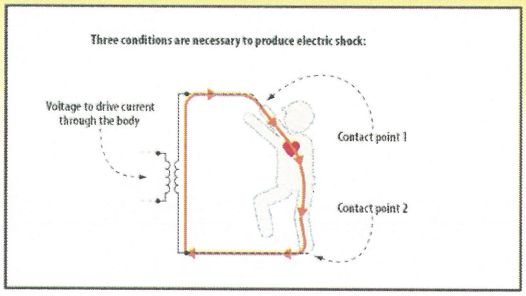
Introduction — Chapter 1



Introduction — Chapter 1

- Series Circuit Through the Human Body
  - A person can become involved in an electrical circuit or provide a pathway for current in a circuit in one of two ways: he or she might be (1) in series contact with the electrical circuit or (2) in parallel contact with the circuit.
  - Electrical injury is usually more severe when the human body is in series with the electrical circuit.

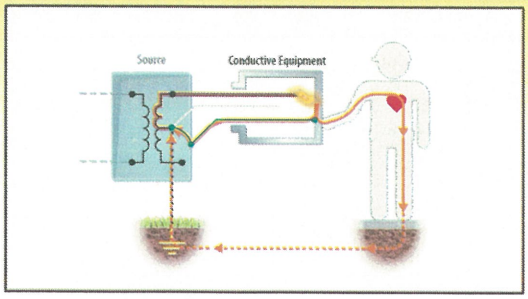
Introduction — Chapter 1



Introduction — Chapter 1

- Parallel Circuit Through the Body
  - In parallel circuit contact, the victim becomes a path in parallel with the EGC or other conductive path(s).

Introduction — Chapter 1



Introduction — Chapter 1

- Parallel Circuit Through the Body (continued)
  - In such parallel contact situations, the effectiveness of the EGC can sometimes prevent electrocution, depending on:
    1. whether or not the ground-fault current reaches the instantaneous trip level of the overcurrent protective device (which is relatively high—greater than 15 amperes);
    2. how fast the overcurrent device reacts;
    3. the voltage level from faulted enclosure to ground; and
    4. the impedance of the grounding paths (composed of connections, contacts, and the equipment grounding conductors).

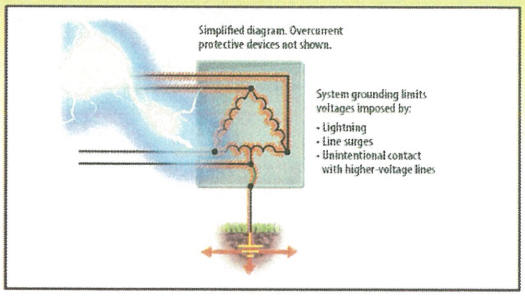
Introduction

Chapter 1

- Grounding and Bonding Concepts Together
  - Grounding and bonding circuits are safety circuits for electrical services, feeders, and branch circuits in today's wiring systems.
  - Electrical systems are grounded to limit potentials (voltages) imposed by lightning, line surges, or unintentional contact with higher-voltage lines.
  - Grounding electrical systems also stabilizes voltages during normal operation.
  - Electrical equipment is grounded to establish the same or close to the same potential between the equipment and the ground (Earth).

Introduction

Chapter 1



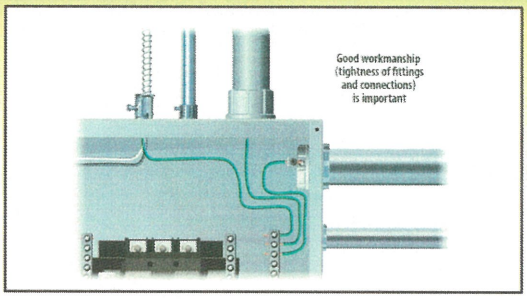
Introduction

Chapter 1

- Purpose of Bonding
  - When electrically conductive parts are effectively bonded together, electrical continuity and conductivity are established.
  - An important part of the grounding and bonding scheme is constructing an effective ground-fault current path.
  - Care must be taken to ensure that good electrical connections are made for all the conductors including but not limited to the service grounding scheme.
  - Good workmanship in Electrical Construction is important (See 110.12)

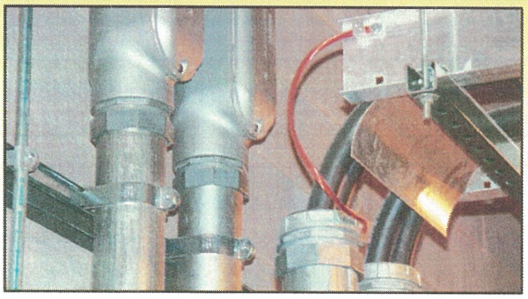
Introduction

Chapter 1



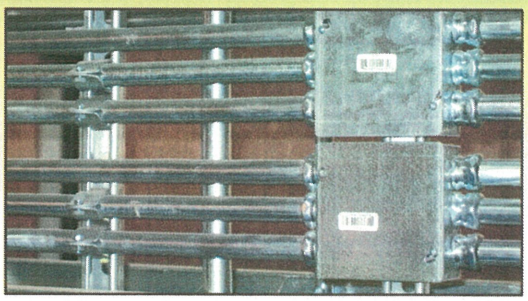
Introduction

Chapter 1



Introduction

Chapter 1



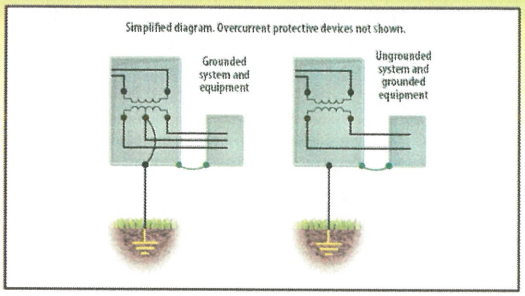
Introduction

Chapter 1

- Performance *Code* Language
  - Section 250.4 provides general provisions that indicate how grounding and bonding of electrical systems and equipment are intended to perform.
    - Section 250.4(A) provides performance provisions for grounded systems.
    - Section 250.4(B) provides performance provisions for ungrounded systems.
  - Grounding and bonding are required for both grounded and ungrounded electrical wiring systems.

Introduction

Chapter 1



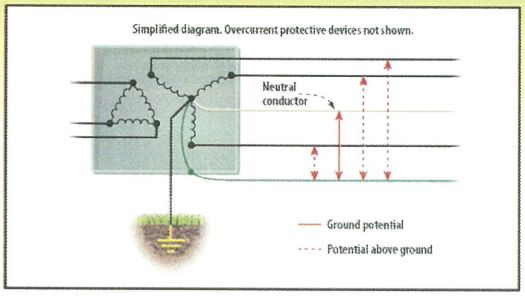
Introduction

Chapter 1

- Grounded Electrical Systems
  - When an electrical system or source is grounded, a voltage-to-ground reference is established for the system's ungrounded conductors.
  - The grounded conductor of the system is forced to take on the same potential as the ground (Earth).

Introduction

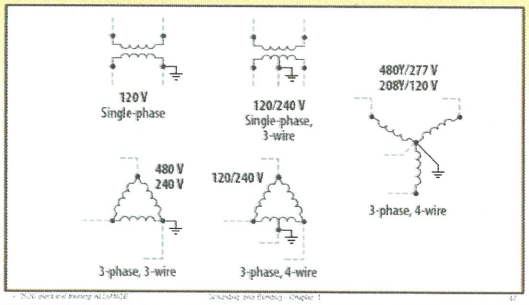
Chapter 1



Introduction

Chapter 1

- Grounded Electrical Systems



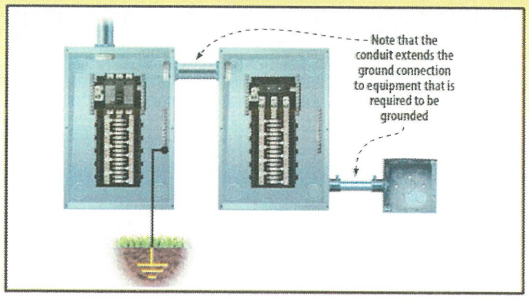
Introduction

Chapter 1

- Grounding Equipment
  - Grounding of electrical equipment involves connecting equipment to the ground (Earth), either directly or through a conductive body that extends the connection to the ground.
  - A conductive body extending the ground connection can be a bonding conductor, a grounding electrode conductor, or an equipment grounding conductor.

Introduction

Chapter 1



Introduction

Chapter 1

- Bonding Equipment
  - Bonding is the process of connecting two or more conductive parts together. These conductive objects are referred to by the *NEC* as normally non-current-carrying conductive parts in the electrical installation.
  - As an example, when a length of metal conduit is attached to a metal box with two locknuts, the function of bonding is occurring.

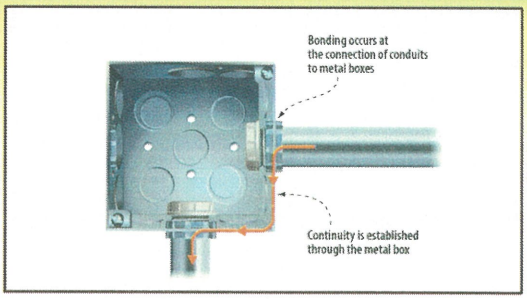
Introduction

Chapter 1

- Bonding Equipment (continued)
  - Once this connection process is complete, the two conductive parts become one electrically and are considered bonded together.
  - Bonding establishes little or no potential differences between conductive parts, which result in the continuity aspect of a bonding function.

Introduction

Chapter 1



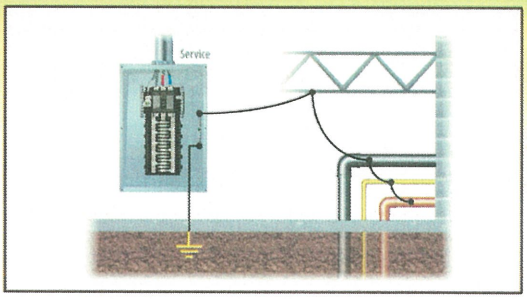
Introduction

Chapter 1

- Bonding Conductive Materials
  - The *Code* provides bonding requirements for conductive materials foreign to the electrical equipment and materials.
  - Examples of such conductive materials within buildings or structures are structural building steel and metal piping systems.
  - The bonding required by Section 250.4(A)(4) is intended to establish a connection to the ground from the bonded material, thus minimizing possible potentials above ground on these materials should they come in contact with electrical circuits.

Introduction

Chapter 1



Introduction

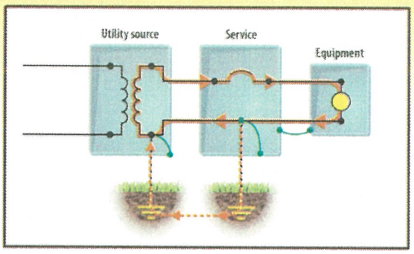
Chapter 1

- Effective Ground-Fault Current Path
  - The effective ground-fault current path is covered in Section 250.4(A)(5).
    - The path for current must be electrically continuous.
    - This path must also be low impedance.
    - This path also must be capable of carrying the maximum fault current likely to be imposed.
  - The Earth is not permitted as an effective ground-fault current path.

Introduction

Chapter 1

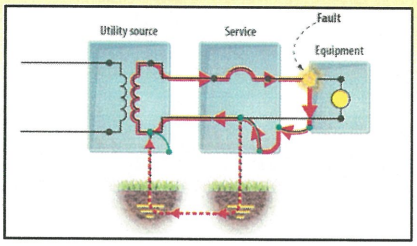
Normal Current Path



Introduction

Chapter 1

Ground-Fault Current Path



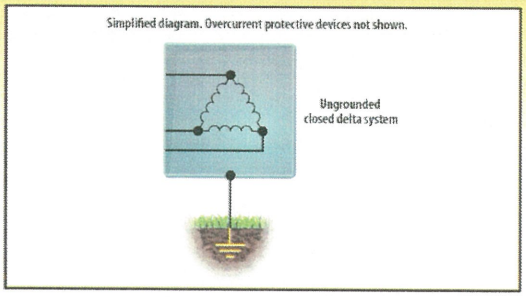
Introduction

Chapter 1

- Ungrounded Electrical Systems
  - Section 250.4(B) provides general performance requirements that apply to systems that are not grounded.
  - Ungrounded systems do not include a conductor that is intentionally grounded.
  - The ungrounded conductors operate without a solid voltage-to-ground reference.

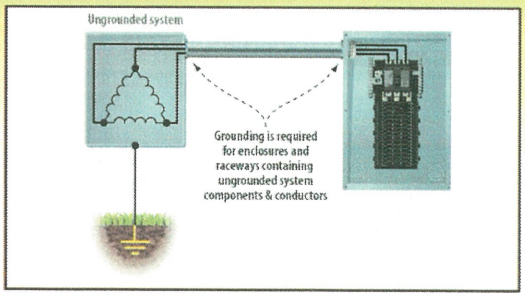
Introduction

Chapter 1



Introduction

Chapter 1



Introduction

Chapter 1

- Leakage Capacitance
  - When the supply conductors from ungrounded AC systems are installed in grounded metal raceways and enclosures, the effects of capacitance coupling are present, creating a potential (voltage) difference between them.
  - This potential difference can appear as voltage-to-ground readings but is the result of leakage capacitance.

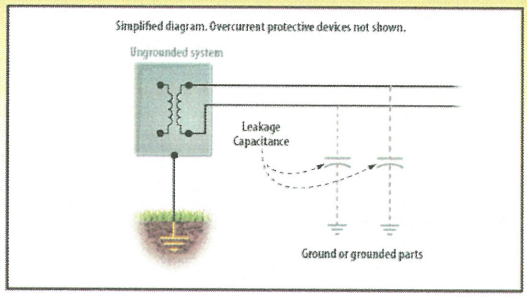
Introduction

Chapter 1

- Leakage Capacitance (continued)
  - An example of an ungrounded AC system is a 3-phase, 3-wire closed delta system.
  - The system shown in the next slide and in Figure 1-23 of the textbook is a single-phase ungrounded system, but leakage capacitance is present in either system.

Introduction

Chapter 1



Introduction

Chapter 1

- Bonding Requirements
  - Electrically conductive materials that are likely to become energized shall be connected (bonded) together and to the supply system grounded equipment in a manner that creates a low-impedance path for ground-fault current that is capable of carrying the maximum fault current likely to be imposed on it.

Introduction

Chapter 1

- Bonding Requirements (continued)
  - Just as for grounded systems, bonding is required for electrical equipment installed in an ungrounded system and for other conductive materials such as metal water piping and structural metal building frames.

Introduction

Chapter 1

- Article 100 Definition
  - Ground Fault Current Path. An electrically conductive path from the point of a ground fault on a wiring system through normally non–current-carrying conductors, grounded conductors, equipment, or the earth to the electrical supply source.

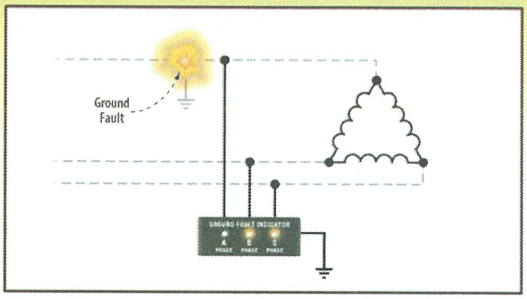
Introduction

Chapter 1

- Ground Detection Systems Required
  - The *NEC* requires a ground detection system so when a phase-to-ground fault event happens on an ungrounded system an indication is provided.
  - This alerts qualified persons of this condition so that they can fix the problem before a second phase-to-ground event on another phase develops.

Introduction

Chapter 1



Introduction

Chapter 1

- Summary
  - Electrical grounding and bonding are actions that happen simultaneously and provide essential safety for persons and property.
  - The performance criteria of these important electrical functions are simple, yet to many they seem complex.
  - Grounding involves connecting electrical systems and equipment to the Earth.

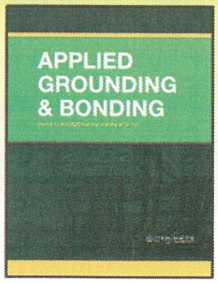
Introduction

Chapter 1

- Summary (continued)
  - Bonding simply means connecting equipment together electrically.
  - It is the process of establishing and maintaining effective continuity and conductive connections between metallic parts.
  - The electrical safety system is heavily reliant upon effective grounding and bonding of equipment and systems.

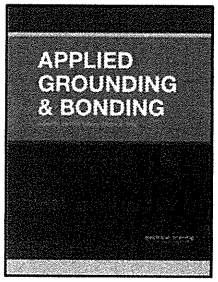
Grounding and Bonding

Introduction to Grounding



Grounding and Bonding

Circuit Basics and Overcurrent Protection



Circuit Basics and Overcurrent Protection

Chapter 2

- Introduction
  - Electrical circuits and systems operate normally when circuits are complete, intact, and without fault conditions.
  - If an electrical circuit is not complete, there can be no current present in that circuit.
  - This means both normal circuits and safety circuits of electrical systems are necessary for supplying utilization equipment.

Circuit Basics and Overcurrent Protection

Chapter 2

- Introduction (continued)
  - Electrical grounding and bonding should be thought of as electrical safety circuits.
  - The operation of overcurrent protective devices is directly related to the effective ground-fault current path installed as part of the overall electrical safety system.

Circuit Basics and Overcurrent Protection

Chapter 2

- Objectives
  - Understand the relationship between normal electrical circuits and grounding and bonding circuits in an electrical system.
  - Understand and apply circuit fundamentals to grounding and bonding and relate these concepts to effective overcurrent device operation.
  - Understand voltage, current, resistance, and impedance in electrical circuits and how to apply Ohm's Law to electrical circuits.

Circuit Basics and Overcurrent Protection

Chapter 2

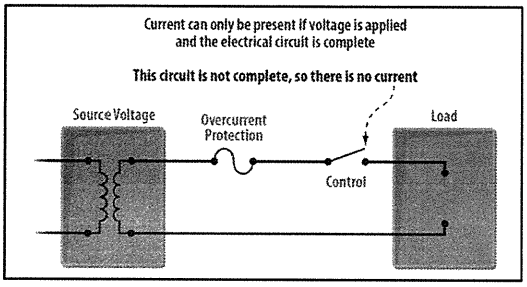
- Objectives (continued)
  - Know the importance of adequate equipment short-circuit current ratings and proper selection of circuit breakers and fuses with adequate interrupting ratings.
  - Understand the importance of conductor insulation integrity, equipment grounding conductor capacity, and not exceeding the maximum withstand ratings of electrical conductors.

Circuit Basics and Overcurrent Protection

Chapter 2

- Circuit Fundamentals
  - Electrical wiring systems include multiple circuits in the form of feeders and branch circuits.
  - The safety system is the grounding and bonding installed with branch circuits and feeders.
  - There is an important relationship between the grounding and bonding systems and overcurrent protection provided in the electric system.
  - Current is only present in complete circuits.

