



IEEE Guide for Maintenance Methods on Energized Power Lines

STANDARDS

IEEE Power and Energy Society

Developed by the
Transmission and Distribution Committee

IEEE Std 516™-2021
(Revision of IEEE Std 516-2009)



IEEE Guide for Maintenance Methods on Energized Power Lines

Developed by the

Transmission and Distribution Committee
of the
IEEE Power and Energy Society

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IEEE SA Standards Board

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Abstract: General recommendations for performing maintenance work on energized power lines are provided. Technical explanations as required to cover certain laboratory testing of tools and equipment, in-service inspection, field maintenance and care of tools and equipment, and work methods for the maintenance of energized lines and for persons working in the vicinity of energized lines are included.

Keywords: energized, equipment, IEEE 516™, maintenance, power lines, tools

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Introduction

This introduction is not part of IEEE Std 516-2021, IEEE Guide for Maintenance Methods on Energized Power Lines.

Live-line maintenance of transmission lines began in the early 1920s and developed into a major working practice as the transmission systems were expanded and the voltages increased.

In the 1950s, when the transmission line voltage exceeded 300 kV line to line, the use of fiberglass to replace wooden tools made a significant change in the industry. Economic conditions prohibited the construction and operation of redundant lines, and the need for live-line maintenance of transmission line increased rapidly.

During the 1950s and 1960s, several papers were written regarding the safety aspects of live-line maintenance. In the early 1970s, the IEEE Transmission and Distribution Committee recognized the need to consolidate information on live-line maintenance, and thus a task group was formed to write a guide. The task group later became the Engineering in the Safety, Maintenance and Operation of Lines (ESMOL) Subcommittee.

This guide was started in the late 1970s and was published in 1986 on a trial-use basis. In 1987, the guide was released as a full-use ANSI/IEEE guide. Since the original publication of the guide, the ESMOL Subcommittee has been working on revisions to the guide to bring it up to the current state of the art and into conformance with other international standards issued in recent years. The ESMOL Subcommittee has added sections from other ESMOL sponsored guides in this edition to expand the scope of the guide to cover more of the industry's needs.

In the guide editions up to 1995, most of table data were obtained from plots. In the 2003 guide, the tables were calculated using the formulas in the guide in a step calculation method.

In the 2009 edition of the guide, the tables were calculated using the formulas in the guide. Additional text was added on the determination of maximum anticipated per-unit transient overvoltage (TOV) T and use of the minimum air insulation distance (MAID) and minimum approach distance (MAD).

During the original development of the guide, it was not intended that it would be used as a document to establish government regulations. However, since its publication in 1986, several government regulatory agencies have used the guide in their rule making. The 2009 edition of the guide included revisions that make it more compatible for use in governmental regulations.

The 2021 edition includes important new information regarding live working ropes, resulting from recent research, advances in rope materials and manufacturing, and laboratory tests. New information on ground potential rise during line work is presented with three-dimensional color graphs for several structure types and grounding arrangements. Also, distances are indicated as uppercase script letter D in equations (for example, D_{MAID} , $D_{\text{L-L}}$), but actual familiar abbreviations are retained in the descriptive text.

Contents

1. Overview	11
1.1 Scope	11
1.2 Purpose	11
1.3 Application	12
1.4 Word usage	12
2. Normative references	13
3. Definitions, acronyms, and abbreviations	15
3.1 Definitions	15
3.2 Acronyms and abbreviations	19
4. Technical considerations	20
4.1 Introduction	20
4.2 Insulating properties	21
4.3 Air as insulation	21
4.4 Factors that affect the air insulation	23
4.5 Air gap distances	23
4.6 Distance equations	28
4.7 Factors used to determine MAID, MTID, MAD, MAD for Tools, and MHAD	33
4.8 Control of TOV	58
4.9 Application of MAID, MTID, MAD, MAD for Tools, and MHAD	64
4.10 Insulation systems	65
5. Tools and equipment	70
5.1 General	70
5.2 Categories of insulating tools and equipment	70
5.3 Equipment rating	72
5.4 Electrical current flows	74
5.5 Tool and equipment testing	74
5.6 Testing of FRP live work tools	77
5.7 Typical tests for insulating tools	79
5.8 Worksite procedures	79
5.9 Shop or laboratory procedures	81
5.10 Insulating rope	89
5.11 Periodic test criteria	90
5.12 Histograms	90
5.13 Electrical test references	91
5.14 Marking and identification—general	91
5.15 Restoration or temporary structures	91
6. In-service checking and care of insulating tools and equipment	92
6.1 Introduction	92
6.2 Scope	93
6.3 Field care, handling, and storage	93
6.4 Periodic inspection and checking	95
6.5 Maintenance and repair of tools and equipment	97
7. Work methods	99
7.1 Introduction	99
7.2 Categories of energized-line maintenance	99

7.3 Precautions when working energized lines	100
7.4 Requirements when working energized lines	102
7.5 Insulating equipment used in energized-line work	104
7.6 Noninsulating equipment used in energized-line work	105
7.7 Insulating devices used in energized-line work	105
7.8 Methods for positioning personnel	106
7.9 Insulator cleaning	111
8. Work in the vicinity of energized lines and devices	111
8.1 Introduction	111
8.2 Physiological aspects of live-line work	111
8.3 Flame-resistant clothing	114
8.4 RF field protection	114
8.5 Precautions when performing live work	116
8.6 Step and touch voltages	116
8.7 Mechanical equipment	120
Annex A (informative) Bibliography	123
Annex B (informative) Sample distance calculations	127
B.1 Introduction	127
B.2 Work at and below 72.5 kV	127
B.3 Work above 72.5 kV	129
Annex C (informative) Sample PPAG calculations	133
C.1 Introduction	133
C.2 Finding line-to-ground MAID and the MAD obtained by using PPAG	133
Annex D (informative) Distance tables	135
D.1 General information for using the tables in this annex	135
D.2 Adjusting T for use in tables when actual line voltage is lower than voltage on which table has been calculated	135
Annex E (informative) Determining maximum anticipated $\{TOV\}_{kV}$ and the per-unit $\{T\}_{p.u.}$	153
E.1 Determining TOV magnitude due to switching transients	153
E.2 Determining T at worksite	153
E.3 Large system studies	157

IEEE Guide for Maintenance Methods on Energized Power Lines

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1. Overview

1.1 Scope

This guide provides the general recommendations for performing maintenance work on energized power lines. It is not intended to include all of the proven practical methods and procedures; however, these selected comprehensive recommendations are based on sound engineering principles, engineering safety considerations, and field experience by many utilities. Included are technical explanations as required to cover certain laboratory testing of tools and equipment, in-service inspection, maintenance and care of tools and equipment, and work methods for the maintenance of energized lines [and](#) for persons working in vicinity of energized lines.

1.2 Purpose

The purpose of this guide is to

- a) Present, in one guide, sufficient details of some of the methods and equipment presently in use to enable the performance of energized line maintenance with maximum safety.

