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IEEE Guide for Selection and Installation of Electrical Cables and Cable Systems in Hazardous (Classified) Locations on Oil and Gas Land Drilling Rigs

STANDARDS

IEEE Industry Applications Society

Developed by the
Petroleum and Chemical Industry Committee

and the

IEEE Power and Energy Society

Developed by the
Insulated Conductors Committee

IEEE Std 2740™-2020

IEEE

IEEE Guide for Selection and Installation of Electrical Cables and Cable Systems in Hazardous (Classified) Locations on Oil and Gas Land Drilling Rigs

Developed by the

Petroleum and Chemical Industry Committee
of the
IEEE Industry Applications Society

Insulated Conductors Committee
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IEEE Power and Energy Society

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IEEE SA Standards Board

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Introduction

This introduction is not part of IEEE Std 2740-2020, IEEE Guide for Selection and Installation of Electrical Cables and Cable Systems in Hazardous (Classified) Locations on Oil and Gas Land Drilling Rigs.

The oil and gas industry depends on working within regulatory requirements, industry standards, and industry guidelines. In the case of oil and gas well land drilling rigs in the United States, there are no standards or governing codes that directly address cables and cable systems. Land drilling rig applications often combine hazardous (classified) locations, extreme ambient temperature ranges, vibration, temporary installations, flexibility, and ability to transport over various terrains. The National Electrical Code® (NEC®) NFPA 70 standard does not cover the selection, performance requirements, and procedures for flexible electrical cables and cable systems installed in hazardous (classified) locations on oil and gas land drilling rigs. Instead, its focus is on fixed installations in hazardous (classified) locations. When users have tried to apply National Electrical Code regulations for fixed hazardous (classified) locations, they have encountered conflicts between portability, flexibility, and solutions permitted for fixed hazardous (classified) locations; therefore, users have relied on the API RP 14F and API RP 14FZ recommended practices for installation methods that are not specific to oil and gas land drilling rigs since they reference offshore facilities. This gap creates confusion for new engineers and inspectors trying to understand cables and cable systems for oil and gas well land drilling rigs. However, within the 2020 edition of NFPA 70, an entirely new article (Article 337) has been added along with new language in Article 501 to address this gap. This guide should be consulted only in addition to consideration and evaluation of site-specific circumstances, risks, and applicable safety requirements.

Contents

IEEE Guide for Selection and Installation of Electrical Cables and Cable Systems in Hazardous (Classified) Locations on Oil and Gas Land Drilling Rigs

1. Overview

1.1 Scope

This guide covers the selection and procedures for electrical cables and cable systems installed in hazardous (classified) locations on oil and gas land drilling rigs.

1.2 Purpose

The intent of this guide is to present generally accepted practices for the selection and installation of electrical cables and cable systems in hazardous (classified) locations on oil and gas land drilling rigs. Experience in the oil and gas land rig drilling industry has shown these practices result in safer, more reliable, efficient, and maintainable operations. The practices in this guide should be applied with sound engineering judgment.

This guide will address gaps in the selection, performance, and installation of cables and cable systems for Class I hazardous (classified) locations on oil and gas land drilling rigs not adequately addressed in present standards, recommended practices, and guides. The key drivers are flexibility, portability, allowance for innovation, and expanded use of cables and systems utilized in other industries.

1.3 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*).

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so 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.

API RP 500, Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Division 1 and Division 2.[3]

API RP 505, Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Zone 0, Zone 1, and Zone 2.

ICEA P-32-382, Short Circuit Characteristics of Insulated Cables.[4]

ICEA P-45-482, Short Circuit Performance of Metallic Shields and Sheaths on Insulated Cables.

ICEA S-75-381/NEMA WC 58, Portable and Power Feeder Cables for Use in Mines and Similar Applications.

ICEA S-95-658/NEMA WC 70, Power Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy.

IEC 60287-1-1, Electric Cables—Calculation of the Current Rating—Current Rating Equations (100% Load Factor) and Calculation of Losses—General.[5]

IEEE Std 45.8™, IEEE Recommended Practice for Electrical Installation on Shipboard—Cable Systems.[6,7]

IEEE Std 835™, IEEE Standard Power Cable Ampacity Tables.