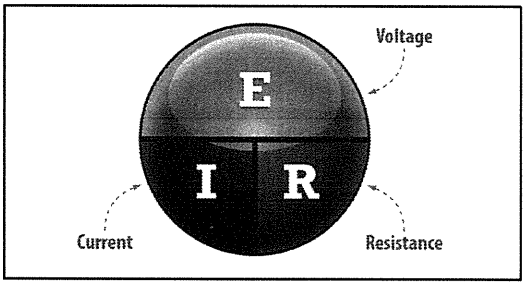
- Components of Electrical Circuits



- Ohm's Law
  - George Simon Ohm discovered the relationship between voltage, resistance, and current and developed Ohm's law.
    - A volt is the unit of electrical pressure or electromotive force in a circuit.
    - An ohm is the unit of electrical resistance in a circuit.
    - An ampere is the unit of measure for the current in a circuit.

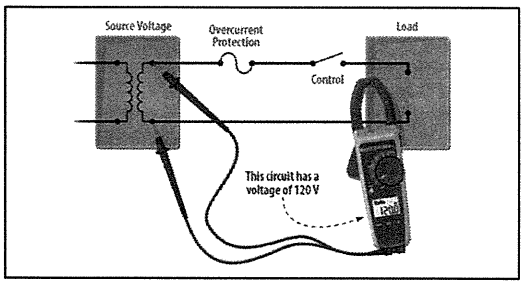
- Ohm's Law (continued)
  - Finding values of voltage, current, and resistance in a circuit is accomplished using two of the known values.

- Basic Ohm's Law



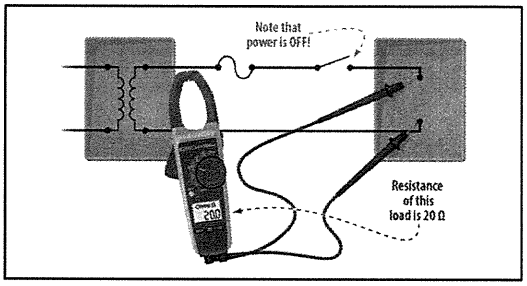
- Voltage (Electromotive Force)
  - The voltage of a circuit forces the electrons of a circuit through wires or other conductive circuit components.
  - The letter E used in Ohm's Law represents the voltage of the circuit.
  - The higher the voltage (electromotive force), the more easily current is forced through the circuit.
  - Voltage can be present in the circuit and no current will be present if the circuit is not completed or closed.

- Voltage in a Circuit



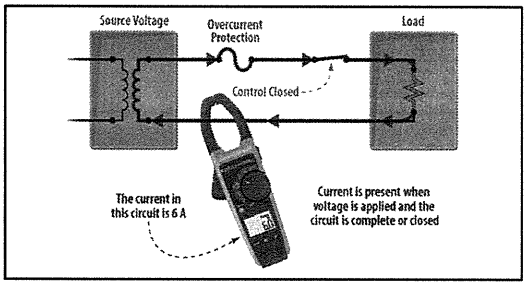
- Ohms (Resistance)
  - Electrical resistance in a circuit is the amount of resistance that allows 1 ampere of current when 1 volt is applied in the circuit.
  - The letter R is used to represent resistance in Ohm's Law.
  - Smaller conductors offer greater resistance in a circuit while larger conductors offer less resistance.
  - This basic analogy does not consider any load resistance present in the circuit.
  - Resistance is the opposition to current in a circuit.

- Resistance in a Circuit



- Amperes (Current)
  - The current in a circuit is represented in Ohm's Law by the letter I which stands for the intensity of current in the circuit.
  - The amount of current in a DC circuit is directly proportional to the voltage applied in the circuit, and the current is inversely proportional to the resistance in the circuit.

- Current in a Circuit



- Applying Ohm's Law

$$E = I \times R$$
$$(\text{Voltage} = \text{Current} \times \text{Resistance})$$
$$I = \frac{E}{R}\left(\text{Current} = \frac{\text{Voltage}}{\text{Resistance}}\right)$$
$$R = \frac{E}{I}\left(\text{Resistance} = \frac{\text{Voltage}}{\text{Current}}\right)$$

- Applying Ohm's Law

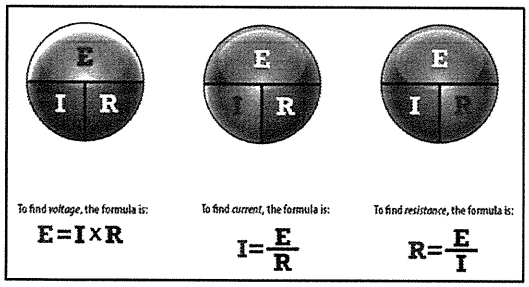
$$R = \frac{E}{I} = \frac{480\text{ V}}{40\text{ A}} = 12\ \Omega$$

$$I = \frac{E}{R} = \frac{120\text{ V}}{40\ \Omega} = 3\text{ A}$$

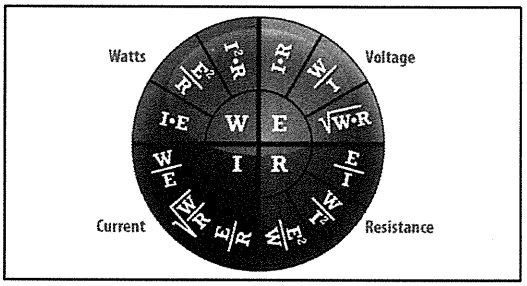
$$E = I \times R = 4\text{ A} \times 60\ \Omega = 240\text{ V}$$

Use of equations to find resistance, amps, and voltage.

- Applying Basic Ohm's Law



- Watts Wheel



- Solving for Power (Watts)

$$W = I \times E$$
$$(\text{Power} = \text{Current} \times \text{Voltage})$$
$$W = I^2R$$
$$(\text{Power} = \text{Current} \times \text{Current} \times \text{Resistance})$$
$$W = \frac{E^2}{R}$$
$$\left(\text{Power} = \text{Voltage} \times \frac{\text{Voltage}}{\text{Resistance}}\right)$$

- Solving for Amperes with Watt's Wheel

$$I = \frac{W}{E}$$
$$= \frac{5000\ \text{W}}{277\ \text{V}}$$
$$= 18.05\ \text{A}$$

- Opposition to Current in Circuits
  - The total opposition to current in a DC circuit is primarily resistance.
  - In an AC circuit, the total opposition to current is known as the impedance of the circuit.
  - The impedance of an AC circuit includes resistance, inductive reactance, and capacitive reactance.
  - The letter Z is used to represent impedance in electrical equations.

- Opposition of Current in an AC Circuit

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

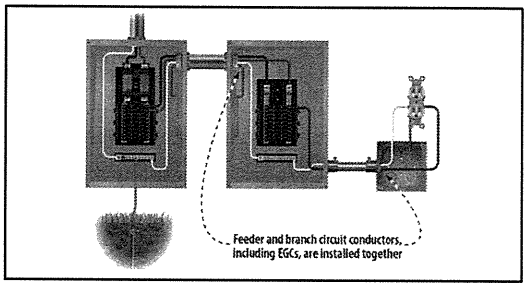
Where
Z = impedance
R = resistance
X_L = inductive reactance
X_C = capacitive reactance

Circuit Basics and Overcurrent Protection — Chapter 2

- Conductors of AC Circuits
  - Sections 300.3(B) and 250.134(2) of the *NEC* require all conductors of an AC circuit must be run together in the same raceway, cable, or trench.
  - Any grounded conductor or equipment grounding conductor must also be run with the AC circuit conductors.
  - This keeps the impedance as low as possible during normal operation and during a ground fault condition.

Circuit Basics and Overcurrent Protection — Chapter 2

- AC Circuit Conductors Together

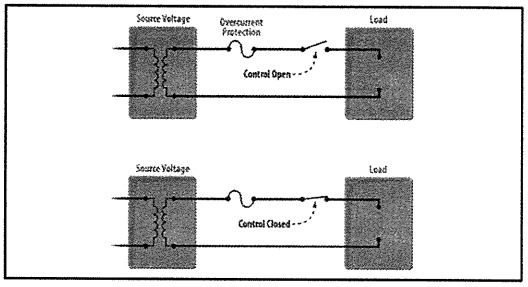


Circuit Basics and Overcurrent Protection — Chapter 2

- Normal and Fault Current in Circuits
  - Current is present only in circuits that are complete.
  - This concept applies to normal current and fault current in any circuit.
  - Grounding and bonding circuits are the protective circuits of electrical wiring systems.
  - Without complete and functional grounding and bonding in electrical circuits, the protective safety system is compromised.

Circuit Basics and Overcurrent Protection — Chapter 2

- No Current in Open Circuits

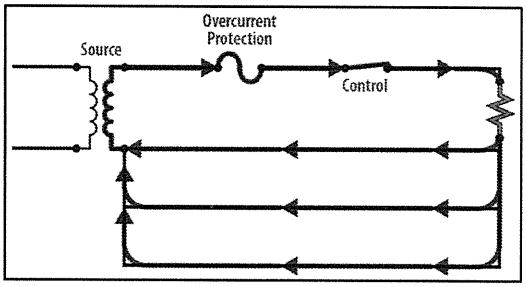


Circuit Basics and Overcurrent Protection — Chapter 2

- Normal and Fault Current in Circuits
  - Current will always return to the source.
  - Current will take all available paths to return to the source.
  - The current will divide over all available paths.
  - The amount of current in any path is related to the amount of impedance (opposition to current) in that particular path.

Circuit Basics and Overcurrent Protection — Chapter 2

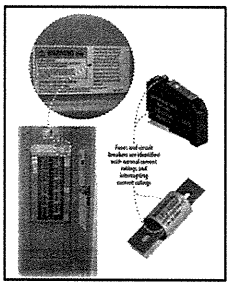
- Current Path(s) Circuits



- Overcurrent Protection Basics
  - A key feature of protecting persons and property from electrical hazards is proper application of overcurrent protection (fuses and breakers).
  - Overcurrent devices must have adequate normal current ratings and adequate interrupting current ratings.
  - A short circuit current rating is the amount of current a component or equipment can withstand without resulting in extensive damage to the equipment or system.
  - See *NEC* Sections 110.9 and 110.10.

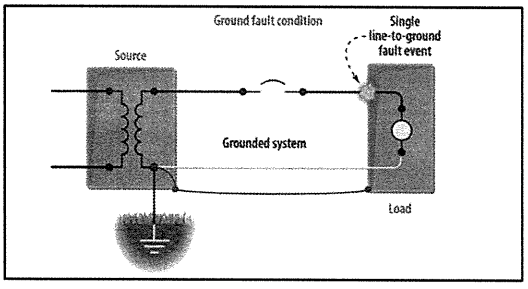
- Article 100 Definitions
  - Fault Current. The current delivered at a point on the system during a short-circuit condition.
  - Fault Current, Available (Available Fault Current). The largest amount of current capable of being delivered at a point on the system during a short-circuit condition.

- Interrupting Ratings

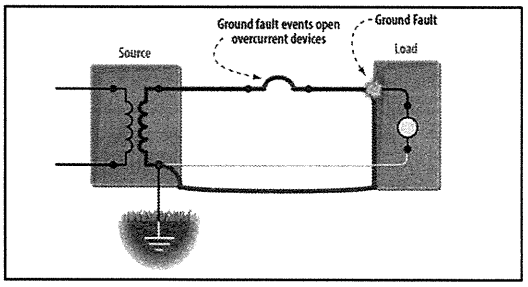


- Article 100 Definitions
  - Interrupting Rating. The highest current at rated voltage that a device is intended to interrupt under standard test conditions.
  - Ground Fault. An unintentional, electrically conductive connection between an ungrounded conductor of an electrical circuit and the normally non–current-carrying conductors, metallic enclosures, metallic raceways, metallic equipment, or earth.

- Ground-Fault Condition

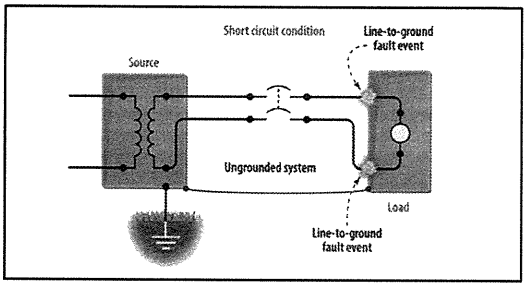


- Ground-Fault Condition

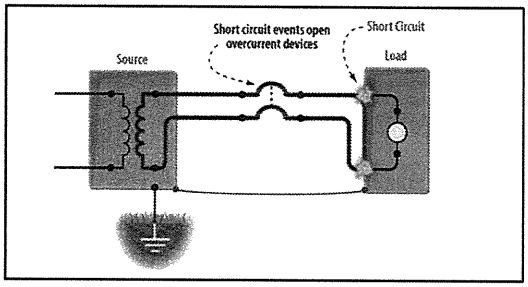


- Short Circuit
  - A short circuit is not defined in the *NEC* but can be described as an unintentional conducting connection between two or more ungrounded conductors of the circuit or between any ungrounded conductor and the grounded conductor of the circuit.
  - A ground fault is a type of short circuit condition except the short is to ground or grounded parts.
  - An overload (low-level overcurrent condition) is not considered a short circuit or ground fault.

- Line to Ground Fault and Short-Circuit Condition



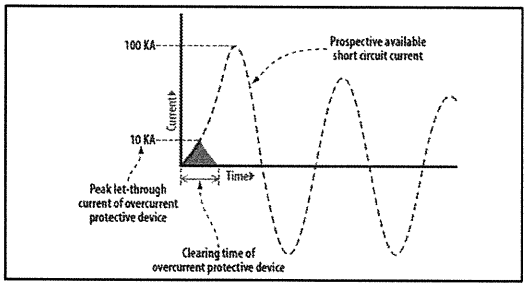
- Ground-Fault and Short-Circuit Condition



- Amperes Operate Overcurrent Devices
  - Overcurrent devices operate based on the level of current through the device.
  - The amount of current that will cause an overcurrent device to open is inversely proportional to the amount of time it takes.
  - In other words, the higher the current, the quicker the overcurrent device operates.
  - Annex C in the textbook provides information about calculating available fault current.

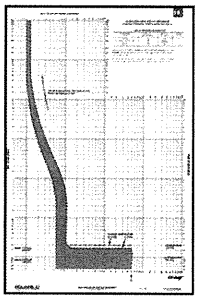
- Time and Current
  - Two concerns in electrical equipment and conductor overcurrent protection are how much current the equipment and conductors handle and for how long.
  - Manufacturers of circuit breakers and fuses provide important information related to their operating time and current characteristics.
  - The time/current curve charts indicate how long it takes for an overcurrent device to open.
  - The time is shown vertically in the graphs and the current is shown horizontally.

- Current and Time



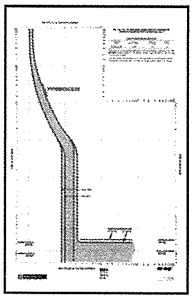
- Circuit Breaker Time-Current Graphs
  - For circuit breakers, the vertical line in the graph represents the instantaneous trip point.
  - The region to the left of this line is the overload region, and the region to the right is the short circuit (or instantaneous) region.
  - The width of the time current curve indicates the manufacturing tolerance; that is, the circuit breaker clears within that band.

- Time current graph for a 20-ampere circuit breaker.
- The time is on the left of the graph (vertical).
- The current level is across the bottom.
- For smaller breakers the instantaneous trip levels are reached sooner than larger breakers.



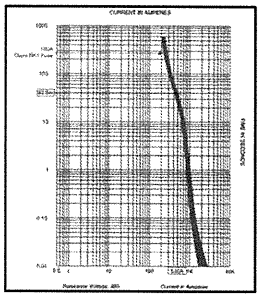
Courtesy of Schneider Electric Square D

- Time current graph for a 100-ampere circuit breaker.
- The time is on the left of the graph (vertical).
- The current level is across the bottom.
- The amount of time for the breaker to react is greater for larger breakers.



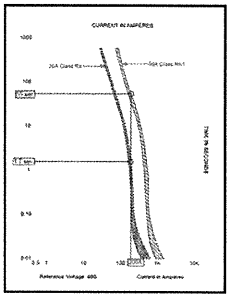
Courtesy of Schneider Electric Square D

- Fuse Time-Current Graphs
  - The operating characteristics of fuses differ slightly from those of circuit breakers.
  - In a fuse time current curve, the time is also shown on the vertical axis and the amount of current is provided along the horizontal axis.
  - A time-current curve for fuses is different in appearance specifically in the short circuit region due to the current-limiting ability of the fuse.



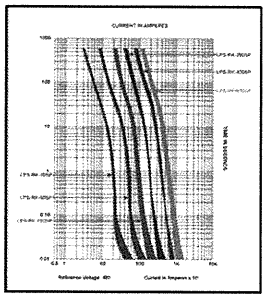
Courtesy of Eaton

- The time is on the left of the graph (vertical).
- The current level is across the bottom.
- For a Class RK1 fuse, a current of 200 amperes will open the 20 A fuse in 1.7 seconds and the 50 A fuse in 55 seconds.



Courtesy of Eaton

- The time is on the left of the graph (vertical).
- The current level is across the bottom.
- The fuse time current curves show various Class RK1 fuse ampere ratings that help determine the clearing times based on the levels of current.



Courtesy of Eaton

- Safety By Design
  - Overcurrent protection is required to protect conductors and equipment from extensive damage.
  - *NEC* 110.10 provides the requirement that addresses this concern.
  - Another method of achieving additional safety in electrical systems is to reduce let-through current so that incident energy is less during a short circuit or ground-fault event.
  - Current-limiting overcurrent devices can provide such protection.

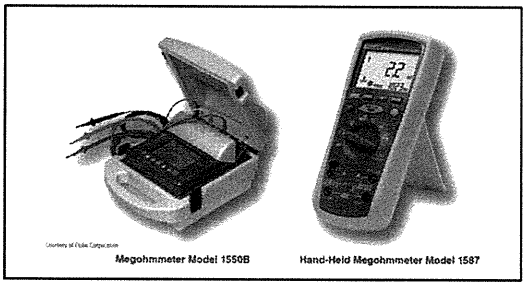
- Article 100 Definition (*NFPA 70E*)
  - Incident Energy. The amount of energy impressed on a surface, a certain distance from the source, generated during an electrical arc event. One of the units used to measure incident energy is calories per centimeter squared (cal/cm^2).

- 240.2 Definition
  - Current-Limiting Overcurrent Protective Device. A device that, when interrupting currents in its current-limiting range, reduces the current flowing in the faulted circuit to a magnitude substantially less than that obtainable in the same circuit if the device were replaced with a solid conductor having comparable impedance.
  - The definition also appears in Article 100 of *NFPA 70E*.

- Protecting Conductor Insulation
  - The *Code* requires conductors and completed wiring installations to be free from short circuits, ground faults, or any ground connections other than as required or permitted by the *NEC*. [*NEC* 110.7]
  - Conductor insulation prevents the flow of electricity between points of different potential in an electrical system.
  - Failure of the insulation system is one of the most common causes of problems in electrical installations, in both high-voltage and low-voltage systems.

- Protecting Conductor Insulation
  - Common causes of insulation failures are heat, moisture, dirt, and physical damage occurring during and after conductor installation.
  - Insulation can fail due to chemical effects, exposure to sunlight, and excessive voltage stresses.
  - Insulation integrity must be maintained during overcurrent conditions.
  - Test instruments (meg-ohm meters) are available for verifying conductor insulation integrity prior to energizing electrical circuits and equipment.