- b) Direct attention to appropriate standards and other documents for the acquisition of knowledge on the inspection, care, and use of required tools and equipment.
- c) Provide guidance for establishing an appropriate work area, taking into consideration safety and the physical effects of the work area on personnel.

It is not intended that this guide should replace present proven utility practices or imply that these recommendations are superior to existing practices and, therefore, should be universally adopted as utility standards. This compilation of many accepted practices is presented specifically in the form of a guide to be used by those electric utilities and agencies that are seeking guidance in establishing methods and procedures for maintenance of energized power lines.

1.3 Application

This guide, although general in scope and purpose, is specific enough to be applicable to all aspects of energized-line maintenance.

Since energized-line maintenance practices for different projects are influenced by the magnitude and nature of each project and by local conditions and circumstances, some alternative methods that have been successfully employed are presented.

The practices described provide for the performance of energized-line maintenance with maximum safety. They are based on practices of operating utilities with many years of successful experience.

The approach used in this guide is to

- a) Indicate the engineering and other technical considerations essential to the performance of energized-line maintenance with maximum safety.
- b) Provide guidance for the necessary test equipment and procedures associated with manufacturer and user acceptance, testing, and care of equipment.
- c) Detail various work methods for working on or near energized lines and associated devices.

Advancement in technology or changes in system design will probably justify modifying the minimum requirements recommended in this guide.

CAUTION

Requirements of federal, state, or local regulations should be observed. When any conflict exists between this guide and the rules of the owner of the line, the owner's rules shall take precedence.

1.4 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).^{1, 2}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

¹ The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

² The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used; therefore, each referenced document is cited in text, and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI/SIA A92.2, American National Standard for Vehicle-Mounted Elevating and Rotating Aerial Devices.^{3 1}

ASTM D 120, Standard Specification for Rubber Insulating Gloves.^{4 2}

ASTM D 1048, Standard Specification for Rubber Insulating Blankets.

ASTM D 1049, Standard Specification for Rubber Insulating Covers.

ASTM D 1050, Standard Specification for Rubber Insulating Line Hose.

ASTM D 1051, Standard Specification for Rubber Insulating Sleeves.

ASTM F 478, Standard Specification for In-service Care of Insulating Line Hose and Covers.

ASTM F 479, Standard Specification for In-service Care of Insulating Blankets.

ASTM F 496, Standard Specification for In-service Care of Insulating Gloves and Sleeves.

ASTM F 696, Standard Specification for Leather Protectors for Rubber Insulating Gloves and Mittens.

^{3 1} ANSI publications are available from the ~~Sales Department~~, American National Standards Institute, ~~25 West 43rd Street, 4th Floor, New York, NY 10036, USA~~ (<http://www.ansi.org/>).

^{4 2} ASTM publications are available from the American Society for Testing and Materials, ~~100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA~~ (<https://www.astm.org/>).

ASTM F 711, Standard Specification for Fiberglass-Reinforced Plastic (FRP) Rod and Tube Used in Live Line Tools.

ASTM F 712, [Standard Test Methods and Specifications for](#) Electrically Insulating Plastic Guard Equipment for Protection of Workers.

ASTM F 855, Standard Specification for Temporary Protective Grounds to be Used on De-Energized Electric Power Lines and Equipment.

~~ASTM F 968, Standard Specification for Electrically Insulating Plastic Guard Equipment for Protection of Workers.~~

ASTM F 1236, Standard Guide for Visual Inspection of Electrical Protective Rubber Products. [_](#)

ASTM F 1701-[12](#), Standard Specification for Unused ~~Polypropylene~~ Rope with Special Electrical Properties.

ASTM F 2522-05, Standard Test Method for Determining the Protective Performance of a Shield Attached on Live Line Tools or on Racking Rods for Electric Arc Hazards.

[ASTM F 3121/3121M-17, Standard Guide for In-Service Inspection, Maintenance, and Electrical Testing of Hand-Held Live-Line Insulating Tools \(Fiberglass-Reinforced Plastic \(FRP\)\).](#)

CSA C225, Vehicle-Mounted Aerial Devices.^{[5](#) [3](#)}

IEC 60060-1:[2010](#), High-voltage test techniques—Part 1: General definitions and test requirements.^{[6](#)}
[4](#)

^{[5](#) [3](#)} CSA publications are available from the Canadian Standards Association (~~Standards Sales~~), 178 Rexdale Blvd., Etobicoke, Ontario, Canada M9W 1R3 (~~<http://www.csa.ca/>~~) (<https://store.csagroup.ca/>).

^{[6](#) [4](#)} IEC publications are available from the ~~Sales Department of the~~ International Electrotechnical Commission (<https://3.rue-de-varembe.ch>), Case Postale 131, CH-1211, Genève 20, Switzerland/Suisse (~~<http://www.iec.ch/>~~). IEC publications are also available in the United States from the ~~Sales Department~~, American National Standards Institute (<https://www.ansi.org/>), 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

IEC 60060-2:[2010](#), High-voltage test techniques—Part 2: Measuring systems.

IEC 60060-3:[2006](#), High-voltage test techniques—Part 3: [Definitions and requirements for on-site testing](#) ~~Measuring Devices~~.

[IEC 60855-1:2016, Edition 2, Live working—Insulating foam-filled tubes and solid rods—Part 1: Tubes and rods of a circular cross-section.](#)

[IEC 60895:2020, Edition 3, Live working—Conductive clothing.](#)

[IEC 60903:2014, Edition 2, Live working—Electrical insulating gloves.](#)

[IEC 60984:2014, Edition 2, Live working—Electrical insulating sleeves.](#)

[IEC 61057:2017, Edition 2, Live working—Electrical insulating aerial devices for mounting on a chassis.](#) [IEC 61111:2009, Edition 2, Live working—Electrical insulating matting.](#)

[IEC 61112:2009, Edition 2, Live working—Electrical insulating blankets.](#)

~~IEC 60060-4, High Voltage Test Techniques—Part 4: Application Guide for Measuring Devices.~~

~~IEC 60625-1, Programmable Measuring Instruments—Interface System (byte serial, bit parallel)—Part 1: Functional, Electrical and Mechanical Specification, System Applications and Requirements for the Designer and User.~~

~~IEC 60625-2, Programmable Measuring Instruments—Interface System (byte serial, bit parallel)—Part 2: Codes, Formats, Protocols and Common Commands.~~

~~IEC 60855, Insulating Foam Filled Tubes and Solid Rods for Live Working.~~

~~IEC 60895, Live working—Conductive clothing for use at Nominal Voltage up to 800 kV AC and 600 kVDC.~~

~~IEC 60903, Specifications for Glovers and Mitts of Insulating Material for Live Working.~~

~~IEC 60984, Sleeves of Insulating Material for Live Working.~~

~~IEC 61057, Aerial Devices with Insulating Boom used for Live Working.~~

~~IEC 61111, Matting of Insulating Material for Electrical Purposes.~~

~~IEC 61112, Blankets of Insulating Material for Electrical Purposes.~~

IEC 61229:[1993, Edition 1.0](#), Rigid protective covers for live working on a.c. installations.