[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.
[3] API publications are available from the American Petroleum Institute (https://www.api.org/).
[4] ICEA publications are available from the Insulated Cable Engineers Association (https://www.icea.org/).
[5] IEC publications are available from the International Electrotechnical Commission (https://www.iec.ch) and the American National Standards Institute (https://www.ansi.org/).
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[7] IEEE publications are available from The Institute of Electrical and Electronics Engineers (https://standards.ieee.org/).

IEEE Std 1580™, IEEE Recommended Practice for Marine Cable for Use on Shipboard and Fixed or Floating Facilities.

NFPA 70, National Electrical Code® (NEC®).[8,9]

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]

3.2 Acronyms and abbreviations

adjustable speed drive (ASD): Electronic power conversion equipment that provides a means of adjusting the speed of an electric motor.

AEx: Required marking prefix for electrical apparatus to be installed in hazardous (classified) locations meeting one or more types of protection in accordance with harmonized American National Standards (ANSI) as defined in Article 505 of the NEC.

approved: Acceptable to the authority having jurisdiction. (Electrical devices that are approved by a Nationally Recognized Testing Laboratory normally are acceptable.)

NOTE—The means for identifying approved equipment can vary for each organization concerned with product evaluation, some of which do not recognize equipment as approved unless it is also labeled. The authority having jurisdiction normally utilizes the system employed by the certifying organization to identify an approved product.[11]

Class I location: A Class I location is one in which flammable gases or vapors are or may be present in the air in quantities enough to produce explosive or ignitable mixtures. (See NEC Article 500, NEC Article 505, API RP 500, and API RP 505.)

Class I, Division 1 location: A Class I, Division 1 location is a location: 1) in which ignitable concentrations of flammable gases or vapors exist continuously, intermittently, or periodically under normal operating conditions; or 2) in which ignitable concentration of such gases or vapors may exist frequently because of repair or maintenance operations or because of leakage; or 3) in which breakdown or faulty operation of equipment or processes might release ignitable concentrations of flammable gases or vapors, and might also cause simultaneous failure of electrical equipment. (See NEC Article 500 and API RP 500.)

Class I, Division 2 location: A Class I, Division 2 location is a location: 1) in which volatile flammable liquids or flammable gases are handled, processed, or used, but in which the hazardous liquids, vapors, or gases will normally be confined within closed containers or closed systems from which they can escape only if accidental rupture or breakdown of such containers or systems or abnormal operation of equipment

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[8] NFPA publications are published by the National Fire Protection Association (https:// www.nfpa.org/).
[9] The NEC is published by the National Fire Protection Association (https://www.nfpa.org/). Copies are also available from the Institute of Electrical and Electronics Engineers (https://standards.ieee.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.
[11] Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

occurs; or 2) in which hazardous concentrations of gases or vapors are normally prevented by positive mechanical ventilation, but that might become hazardous through failure or abnormal operation of the ventilating equipment; or 3) that is adjacent to a Class I, Division 1 location, and to which hazardous concentration of gases or vapors might occasionally be communicated unless such communication is prevented by adequate positive-pressure ventilation from a source of clean air, and effective safeguards against ventilation failure are provided. (See NEC Article 500 and API RP 500.)

Class I, Zone 0: A Class I, Zone 0 location is a location 1) in which ignitable concentrations of flammable gases or vapors are present continuously; or 2) in which ignitable concentrations of flammable gases or vapors are present for long periods of time. (See NEC Article 505 and API RP 505.)

Class I, Zone 1: A Class I, Zone 1 location is a location 1) in which ignitable concentrations of flammable gases or vapors are likely to exist under normal operating conditions; or 2) in which ignitable concentrations of flammable gases or vapors may exist frequently because of repair or maintenance operations or because of leakage; or 3) in which equipment is operated, or processes are carried on, of such a nature that equipment breakdown or faulty operations could result in the release of ignitable concentrations of flammable gases or vapors and also cause simultaneous failure of electrical equipment in a mode to cause the electrical equipment to become a source of ignition; or 4) that is adjacent to a Class I, Zone 0 location from which ignitable concentrations of vapors could be communicated, unless communication is prevented by adequate positive-pressure ventilation from a source of clean air and effective safeguards against ventilation failure are provided. (See NEC Article 505 and API RP 505.)