- Conductor Insulation Test Equipment



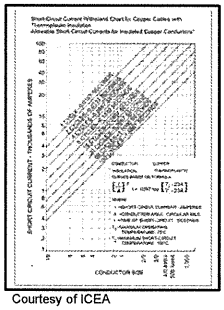
Megohmmeter Model 1550B Hand-Held Megohmmeter Model 1587

Courtesy of Fluke

- Protecting Conductor Insulation
  - The greater the overcurrent is, the less time a conductor can safely withstand the current.
  - A good set of guidelines addressing conductor insulation abilities has been established through engineering research by the Insulated Cable Engineers Association (ICEA).

- Protecting Conductor Insulation
  - The short circuit current, conductor cross-sectional area, and overcurrent protective devices in the circuit should be applied in a manner that does not exceed the maximum short circuit times in the ICEA chart.
  - Wire-type EGCs must be selected and applied in system designs in a manner that does not leave them vulnerable to high current levels for periods that exceed their withstand ratings.

- Conductor Withstand Ratings
- The ICEA Short-Circuit Current Withstand Chart provides information about the maximum current handling capabilities for various sizes of insulated conductors over a duration of time (cycles).
- This is based on the 5-second conductor withstand formulas developed by the ICEA.



Courtesy of ICEA

- Conductor Withstand Ratings
  - The ICEA demonstrated that for every 42.25 circular mils of area, an insulated conductor can safely carry 1 ampere for 5 seconds.
  - The measure of heat energy developed in a circuit during a short circuit or ground fault event is characterized in formulas as I^2t.
  - This formula is simply the current (I) squared multiplied by the time (t), in seconds.
  - Using Table 8 in Chapter 9 of the *NEC*, one can easily calculate the 5-second withstand rating of a conductor.

- Protecting Equipment Grounding Conductors
  - EGCs must be installed in systems within their withstand capabilities.
  - Design criteria must consider the size of wire-type EGCs, their withstand ratings, the magnitude of ground-fault currents, and the operating (time-current) characteristics of the overcurrent protective devices.
  - Protective devices that do not operate fast enough might leave EGCs vulnerable to severe damage during a ground-fault event.

Circuit Basics and Overcurrent Protection — Chapter 2

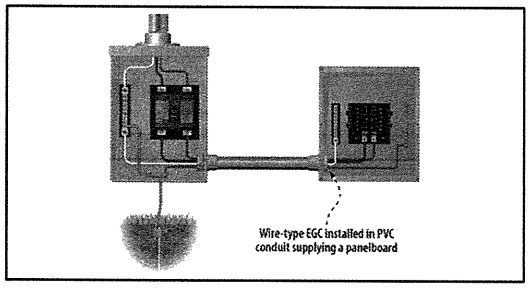
- Equipment Grounding Conductor Capacity
  - *NEC* Table 250.122 provides minimum sizes for wire-type equipment grounding conductors.
  - Sections 250.4(A)(5) and 250.4(B)(4) provide performance criteria for EGCs.
  - A mandatory note at the bottom of *NEC* Table 250.122 refers to those sections.

Circuit Basics and Overcurrent Protection — Chapter 2

- Equipment Grounding Conductor Capacity
  - The minimum sizes required for wire-type EGCs must be able to effectively perform during ground-fault conditions.
  - They must be able to withstand the fault current for the amount of time it takes the overcurrent device to open.
  - They must perform as an effective ground-fault current path to facilitate overcurrent device operation and not be damaged doing so.
  - See *NEC* 110.10, 250.4(A)(5) and 250.4(B)(4).

Circuit Basics and Overcurrent Protection — Chapter 2

- Conductor Withstand Ratings



Circuit Basics and Overcurrent Protection — Chapter 2

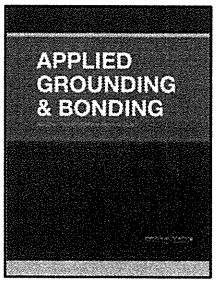
- Summary
  - For current to be present in a circuit, the circuit must be complete and current will always return to its source.
  - For an effective ground-fault current path to provide the intended protective function, electrical circuit characteristics must be carefully analyzed and applied in systems.

Circuit Basics and Overcurrent Protection — Chapter 2

- Summary (continued)
  - The total circuit impedance, overcurrent protective devices, component short circuit current ratings, and other circuit characteristics must be selected and coordinated so that the circuit protective devices can effectively respond and operate during a ground-fault or short circuit event.
  - Overcurrent devices must prevent extensive damage to the electrical equipment or conductors, including the EGCs.

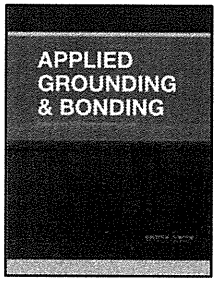
Grounding and Bonding

Circuit Basics and Overcurrent Protection



Grounding and Bonding

Using the *National Electrical Code®*



Using the National Electrical Code®

Chapter 3

- Introduction
  - The purpose of the *NEC* is the practical safeguarding of persons and property from hazards that arise from the use of electricity.
  - The *NEC* provides the minimum safety requirements, meaning that it is the least that must be done for compliance.

Using the National Electrical Code®

Chapter 3

- Introduction (continued)
  - An important part of electrical construction is proper application of *Code* rules to installations and systems.
  - It is important to understand all general *NEC* requirements and know when and how these rules are modified due to special occupancies, special or unique conditions, and special equipment.

Using the National Electrical Code®

Chapter 3

- Objectives
  - Understand the purpose of the *NEC* and the arrangement of Article 250.
  - Understand key defined grounding and bonding terms in Article 100.
  - Determine key requirements in the *NEC* that relate specifically to electrical grounding and bonding.

Using the National Electrical Code®

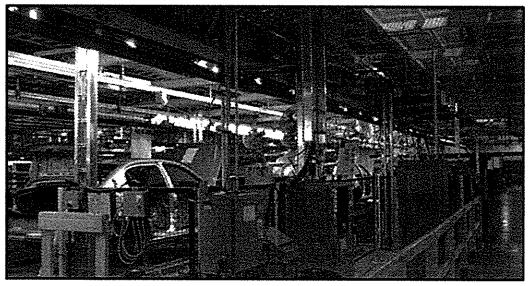
Chapter 3

- Objectives (continued)
  - Distinguish performance requirements from prescriptive requirements in the *NEC*.
  - Understand how Chapters 5 though 7 of the *NEC* can modify or amend the general requirements in the *NEC*.
  - Understand the *NEC* tables related to grounding and bonding conductor sizing.

Using the National Electrical Code®

Chapter 3

- Purpose of the *Code*



Using the National Electrical Code®

Chapter 3

- Building a Solid Foundation
  - *NEC* knowledge is essential to proper application of requirements in electrical design and installations.
  - This chapter reviews the arrangement of the *NEC* and provides guidelines on how to effectively and accurately apply requirements to grounding and bonding systems.

Using the National Electrical Code®

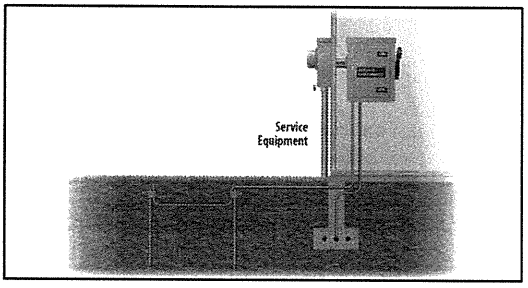
Chapter 3

- Building a Solid Foundation (continued)
  - A solid foundation of *NEC* knowledge is essential to understanding and meeting minimum safety rules related to electrical grounding and bonding.
  - The foundation of a grounding system is the grounding electrode system.

Using the National Electrical Code®

Chapter 3

- Foundation of Electrical Systems



Using the National Electrical Code®

Chapter 3

- *NEC* Arrangement and Application
  - Article 90 serves as the introduction and provides essential information about how *NEC* rules apply to electrical installations.
  - Chapters 1 through 4 of the *NEC have* general application and apply to all electrical installations.
  - Chapters 5, 6, and 7 include rules for special occupancies, special equipment, and other special conditions.
  - Chapters 5, 6, and 7 modify or amend the general requirements in Chapters 1 through 7.

Using the National Electrical Code®

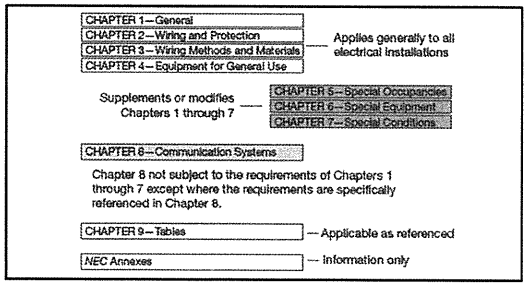
Chapter 3

- *NEC* Arrangement and Application (continued)
  - Chapter 8 is not subject to the general requirements of the other chapters except where the other rules are referenced from within Chapter 8.
  - Chapter 9 of the *NEC* includes tables that are used in applying the other requirements of the *Code*.
  - The annexes in the *NEC* are informative Annexes and are not mandatory requirements.

Using the National Electrical Code®

Chapter 3

- 90.3 Arrangement



Using the National Electrical Code®

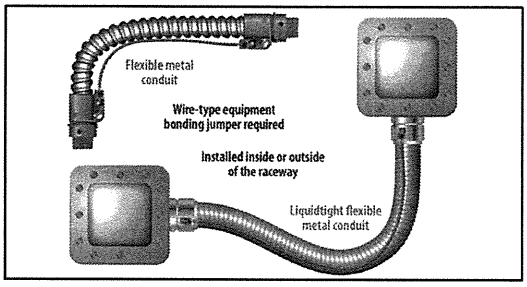
Chapter 3

- Sample Chapter 5 Modification
  - Section 250.118 list items (5) and (6) recognize listed flexible metal conduit and liquidtight flexible metal conduit as equipment grounding conductors under specific conditions without having to install a wire-type EGC or bonding jumper.
  - Section 501.30(B) specifically restricts flexible metal conduit and liquidtight flexible metal conduit from being used as an EGC and bonding means.

Using the National Electrical Code®

Chapter 3

- Bonding in Hazardous Locations



Using the National Electrical Code®

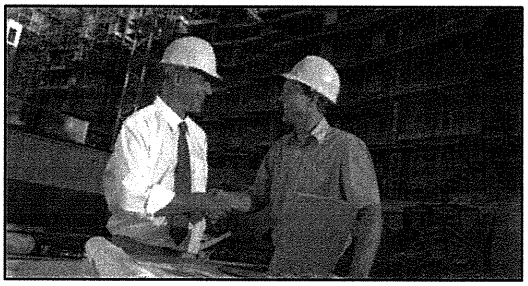
Chapter 3

- Enforcement and Approvals
  - The authority having jurisdiction (AHJ) is defined in Article 100 as a person or organization that is responsible for enforcing the *Code* and issuing approvals of installations and equipment covered by the *NEC*.
  - The AHJ (inspector) is also responsible for interpreting the requirements and granting special permission as provided in some of the rules.

Using the National Electrical Code®

Chapter 3

- Authority Having Jurisdiction



Using the National Electrical Code®

Chapter 3

- Requirements
  - To effectively apply the requirements in the *NEC, the* difference between mandatory requirements, permissive, and informational provisions must be understood.
  - The mandatory requirements in the *Code* are characterized by the use of *shall* or *shall not.*

    Example:

    Section 250.68(A) Accessibility. All mechanical elements used to terminate a grounding electrode conductor or bonding jumper to a grounding electrode shall be accessible.

Using the National Electrical Code®

Chapter 3

- Exceptions
  - Exceptions in the *NEC* modify only the rule they immediately follow unless stated differently in the exception.

Using the National Electrical Code®

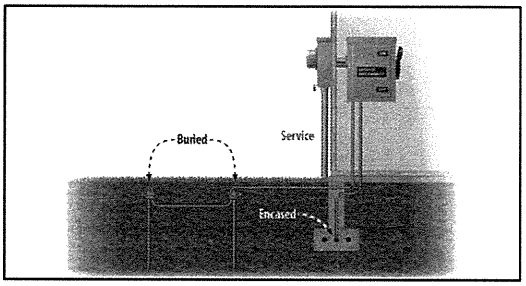
Chapter 3

- Exceptions (continued)
  - Example:
    - 250.68(A) Accessibility. All mechanical elements used to terminate a grounding electrode conductor or bonding jumper to a grounding electrode shall be accessible.
    - *Exception No. 1: An encased or buried connection to a concrete-encased, driven, or buried grounding electrode shall not be required to be accessible.*

Using the National Electrical Code®

Chapter 3

- Applying Exceptions to Rules



Using the National Electrical Code®

Chapter 3

- Mandatory Exceptions
  - There are also mandatory exceptions that use the terms *shall or shall not.*
  - An example of a mandatory exception follows Section 230.95.
  - Mandatory exceptions have to be followed if the installation is covered in the exception.

Using the National Electrical Code®

Chapter 3

- Explanatory Information
  - Explanatory material is provided in the form of informational notes.
  - The informational notes are for user guidance and are not enforceable as requirements.
  - Often, informational notes clarify the requirement that precedes the note.
  - Examples of informational notes are references to other standards, references to related sections of the *Code*, or information related to a rule.

Using the National Electrical Code®

Chapter 3

- Permissive *Code* Language
  - Permissive provisions in the *NEC* are characterized by the use of phrases such as *shall be permitted* or *shall not be required.*
  - Permissive rules are options or alternative methods of achieving equivalent safety; they are generally not requirements.
  - The qualifying feature of permissive rules often involves determination by the AHJ as indicated in Section 90.4.

Using the National Electrical Code®

Chapter 3

- Permissive *Code* Language (continued)
  - Informational notes should not be confused with notes to tables which are mandatory requirements.
  - Examples of mandatory notes that apply to tables can be found following Table 300.5 and Table 250.122.

- Notes to Tables

Table 250.122 Minimum Size Equipment Grounding Conductors for Grounding Raceway and Equipment (in part)

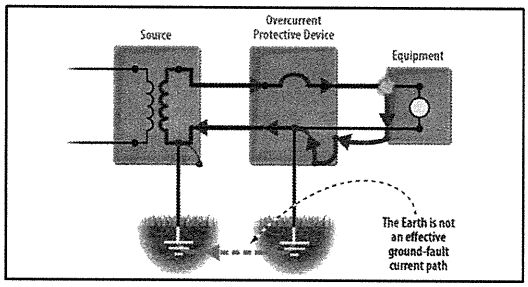
Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Conduit, etc., Not Exceeding (Amperes)	Size (AWG or kcmil)	
	Copper	Aluminum or Copper-Clad Aluminum*
1000	2/0	4/0
1200	3/0	250
1600	4/0	350
2000	250	400
2500	350	600
3000	400	600
4000	500	750
5000	700	1200
6000	800	1200

Note: Where necessary to comply with 250.4(A)(5) or 250.4(B)(4), the equipment grounding conductor shall be sized larger than given in this table.

* See installation restrictions in 250.120.

- Use of Defined Terms
  - Defined terms help clarify the meaning of a rule in which they appear.
  - Article 100 contains all defined words and terms related to grounding and bonding.
  - Section 250.2 no longer contains any definitions.
  - Examples of grounding and bonding words and terms are "grounded (grounding)", "bonded (bonding)" and the term "effective ground-fault current path."

- Effective Ground-Fault Current Path



- Use of Defined Terms
  - Defined terms help clarify the meaning of a rule in which the term appears.
  - To fully understand how the *NEC* applies to grounding and bonding systems, a clear method or language of communication has to be established.
  - Slang words and phrases mean different things to many.
  - Using the defined words and terms in the *NEC* promotes accurate, effective *NEC* application.

- *Code* Language of Communication
  - *Example 1 incorrect:*
    - A grounding conductor is required to be grounded to the equipment grounding terminal bar of a panelboard.
  - *Example 2 correct:*
    - The equipment grounding conductor (EGC) is required to be connected to the equipment grounding terminal bar of the panelboard.

- *Code-Making* Panel Responsibilities
  - In the 2020 edition of the *Code* there are 19 *NEC* technical "subcommittees" that are referred to as *Code-Making* panels.
  - *Code-Making Panel 5* is responsible for definitions of terms related to grounding and bonding and for Articles 200 and 250.

Using the National Electrical Code®

Chapter 3

- *NEC* Article 100
  - Article 100 in the *NEC provides* the definitions of common terms related to grounding and bonding.
  - Within the *NEC*, the definitions are usually presented in the simplest form.
  - The rule in which a defined term is used often indicates what is intended to be accomplished.
  - The intended meaning of a rule is supported by a definition(s) of the term(s) used in the rule.

Using the National Electrical Code®

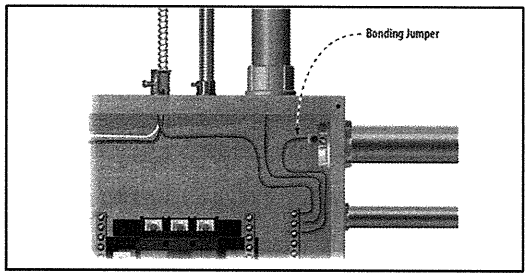
Chapter 3

- Article 100 Definitions
  - Bonded (Bonding). Connected to establish electrical continuity and conductivity.
  - Bonding Conductor or Jumper. A reliable conductor to ensure the required electrical conductivity between metal parts required to be electrically connected.
  - Bonding Jumper, Equipment. The connection between two or more portions of the equipment grounding conductor.

Using the National Electrical Code®

Chapter 3

- Bonding and Bonding Jumpers



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Chapter 3

- Equipment Bonding Jumper
  - An equipment bonding jumper is usually a short conductor that establishes a connection between two or more portions of an EGC.
  - For example, if an expansion, deflection-expansion, or deflection fitting is used across a structural steel expansion joint in a building, an equipment bonding jumper is often installed to ensure bonding across the special fitting that is designed to expand and contract as the building moves.

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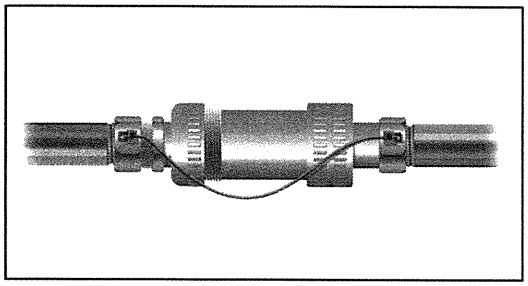
Chapter 3

- Equipment Bonding Jumpers



Using the National Electrical Code®

Chapter 3

- Article 100 Definitions
  - Bonding Jumper, Main. The connection between the grounded circuit conductor and the equipment grounding conductor at the service.
  - This definition clarifies that a main bonding jumper is installed only in the service disconnecting means enclosure.
  - Main bonding jumpers are made of copper or other corrosion-resistant material and can be a wire, bus, screw, or similar suitable conductor.

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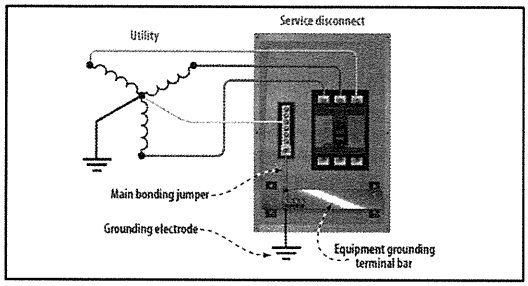
Chapter 3

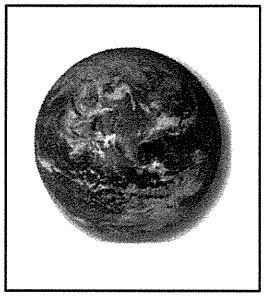
- Main Bonding Jumper



Using the National Electrical Code®

Chapter 3

- Article 100 Definition
  - Ground. The earth.
  - The term *ground* simply means the Earth.
  - When this term is used in the *NEC*, the planet Earth is what is implied.