IEC 61230:[2008, Edition 2](#), Live working—Portable equipment for earthing or earthing and short-circuiting.

IEC 61235:[1993, Edition 1](#), Live working—Insulating hollow tubes for electrical purposes. [IEC 61236:2010, Edition 2, Live working—Saddles, stick clamps and their accessories.](#)

[IEC 61472:2013, Edition 3, Live working—Minimum approaching distance for a.c. systems in the voltage range 72.5 kV to 800 kV—A method of calculation.](#)

IEEE Std 4TM-1995, IEEE Standard Techniques for High-Voltage Testing.[7,8](#)

~~IEC 61236, Saddles, Pole Clamps (Stick Clamps) and Accessories for Live Working.~~

IEEE Std 62TM, IEEE Guide for Diagnostic Field Testing of Electric Power Apparatus—Part 1: Oil Filled Power Transformers, Regulators, and Reactors.[5,6](#)

IEEE Std 524TM, IEEE Guide to the Installation of Overhead Transmission Line Conductors.

~~IEEE Std 935TM, IEEE Guide on Terminology for Tools and Equipment to be Used in Live Line Working.~~

IEEE Std 957TM, IEEE Guide for Cleaning Insulators.

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IEEE Std 1070™, IEEE Guide for the Design and Testing of Transmission Modular Restoration Structure Components.

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~~IEEE Std 1313.2™, IEEE Guide for the Application of Insulation Coordination.~~

IEEE Std C62.92.1™, ~~2000 (Reaff 2005)~~, IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems—Part I: Introduction.

ISO 2307, [Fibre](#) ~~Fiber~~ Ropes—Determination of Certain Physical and Mechanical Properties.^{2 7}

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.¹⁰

~~This subclause provides definitions for terms used in this guide. Additional terminology can be found in IEEE Std 935.⁸ For terminologies not listed below or in IEEE Std 935, consult *The Authoritative Dictionary of IEEE Standards Terms* [B22].⁹~~

^{2 7} ISO publications are available from the [International Standards Organization](#) ~~ISO Central Secretariat, 1 ch. de la Voie-Creuse, Case Postale 56, CH-1211, Genève 20, Switzerland/Suisse~~ (<https://www.iso.org>). ISO publications are also available in the United States from the ~~Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA~~ (<https://www.ansi.org/>).

¹⁰ *IEEE Standards Dictionary Online* is available at <http://dictionary.ieee.org>. An IEEE account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

~~⁸ Information on references can be found in Clause 2.~~

aerial work: Work performed on equipment used for the transmission and distribution of electricity and performed in an elevated position on various structures, conductors, associated equipment from the structure, an insulating device, or a helicopter for barehand work.

barehand work: A technique of performing live maintenance on energized wires and equipment whereby one or more line workers work directly on an energized part after having been raised and bonded to the same potential as the energized wire or equipment. These line workers are normally supported by an insulating ladder, insulating rope, insulating aerial device, helicopter, or the energized wires or equipment on which they are working. Most barehand work includes the use of insulating tools.

bonded: The [electrical and](#) mechanical interconnection of conductive parts to maintain a common electrical potential. *Syn:* **connected**.

bucket: A device designed to be attached to the boom tip of a line truck, crane, or [insulating mobile elevating work platform](#) ~~aerial device~~ and used to support workers in an elevated working position. It is normally constructed of fiberglass to reduce its physical weight, maintain strength, and obtain good dielectric characteristics. For some applications, the device is a platform with a railing generally constructed of conductive material. *Syn:* **basket; platform**.

capacitive current: The component of the measured current that leads the applied voltage by 90° due to the capacitance of the tool or equipment.

clear live tool insulation distance [\(line-to-ground\)](#): The distance measured longitudinally along the insulating part of the tool between the [metal end fittings of](#) ~~points where~~ the tool, [where one metal end fitting](#) contacts [a the-live part](#) ~~parts~~ and [the other end fitting contacts a part](#) ~~parts~~ at ground potential. [This definition applies to tools without metal along the length of the insulating part that might create a floating object. See also: minimum tool insulation distance \(MTID\).](#)

conducting body: A conductive object or mass such as a steel structure [or metal component](#).

~~3.1.7 clearance: See: work permit.~~

conduction current: The component of the measured current in phase with the applied voltage that is delivered to the volume of the tool or equipment due to the electrical resistance of the material comprising the tool or equipment.

conductive clothing: Clothing made of natural or synthetic material that is either conductive or interwoven with conductive thread to provide mitigation of the effects of the electric fields of high-voltage energized electrical conductors and equipment, and of [the](#) radio frequency (RF) fields of public communication system (PCS) antennas.

conductor: A wire or combination of wires not insulated from one another, suitable for carrying an electrical current. Conductors can be bare or insulated. *Syn:* **cable; wire.**

cover-up equipment: Equipment designed to protect persons from brush or inadvertent contact to energized parts in a specific worksite. Many different types are available to cover conductors, insulators, dead-end assemblies, structures, and apparatus. Cover-up material might be either flexible or rigid. *Syn:* **blanket; cover-up; eel; hard cover; hose; snake.**

critical flashover (CFO) voltage: Fifty percent probability of sparkover voltage.

current-carrying part: A conducting part intended to be connected in an electric circuit to a source of voltage. Noncurrent-carrying parts are parts not intended to be connected in such a manner.

de-energized: Disconnected from all intentional sources of electrical supply by open switches, jumpers, taps, or other means. De-energized conductors or equipment could be electrically charged or energized through various means, e.g., induction from energized circuits, portable generators, lightning.

disruptive discharge: The phenomenon associated with the failure of insulation, under electric stress, that includes a collapse of voltage and the passage of current. The term applies to electrical breakdown in solid, liquid, and gaseous dielectrics and combinations of these.

energized: Electrically connected to a source of potential difference or electrically charged to have a potential different from that of the ground. *Syn:* **alive; current-carrying; hot; live.**

equipotential: A nearly identical state of electrical potential for two or more items.

equivalent salt deposit density (ESDD): The amount of salt that, when dissolved in demineralized water, gives the same volume conductivity as that of the highly soluble natural deposit removed from a given surface of the insulator divided by the area of this surface; generally expressed in mg/cm^2 . However, for discussion of ESDD on live-line tools, units of $\mu\text{g}/\text{cm}^2$ are recommended to convey the necessary precision of accuracy.

NOTE—See IEEE Std 1820™-2020 [B48]. 11, 12

flashover: A disruptive discharge through air around and over a surface of solid or liquid insulation, between parts at different potential or polarity, produced by application of voltage wherein the breakdown path becomes sufficiently ionized to maintain an electric arc.

floating object: An object that may or may not be conductive in the air gap at unknown potential.

floating potential: Electric potential of a ~~An electric charge impressed upon~~ conductive object ~~objects~~ suspended in the air gap that is ~~are~~ not electrically connected to the energized conductor or ground.

gloving: A method of performing live work on energized electrical conductors and equipment where one or more qualified electrical workers, wearing specially made and tested insulating gloves, with or without sleeves, work directly on the energized electrical conductor or equipment.

ground potential: Potential equal to or near that of ground, normally zero volts.

grounded: Connected to earth or to some extended conducting body that serves instead of the earth.
Syn: earthed.