Class I, Zone 2: A Class I, Zone 2 location is a location 1) in which ignitable concentrations of flammable gases or vapors are not likely to occur in normal operation, and if they do occur, will exist only for a short period; or 2) in which volatile flammable liquids, flammable gases, or flammable vapors are handled, processed, or used, but in which the liquids, gases, or vapors normally are confined within closed containers or closed systems from which they can escape only as a result of accidental rupture or breakdown of the containers or system, or as the result of the abnormal operation of the equipment with which the liquids or gases are handled, processed, or used; or 3) in which ignitable concentrations of flammable gases or vapors normally are prevented by positive mechanical ventilation, but which may become hazardous as the result of failure or abnormal operation of the ventilation equipment; or 4) that is adjacent to a Class I, Zone 1 location, from which ignitable concentrations of flammable gases or vapors could be communicated, unless such communication is prevented by adequate positive-pressure ventilation from a source of clean air, and effective safeguards against ventilation failure are provided. (See NEC Article 505 and API RP 505.)

classified location: A hazardous (classified) location is a location classified as Division 1 or Division 2, or Zone 0, Zone 1, or Zone 2.

communication and electronics circuits: Electrical circuits supplying equipment and systems for voice, sound, or data transmission, such as telephone, data communication, interior communication, paging systems, wired music systems, fire and general alarm systems, smoke and fire detection systems, closed circuit television, and microprocessor-based automated alarm and control systems.

double-banked: The arrangement of cables in a cable tray or raceway wherein the cables are stacked in two layers.

drag chain: A reciprocating cable-management system that can contain cables and/or hoses that are allowed free movement within the drag chain. Cables and/or hoses can be in single or multiple layers.

explosionproof cable seal: A cable gland filled with compound and designed to contain an explosion in the enclosure to which it is attached or to minimize passage of flammable gases or vapors from one location to another. An explosionproof conduit seal may also be used in combination with a cable termination fitting as an explosionproof cable seal.

explosive atmosphere: A mixture with air, under atmospheric conditions, of flammable substances in the form of gas, vapor, mist, or dust in which, after ignition, combustion spreads throughout the unconsumed mixture.

festoon: A mechanical non-motorized trolley or trolleys capable of carrying single or multiple cable and/or hoses on a manufactured steel rail or steel I-beam.

flammable: Capable of igniting easily, burning intensely, or having a rapid rate of flame spread.

intrinsically safe circuit: A circuit in which any spark or thermal effect is incapable of causing ignition of a mixture of flammable or combustible material in air under prescribed test conditions.

jacket/sheath: A nonmetallic protective covering over the cable core is considered a jacket. When it is applied over the armor, it is considered a sheath.

marine shipboard Type P cable: Impervious sheathed armored or unarmored cable addressed in the National Electrical Code, constructed in accordance with IEEE Std 1580™ and UL 1309, except that an overall impervious sheath is required over the armored construction, and approved as "Shipboard Cable, Marine" by a Nationally Recognized Testing Laboratory (NRTL).

Nationally Recognized Testing Laboratory (NRTL): A U.S. Occupational Safety and Health Administration (OSHA) designation given to testing facilities that provide product safety testing and certification services to manufacturers. OSHA publishes a current list of NRTL on its website. The means for identifying approved equipment can vary for each organization concerned with product evaluation, some of which do not recognize equipment as approved unless it is also labeled. The authority having jurisdiction normally utilizes the system employed by the certifying organization to identify an approved product.

single-banked: The arrangement of cables in a cable tray or raceway wherein the cables are installed in a single layer.

sunlight resistant: Ability to withstand exposure to direct sunlight as defined by UL 2556.

TC-ER-HL cable: Power and control tray cable that is suitable for Class I, Division 1 locations as specified in the National Electrical Code.

umbilical: Single or group of functional components, such as electrical cables, optical fiber cables, hoses, and tubes, laid up or bundled together, that generally includes an unsupported, suspended section.

unclassified location: An unclassified location is a location not classified as Division 1 or Division 2, or Zone 0, Zone 1, or Zone 2. The term *unclassified location* is used synonymously with the term *nonclassified location*.

variable frequency drive (VFD): A type of adjustable speed drive where a converter, using controlled rectifier or transistor devices having the capability of adjusting the frequency and proportional voltage of the output waveform, provides speed control of an ac motor.

zone: A method of specifying the probability that a location is made hazardous by the presence, or potential presence, of flammable concentrations of gases and vapors, or combustible mixtures of dusts.