Using the National Electrical Code®

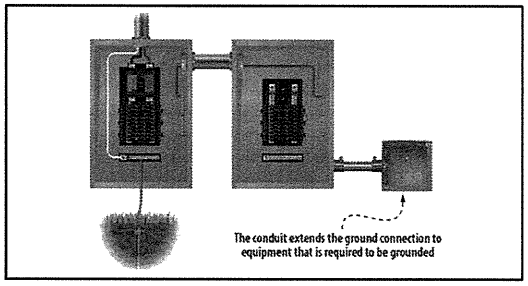
Chapter 3

- Article 100 Definitions
  - Grounded (Grounding). Connected (connecting) to ground or to a conductive body that extends the ground connection.
  - Grounded, Solidly. Connected to ground without inserting any resistor or impedance device.

Using the National Electrical Code®

Chapter 3

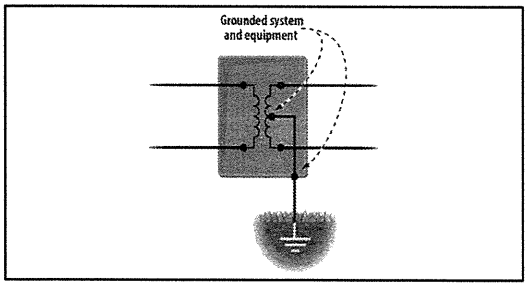
- Extending the Ground Connection



Using the National Electrical Code®

Chapter 3

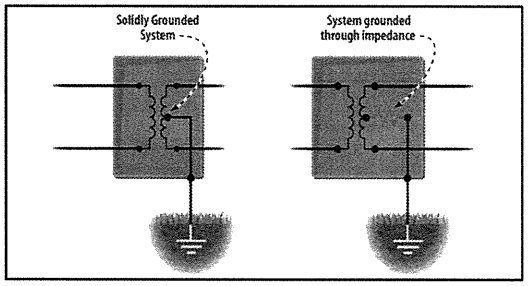
- Grounded System and Equipment



Using the National Electrical Code®

Chapter 3

- Solid and Impedance Grounding



Using the National Electrical Code®

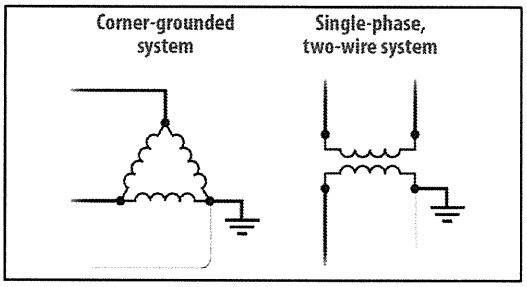
Chapter 3

- Article 100 Definitions
  - Grounded Conductor. A system or circuit conductor that is intentionally grounded.
  - Most neutral conductors are grounded, but not all grounded conductors are neutral conductors.
  - For example, a corner-grounded system has a grounded phase conductor that is not a neutral conductor and the system has no neutral point.
  - See the definitions of the terms *neutral conductor* and *neutral point* for additional information.

Using the National Electrical Code®

Chapter 3

- Grounded System and Equipment



Using the National Electrical Code®

Chapter 3

- Article 100 Definitions
  - Grounding Conductor, Equipment (EGC). The conductive path(s) that is part of a ground-fault path and connects normally non-current-carrying metal parts of equipment together and to the system grounded conductor or to the grounding electrode conductor, or both.
  - Informational Note No. 1: It is recognized that the equipment grounding conductor also performs bonding.
  - Informational Note No. 2: See 250.118 for a list of acceptable equipment grounding conductors.

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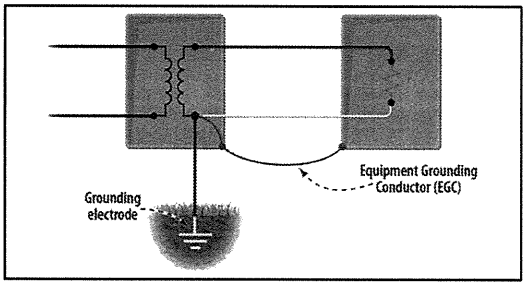
Chapter 3

- Equipment Grounding Conductor (EGC)



Using the National Electrical Code®

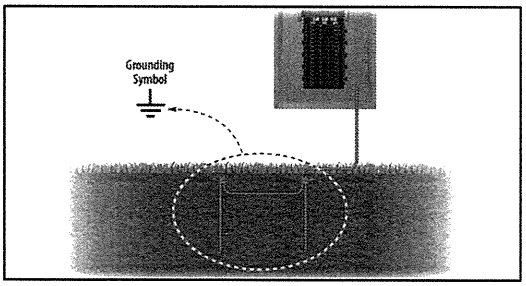
Chapter 3

- Article 100 Definitions
  - Grounding Electrode. A conducting object through which a direct connection to earth is established.
  - Grounding Electrode Conductor. A conductor used to connect the system grounded conductor or the equipment to a grounding electrode or to a point on the grounding electrode system.

Using the National Electrical Code®

Chapter 3

- Grounding Electrode



Using the National Electrical Code®

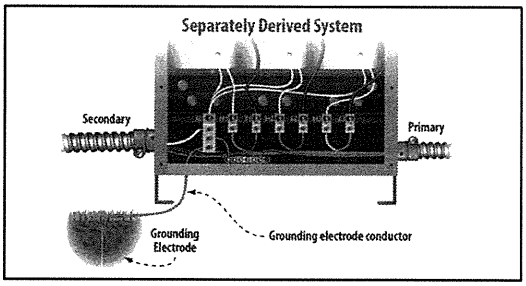
Chapter 3

- Article 100 Definition
  - Bonding Jumper, System. The connection between the grounded circuit conductor, and the supply-side bonding jumper, or the equipment grounding conductor, or both, at a separately derived system.

Using the National Electrical Code®

Chapter 3

- Grounding Electrode Conductor



Using the National Electrical Code®

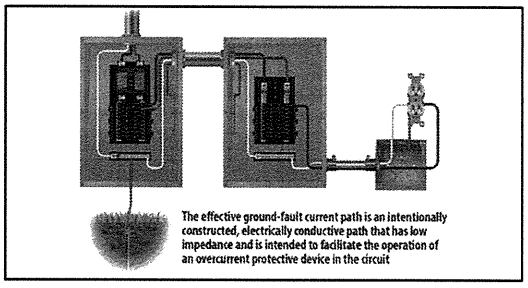
Chapter 3

- Article 100 Definition
  - Effective Ground-Fault Current Path. An intentionally constructed, low impedance electrically conductive path designed and intended to carry current during ground-fault conditions from the point of a ground fault on a wiring system to the electrical supply source and that facilitates the operation of the overcurrent protective device or ground-fault detectors on high-impedance grounded systems.

Using the National Electrical Code®

Chapter 3

- Effective Ground-Fault Current Path



Using the National Electrical Code®

Chapter 3

- Article 100 Definition
  - Ground-Fault Current Path. An electrically conductive path from the point of a ground fault on a wiring system through normally non– current-carrying conductors, grounded conductors, equipment, or the earth to the electrical supply source.

Using the National Electrical Code®

Chapter 3

- Article 100 Definition
  - Bonding Jumper, Supply-Side. The conductor installed on the supply side of a service or within a service equipment enclosure(s), or for a separately derived system, that ensures the required electrical conductivity between metal parts required to be electrically connected.

Using the National Electrical Code®

Chapter 3

- Article 200 Use and Identification of Grounded Conductors
  - Article 200 of the *NEC* covers use and identification of grounded conductors.
  - In general, grounded conductors are required to be identified using the colors white or gray.

Using the National Electrical Code®

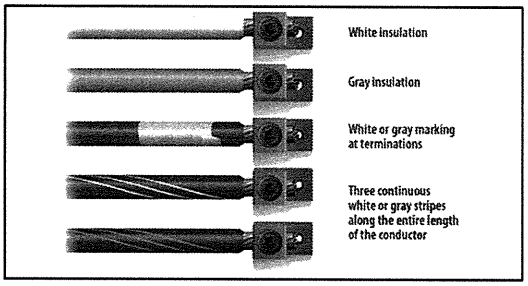
Chapter 3

- Article 200 Use and Identification of Grounded Conductors (continued)
  - Conductors in sizes 4 AWG and larger can be identified by a continuous white or gray insulation color or by three continuous white stripes along the entire length of a conductor insulation any color other than green; alternatively, a distinctive white or gray marking can be used at the conductor terminations.

Using the National Electrical Code®

Chapter 3

- Identification of Grounded Conductors



Using the National Electrical Code®

Chapter 3

- Article 250 Arrangement and Use
  - Part I—General
  - Part II—System Grounding
  - Part III—Grounding Electrode System and Grounding Electrode Conductor
  - Part IV—Enclosure, Raceway, and Service Cable Connections
  - Part V—Bonding

Using the National Electrical Code®

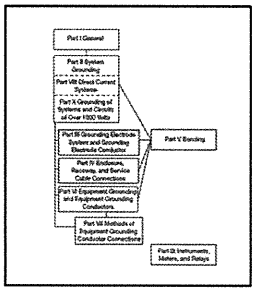
Chapter 3

- Article 250 – Arrangement and Use (continued)
  - Part VI—Equipment Grounding and Equipment Grounding Conductors
  - Part VII—Methods of Equipment Grounding Conductor Connections
  - Part VIII—Direct-Current Systems
  - Part IX—Instruments, Meters, and Relays
  - Part X—Grounding of Systems and Circuits of Over 1 kV

Using the National Electrical Code®

Chapter 3

- Figure 250.1
  - Figure 250.4 provides a convenient roadmap of Article 250.
  - This figure also indicates which parts cover grounding and which parts cover bonding and the relationship between the parts of the article.



Using the National Electrical Code®

Chapter 3

- *NEC* Table 250.66
  - Table 250.66 is titled *Grounding Electrode Conductor for Alternating-Current Systems*.
  - Table 250.66 is also used for sizing other conductors in the grounding and bonding scheme.
  - When used for sizing a grounding electrode conductor, the maximum size required is 3/0 copper or 250 kcmil aluminum or copper-clad aluminum conductor.

Using the National Electrical Code®

Chapter 3

- Table 250.66

Table 250.66 Grounding Electrode Conductor for Alternating-Current Systems (in part without notes)

Size of Largest Ungrounded Service-Entrance Conductor or Equivalent Area for Parallel Conductors (AWG/kcmil)		Size of Grounding Electrode Conductor (AWG/kcmil)	
Copper	Aluminum or Copper-Clad Aluminum	Copper	Aluminum or Copper-Clad Aluminum
2 or smaller	1/0 or smaller	8	6
1 or 1/0	2/0 or 3/0	6	4
2/0 or 3/0	4/0 or 250	4	2
Over 3/0 through 350	Over 250 through 500	2	1/0
Over 350 through 600	Over 500 through 900	1/0	3/0
Over 600 through 1100	Over 900 through 1750	2/0	4/0
Over 1100	Over 1750	3/0	250

Reproduction of NEC Table 250.66 (in part)

Using the National Electrical Code®

Chapter 3

- *NEC* Table 250.102(C)(1)
  - Table 250.102(C)(1) is used for sizing supply side bonding jumpers, grounded conductors (minimum), or main bonding jumpers/system bonding jumpers, the minimum sizes in the table apply.
  - There is one exception: When the size of the largest ungrounded service conductor or largest derived system phase conductor exceeds 1,100 kcmil copper or 1,750 kcmil aluminum, then the 12.5% rule must be applied.

Using the National Electrical Code®

Chapter 3

- *NEC* Table 250.102(C)(1) (continued)
  - The 12.5% rule does not apply to grounding electrode conductor sizing or sizing bonding jumpers of the grounding electrode system.

Using the National Electrical Code®

Chapter 3

Table 250.102(C)(1) Grounded Conductor, Main Bonding Jumper, System Bonding Jumper, and Supply-Side Bonding Jumper for Alternating Current Systems (in part without all notes)

Size of Largest Ungrounded Conductor or Equivalent Area for Parallel Conductors (AWG/kcmil)		Size of Grounded Conductor or Bonding Jumper* (AWG/kcmil)	
Copper	Aluminum or Copper-Clad Aluminum	Copper	Aluminum or Copper-Clad Aluminum
2 or smaller	1/0 or smaller	8	6
1 or 1/0	2/0 or 3/0	6	4
2/0 or 3/0	4/0 or 250	4	2
Over 3/0 through 350	Over 250 through 500	2	1/0
Over 350 through 600	Over 500 through 900	1/0	3/0
Over 600 through 1100	Over 900 through 1750	2/0	4/0
Over 1100	Over 1750	See Notes.	

Notes (in part):
1. If the ungrounded supply conductors are larger than 1100 kcmil copper or 1750 kcmil aluminum, the grounded conductor or bonding jumper shall have an area not less than 12 ½ percent of the area of the largest ungrounded supply conductor or...

Using the National Electrical Code®

Chapter 3

- *NEC* Table 250.122
  - Equipment Grounding Conductors for Grounding Raceway and Equipment.
  - The key feature of this table is the determination of minimum sizes of wire-type EGCs based on overcurrent device sizes.
  - Factors, such as voltage drop and high available fault currents, can affect the minimum sizes required for wire-type EGCs.

- *NEC* Table 250.122 (continued)
  - The note at the bottom of Table 250.122 provides a valuable reminder that designs must meet the minimum sizes in the table, but in some cases, the size needs to be larger to ensure that an effective path for ground-fault current is achieved.

- Examples Using *NEC* Table 250.122
  - A 1,000-ampere feeder requires a wire-type EGC not smaller than 2/0 AWG copper or 4/0 AWG aluminum or copper-clad aluminum.
  - An 80-ampere feeder requires a copper wire-type EGC not smaller than 8 AWG.
  - A 400-ampere feeder requires an aluminum wire-type EGC not smaller than 1 AWG.
  - Try other sizing examples to ensure effective use of this table.

- Table 250.122

Table 250.122 Minimum Size Equipment Grounding Conductors for Grounding Raceway and Equipment (in part)

Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Conduit, etc., Not Exceeding (Amperes)	Size (AWG or kcmil)	
	Copper	Aluminum or Copper-Clad Aluminum*
15	14	12
20	12	10
60	10	8
100	8	6
200	6	4
300	4	2
400	3	1

Note: Where necessary to comply with 250.4(A)(5) or 250.4(B)(4), the equipment grounding conductor shall be sized larger than given in this table.

* See installation restrictions in 250.120.

Reproduction of NEC Table 250.122 (in part)

- Table 250.122

Table 250.122 Minimum Size Equipment Grounding Conductors for Grounding Raceway and Equipment (in part)

Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Conduit, etc., Not Exceeding (Amperes)	Size (AWG or kcmil)	
	Copper	Aluminum or Copper-Clad Aluminum*
1000	2/0	4/0
1200	3/0	250
1600	4/0	350
2000	250	400
2500	350	600
3000	400	600
4000	500	750
5000	700	1200
6000	800	1200

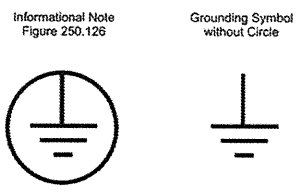
Note: Where necessary to comply with 250.4(A)(5) or 250.4(B)(4), the equipment grounding conductor shall be sized larger than given in this table.

* See installation restrictions in 250.120.

Reproduction of NEC Table 250.122 (in part)

- Grounding Symbols
  - The *NEC* includes a grounding symbol in the Informational Note Figures in Sections 250.126 and 406.9.
  - These figures are in the form of informational notes because it is understood that there are other methods of identifying equipment grounding terminals on devices such as receptacles and switches.
  - The grounding symbol is also often used on construction plans to indicate a grounding electrode system. The symbol should not be taken as an indication of a grounding rod-type electrode, but as a grounding electrode system.

- Informational Note Figure 250.126



Informational Note Figure 250.126 provides an example of a symbol used to identify the grounding termination point for an equipment grounding conductor.

Using the National Electrical Code®

Chapter 3

- Special Occupancies, Conditions, and Equipment
  - Section 90.3 indicates that Chapters 5, 6, and 7 of the *NEC* modify or supplement the general provisions in Chapters 1 through 7.
  - Often the grounding and bonding rules in these later chapters are more restrictive than the general requirements.
  - All general rules in Chapters 1 through 4 apply in addition to any modifications required by Chapters 5, 6, or 7.
  - The following provides examples of more restrictive grounding and bonding requirements in Chapters 5, 6, and 7.

Using the National Electrical Code®

Chapter 3

- Example Modification *NEC* Chapter 5
  - Sections 517.13(A) and (B) address branch circuits serving patient care spaces and requires two separate EGC paths in the form of (1) a suitable metallic raceway or cable armor and (2) a contained insulated copper EGC.
  - This more restrictive requirement provides two EGC paths for redundancy to ensure there is effective grounding and bonding and ensure overcurrent protective device operation in the event of a ground fault on circuits serving these locations.

Using the National Electrical Code®

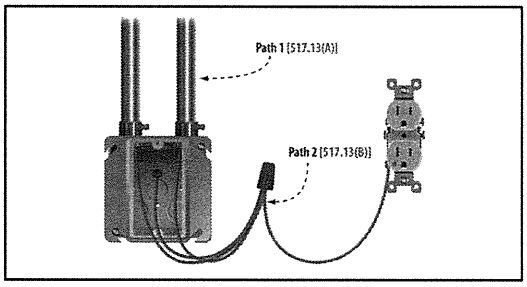
Chapter 3

- Example Modification *NEC* Chapter 5
  - This is a modification of the general equipment grounding requirements contained in Part VI of Article 250.
  - These modifications are more restrictive than the general rules and must be applied to branch circuit serving patient care spaces in health care facilities.

Using the National Electrical Code®

Chapter 3

- Two EGCs in Patient Care Spaces



Using the National Electrical Code®

Chapter 3

- Example Modification *NEC* Chapter 6
  - Section 600.7(B)(7) permits a bonding conductor larger than or equal to 14 AWG copper for neon transformers that are supplied by 20- or 30-ampere branch circuits.
  - Normally these bonding conductors would be based on the rating of the fuse or circuit breaker protecting the branch circuit supplying the equipment, which would be 12 AWG or 10 AWG copper, respectively.

Using the National Electrical Code®

Chapter 3

- Example Modification *NEC* Chapter 6
  - Transformer secondary circuits supplying the luminous tube(s) are high voltage resulting in secondary currents that are only in the milliamp range.
  - In addition to the low current on the secondary side, these circuits for sign and outline lighting systems are required to be equipped with transformers that provide secondary-circuit ground-fault protection.