¹¹ ⁹ The numbers in brackets correspond to the numbers in the bibliography in Annex A.

¹² Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement the standard.

helicopter work: A technique of using a helicopter for performing live work on energized wires and equipment, where one or more line [qualified electrical](#) workers work directly on an energized part after being raised and bonded to the energized wire or equipment. *See also:* **aerial work; barehand work.**

hot: *See:* **energized.**

insulated tool or device: A tool or device that has conductive parts and is either coated or covered with a dielectric material to provide electrical insulation.

[Insulating](#) ~~insulated~~ personal equipment: Personal equipment made of natural or synthetic material that is designed primarily to provide electric insulation from an energized part or conductor.

insulating tool or device: (A) A tool or device designed primarily to provide insulation from an energized part or conductor. It can be composed entirely of insulating materials. Examples include conductor cover, stick, and insulating tape. (B) A tool or device that has conductive parts separated by dielectric parts. *Syn:* hot stick.

insulator cover: Electrical protection equipment designed specifically to cover insulators. Examples include dead-end cover, pole-top cover, and ridge-pin cover. *Syn:* **hood; pocketbook.** *See also:* **cover-up equipment.**

isolated: (A) Physically separated, electrically and mechanically, from all sources of electric energy. Such separation may not eliminate the effects of electric or magnetic induction. (B) Not readily accessible to persons unless special means for access are used.

leakage current: A component of the measured current that flows along the surface of the tool or equipment, due to the properties of the tool or equipment surface, including any surface deposits.

line work: Various operations performed by a person on electrical facilities, including groundwork, elevated work, aerial work, and associated maintenance.

line worker: A person qualified to perform various line work operations, including elevated aerial and groundwork. *Syn:* **lineman**. *See also:* [qualified electrical worker](#).

live: *See:* **energized**.

live parts: Items at the normal line operating voltage or [electrical](#) ~~some~~ potential above ground potential.

live work: Work on or near energized or potentially energized lines (i.e., grounding, insulating tool work, gloving, barehand work). *Syn:* live-line work; hot stick work.

maximum power frequency operating voltage (VM): The maximum system operating root-mean-square (rms) line-to-line (or line-to-ground for single phase or pole-to-ground for dc) voltage, which is also equal to the 1 per-unit (p.u.) base.

NOTE—For purposes of this guide, the maximum operating voltage is 5% higher than the rated (nominal) system voltage: $1.05 \times \text{rated (nominal) system voltage}$. [13](#) ~~10~~

minimum air insulation distance (MAID): The shortest distance in air between an energized electrical apparatus and/or a line worker's body at different potential. This distance, with a floating electrode in the gap, is equal to or greater than the sum of the individual minimum [air insulation approach](#) ~~distances~~ (MADs). This is the electrical component and does not include any factor for inadvertent movement. ~~*Syn:* electrical distance.~~

~~NOTE—For the definition of electrical distance, see IEC 61472 [B21].~~

minimum approach distance (MAD): The minimum air insulation distance (MAID) plus a factor for inadvertent movement.

[13](#) ~~10~~ Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the guide.

minimum approach distance for [line-to-ground](#) tools (MAD for Tools): The minimum length of insulation distance required, measured using the shortest distance between the conducting part at the live end and the closest point at ground potential. This term applies to tools that are subject to inadvertent movement.

minimum helicopter approach distance (MHAD): The shortest distance in air between an energized conductor and the closest point of helicopter [\(air insulation distance\) including inadvertent movement](#).

minimum tool insulation distance (MTID): The minimum length of insulation distance required, measured using the shortest distance between the conducting part at the live end and the closest point at ground potential. [If floating objects are present, such as metal pins on an adjustable strain stick, the MTID is the shortest distance between the conducting part at the live end and the closest point at ground potential minus the sum of the lengths of the individual floating objects.](#) This term applies to tools that are not subject to inadvertent movement.

[operating clearance:](#) *See:* [work permit](#).

overvoltage: Voltage that exceeds the maximum operating line-to-ground voltage. This voltage may be the result of a transient or switching surge. *Syn:* **transient overvoltage (TOV)**.

portable protective air gap (PPAG): A gap placed between live parts and ground to limit the overvoltage that may otherwise occur. *Syn:* **personal protective air gap**.

power loss: A means used to determine dielectric strength of an object by measuring the power loss through the object. *Syn:* **Doble Test; watts loss**.

protective grounding equipment: *See:* **temporary protective grounding equipment**.

puncture: A disruptive discharge through the body of a solid dielectric.

qualified [electrical worker](#): Having been trained in and having demonstrated adequate knowledge of the installation, construction, or operation of lines and equipment and the hazards involved, including identification of, and exposure to, electric supply and communication lines and equipment in, or near, the workplace. An employee, who is undergoing on-the-job training and who, in the course of such training, has demonstrated an ability to perform duties safely at his or her level of training, and who is under the direct supervision of a qualified person, is considered to be a qualified person for the performance of those duties.

rigging: An assembly of material used to manipulate or support various tools and equipment in energized, de-energized and not grounded, and grounded line work.

sparkover: A disruptive discharge between preset electrodes in either a gaseous or a liquid dielectric.

sparkover voltage: A voltage level at which a sparkover probably will occur under the stated conditions.

statistical sparkover voltage: A transient overvoltage (TOV) level that produces a 97.72% probability of sparkover (i.e., two standard deviations above the 50% sparkover voltage value).

statistical withstand voltage: A transient overvoltage (TOV) level that produces a 0.[13](#) ~~14~~% probability of sparkover (i.e., three standard deviations below the 50% sparkover voltage value).

stick: A type of insulating tool used in various operations of live work. Syn: hot stick; live-line tool; pole; work pole; work stick.

stray current: Currents or components that do not constitute information desired for measurement. Examples are currents due to the stray capacitance of an object to the ground plane, walls, etc.

structure: Material assembled to support conductors or associated apparatus, or both, used for transmission and distribution of electricity (e.g., service pole, tower).

suspension of reclosing: To make inoperative automatic reclosing equipment. *Syn:* **auto-reclosing off; block reclosing; hold off; hold order; hold out; live-line permit; non-reclose.**

switching surge: An overvoltage resulting from the operation of a circuit-interrupting device. *Syn:* **switching impulse.**

temporary protective grounding equipment: A system of ground clamps, ferrules, cluster bar, and covered cables designed and suitable for carrying maximum anticipated fault current and grounding conductive objects.