4. General

The National Electrical Code (NFPA 70) has evolved through careful development over a long time, during which time utility power systems, utility communication systems, railroad activities, mining activities, and marine activities were excluded from its scope. For this reason, literal application of the NEC provisions to the power systems, communications, transportation, and subsurface activities of the oil and gas land drilling industry may not always be practicable. This guide distinguishes itself from the NEC in some places. Based on the installation of electrical cables and cable systems following generally accepted practices, the oil and gas land rig drilling industry has demonstrated the results can be safer, more reliable, efficient, and maintainable.

5. Conductor and cable selection

5.1 Overview

Conductor and cable selection in this guide will focus entirely on the unique needs of the oil and gas land drilling rig industry with regards to the selection of flexible electrical cables in hazardous (classified) locations and with an emphasis on the use of Type P cable which is described in Article 337 of NFPA 70-2020 (NEC). This guide will not provide a comprehensive discussion on all the various hazardous (classified) location wiring methods and cable types allowed in the NEC; which are primarily for fixed buildings and installations. The reader is advised to refer to the NEC for guidance on these other wiring methods. The oil and gas land drilling rig industry has primarily and historically used IEEE Std 1580™, Type P cable manufactured with flexible tinned copper stranded conductors per Table 11 in IEEE Std 1580 to cable and interconnect the various machines and equipment that make up the drilling rig. These cables may also be Nationally Recognized Testing Laboratory (NRTL) approved as UL 1309 cables. The flexible and rugged IEEE Std 1580, Type P cables can be better suited for the oil and gas well drilling land rig applications because of characteristics that resist drilling muds that contain various chemicals, abrasives, and petroleum-based additives. These cables can also resist damage from vibration and movement that occurs during the drilling process, and the rigors of rig-up and rig-down. These cables may also be suited because of their ability to perform in extreme cold weather conditions which is demonstrated by passing a -40 °C (or colder) cold bend test and a −35 °C cold impact test. See Table 8 in IEEE Std 1580 for additional information. In addition to their flexibility and mechanical ruggedness as just described, the IEEE Std 1580, Type P, cable:

— Is rated 600/1000 V or 2000 V, which makes it suitable for use on both dc and ac powered drilling rigs including rigs with variable frequency drive (VFD) powered drilling machines

— Has a maximum conductor temperature rating of 110 °C

— Has a flexible tinned-copper stranded conductor that resists oxidation

— Passes an IEEE 1202 vertical cable tray flame test

In addition, the flexible tinned-copper conductors are available in sizes such as 444 kcmil, 535 kcmil, 646 kcmil, and 777 kcmil, which are sizes commonly used on the drilling rigs.

These cables are also available with a metallic basket-weave braided armor with non-metallic impervious sheath over the armor, which is used in certain locations on the rig, including hazardous (classified) locations, that enhances their durability. Metallic basket-weave braided armor helps provide crush, impact, and cut-through resistance, and is less susceptible to failure due to fatigue and cracking compared to other armor types (properties that are important in the drilling environment).

5.2 General

Conductor sizing in power and lighting circuits is determined by the allowable ampacity of the conductor, the wiring method, short-circuit capability, raceway selection, ambient temperatures, allowable voltage drops in the circuits, and the temperature limitations of the device's terminals. It is recommended that the conductor sizing and cable selection criteria be documented.

5.3 Ampacity

The allowable ampacity is based on the maximum allowable conductor temperature, which, in turn, is controlled by the temperature rating of the insulation. The allowable ampacities for low voltage copper conductors shall be determined by one of the following methods.

a) Ampacities for NRTL-approved, IEEE 1580 Type P cables as shown in Table 1 or Table 2.

b) Ampacities calculated under engineering supervision in accordance with IEEE Std 835™.

c) Ampacities calculated under engineering supervision in accordance with NEC-2020 Article 310.14.

d) Ampacities as discussed in NEC-2020 Article 310.15, including the tables and the accompanying notes and correction factors in Article 310.

NOTE 1—Termination considerations are also a limiting factor in the ampacity selection of conductors, see 5.7.

NOTE 2—See ICEA P-32-382 to determine conductor short-circuit withstand currents.