Using the National Electrical Code®

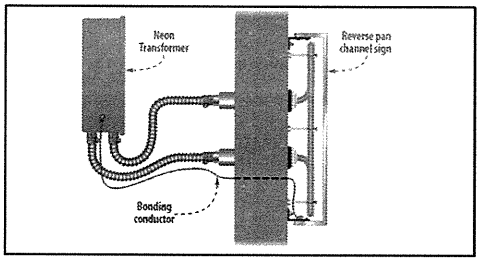
Chapter 3

- Example Modification *NEC* Chapter 6
  - The 14 AWG copper bonding conductor is required to keep conductive parts on the secondary side of such systems at or as close to ground (Earth) potential as possible.

Using the National Electrical Code®

Chapter 3

- Bonding Conductor for Neon Signs



Using the National Electrical Code®

Chapter 3

- Example Modification *NEC* Chapter 7
  - Section 770.100 requires noncurrent-carrying conductive members of optical fiber cables to be grounded by the methods specified in 770.100.
  - This modifies the general rules in Article 250.
  - Section 770.100 provides specific installation and sizing requirements for grounding and bonding systems for fiber optic installations.

Using the National Electrical Code®

Chapter 3

- Chapter 8 Communications Systems
  - Chapter 8 covers communications systems installations and equipment.
  - This *NEC* chapter is not subject to the requirements in Chapters 1 through 7 except where the rules are referenced from Chapter 8.

Using the National Electrical Code®

Chapter 3

- Chapter 8 Communications Systems
  - Section 800.100(A)(3) indicates that the bonding conductor or grounding electrode conductor for communications systems and equipment shall not be smaller than a 14 AWG copper conductor.
  - This is a modification to the normal use of Table 250.66 for sizing grounding electrode conductors for electrical services or separately derived systems.
  - Article 800 provides the specific sizing and installation rules for grounding electrode conductors installed for communications systems.

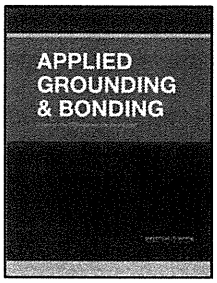
Using the National Electrical Code®

Chapter 3

- Summary
  - A thorough working knowledge of the *NEC* is essential to fully understand electrical grounding and bonding and how the rules apply to installations and systems.
  - It is equally important to understand defined terms related to grounding and bonding and the arrangement of *NEC* Article 250.
  - Grounding and bonding terms are all defined in Article 100 of the *NEC*.
  - Proper use and application of the *NEC* is essential for students of the *Code* and for seasoned professionals as well.

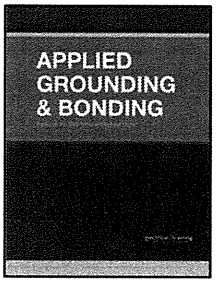
Grounding and Bonding

Using the *National Electrical Code®*



Grounding and Bonding

Grounding Electrodes and the Grounding Electrode System



Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Introduction
  - When a construction project begins, one of the first steps in the process is to install a footing and foundation system to support the building or structure.
  - Because footings effectively connect the building to the Earth and provide a foundation of support, they often provide excellent grounding electrodes for electrical services and for systems installed later during construction.
  - The *NEC*® requires that all grounding electrodes at each building or structure served to be connected together to form a grounding electrode system.

Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Objectives
  - Understand what constitutes a grounding electrode by definition and understand the purpose served by grounding electrodes.
  - Determine the requirements for a grounding electrode system at a building or structure supplied by electrical services or feeders.
  - Identify grounding electrodes that are inherent to the construction of a building or structure.

Grounding Electrodes and the Grounding Electrode System

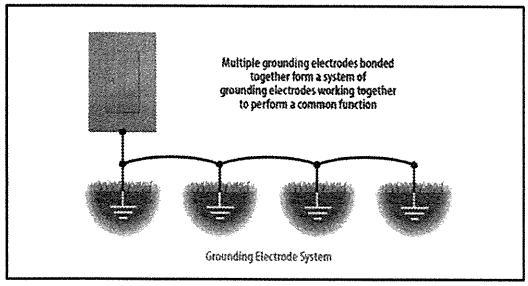
Chapter 4

- Objectives (continued)
  - Identify the types of grounding electrodes acceptable in accordance with the *NEC*.
  - Determine proper installation requirements for grounding electrodes that must be installed.
  - Understand the role of a lightning protection system in relation to a grounding electrode system for the power service or system of a building.

Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Grounding Electrode System



Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Electrical System Foundation
  - Buildings or structures must have a solid footing or foundation on which they are built.
  - As the footing and foundation along with various other underground systems are installed during the early phases of construction, grounding electrodes are often concurrently established because they are inherent to the construction process; they are part of the building.
  - Grounding electrodes connect electrical equipment and systems to ground (Earth).

Grounding Electrodes and the Grounding Electrode System

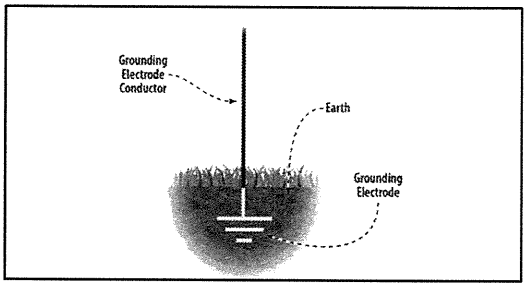
Chapter 4

- Article 100 Definition
  - Grounding Electrode. A conducting object through which a direct connection to Earth is established.
  - Key components of the definition are:
    - Must be a conductive object
    - Must establish a direct connection to Earth
  - A grounding electrode not only establishes the connection to ground, but it also maintains this connection.

Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Grounding Electrode



Grounding Electrodes and the Grounding Electrode System

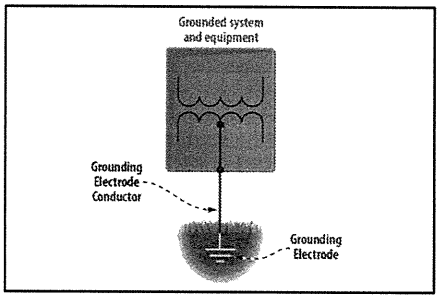
Chapter 4

- Purpose and Performance of Electrodes
  - The purpose of a grounding electrode is to function as the connection between grounded electrical systems and equipment and the Earth.
  - The objective is to establish and maintain a connection to Earth.
  - The *Code* does not provide details about the effectiveness or resistance of a grounding electrode or grounding electrode system, other than for a single rod, pipe, or plate electrode.
  - The *NEC* does not address end-of-life or life expectancy issues related to grounding electrodes.

Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Connection to Earth



Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Purpose and Performance of Electrodes
  - Grounding electrode connections to the Earth vary in resistance.
  - The connection to the Earth is better when the ground is moist or wet and tends to be less effective in dry or rock soil conditions.
  - The resistance between the Earth and a grounding electrode varies depending on geographical location; seasonal conditions; mineral content of the soil; and other influencing factors, such as ambient temperatures and Earth temperatures.

Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Purpose and Performance of Electrodes
  - Grounding electrode performance is essential as long as electrical services and systems are energized.
  - Grounding electrodes have little or no effect in facilitating overcurrent protective device operation.
  - The Earth is not suitable as an effective ground-fault current path.

Grounding Electrodes and the Grounding Electrode System

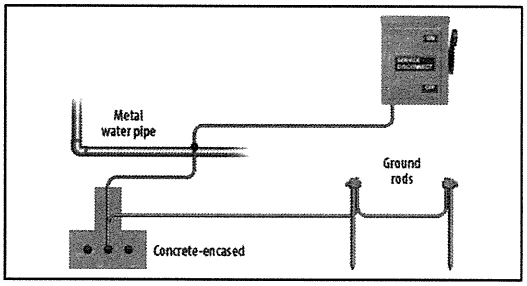
Chapter 4

- Grounding Electrode System Requirements
  - The *Code* provides rules that state which electrodes have to be used for grounding electrode systems.
  - Grounding electrodes and the grounding electrode system are covered in Part III of Article 250.
  - Section 250.50 outlines the general requirement that all grounding electrodes at a building or structure be used to form a grounding electrode system.
  - The grounding electrodes addressed in 250.52(A) include those that are inherent to building construction and electrodes that workers must install.

Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Grounding Electrode System



Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Grounding Electrode System Requirements
  - A system of multiple grounding electrodes performs better than a single grounding electrode.
  - All grounding electrodes at a building or structure must be interconnected to function as a system (network) of electrodes for the life of the building or structure.

Grounding Electrodes and the Grounding Electrode System

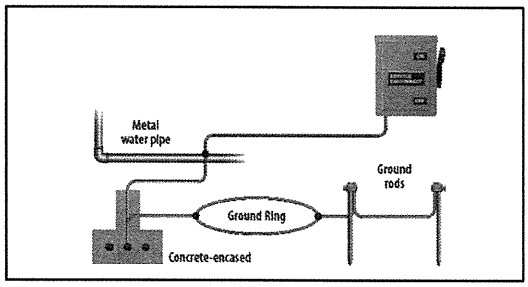
Chapter 4

- Establishing a Grounding Electrode System
  - There is a bonding requirement in 250.50 that is an important aspect of how the grounding electrode system should be developed on the construction project.
  - Section 250.53(C) addresses bonding jumpers or conductors that are used to connect grounding electrodes together to form a grounding electrode system.

Grounding Electrodes and the Grounding Electrode System

Chapter 4

- System of Electrodes



Grounding Electrodes and the Grounding Electrode System

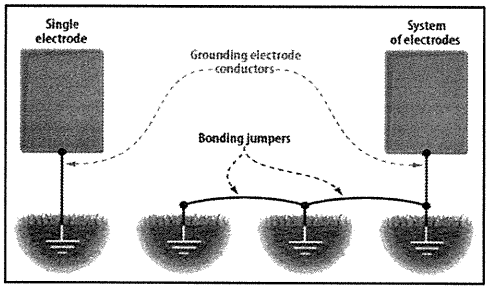
Chapter 4

- Establishing a Grounding Electrode System
  - The bonding jumpers used to form a grounding electrode system must meet the installation requirements in 250.64 and must be sized using 250.66.
  - The connections must meet the rules for grounding electrode conductor connections in 250.70.

Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Bonding Electrodes Together



Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Mandatory Grounding Electrodes
  - The *NEC* offers no option to choose among the grounding electrodes for convenience or any other reason—if the electrodes are present, they must be used in the system.
  - Where there are no grounding electrodes inherent to the construction of a building and the building is supplied with electrical power, a grounding electrode must be installed.
  - There are a few choices for installing a grounding electrode such as rod, pipe, or plate electrodes; ground rings; or other listed electrodes.

Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Types of Grounding Electrodes
  - The types of grounding electrodes recognized in the *NEC* are provided in 250.52(A).
  - This section provides the details and descriptions of each grounding electrode recognized for use.
  - The list of grounding electrodes in 250.52(A) provides guidance for installers as to the electrode content for the entire grounding electrode system.
  - Specific installation requirements for grounding electrodes are provided in 250.53.

Grounding Electrodes and the Grounding Electrode System

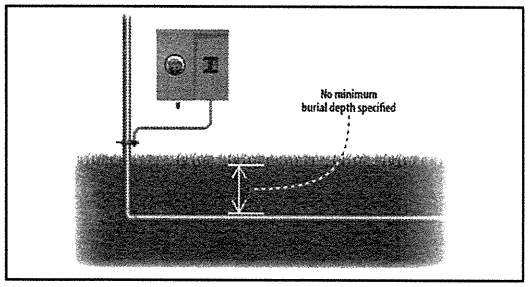
Chapter 4

- Underground Water Pipe Electrodes
  - The underground metal water pipe electrode is described in 250.52(A)(1).
  - A metal water pipe electrode must have a minimum of 10 feet of metal underground water piping in direct contact with the Earth.
  - No burial depth is required in this description of a metal water pipe electrode, only that direct contact with the earth is established.

Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Water Pipe Electrode



Grounding Electrodes and the Grounding Electrode System

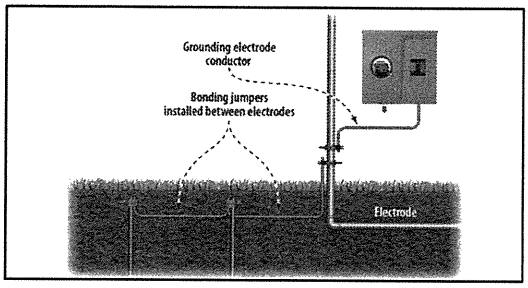
Chapter 4

- Underground Water Pipe Electrodes
  - The *Code* includes a requirement for any metal water pipe electrode to be supplemented by another grounding electrode.
  - The idea is to have a backup in case the original water pipe electrode were to be removed or replaced with a nonmetallic pipe, thus eliminating the grounding connection for electrical services and systems at the building or structure served.
  - The supplemental electrode can be any of those provided in 250.52(A)(2) through (8) but is often a ground rod(s).

Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Supplemental Grounding Electrode(s)



Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Underground Water Pipe Electrodes
  - The connection of a supplemental grounding electrode for a metal underground water pipe electrode must generally be made to one of the following:
    - A grounding electrode conductor
    - A grounded service conductor
    - A nonflexible grounded service raceway
    - Any grounded service enclosure
    - As provided in 250.32(B)

Grounding Electrodes and the Grounding Electrode System

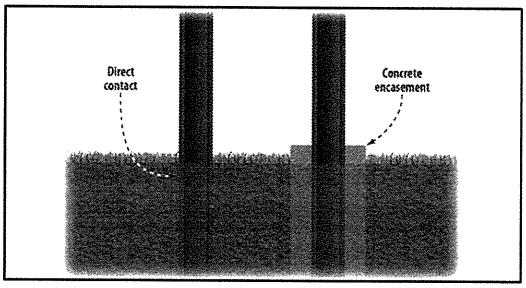
Chapter 4

- Metal In-Ground Support Structures
  - Section 250.52(A)(2) indicates that a metal in-ground support structure must meet specific criteria to qualify as a grounding electrode as follows:
    - At least one metal in-ground support structure that is in direct contact with the Earth for 10 feet or more, with or without concrete encasement.

Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Metal In-Ground Support Structure Electrode(s)



Grounding Electrodes and the Grounding Electrode System

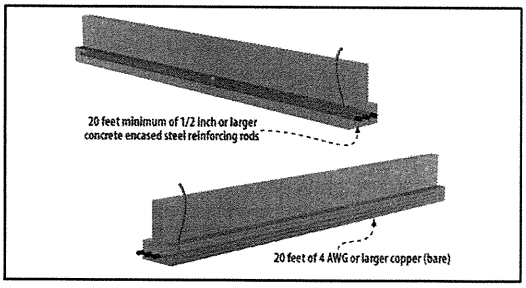
Chapter 4

- Concrete-Encased Electrodes
  - Concrete-encased electrodes are described in 250.52(A)(3).
  - If multiple separate concrete-encased electrodes are present, 250.50 requires at least one concrete-encased electrode, described in 250.52(A)(3), be included in the grounding electrode system for buildings or structures.
  - Concrete-encased electrodes can be installed vertically or horizontally as long as a minimum of 20 feet is in contact with the earth.

Grounding Electrodes and the Grounding Electrode System

Chapter 4

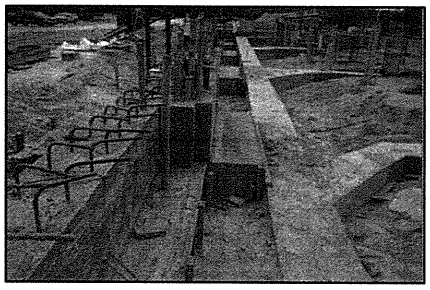
- Concrete-Encased Electrode(s)



- Concrete-Encased Electrodes
  - Concrete-encased electrodes are bare or zinc galvanized or other electrically conductive coated steel reinforcing bars or rods of not less than ½ in. in diameter, installed in one continuous 20-foot length, or if in multiple pieces connected together by the usual steel tie wires, exothermic welding, welding, or other effective means to create a 20-foot or greater length.

- Concrete-Encased Electrodes
  - A concrete-encased electrode can also be constructed using 20 feet or more of bare copper not smaller than 4 AWG.
  - Note that the 20 feet of conductive rods or bare wire used in a concrete-encased electrode only establishes the connection to the concrete.

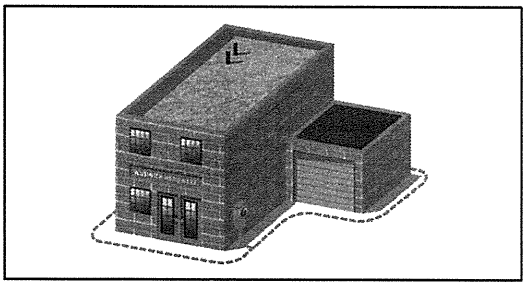
- Concrete-Encased Electrode(s)



- Concrete-Encased Electrodes
  - The concrete-encased electrode has proven that it offers optimal performance and longevity.
  - The footing or foundation of any building will typically be present as long as the building is.
  - Annex A of the textbook provides information about Herbert G. Ufer and how this work and his finding evolved into the *NEC* requirements for concrete-encased electrodes.

- Ground Ring Electrodes
  - Ground ring electrodes are described in 250.52(A)(4).
  - The ground ring electrodes are not inherent in the construction of a building; they must be installed.
  - A ground ring electrode must circle the entire building or structure and be not less than 20 feet long.
  - The minimum size for a ground ring electrode is 2 AWG copper.

- Ground Ring Electrode(s)



Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Rod and Pipe Electrodes
  - Rod and pipe electrodes are described in 250.52(A)(5) and are required to be at least 8 feet in length.
  - Pipe or conduit used as grounding electrodes must not be smaller than metric designator 21 (trade size ¾).
  - If the electrode is made of steel, it must have an outer surface that is galvanized or otherwise metal coated for corrosion protection.

Grounding Electrodes and the Grounding Electrode System

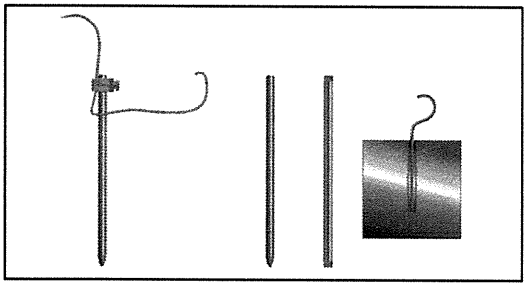
Chapter 4

- Rod and Pipe Electrodes (continued)
  - Stainless steel grounding electrodes and copper- or zinc-coated steel electrodes have to be at least 15.87 mm (⅝ inch) in diameter, unless they are listed by a qualified electrical testing laboratory and are sized not less than 12.70 mm (½ inch) in diameter.

Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Rod, Pipe, and Plate Electrode(s)



Grounding Electrodes and the Grounding Electrode System

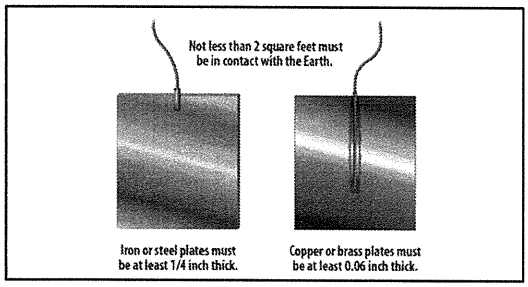
Chapter 4

- Plate Electrodes
  - Plate electrodes are described in 250.52(A)(7).
  - A plate electrode must have not less than 2 square feet of surface contact between the plate and the soil. A 1-foot square plate with two sides in contact with the Earth accomplishes this.
  - Plate electrodes made of bare or conductively coated iron or steel must be at least ¼ inch in thickness.
  - Plate electrodes of nonferrous metal such as copper or brass must be at least 0.06 inch in thickness.

Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Plate Electrode(s)



Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Other Electrodes
  - The *Code* recognizes local metal underground systems or structures as grounding electrodes in 250.52(A)(8).
  - Examples of these types of electrodes are metal piping systems, conductive underground tanks, and underground metal well casings that are not bonded to a metal water pipe.
  - The underground metal system or structure must meet the criteria for a grounding electrode and establish as direct connection to Earth.
  - Note that anti-corrosion coatings can prevent direct contact.

Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Grounding Electrode Installations
  - Section 250.53 provides grounding electrode installation rules that apply to those electrodes that are installed.
  - Electrodes inherent to constructed buildings or structures are established through the construction of the building or structure.
  - Electrodes that are installed include rods, pipes, plates, ground rings, and other listed electrodes.

Grounding Electrodes and the Grounding Electrode System

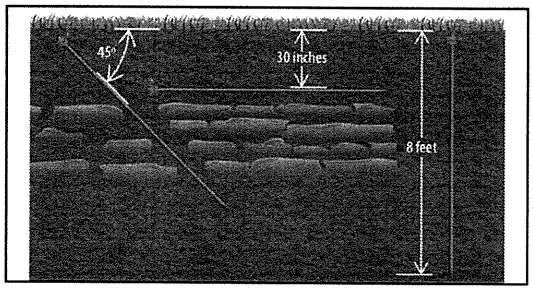
Chapter 4

- Rod, Pipe and Plate Installation
  - Rod, pipe and plate electrode installation is covered in 250.53(A).
  - A rod, pipe, or plate electrode must be supplemented by an additional electrode of any type specified in 250.52(A)(2) through (A)(8).
  - An exception permits using a single rod, pipe, or plate grounding electrode when the single electrode has a resistance to Earth of 25 ohms or less.
  - The resistance of a single rod, pipe, or plate electrode can be determined through earth resistance testing.

Grounding Electrodes and the Grounding Electrode System

Chapter 4

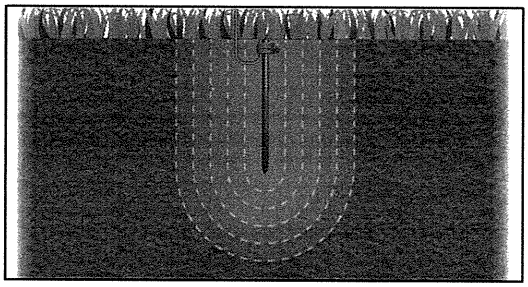
- Rod or Pipe Electrode Installation



Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Soil Resistivity



Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Soil Resistivity
  - The overall resistivity has a lot to do with the connection to the Earth.
  - Resistivity values differ from location to location.
  - In some areas of the world, the soil is rich with mineral content and stays relatively moist throughout the year, keeping the resistivity values low.
  - This provides for low resistivity values between the grounding electrode and the surrounding Earth.

Grounding Electrodes and the Grounding Electrode System

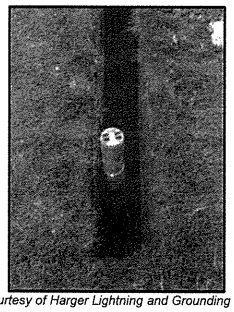
Chapter 4

- Soil Resistivity
  - One common solution is to increase the size or length of the grounding electrode.
  - Rod or pipe electrodes can be installed deeper into the Earth, which tends to lower the resistance of the grounding electrode connection to the Earth.
  - Special grounding electrode couplings are available for lengthening rod-type electrodes.
  - Installing multiple grounding electrodes is another effective method of lowering the resistance in the grounding electrode connection to Earth.

Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Treating the Soil
  - Another effective method for lowering the Earth resistance is to treat the soil with suitable chemicals.
  - Special listed chemical electrodes are available for this use.



Courtesy of Harger Lightning and Grounding

Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Earth Resistance Testing
  - Earth resistance testing applies the basic principles of Ohm's Law.
  - Ground resistance can be measured using separate voltage supply, a voltage meter, and an ammeter.
  - There are instruments and equipment available that provide electrode-testing functions in a single unit.

Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Earth Resistance Testing
  - One common method of Earth resistance testing is the three-point method, sometimes called the "fall-of-potential" or three-terminal grounding resistance testing method.
  - This method uses two test electrodes in addition to the electrode being tested.
  - This test method is also commonly referred to as the 62% test method.
  - The first step is to ensure that the electrode being tested is not connected to the building electrode system.

Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Ground Resistance Testing
  - One test electrode should be installed approximately 100 feet from the electrode under test.
  - The second test electrode should be installed approximately 62 feet from the electrode under test.
  - The two test electrodes should be in line with the electrode under test.
  - The test leads of the resistance tester need to be connected to the grounding electrode under test and the other temporary testing electrodes.

Grounding Electrodes and the Grounding Electrode System

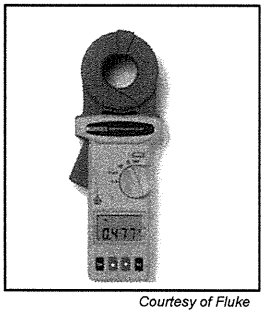
Chapter 4

- Ground Resistance Testing
  - The Earth resistance reading should be measured and recorded.
  - Then the test electrode should be moved in the middle one way or the other in 10-foot increments until the resistivity values are basically the same.
  - This means the plateau area of the test has been determined.
  - Always follow the specific instructions provided by the test instrument manufacturer.

Grounding Electrodes and the Grounding Electrode System

Chapter 4

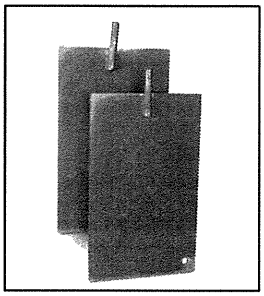
- Earth Resistance Testing
  - There are clamp-on test instruments that can provide ground resistance readings.
  - These instruments incorporate a transmitter and receiver and are designed to measure circuit current, resistance, and leakage current.



Courtesy of Fluke

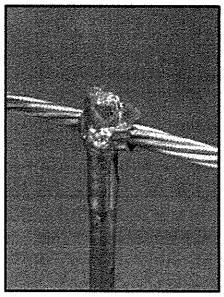
- Plate Installation
  - When installing plate electrodes, the installation has to provide a depth of not less than 2½ feet.
  - The connection between the plate and the grounding electrode conductor will have to be buried in the soil, which drives the requirement that the connection means be listed as suitable for direct burial applications.
  - The connection means also must be compatible with the plate metal and the grounding electrode conductor.
  - Some plate electrodes are available with a lead already connected by means of exothermic welding.

- Plate Electrode Connections
  - Exothermic welding connections are often used to connect grounding electrode conductors to plate electrodes.
  - Other types of connections should be listed for direct burial applications.



Courtesy of ABB

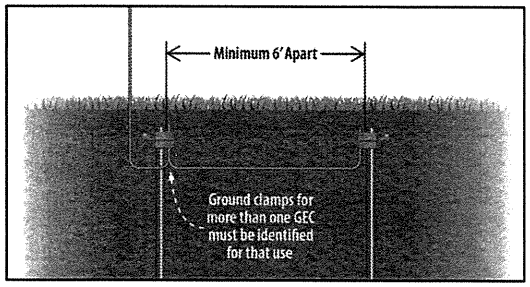
- Exothermic Welding Connections
- Grounding electrode conductor connections to a rod, pipe, or plate electrode is by the exothermic welding process.
- The welding process fuses two metals together to become one electrically providing an effective electrical connection.
- Follow the manufacturer's installation instructions and use protective equipment for safety.



Courtesy of ERICO International Corp.

- Electrode Spacing Requirements
  - If rod, pipe, or plate electrodes are installed, each electrode must be spaced a minimum 6 feet from another electrode of another grounding electrode system.
  - The purpose of the spacing requirement is to reduce the effects of overlapping spheres of influence associated with each electrode.
  - The paralleling efficiency of rods is increased by spacing them twice the length of the longest rod as indicated in the informational note to 250.53(A)(3).
  - This is not an *NEC* requirement.

- Spacing Between Electrodes

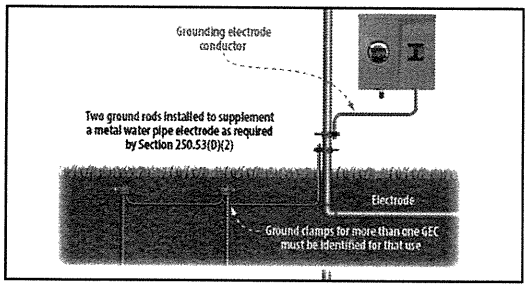


- Supplementing Water Pipe Electrodes
  - Section 250.53(D) indicates that metal underground water pipe electrodes be supplemented by an additional electrode of a type specified in 250.52(A)(2) through (A)(8).
  - A common practice in the field is to install a ground rod to serve as the required supplemental electrode.
  - When the supplemental electrode is a rod, pipe, or plate type, the installation has to meet the provisions in 250.53(A), meaning two such electrodes have to be installed unless a single electrode has a resistance of 25 ohms or less.

Grounding Electrodes and the Grounding Electrode System

Chapter 4

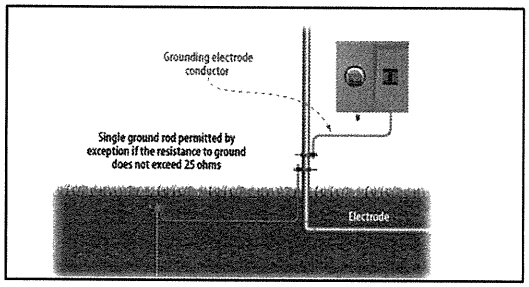
- Supplemental Electrode(s)



Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Supplemental Electrode(s)



Grounding Electrodes and the Grounding Electrode System

Chapter 4

- Auxiliary Grounding Electrodes
  - Auxiliary electrodes are those that are installed by choice and not to meet a requirement in the *NEC.*
  - Auxiliary grounding electrodes are sometimes specified by electrical equipment manufacturers, electrical designers, and facility owners.
  - It should be understood that the auxiliary grounding electrode is a connection to the Earth that is usually in close proximity to the equipment it supplements.
  - Section 250.54 addresses auxiliary grounding electrodes.

Grounding Electrodes and the Grounding Electrode System

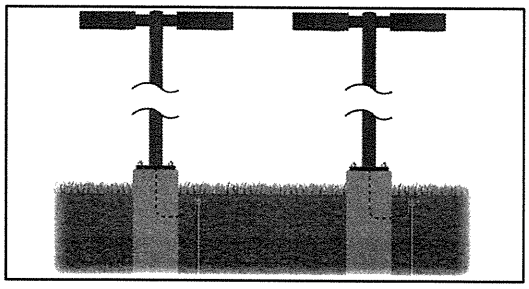
Chapter 4

- Auxiliary Grounding Electrodes
  - An important aspect of the auxiliary grounding electrode installation is that it is connected to equipment that is also connected to an equipment grounding conductor (EGC).
  - A good example of commonly installed auxiliary electrodes is when grounding electrodes are installed at lighting pole bases in parking lots.

Grounding Electrodes and the Grounding Electrode System

Chapter 4

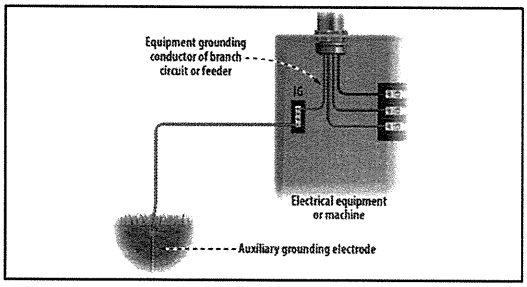
- Auxiliary Grounding Electrode(s)



Grounding Electrodes and the Grounding Electrode System

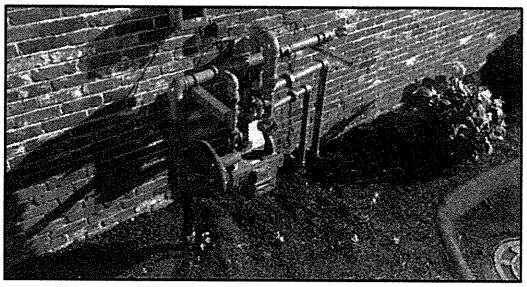
Chapter 4

- Auxiliary Grounding Electrode(s)



- Not Permitted as Grounding Electrodes
  - Some conductive materials are not compatible with the Earth and are vulnerable to corrosion and deterioration.
  - Section 250.52(B) provides restrictions for using aluminum materials and metal gas piping systems as grounding electrodes.
  - Metal gas piping systems are required to be bonded in accordance to 250.104(B), where likely to become energized.

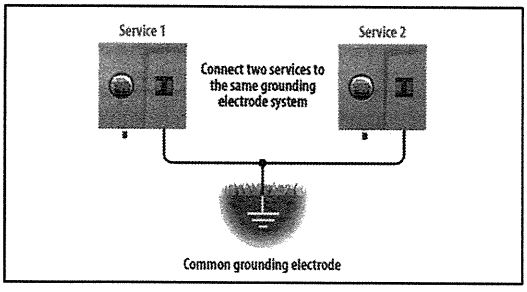
- Not Permitted as Electrode(s)



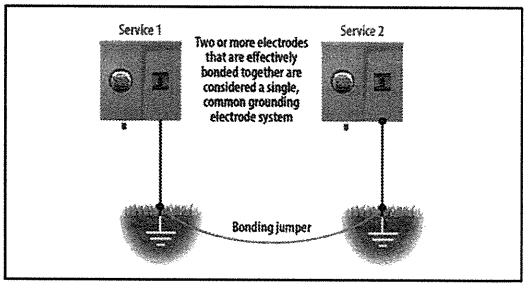
- Not Permitted as Grounding Electrodes
  - The structures and structural reinforcing steel for in-ground pools as described in 680.26(B)(1) and (B)(2) are not permitted as grounding electrodes.

- Grounding Electrodes and Utility Services
  - When an AC system or service is connected to a grounding electrode in or at a building or structure, the *NEC* requires the same electrode be used for grounding conductor enclosures and equipment installed at that building or structure.
  - When more than one service, feeder, or branch circuit supplies a building, they must be connected to the same grounding electrode(s).
  - This requirement is satisfied by bonding two or more grounding electrodes or grounding electrode systems together as specified in 250.50 and 250.58.

- Two Services on One Building

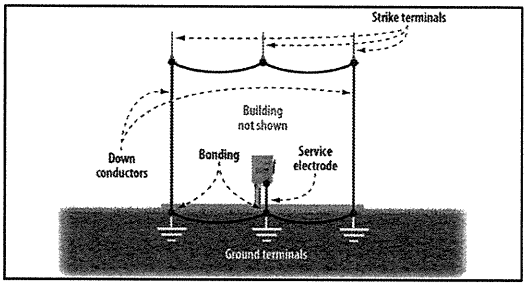


- Two Services on One Building



- Lightning Protection System Grounding Electrodes
  - Section 250.60 restricts using a lightning protection system as a grounding electrode for electrical power systems.
  - The requirement to bond the two systems together must be adhered to, as required in 250.106.
  - This rule specifies that the grounding electrode system (grounding network) of the lightning protection system be bonded to the electrical service grounding electrode system.

- Lightning Protection Electrode Network

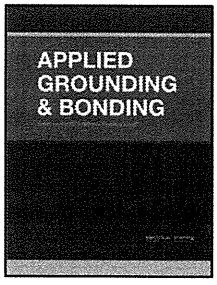


- Summary
  - Grounding electrodes provide a direct Earth connection and are ineffective in facilitating overcurrent device operation.
  - All grounding electrodes present at a building or structure served have to be included in the grounding electrode system.

- Summary (continued)
  - Grounding electrodes connect systems and equipment to the Earth and function to maintain those conductive parts at or as close to Earth as possible.
  - The grounding network of lightning protection systems must be bonded to the grounding electrode system used for the electrical service serving the building or structure.

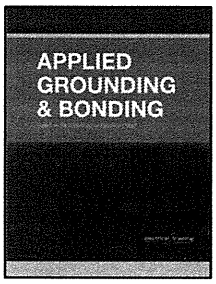
Grounding and Bonding

Grounding Electrodes and the Grounding Electrode System



Grounding and Bonding

Requirements for Grounded Conductors at Services



Requirements for Grounded Conductors at Services

Chapter 5

- Introduction
  - Premises wiring systems are typically supplied from a serving utility through conductors and equipment that make up an electrical service.
  - Service equipment is required to be listed for service use and is made up of equipment enclosures that contain switches, overcurrent protective devices, and other accessories.
  - The service equipment is where the service conductors supplying the building or structure are connected.
  - The first point of grounding and bonding for a premises wiring system typically occurs at or within the service equipment.

Requirements for Grounded Conductors at Services

Chapter 5

- Objectives
  - Understand the roles of the grounded conductor at the service equipment.
  - Determine the required grounding electrode conductor connection location(s) at the service equipment and outside the building or structure served.
  - Understand the installation and sizing requirements for the grounded conductor at services supplied by grounded systems.

Requirements for Grounded Conductors at Services

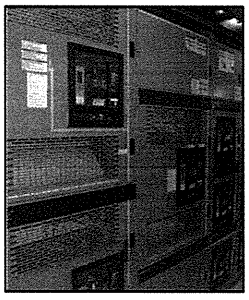
Chapter 5

- Objectives (continued)
  - Understand the physical characteristics and minimum sizing requirements for main bonding jumpers in service equipment.
  - Understand the purpose of, and location of the grounded conductor disconnecting means (neutral disconnecting link) in service equipment enclosures.
  - Understand grounding requirements for equipment installed on the supply side of the service disconnect and not supplied by a utility source.

Requirements for Grounded Conductors at Services

Chapter 5

- Grounded Utility Supply Systems
  - Premises wiring systems are generally supplied by utility systems that are grounded.
  - Where the service is supplied from a grounded system, the service conductors routed to the premises wiring equipment and systems must include a conductor that is grounded.



Requirements for Grounded Conductors at Services

Chapter 5

- Article 100 Definitions
  - Service. The conductors and equipment connecting the serving utility to the wiring system of the premises served.
  - Service Conductors. The conductors from the service point to the service disconnecting means.

Requirements for Grounded Conductors at Services

Chapter 5

- Article 100 Definition
  - Service Equipment. The necessary equipment, usually consisting of a circuit breaker(s) or switch(es) and fuse(s) and their accessories, connected to the serving utility and intended to constitute the main control and disconnect of the serving utility.
  - Grounded Conductor. A system or circuit conductor that is intentionally grounded.