NOTE—See ASTM F 855, IEC 61230:[2008](#), IEEE Std 1048.¹⁴

tool or equipment leakage current: The total leakage current delivered to the tool or equipment. The tool or equipment provides only one path for the current, and this current is equal to the leakage current. *See also:* **leakage current.**

withstand voltage: A voltage level at which a sparkover probably will not occur under the stated conditions.

work permit: The authorization to perform work, such as work on a circuit. It is often part of a lockout-tagout procedure. *Syn:* [operating clearance](#), ~~guarantee~~.

3.2 Acronyms and abbreviations

<i>a</i>	switching surge air saturation factor
<i>A</i>	altitude correction factor
<i>C1</i>	factor in ft/kV determined from 60 Hz tests on rod-to-rod gap at 100 kV rms per foot of tool length withstand (100 kV rms/ft)
<i>C2</i>	insulating ~~the~~ tool factor

¹⁴ [Information on normative references can be found in Clause 2.](#)

CFO critical flashover [voltage](#)

[ESDD](#) [equivalent salt deposit density](#)

~~DCM~~ ~~distance in centimeters~~

~~DFT~~ ~~distance in feet~~

~~DM~~ ~~distance in meters~~

~~EMAX~~ ~~maximum transient overvoltage (TOV_{MAX})~~

FRP fiberglass-reinforced plastic

[GPR](#) [ground potential rise](#)

~~I_W~~ ~~only the current in the phase from watt loss testing, in amperes~~

k gap factor

[KF](#) [floating conductive factor](#)

M inadvertent movement factor

MAD minimum approach distance ([also DMAD in equations](#))

MAID minimum air insulation distance ([also DMAID in equations](#))

MHAD minimum helicopter approach distance ([also DMHAD in equations](#))

MTID minimum tool insulation distance ([also DMTID in equations](#))

PPAG portable protective air gap

p.u. per unit

Peak transient peak (crest)

RF	radio frequency
rms	root mean square
T	maximum anticipated per-unit transient overvoltage (TOV) TOV
rms	transient overvoltage
TOV_{peak}	peak transient overvoltage
TTOCD	temporary transient overvoltage control ~~device~~ devices
V_{50}	transient or temporary overvoltage level that produces a 50% probability of sparkover, ~~in kilovolts~~
V_{L-G}	ac voltage line-to-ground (rms), ~~in kilovolts~~
<u>kV_{L-G}</u>	<u>line-to-ground voltage (rms)</u>
V or V_{L-L}	ac voltage line-to-line (rms), ~~in kilovolts~~
V_M	maximum power frequency operating voltage (rms), ~~in kilovolts~~ , line-to-line
~~V_{MPC}~~	~~maximum power frequency operating voltage (rms), in kilovolts, pole-to-ground~~
V_{Neg}	peak voltage of the negative side of a sine wave
V_{P-G}	dc voltage pole-to-ground, ~~in kilovolts~~
V_{P-P}	dc voltage pole-to-pole, ~~in kilovolts~~
V_{Pos}	peak voltage of the positive side of a sine wave
V_{peak}	switching surge or transient overvoltage peak or crest voltage, ~~in kilovolts~~
~~V_R~~	~~manufacturer's rating, in kilovolts~~

~~V_R Peak~~ ~~manufacturer's rating, in kilovolts, peak~~

VW withstand voltage, peak

α (Greek small letter alpha) line-to-line insulation strength, which is the proportion of negative switching impulse voltage in the total line-to-line impulse voltage

σ (Greek small letter sigma) probability [standard deviation](#)

μ (Greek small letter mu) 50% critical sparkover [voltage](#) value ([mean value](#))

$\mu + 2\sigma$ sparkover voltage

$\mu - 3\sigma$ withstand voltage

4. Technical considerations

4.1 Introduction

The performance of live work requires the use of equipment and tools that in many cases are specific to the work operation. Development of equipment and tools is based on requirements generated from field needs and experiences related to technical considerations and work method safety. For live work, minimum air insulation distance (MAID), minimum tool insulation distance (MTID), minimum approach distance (MAD), minimum approach distance for tools (MAD for Tools), and minimum helicopter approach distance (MHAD) have been developed in this clause for operating voltages up to 800 kV. These distances are used when working near the following:

- Overhead conductors supported by suspension and tension insulators
- Overhead conductors supported by post insulators
- Overhead tubular bus supported by post insulators
- Equipment entrance bushing and cable potheads

- Live equipment such as “live tank” circuit breakers, high-speed circuit switching devices, isolating switches, wave traps, series capacitors and reactors
- Insulated phase conductors not covered with a continuous conducting shield or sheath at ground potential and supported from a conductor at ground potential^{15 11}

The major hazard in live work on high-voltage lines and equipment is a sparkover of air gap insulation to ground at the worksite. This results in the rapid release of a large amount of energy, which may cause injury to the workers and/or damage equipment.

In an operating electrical power supply system, the phase conductors are insulated from each other and ground using the support insulators and air. When live work is performed on high-voltage systems, the primary insulation is air. However, in systems below 72.5 kV, rubber [insulating](#) gloves and sleeves, insulating cover-up, and insulating barriers can provide additional protection for the worker. Insulating cover-up is designed only for inadvertent contact, i.e., brush contact.

4.2 Insulating properties

[4.2.1 General](#)

Personal safety and operational security during energized-line work depend on the insulating properties of the air gap and the insulating materials that are placed in the air gap for the live work.

4.2.2 Sparkover of air gap

A sparkover of the air gap insulation at the worksite can be caused by any of the following:

- a) A reduction of the air gap distance caused by the introduction of conductive objects

^{15 11} Since the condition of the conductor insulation is not known, conductors should be considered as live at their operating voltage.

- b) Transient overvoltages (TOVs)
- c) Tool insulation breakdown

4.2.3 Preventing sparkover of air gap insulation at worksite

For live work, MAID, MTID, MAD, MAD for Tools, and MHAD have been developed, based on the maximum operating voltage of the system and the maximum anticipated [TOV \(and](#) per-unit ~~TOV~~ ϵT) of the line, to provide guidance to the workers on the required air gap insulation.

4.3 Air as insulation

[4.3.1 General](#)

The insulating characteristics of air are defined in terms of its dielectric strength and its capability to withstand electric stresses. The dielectric strength of air is expressed in the unit of kilovolts/meter or an equivalent unit. The dielectric strength of the air gap should be greater than the electric stress to which it is exposed. The dielectric strength of air is influenced by the following:

- a) Temperature
- b) Barometric pressure
- c) Altitude (height of the worksite above sea level)
- d) Relative humidity
- e) Airborne impurities in the air gap
- f) Dimensions, shape of electrodes, and configuration of the spacing g) Time-dependent characteristics of the applied voltage

4.3.2 Insulating materials and tools used in live work

Insulating materials are generally defined in terms of their dielectric strength. The dielectric strength of the insulating material or tool should be greater than the electrical stress to which it is exposed. When two or more insulating materials are used in series within the air gap, the dielectric strength of each should be greater than the electrical stress to which each is exposed. See 4.10.54.1.