5.4 Voltage

The ac voltage range of 600 V and less is commonly used to supply utilization equipment such as motors and lighting. Typical voltages utilized are 600 V, three-phase; 480 V, three-phase; 208Y/120 V, three-phase; and 120/240 V, single-phase. AC voltage ranges greater than 600 V, such as 4160 V and 13 800 V, are used in some specialized oil and gas well drilling land rig applications, but in general are not common. While 750 V dc powered drilling machines are still employed in the oil and gas land rig drilling industry, they are not as prevalent as they once were because of advances in ac variable frequency drive (VFD) technology.

Voltage drop should be considered when selecting conductor sizes, although it normally will not be the controlling factor. Conductors in branch or feeder circuits sized to prevent voltage drops exceeding 3% will provide reasonable efficiency of operations, provided that the total voltage drop between the point of voltage transformation and the utilization equipment does not exceed 5%. Individual motor feeders may have greater voltage drops, provided that the operating voltage is within the tolerance defined herein. Higher voltage drops may limit the available fault currents to protective devices resulting in a circuit breaker or protective device that may not operate within the expected clearing time.

The supply voltage and frequency should be as near the nameplate rating as practical and should not deviate more than 10% in voltage and 5% in frequency, above or below rating. The sum of voltage and frequency deviations may total 10%, provided the frequency deviation does not exceed 5%.

5.5 Ambient temperature

Oil and gas well drilling lands rigs work in many different geographical regions where the ambient temperatures can be on the extreme low side or extreme high side. Therefore, engineering consideration must be given to the application and expected ambient temperatures in the geographical regions where the rig will be drilling. Cables should be sized using an ambient temperature of 45 °C as a baseline. However, for hotter regions, an ambient temperature of 50 °C or 55 °C may need to be considered. Conversely in colder regions, cables may be required to operate and be stored at low temperatures such as −40 °C or −45 °C. In some cases, application-specific special purpose cables may be required that can perform at extreme low ambient temperatures such as −60 °C, but may have limited abilities at higher ambient temperatures.

5.6 Duty factors

The guidelines in this section apply to drilling rig motors nominally rated up to 750 V.

The cable shall have a current-carrying capacity determined by multiplying the duty factor times the lesser of a) the continuous current rating of the motor, or b) the continuous current limit setting of the power supply.

The voltage rating of power cables for motors shall be 1000 V minimum.

The minimum duty factors, based on historical values, that should be used for drilling rig motors are as follows:

a) AC and dc mud pumps and cement pumps: 0.80
b) AC and dc rotary tables: 0.65
c) AC and dc top drives and power swivels: 0.80
d) DC drawworks: 0.65
e) AC drawworks: 1.00

Duty factors shall not be construed as a fixed rule without regard to sound engineering judgment. Consideration must be given to the application of the drilling machine and its intended use during the drilling process. The potential for the power cable selected to reach or exceed its emergency overload temperature rating and the overall effect this can have on the cable and its surrounding environment, including terminations, must also be considered when the drilling rig motor is operating at its maximum continuous current rating. Guidance on cable emergency overload temperatures is provided in Appendix C of ANSI/NEMA WC 70/ICEA S-95-658. Interpolation between published temperatures in the table within Appendix C to determine a cable’s emergency overload temperature rating is allowed.

5.7 Termination

5.7.1 Overview

Conductors should be sized to limit conductor operating temperatures to those designated for the termination devices involved. Other factors, such as ambient temperature within enclosures and the single-conductor configuration of most terminations, also can be considered when determining the actual conductor temperatures attainable. The ampacities are based on the conductor temperature rise in a given ambient. When selecting conductor sizes and insulation ratings, the actual conductor operating temperature shall be compatible with the connected equipment, especially at the connection points.

Table 1—Ampacities for Type P marine shipboard distribution, control, and signal cables, 2000 V or less, ac or dc, copper conductors, single-banked (single-layered), maximum current-carrying capacity based on 45 °C (113 °F) ambient