Requirements for Grounded Conductors at Services

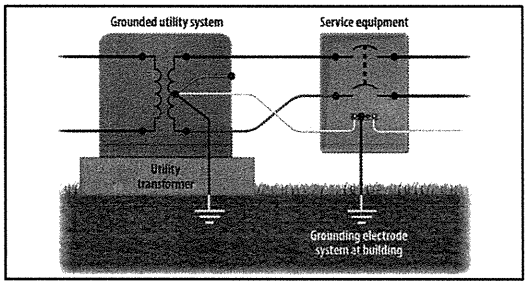
Chapter 5

- First Line of Defense
  - The grounded system is typically a pad-mounted transformer or one or more transformers mounted on a utility pole.
  - This is the usual location for the first system grounding connection of the system supplying the premises.
  - The connection to ground is established either at the transformer pad or at the base of the pole.

Requirements for Grounded Conductors at Services

Chapter 5

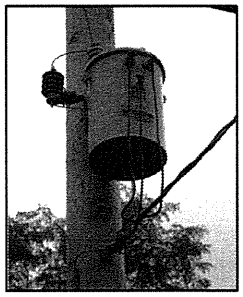
- Grounded Utility System



Requirements for Grounded Conductors at Services

Chapter 5

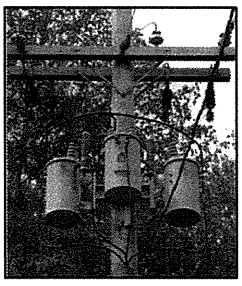
- Pole-Mounted Transformer
  - The grounding connection for a pole-mounted transformer is a first line of defense or protection for premises wiring systems served by grounded utility sources.
  - A single-phase, 3-wire grounded supply system is shown as a pole-mounted transformer.



Requirements for Grounded Conductors at Services

Chapter 5

- Pole-Mounted Transformer Bank
  - The grounding connection for a pole-mounted transformer is a first line of defense or protection for premises wiring systems served by grounded utility sources.
  - A 3-phase, 4-wire grounded supply system is shown as a pole-mounted transformer bank.



Requirements for Grounded Conductors at Services

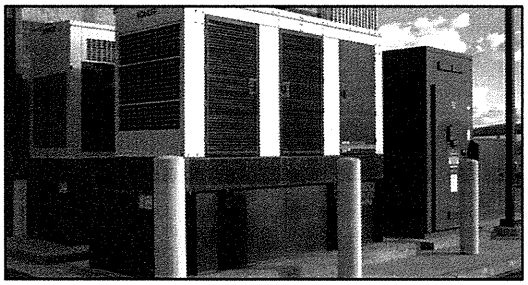
Chapter 5

- Grounding Scheme for Services
  - The grounding requirements on the load side of the service point are usually the responsibility of the electrical contractor and are accomplished when installing the service equipment.
  - Installers must verify that the service equipment is marked indicating it is either "suitable for use as service equipment" or "suitable for use only as service equipment." [*NEC* 230.66]

Requirements for Grounded Conductors at Services

Chapter 5

- Grounding Electrode at Outside Location



Requirements for Grounded Conductors at Services

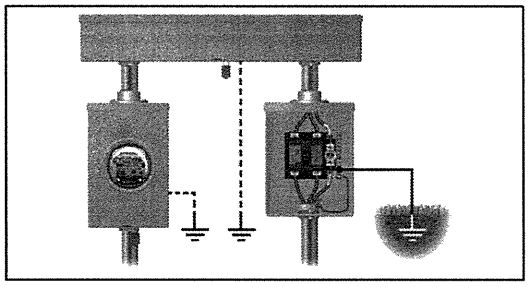
Chapter 5

- Grounding Connection Location
  - The *NEC* requires a grounding connection to be made at an accessible point anywhere from the load side of the overhead or underground service conductors, or the service drop or lateral up to the service equipment enclosure.
  - The grounding connection is typically made within the service equipment enclosure.
  - The conductor used to accomplish the grounding is the grounding electrode conductor.
  - Equipment that is suitable for use as service equipment is equipped with provisions for connecting a grounding electrode conductor.

Requirements for Grounded Conductors at Services

Chapter 5

- Accessible Connection Location(s)



Requirements for Grounded Conductors at Services

Chapter 5

- Four Conductors at the Service
  - For a service supplied by a grounded system, there are four conductors connected together in the service equipment.

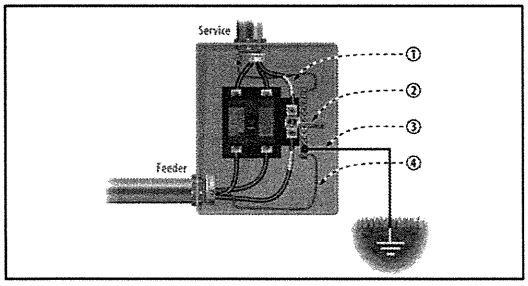
    (1) The grounded conductor
    (2) The main bonding jumper
    (3) The grounding electrode conductor
    (4) The equipment grounding conductor

  - For a service supplied by an ungrounded system, there is no grounded conductor.

Requirements for Grounded Conductors at Services

Chapter 5

- Four Conductors at the Service



Requirements for Grounded Conductors at Services

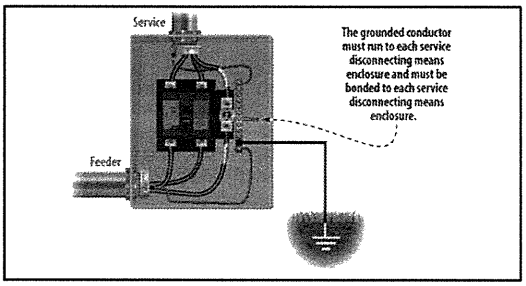
Chapter 5

- Grounded Conductor Routing and Connections
  - The grounded conductor is required to be routed to the service equipment and connected to the equipment enclosure. [*NEC* 250.24(C)]
  - This rule is one of paramount importance in the grounding and bonding scheme for service equipment.
  - This requirement applies to services operating at 1,000 volts or less.
  - The connection of the grounded conductor to the service equipment enclosure is generally established through a main bonding jumper.

Requirements for Grounded Conductors at Services

Chapter 5

- Grounded Conductor Brought to Service



Requirements for Grounded Conductors at Services

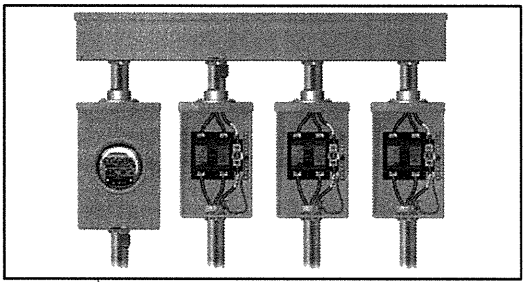
Chapter 5

- Main Bonding Jumper
  - The main bonding jumper requirement applies to each service disconnecting means on the premises served, whether the service disconnecting means is a single main or is a group of service disconnects as permitted in 230.71.
  - If up to six service disconnects are installed in separate enclosures, a main bonding jumper is required in each separate enclosure.
  - Section 230.71(B)(4) provides a requirement for listed service equipment that includes up to six service disconnects in a single enclosure that are in separate compartments.

Requirements for Grounded Conductors at Services

Chapter 5

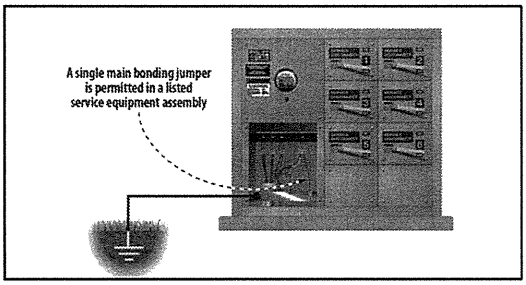
- Main Bonding Jumper(s) Required



Requirements for Grounded Conductors at Services

Chapter 5

- One Main Bonding Jumper



Requirements for Grounded Conductors at Services

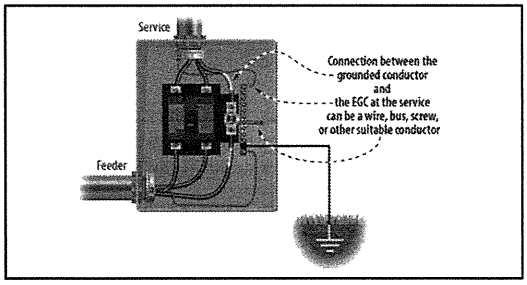
Chapter 5

- Main Bonding Jumpers in Service Equipment
  - The term *main bonding jumper* is defined in Article 100 as the connection between the grounded conductor and the equipment grounding conductor at the service.
  - The definition makes it clear that this connection is made only at the service disconnecting means.
  - Main bonding jumpers must be copper, aluminum, copper-clad aluminum, or other corrosion resistant material and can be in the form of a screw, bus, wire, or other suitable conductor.
  - Where the main bonding jumper is a screw it must be identified by using the color green.

Requirements for Grounded Conductors at Services

Chapter 5

- Main Bonding Jumper Properties



Requirements for Grounded Conductors at Services

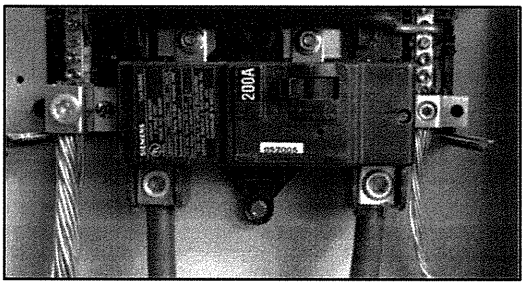
Chapter 5

- Bus Main Bonding Jumper

Requirements for Grounded Conductors at Services

Chapter 5

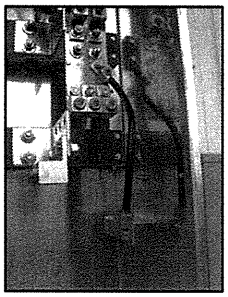
- Screw Main Bonding Jumper



Requirements for Grounded Conductors at Services

Chapter 5

- Main Bonding Jumper – Wire-Type
  - The size for wire-type main bonding jumpers in each enclosure must be in accordance with 250.28(D)(1), based on the size of the largest ungrounded service conductor serving that individual enclosure.
  - Use Table 250.102(C)(1) or the 12.5% rule as required for this sizing requirement.



Requirements for Grounded Conductors at Services

Chapter 5

- MBJ Sizing Examples (Wire-Type)
  1. Service size: 400 amperes with aluminum service-entrance conductor sized at 750 kcmil aluminum:
     - Main bonding jumper 3/0 AWG aluminum minimum
     - Main bonding jumper 1/0 AWG copper minimum
  2. Service size: 800 amperes with copper service-entrance conductor size (2) 600-kcmil conductors or one 1200-kcmil conductor:
     - Main bonding jumper 250 kcmil aluminum (minimum)
     - Main bonding jumper 3/0 AWG copper (minimum)

Requirements for Grounded Conductors at Services

Chapter 5

- Listed Service Equipment
  - Main bonding jumpers supplied with listed service equipment, such as switchboards and panelboards, can be installed without calculation of size.
  - The manufacturer has built the equipment to meet or exceed the requirements in the applicable product safety standards, which includes grounding and bonding provisions.

Requirements for Grounded Conductors at Services

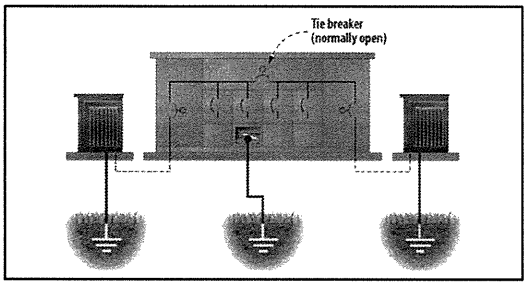
Chapter 5

- Dual-Fed Service Equipment
  - When service equipment in a single enclosure or a group of separate enclosures is fed from two sources (dual-fed service), the grounding electrode conductor connection is permitted to be by a single grounding electrode conductor.
  - Service equipment arranged in this fashion is typically equipped with a tie breaker.
  - The single grounding electrode conductor connection is permitted to be made at the tie point of the grounded conductor terminal bars supplied by separate power sources.

Requirements for Grounded Conductors at Services

Chapter 5

- Dual-Fed Service Equipment



Requirements for Grounded Conductors at Services

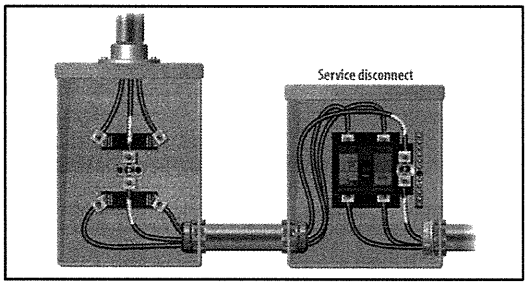
Chapter 5

- Minimizing Impedance in Grounded Service Conductors
  - The grounded conductor for an AC service must be routed with its associated ungrounded conductors.
  - This is a general requirement in the *NEC*, as covered in Section 300.3(B).
  - Routing the grounded conductor with the ungrounded phase conductors keeps the impedance of the circuit as low as possible during normal operation and during abnormal events such as ground faults or short circuits.

Requirements for Grounded Conductors at Services

Chapter 5

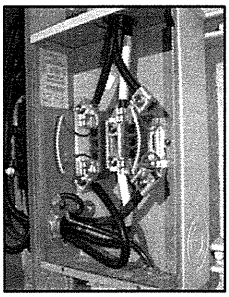
- Routing of Grounded Conductor



Requirements for Grounded Conductors at Services

Chapter 5

- Grounded Conductor Routing
  - The grounded conductor must be routed to the service disconnect means enclosure.
  - Often there is a utility meter enclosure to which the grounded (usually the neutral) conductor is connected.



Requirements for Grounded Conductors at Services

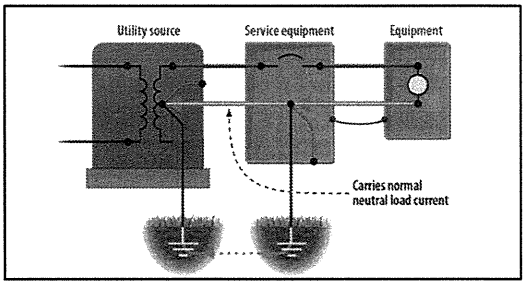
Chapter 5

- Functions (Purposes) of the Grounded Service Conductor
  - The grounded conductor at the service provides two essential functions for the premises wiring system.
  - First it is a current-carrying conductor for the load supplied (typically carrying the maximum unbalanced line-to-neutral current).
  - The grounded conductor of a service is usually a neutral conductor, but it may also be a phase conductor depending on the type of system.
  - The grounded neutral conductors typically carry the maximum unbalanced neutral current to the system neutral point.

Requirements for Grounded Conductors at Services

Chapter 5

- Function(s) of Grounded Conductor



Requirements for Grounded Conductors at Services

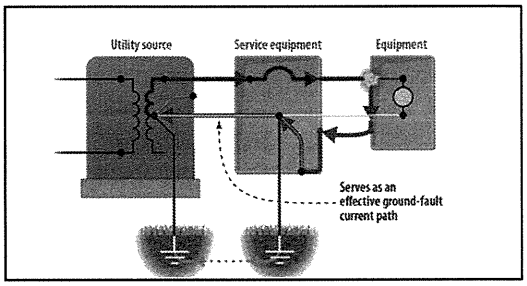
Chapter 5

- Functions (Purposes) of the Grounded Service Conductor
  - The second essential function of the grounded conductor is to perform as an effective ground-fault current path during ground-fault events at the service or at any point on the load side of the service equipment.
  - The grounded conductor at the service is used for the intentionally constructed, low-impedance, effective ground-fault current path addressed in Section 250.4(A)(5).

Requirements for Grounded Conductors at Services

Chapter 5

- Function(s) of Grounded Conductor



Requirements for Grounded Conductors at Services

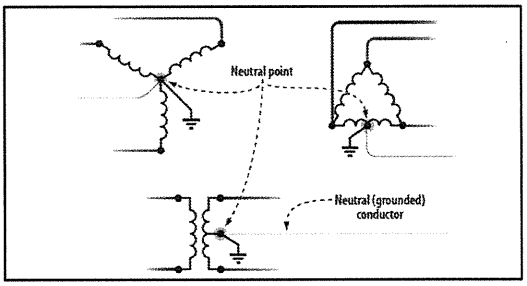
Chapter 5

- Article 100 Definitions
  - Neutral Conductor. The conductor connected to the neutral point of a system that is intended to carry current under normal conditions.
  - Neutral Point. The common point on a wye-connection in a poly-phase system or midpoint on a single-phase, 3-wire system, or midpoint of a single-phase portion of a 3-phase delta system, or a midpoint of a 3-wire, direct-current system.

Requirements for Grounded Conductors at Services

Chapter 5

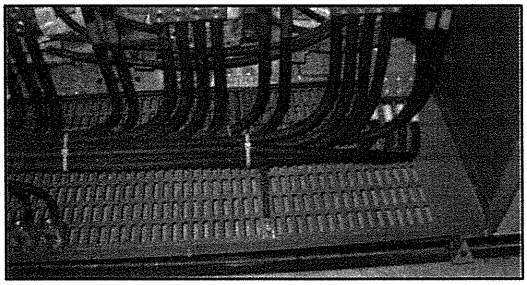
- Neutral Conductor and Neutral Point



Requirements for Grounded Conductors at Services

Chapter 5

- Neutral Conductor and Neutral Point



Requirements for Grounded Conductors at Services

Chapter 5

- Grounded Conductor Sizing Requirements
  - The grounded service conductor is generally a current-carrying conductor during normal conditions but during abnormal conditions, it must be capable of carrying fault current.
  - Therefore, it must meet minimum sizing requirements to ensure adequate capacity to serve both functions.
  - The neutral conductor for services or feeders must have adequate capacity for the load served, as indicated in Section 220.61.

Requirements for Grounded Conductors at Services

Chapter 5

- Minimum Size Examples
  - Table 250.102(C)(1) is also used to determine the minimum size required for service grounded conductors.
  - This rule applies whether there is a load on the neutral or not.
  - The grounded conductor be smaller than specified in Table 250.102(C)(1).
  - Example: 400-ampere service with 600 kcmil copper ungrounded service-entrance conductors requires a minimum 1/0 CU or 3/0 AL grounded conductor.

Requirements for Grounded Conductors at Services

Chapter 5

- Sizing Examples

Size of Largest Service-Entrance Conductor (Copper)	Minimum Size of Grounded Conductor (Copper)	Minimum Size of Grounded Conductor (Aluminum)
1 AWG	6	4
4/0 AWG	2	1/0
500 kcmil	1/0	3/0
750 kcmil	2/0	4/0

The minimum size grounded conductors are established using *NEC* Table 250.102(C)(1). Use the 12.5% rule for larger services.

Requirements for Grounded Conductors at Services

Chapter 5

- 12.5% Rule Size Examples
  - The 12.5% rule must be used for sizing the grounded conductor where the size of the largest ungrounded service conductor exceeds 1,100-kcmil copper or 1,750-kcmil aluminum or copper clad aluminum.
  - Example: 800-ampere service with 1,200 kcmil copper ungrounded service-entrance conductors (parallel 600 kcmil copper) requires a minimum 150 kcmil (calculated value) or rounded up to 3/0 AWG copper.