The primary factors that affect the electrical performance of insulating materials are the following:

- a) Temperature
- b) Barometric pressure
- c) Altitude (height of the worksite above sea level)
- d) Relative humidity
- e) Airborne impurities
- f) Dimensions, shape of electrodes, and the configuration of the spacing
- g) Time-dependent characteristics of the applied voltage
- h) Surface contamination
- i) Impurities
- j) Aging

4.3.3 Insulating tools used in live work in air gap insulation

When insulating devices (e.g., live work tools, insulating aerial lift devices, insulating ladders, rope) are used in the air gap, they are generally defined in terms of their dielectric strength. The dielectric strength or rating of this equipment should be greater than the operating voltage to which it is being applied. When two or more insulating devices are used in series within the air gap, the rating of each should be greater than the voltage to which it is being applied.

The desirable property of the insulating devices is their ability to reduce the flow of current through them to a very low value. Dielectric strength is defined as the potential gradient at which electric failure or breakdown occurs.

Factors that affect the electrical performance of insulating materials include the following:

- a) Temperature
- b) Barometric pressure
- c) Altitude (height of the worksite above sea level)
- d) Relative humidity
- e) Airborne impurities
- f) Dimensions, shape of electrodes, and configuration of the spacing
- g) Time-dependent characteristics of the applied voltage
- h) Surface contamination
- i) Impurities
- j) Aging

4.4 Factors that affect the air insulation

4.4.1 Atmospheric conditions

The laboratory test data used to develop the formulas and tables in the guide were obtained under atmospheric conditions that are defined as temperatures above freezing, wind speed under 24 km/h (15 mph), unsaturated air, normal barometric pressure [76 cm (29.92 in) of mercury] at sea level, and uncontaminated air, with clean and dry insulators.

4.4.2 Contamination

The equipment used for gloving, cover-up materials, and insulating sections of aerial devices and tools shall be kept free from contamination. Live work ~~may~~ ~~can~~ be performed on dry contaminated insulators. Work on wet contaminated insulator should be avoided.

4.4.3 Adverse weather conditions

Live work should not be performed when the following adverse conditions exist:

- a) Lightning activity in the worksite area
- b) Relative humidity at or near 100%
- c) Relative humidity at or above 85% for high-voltage dc work above 72.5 kV
- d) Rain or snow

4.5 Air gap distances

4.5.1 General

This subclause describes the two methods for determining the MAID, MTID, MAD, MAD for Tools, and MHAD for use in work involving energized lines and equipment.

- a) Calculation of distances using the formulas in 4.6 and 4.7 is recommended.
- b) Distance tables calculated from the formulas in 4.6 and 4.7 have been provided in Annex D.

~~The distance tables for line-to-line voltages above 72.5 kV are applicable for live work only when the worksite altitude is below 900 m (3000 ft) above sea level. To use the table distances when the worksite altitude is above 900 m (3000 ft) above sea level, an altitude correction should be applied. See 4.7.6.~~

NOTE—The MAID, MTID, and MAD should not be confused with other electrical distances, such as insulator creepage distance and National Electrical Safety Code[®] (NESC[®]) (Accredited Standards Committee C2-2007) [B1] conductor spacing, etc.

This guide does not address live work on lines and equipment with an ac and dc line-to-line or line-to-ground or pole-to-ground voltage below 50 V.

This guide recommends that contact be avoided for live work on lines with an ac and dc line-to-line or line-to-ground or pole-to-ground voltage between 51 [V](#) and 300 V.

CAUTION

Additional precautions may be required when working on lines and conductors used on distribution network, transportation system catenary, and long low-capacity rural distribution circuits due to fault clearing. In some of these cases, the primary current source may not be automatically opened or interrupted if the fault is beyond the reach of the protection.

Additional precautions may also be required on dc and low-frequency circuits since a considerably larger switch gap is required to break the arc when opening a circuit.

This guide recommends the following rounding-up of the distance and switching surge air saturation factor calculation:

Item	Number of decimal places
Distance in meters	2
Distance in feet	2
Distance in centimeters	2
Switching surge air saturation factor, a	7

[\(New\)](#)

Item	Number of decimal places
Distance in meters, D_M	2
Distance in feet, D_{FT}	2
Distance in centimeters, D_{CM}	2
Switching surge air saturation factor, "a"	7

(Deleted)

To round up, add 1 to the last decimal place to be retained if the next decimal place is not zero.

Example: 2.2224 rounded up to 3 decimal places is 2.223

4.5.2 Minimum air insulation distance (MAID)

4.5.2.1 General

The MAID for line-to-ground work is the minimum air gap distance required to prevent a sparkover at the worksite between the energized parts and a conducting object at ground potential during live work. This distance is normally measured in meters or feet along a straight line between the conductor or energized metal hardware and the ~~and~~ nearest item at ground potential. The nearest item at ground potential may be the worker or part of the supporting structure.

The MAID for line-to-line work is the minimum air gap distance required to prevent a sparkover at the worksite between the energized parts of two different phases ~~phase conductors~~ during live work. This distance is normally measured in meters or feet along a straight line between the conductors or energized metal hardware.

4.5.2.2 Determining MAID for line-to-ground and line-to-line work for ac and dc pole ~~line-to-pole~~ line voltages between ~~from~~ 300 V and ~~below~~ 72.5 kV

The MAID is the required undisturbed air insulation distance required to prevent a sparkover at the worksite during a system event that results in the maximum anticipated TOV (and T).

The formulas for [distances](#) ~~MAIDs~~ for line-to-line voltages below 72.5 kV are based on the 60 Hz rod-to-rod gap test data from IEEE Std 4-TM 1995, ~~[B28]~~. See 4.6.2 ~~1~~, 4.7.1.1, 4.7.1.2, 4.7.4.2 ~~1~~, and 4.7.5 for further details.

For dc lines, see also 4.7.4.6 ~~4~~.

4.5.2.3 Determining MAID for line-to-ground work for ac line-to-line voltages above 72.5 kV

~~The MAID is the required undisturbed air insulation distance required to prevent a sparkover at the worksite during a system event that results in the maximum anticipated TOV.~~

The formulas for ~~MAID~~-line-to-ground [MAID values](#) ~~distances~~ for line-to-line voltages above 72.5 kV are based on the rod gap test data from [IEEE paper](#) "Recommendations for safety [in live-line maintenance](#)" ~~[B42]~~ ~~[B25]~~. See 4.6.3 ~~2.1~~ and 4.7.1.3 for further details.

4.5.2.4 Determining MAID for line-to-line work for ac line-to-line voltages above 72.5 kV

~~The MAID is the required undisturbed air insulation distance required to prevent a sparkover at the worksite during a system event that results in the maximum anticipated TOV.~~

The formulas for [line-to-MAID](#)-line [MAID values](#) ~~to-line distance~~ for line-to-line voltages above 72.5 kV are based on test data (for the live-to-line gap) published the 1993 paper by Vaisman et al. ~~[B60 B41]~~. The paper presents and compares such published test data from five laboratories found in the literature. These test data are fitted with a modified Gallet equation used to determine line-to-line MAID (see Gallet et al. ~~[B27 B16]~~ and ~~[B26 B17]~~). See 4.6.3 ~~2.2~~ and 4.7.1.4 for further details.

4.5.2.5 Reducing MAID

When using cover-up material, rubber [insulating](#) gloves and sleeves, or insulating barriers that are properly rated and tested for the operating voltage on which the work is being done, the distance from the worker to the task location may be reduced. However, the air distance to exposed energized parts should be maintained in the area where these are applied or used. [See 4.5.4.3 for further details.](#)

Insulated conductors supported by a conductive material at ground potential and insulated conductors supported by insulating material from conductive material at ground potential should be considered as live at their line-to-ground voltage since the condition of conductor insulation is not known.

Insulated conductors with a continuous concentric metal shield that is maintained at ground potential should be considered as being at ground potential.

4.5.3 Minimum tool insulation distance (MTID)

[4.5.3.1 General](#)

The MTID [for line-to-ground work](#) is the required undisturbed air insulation distance that is needed to prevent a tool flashover at the worksite during a system event that results in the maximum anticipated TOV [\(and T\)](#).

[4.5.3.2 Determining MTID for ~~ac and dc~~ line-to-ground and line-to-line work for ac and dc pole-to-pole voltages between 300 V at and below 72.5 kV](#)

The MTID for ac and dc line-to-line voltages at and below 72.5 kV has not been determined. Industry [uses MAID since MTID is not available at and below 72.5 kV. See 4.5.2.2 practices normally use an MTID that is the same as or greater than the MAID. See 4.5.1.1.](#)

4.5.3.3 Determining MTID for ac and dc line-to-ground work with line-to-line voltages above 72.5 kV

When any foreign object, such as tools or other devices used to perform work on the line, is placed in the air gap, the MTID is used.

This guidance includes floating objects, insulating maintenance tools, and aerial devices that are tested and rated for the line-to-ground or line-to-line voltage applied across them. This distance is normally measured in meters or feet along a straight line between the conductor and nearest item at ground potential. Small conducting items [e.g., tool splices (used to join tool sections together), clamps, cradle brackets] placed on or within the insulating medium do not affect this distance.

The MTID is calculated using a similar formula as the MAID with the addition of the C₂ factor. See 4.6.3.1 and 4.7.2 for further details.

4.5.3.4 Determining MTID for ac ~~and dc~~ line-to-line and dc pole-to-pole work with line-to-line voltages above 72.5 kV

The definition of MTID applies only to line-to-ground application. It is rare that a worker would be at the potential of one phase while working on another phase. If a nonconductive object, such as an insulating ~~insulated~~ tool, is placed in the air gap joining two ac phases or dc poles, an engineering study should be performed. Additional ~~Addition~~ testing is required to develop ac a line-to-line and dc pole ~~MTID. If a line-to-pole MTID line MTID is required, the same factor as used in the line-to-ground distance may be used. Industry practices normally use an MTID that is the same as or greater than the MAID.~~

~~4.5.2.4 Determining MTID for ac and dc line-to-ground work with line-to-line voltages above 72.5 kV~~

~~The MTIDs are calculated using a similar formula as the MAIDs with the addition of the C₂ factor. See 4.6.2.1 and 4.7.2 for further details.~~

4.5.2.5 Determining MTID for ac and dc line-to-line work with line-to-line voltages above 72.5 kV

Line-to-line live working methods are normally based on when the worker is only at the potential of the phase on which live work is being conducted. In other words, the worker is not at the potential of one phase while working on the other phase. For this reason, the application of [insulating insulated](#) tools between phases is very limited. If a nonconductive object, such as [insulating insulated](#) tool, is placed in the air gap between two phases, the application of C2 factor (which is used in line-to-ground MTID) is questionable because there are no test data to support this. Until such test data are available, the line-to-line MTID is not provided in this guide. However, page 520 of the [2005](#) EPRI *Red Book* [[B13](#) ~~B9~~] states “tests performed with a nonceramic insulator string between two conductors at midspan of the test line have shown that the flashover pattern, also, is not appreciably altered by the presence of the string and its associated hardware.” Additional tests are planned in the ~~near~~-future.

4.5.4 Minimum approach distance (MAD)

4.5.4.1 General

To provide additional protection for workers during energized-line maintenance or while working in the vicinity of other energized lines, MAD has been developed. This distance allows for any inadvertent movement that may occur during live work.

4.5.4.2 Determining MAD for ac and dc line-to-line voltages at and above [301](#) ~~300~~ V

The MAD is determined from the MAID, plus a factor for inadvertent movement (M). The M factor is not adjusted for altitude. See 4.6.[2](#) ~~1~~ and 4.6.[3](#) ~~2~~ for further details. See also 4.5.[2.2](#) ~~1.1~~.

4.5.4.3 Reducing MAD

The use of barriers that physically limit the worker's inadvertent movement can [be used to calculate reduced MAD](#) ~~reduce the MADs~~ between the worker and the energized or grounded parts. [These reduced distances](#) ~~They~~ can be used on any voltage lines or equipment provided proper MAID is observed. Barriers are not relied on for electrical insulation, but act only as physical barriers.

[When working on voltages below 36 kV using cover-up material, rubber insulating gloves and sleeves, or insulating barriers that are properly rated and tested for the operating voltage on which the work](#) ~~An exception to this~~ [is being done, the distance from the worker to the task location may be reduced.](#) When the worker is using the rubber gloving method: ~~In this case,~~ the distance to the exposed energized conductor may be reduced by eliminating or reducing the inadvertent movement factor distance when the worker's movement is restricted. ~~When using the rubber gloving method, secondary supporting insulation, such as insulating footwear, an insulating platform, or an insulating aerial device, is utilized.~~ Insulating cover-up is designed only for inadvertent contact. It may be necessary to use insulating aerial devices or insulating platforms to limit the leakage current below the worker's threshold of [perception](#) ~~feeling~~ (see Kolcio [[B50](#) ~~B31~~]). Insulating aerial devices act as the principal insulation should the rubber gloves fail or should the worker accidentally contact the conductor.

4.5.5 Minimum approach distance for tools (MAD for Tools)

[4.5.5.1 General](#)

To provide additional protection for workers during energized-line maintenance or while working in the vicinity of other energized lines when any foreign object, such as tools or other devices used to perform work on the line, is placed in the air gap, the MAD for Tools is used. See 4.6.[2](#) ~~1~~ and 4.6.[3](#) ~~2~~ for further details.

4.5.5.2 [Determining](#) MAD for Tools for ac and dc line-to-line voltages at and below 72.5 kV

The [MAD for Tools is determined from the MTID, plus a factor for inadvertent movement \(\$M\$ \)](#). [However, the](#) MTID for ac and dc line-to-line voltages at and below 72.5 kV has not been determined. Industry practices normally use an MTID that is the same as or greater than the MAID. See 4.5.2.2 ~~1.1~~.