Requirements for Grounded Conductors at Services

Chapter 5

- Sizing Examples

Size of Largest Service-Entrance Conductor (Copper)	Calculated Value (Copper)	Minimum Size of Grounded Conductor (Copper)
1200 kcmil	150 kcmil	3/0 AWG
1800 kcmil	225 kcmil	250 kcmil
2500 kcmil	312,500 cm	350 kcmil
3000 kcmil	375 kcmil	400 kcmil

The 12.5% rule must be used for sizing the grounded conductor where the size of the largest ungrounded service-entrance conductor exceeds 1100 kcmil copper or 1750 kcmil aluminum

Requirements for Grounded Conductors at Services

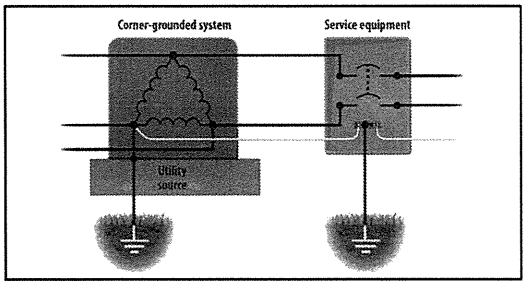
Chapter 5

- Corner-Grounded System
  - If a 3-phase, 3-wire, corner-grounded delta service is supplied, the grounded conductor must be sized the same as the ungrounded service-entrance conductors.
  - No line-to-neutral loads are served by corner-grounded systems.
  - Size the grounded conductor the same size as the ungrounded conductors supplying the service.

Requirements for Grounded Conductors at Services

Chapter 5

- Ungrounded Systems

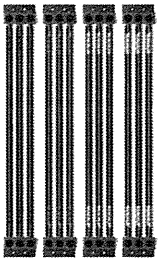


Requirements for Grounded Conductors at Services

- Rules for Parallel Conductors
  - The general requirements for conductors installed in parallel are provided in Section 310.10(G) of the *NEC*.
  - Conductors in parallel generally must be:
    - The same size
    - The same length
    - The same conductor material
    - They must have the same insulation type
    - Terminated in the same manner
    - Not smaller than 1/0 (generally)

Requirements for Grounded Conductors at Services

- Parallel Conductor Requirements



Conductors in parallel must:

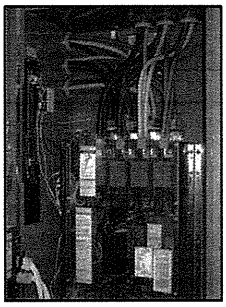
1. Be the same length
2. Be of the same conductor material
3. Have the same type of insulation
4. Be terminated in the same manner
5. Be the same size
6. Not be smaller than 1/0 (in general)

Requirements for Grounded Conductors at Services

- Sizing Grounded Conductors for Parallel Installations
  - The minimum size grounded service conductor in parallel arrangements is based on the total circular mil area of all the ungrounded service conductors in parallel.
  - Once the total circular mil area is determined for the largest ungrounded service-entrance conductor, Table 250.102(C)(1) is then used to determine the minimum size grounded service conductor required to be installed in each conduit.
  - Grounded conductors installed in parallel arrangements must generally not be smaller than 1/0.

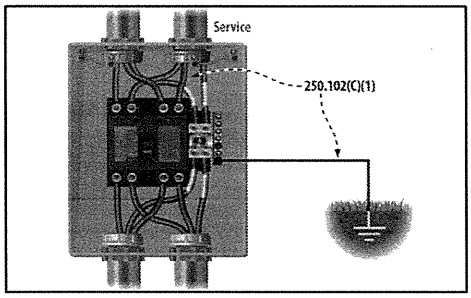
Requirements for Grounded Conductors at Services

- Grounded Conductor Sizing for Parallel Installations
- The 12.5% requirement applies to parallel service conductor arrangements that are larger than 1,100-kcmil copper or 1,750-kcmil aluminum or copper-clad aluminum and is used to determine the minimum-size grounded conductor.
- Use the total circular mil area of the largest ungrounded service-entrance conductor and multiply by 12.5%.
- Use Table 8 Chapter 9



Requirements for Grounded Conductors at Services

- Minimum Size of Grounded Conductor



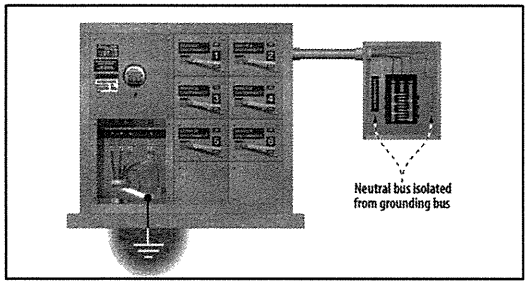
Requirements for Grounded Conductors at Services

- Grounded Conductor (Load Side Use)
  - Section 250.24(A)(5) restricts load-side grounding connections to the grounded conductor; essentially connections on the load side of the service disconnecting means are not permitted.
  - The same restriction is included for separately derived systems, as provided in Section 250.30(A).
  - The informational notes following Sections 250.24(A)(5) and 250.30(A) indicate a few installations for which using the grounded conductor for grounding is permitted.

Requirements for Grounded Conductors at Services

Chapter 5

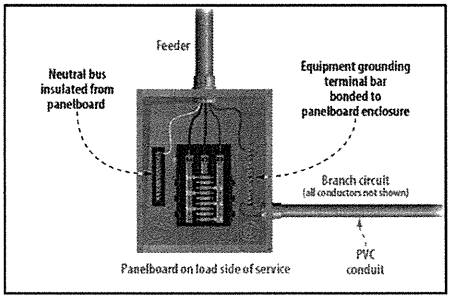
- Isolate Neutrals from Ground



Requirements for Grounded Conductors at Services

Chapter 5

- Isolate Neutrals from Ground



Requirements for Grounded Conductors at Services

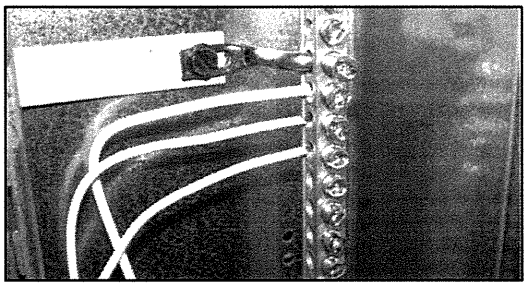
Chapter 5

- Grounded Conductor Identification
  - Identification requirements apply specifically to grounded conductors, whether they are grounded neutral conductors or grounded phase conductors.
  - *NEC* Article 200 provides the identification requirements for grounded conductors.
  - Grounded conductors in sizes 6 AWG and smaller must be generally identified using the colors white or gray.
  - Under certain conditions, the grounded conductor at a service could be a bare conductor, such as in service-entrance cables.

Requirements for Grounded Conductors at Services

Chapter 5

- Grounded Conductor Identification



Requirements for Grounded Conductors at Services

Chapter 5

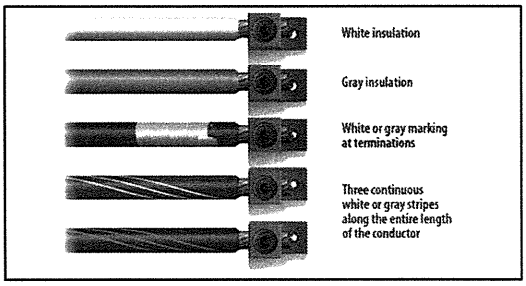
- Identifying Sizes 4 AWG and Larger
  - Grounded conductors in sizes 4 AWG and larger are permitted to be identified using any of the following methods:

    1. A continuous white or gray outer finish
    2. Three continuous white or gray stripes along its entire length on other than green insulation
    3. A distinctive white or gray marking at terminations that encircles the conductor

Requirements for Grounded Conductors at Services

Chapter 5

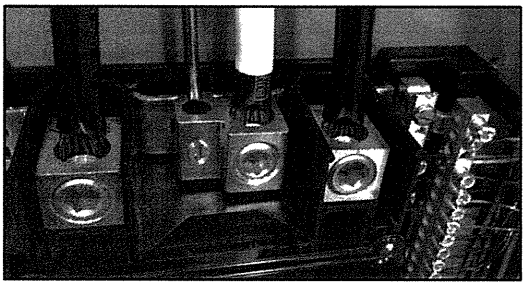
- Identifying Sizes 4 AWG and Larger



Requirements for Grounded Conductors at Services

Chapter 5

- Identifying Sizes 4 AWG and Larger



Requirements for Grounded Conductors at Services

Chapter 5

- Requirements for Service Equipment (Listing)
  - Service equipment must be listed and identified for use as service equipment.
  - These requirements are found in 230.66.
  - Equipment that is suitable for use as service equipment has been manufactured and evaluated to meet product safety standards.
  - Some equipment that could carry the identification as suitable for service use are switchboards, enclosed switches, panelboards, motor control centers, and power outlets, among others.

Requirements for Grounded Conductors at Services

Chapter 5

- Applicable Product Standards

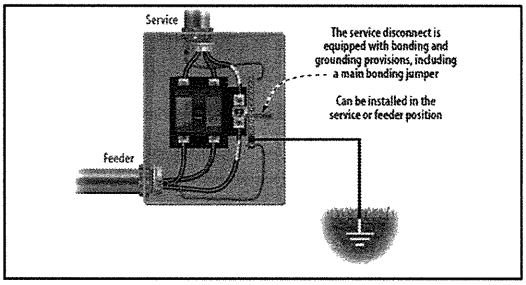
- Examples of equipment that is listed as suitable for use as service equipment are as follows:

Switchboards	UL 891 Deadfront Switchboards
Panelboards	UL 67 Panelboards
Service power outlets	UL 231 Power Outlets
Enclosed switches	UL 98 Enclosed Switches
Motor control centers	UL 845 Motor Control Centers

Requirements for Grounded Conductors at Services

Chapter 5

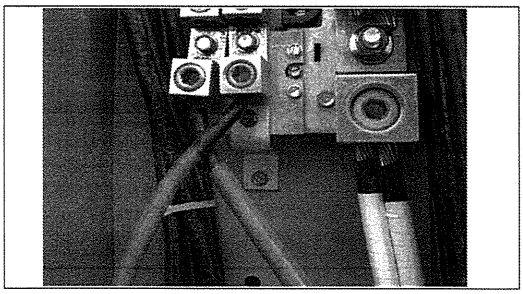
- Suitable for Use as Service Equipment



Requirements for Grounded Conductors at Services

Chapter 5

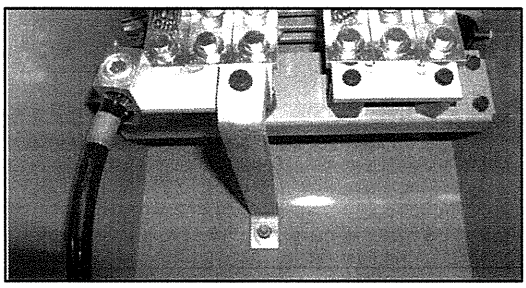
- Suitable for Use as Service Equipment



Requirements for Grounded Conductors at Services

Chapter 5

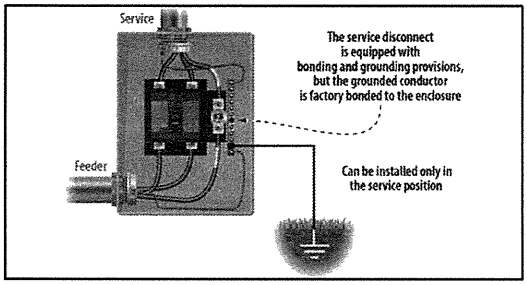
- Suitable for Use as Service Equipment



Requirements for Grounded Conductors at Services

Chapter 5

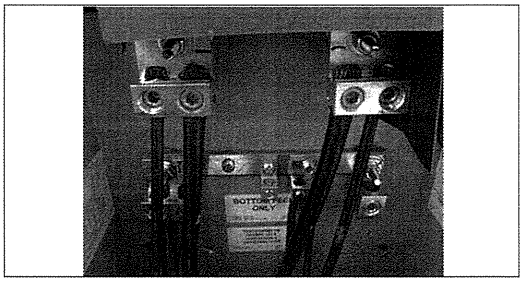
- Suitable for Use Only as Service Equipment



Requirements for Grounded Conductors at Services

Chapter 5

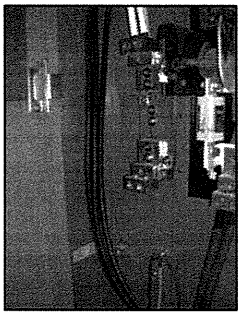
- Suitable for Use Only as Service Equipment



Requirements for Grounded Conductors at Services

Chapter 5

- Suitable for Use Only as Service Equipment
  - Equipment that is suitable for use only as service equipment has the bus for the grounded conductor connected directly to the service equipment enclosure.
  - No main bonding jumper is present.



Requirements for Grounded Conductors at Services

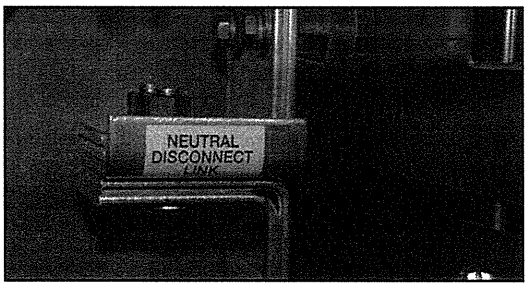
Chapter 5

- Grounded Conductor (Neutral) Disconnect Requirement for Services
  - An important requirement for service equipment is that provisions for disconnecting the grounded conductor (usually a neutral) are required by 230.75.
  - Listed service equipment includes such provisions either in the form of a busbar or terminal.
  - This means of disconnect is typically identified as a neutral disconnect link.
  - The means of disconnect can be the terminal lug where the grounded conductor terminates in the service disconnecting means enclosure.

Requirements for Grounded Conductors at Services

Chapter 5

- Neutral Disconnect at Service



Requirements for Grounded Conductors at Services

Chapter 5

- Requirements in Product Standards
  - The product standard requires that the enclosure identify which vertical section the grounded conductor (neutral) disconnect link and main bonding jumper are located.
  - This requirement is especially important in multi-section service switchboards.

Requirements for Grounded Conductors at Services

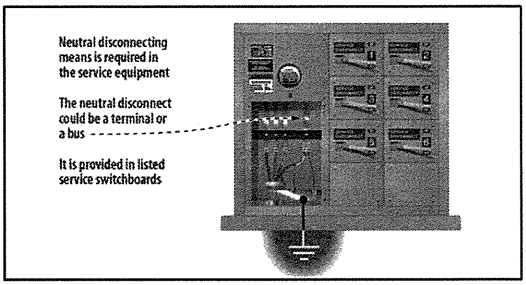
Chapter 5

- Switchboard Labeling Requirements

Requirements for Grounded Conductors at Services

Chapter 5

- Neutral Disconnect Link



Requirements for Grounded Conductors at Services

Chapter 5

- Services Supplied by Ungrounded Systems
  - The *NEC* includes rules for services supplied by ungrounded utility sources in Section 250.24(E).
  - Although the system is not grounded, grounding and bonding requirements are included for metallic raceways and enclosures that contain conductors and equipment used with ungrounded systems.
  - The metal service equipment enclosure must have a grounding electrode conductor connection to a grounding electrode or grounding electrode system as provided in Part III of Article 250.

Requirements for Grounded Conductors at Services

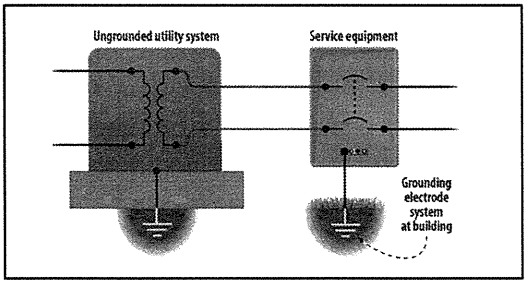
Chapter 5

- Services Supplied by Ungrounded Systems
  - The grounding electrode conductor size is determined by using Table 250.66, which bases sizing on the size of the largest ungrounded service-entrance conductor.
  - The general performance requirements for ungrounded systems are covered in Section 250.4(B), which provides all grounding and bonding functions except for system grounding.
  - No system conductor is solidly connected to ground.

Requirements for Grounded Conductors at Services

Chapter 5

- Services Supplied by Ungrounded Systems



Requirements for Grounded Conductors at Services

Chapter 5

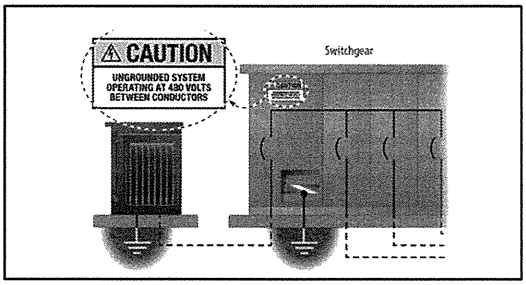
- Ground Detection is Required
  - Ground detection is required for ungrounded systems as indicated in 250.21(A) and (B).
  - The ground detection sensing devices must be installed as close as practicable to the service or source.
  - This requirement ensures that ground detection monitoring remains active even if feeder or branch circuits are disconnected.

Requirements for Grounded Conductors at Services

- Marking Ungrounded Systems
  - Equipment enclosures for ungrounded systems must be marked as ungrounded systems. [*NEC* 250.21(C)]
  - Section 408.3(F)(2) requires switchboards and panelboards containing ungrounded electrical systems to be legibly and permanently field marked to indicate it is supplied by an ungrounded system.
  - This marking must be suitable for the environment in which it is installed.

Requirements for Grounded Conductors at Services

- Marking Ungrounded Systems



Requirements for Grounded Conductors at Services

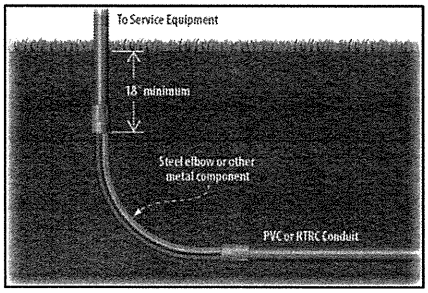
- Grounding Service Raceways and Enclosures
  - Section 250.80 provides requirements for grounding metal raceways and enclosures for service conductors and equipment.
  - They must be connected to the grounded system conductor if the service is supplied by a grounded electrical supply system.
  - If supplied by an ungrounded system, they must be connected directly to a grounding electrode.

Requirements for Grounded Conductors at Services

- Exception for Metal Components
  - The *Code* relaxes the requirement (by exception) for grounding metal components installed in a run of underground nonmetallic raceway where the metal component is isolated from possible contact by a minimum cover of 18 inches to any part of the elbow. [*NEC* 250.80 Exception]
  - Common metal components could include metallic fittings and metal elbows.

Requirements for Grounded Conductors at Services

- Exception for Metal Components (such as elbows)



Requirements for Grounded Conductors at Services

- Summary
  - A grounded conductor is required to be routed with the ungrounded service-entrance conductors, brought to each service disconnecting means enclosure, and connected to the enclosure.
  - Grounded (often neutral) service conductors at the service cannot be smaller than that of the required grounding electrode conductor.
  - The grounded conductor minimum size is determined based on the load served using Section 220.61; at a minimum it is sized using Table 250.102(C)(1) or the 12.5% rule as required for larger services.
  - Equipment used as service equipment is required to be listed and identified for such use.

Grounding and Bonding

Requirements for Grounded Conductors at Services