[The \$M\$ factor is not adjusted for altitude.](#)

4.5.5.3 Determining line-to-ground MAD for Tools for ac and dc line-to-line voltages above 72.5 kV

The MAD for Tools is determined from the MTID, plus a factor for inadvertent movement (M). The M factor is not adjusted for altitude.

4.5.5.4 Determining line-to-line MAD for Tools for ac and dc line-to-line voltages above 72.5 kV

Addition testing is required to develop a MAD for Tools for line-to-line voltages above 72.5 kV. If a line-to-line MAD for Tools is required, the same factor as used in the line-to-ground distance may be used. Industry practices normally use a MAD for Tools that is the same as or greater than the MAD.

4.5.6 Minimum helicopter approach distance (MHAD)

[4.5.6.1 General](#)

To provide additional protection for workers during energized-line maintenance from helicopters, the MHAD has been developed. This distance covers possible corona on the helicopter, rotor wash, and movement due to wind.

4.5.6.2 Determining MHAD for ac line-to-line voltages above 72.5 kV

The MHAD is derived from the MAD, plus an industry suggested value of 10% MAD. Data for this subclause was obtained from [EPRI report “Full-Scale AC and Switching Impulse Tests of “Helicopter-Based Live Work: 230 kV Vertical Phase Configuration with Jumper Loop” \[B16 B10\]](#)-. See 4.6.2 4 and 4.6.3 2 for further details.

4.6 Distance equations

4.6.1 General

When a distance equation is used, the distances that result are in the same units as the reference data source. In the United States, most of the line workers use the “English” or feet measurement in their work, and in other countries, the metric measurements are used.

For this reason, ~~formulas and~~ tables have been developed in both measurement systems. Table 1 lists the distance conversion factors used in this guide.

Table 1—Distance conversion factors

To convert to	From		
	Centimeters	Feet	Meters
	Multiply by		
Feet	0.0328	1.0	3.281
Meters	0.01	0.3048	1.0

The distances obtained from the equations in 4.6 should be rounded up.

4.6.2 Work on ac and dc line conductors and equipment for line-to-ground and line-to-line voltages from 50 V to 72.5 kV

4.6.2.1 General

These distances apply to conductors and equipment supported by insulators where air is the primary insulating medium. They do not apply to insulated cables where it has been determined that insulation is good.

The following terms are used in the formulas in this subclause:

D_M is distance, in meters

~~D_{FT} is distance, in feet~~

TOV_{peak} is the maximum anticipated peak transient overvoltage (see 4.6.2.5 4.4) for a given voltage, in kilovolts (see 4.7.1)

T_{peak} is the maximum anticipated peak transient overvoltage expressed as per-unit of TOV on the line (see 4.7.4)

V_{L-G} is the line-to-ground rms voltage, in kilovolts (see 4.7.5)

V_{L-L} is the line-to-line rms voltage, in kilovolts (see 4.7.5)

M is the inadvertent movement factor (see 4.7.7)

The equations in 4.6.1.2.3 through 4.6.2.7 4.6 were developed from the 60 Hz sparkover distance for rod-to-rod configuration for a given voltage in kilovolts. See 4.7.1 for further details.

4.6.2.2 Work on ac and dc line conductors and equipment for line-to-ground and line-to-line voltages between ~~from~~ 50 V and ~~to below~~ 300 V

When the line-to-ground and line-to-line voltage is between 50 V and 300 V, this guide recommends that contact be avoided.

4.6.2.3 Work on ac and dc line conductors and equipment for line-to-ground and line-to-line voltages between 301 ~~from 300~~ V and to below 750 V

When the line-to-ground and line-to-line voltage is between 301 V ~~300~~ and 750 V, sufficient test data are not available to calculate the MAID, which is less than 2 cm (~~or~~ 0.07 ft). This guide recommends the following:

- a) DMAID ~~MAD~~, line-to-ground and line-to-line

$$\{D_{\text{MAD,L-G}}\}_m = 0.02; \quad \{D_{\text{MAD,L-L}}\}_m = 0.02$$

(New)

1) ~~$D_M = 0.02$~~

2) ~~$D_{FT} = 0.07$~~

- b) DMAD ~~MAD~~, line-to-ground and line-to-line

$$\{D_{\text{MAD,L-G}}\}_m = 0.32; \quad \{D_{\text{MAD,L-L}}\}_m = 0.32$$

(New)

1) ~~$D_M = 0.32$~~

2) ~~$D_{FT} = 1.07$~~

4.6.2.4 Work on ac and dc line conductors and equipment for line-to-ground and line-to-line voltages between 751 ~~above 750~~ V and ~~below 5.0~~ kV

When the line-to-ground and line-to-line voltage is between 751 ~~750~~ V and 5.0 kV, sufficient test data are not available to calculate the MAID, which is less than 2 cm (~~or~~ ~~0.07~~ ft). This guide recommends the following:

- a) DMAID,L-G ~~MAD~~, line-to-ground and line-to-line

$$\left\{ D_{\text{MAID,L-G}} \right\}_m = 0.02; \quad \left\{ D_{\text{MAID,L-L}} \right\}_m = 0.02$$

(New)

1) ~~$D_M = 0.02$~~

2) ~~$D_{FT} = 0.07$~~

- b) DMAD,L-L ~~MAD~~, line-to-ground and line-to-line

$$\left\{ D_{\text{MAD,L-G}} \right\}_m = 0.63; \quad \left\{ D_{\text{MAD,L-L}} \right\}_m = 0.63$$

(New)

1) ~~$D_M = 0.63$~~

2) ~~$D_{FT} = 2.07$~~

4.6.2.5 Work on ac and dc line conductors and equipment for line-to-line voltages from above 5.0 kV to 72.5 kV

To find which equation to use when the line-to-line voltage is above ~~between~~ 5.0 kV to ~~and~~ 72.5 kV, first determine the peak transient overvoltage, TOV_{peak} .

a) For line-to-ground work

$$\{TOV_{L-G}\}_{kV} = \sqrt{2} \times \{T_{L-G}\}_{pu} \times \{V_{L-G,rms}\}_{kV} \quad (1)$$

(New)

$$TOV_{L-G,Peak} = \sqrt{2} (T) (V_{L-G}) \quad (1)$$

~~(Deleted)~~

b) For line-to-line work

$$\{TOV_{L-L}\}_{kV} = \sqrt{2} \times \{T_{L-L}\}_{pu} \times \{V_{L-L,rms}\}_{kV} \quad (2)$$

(New)

$$TOV_{L-L,Peak} = \sqrt{2} (T) (V_{L-L}) \quad (2)$$

~~(Deleted)~~

If the TOV_{peak} is less than 27.00 kV, use 4.6.2.6~~1.5~~.

If the TOV_{peak} is equal to or greater than 27.00 ~~0084.88~~ kV, use 4.6.2.7 ~~1.6~~. For dc line conductors, see 4.7.4.6 ~~4~~, 4.7.5.6, and 4.7.5~~and 4.7.5.6~~.