AWG or kcmil	mm²	Circular mils	Maximum conductor insulation temperature ratings											
			Single-conductor cable				Two-conductor cable				Three-conductor cable			
			75 °C	90 °C	100 °C	110 °C	75 °C	90 °C	100 °C	110 °C	75 °C	90 °C	100 °C	110 °C
22	0.355	700	7	8	9	10	6	7	8	9	5	6	7	8
20	0.52	1020	9	11	12	13	8	9	10	11	6	8	9	10
18	0.82	1620	13	15	16	17	11	13	14	15	9	11	12	13
16	1.31	2580	18	21	23	25	15	18	19	20	13	15	16	17
14	2.08	4110	28	34	37	40	24	27	31	33	20	24	25	27
12	3.31	6530	35	43	45	48	31	36	40	43	24	29	31	33
10	5.26	10 380	45	54	58	62	38	46	49	52	32	38	41	44
8	8.37	16 510	56	68	72	77	49	60	64	69	41	48	52	56
7	10.55	20 820	65	77	84	88	59	72	78	82	48	59	63	67
6	13.30	26 240	73	88	96	103	66	79	85	91	54	65	70	75
5	16.77	33 090	84	100	109	117	78	92	101	108	64	75	82	88
4	21.15	41 740	97	118	128	137	84	101	110	118	70	83	92	99
3	26.66	52 620	112	134	146	156	102	121	132	141	83	99	108	116
2	33.62	66 630	129	156	169	181	115	137	149	160	93	111	122	131
1	44.21	83 690	150	180	194	208	134	161	174	186	110	131	143	153
1/0	53.50	105 600	174	207	227	243	153	183	199	213	126	150	164	176
2/0	67.44	137 100	202	240	262	281	187	233	242	259	145	173	188	201
3/0	85.02	167 800	231	278	300	321	205	245	265	284	168	201	218	234
4/0	107.20	211 600	271	324	351	376	237	284	307	329	194	232	252	270
250	126.70	250 000	300	359	389	409	264	316	344	360	217	259	282	295
262	133.10	262 600	314	378	407	436	278	333	358	383	228	273	294	315
313	158.60	313 100	351	423	455	487	303	363	391	419	249	298	321	344
350	177.30	350 000	372	446	485	508	324	387	421	441	265	317	344	361
373	189.30	373 700	393	474	516	553	339	406	442	473	277	332	361	387
444	225.20	444 400	453	546	588	630	391	468	504	540	319	382	411	440
500	253.30	500 000	469	560	609	638	401	479	520	546	329	393	428	448
535	271.20	535 300	485	579	630	676	415	496	538	576	340	407	443	475
646	327.50	646 400	557	671	731	783	485	581	632	677	396	474	516	553
750[a]	380.00	750 000	605	723	786	824	503	602	656	686	413	494	537	563
777[a]	394.00	777 700	627	755	822	881	525	629	684	733	431	516	562	602
1000[a]	506.70	1 000 000	723	867	939	988	—	—	—	—	—	—	—	—
1111[a]	563.10	1 111 000	767	942	1025	1098	—	—	—	—	—	—	—	—
1250[a]	633.30	1 250 000	824	990	1072	1128	—	—	—	—	—	—	—	—
1500[a]	760.00	1 500 000	917	1100	1195	1254	—	—	—	—	—	—	—	—
2000[a]	1013.30	2 000 000	1076	1292	1400	1473	—	—	—	—	—	—	—	—

AWG or kcmil	mm^2	Circular mils	Maximum conductor insulation temperature ratings											
			Single-conductor cable				Two-conductor cable				Three-conductor cable			
			75 °C	90 °C	100 °C	110 °C	75 °C	90 °C	100 °C	110 °C	75 °C	90 °C	100 °C	110 °C

NOTE 1—The current-carrying capacities are for single-banked cables with maintained spacing of less than one cable diameter between adjacent cables and are 85% of the calculated free air values from IEEE Std 835. Ampacity values are for a given maximum conductor temperature based on an ambient temperature of 45 °C, no solar heat, and no wind. For those instances where cables are double-banked, the current-carrying capacities shall be decreased by multiplying the value shown by 0.8.

NOTE 2—For cables with maintained spacing of at least one cable diameter apart, the ampacities may be increased by dividing the values shown by 0.85.

NOTE 3—Current-carrying capacity of four-conductor cables where one conductor is not a current-carrying phase conductor (e.g., neutral or grounding conductor) is the same as three-conductor cables.

NOTE 4—For more than three conductors in a cable with no load diversity, see ampacity adjustment factors in Table 3.

NOTE 5—If ambient temperatures differ from 45 °C (113 °F), cable ampacities should be multiplied by the factors in Table 4.

NOTE 6—Ampacity values for single-conductor single-banked cable may be used for single-conductor cables, sizes 1/0 and larger, that are installed in a triangular configuration consisting of phases A, B, and C. If more than one circuit, or parallel runs of the same circuit are installed, there should be a maintained minimum spacing of 2.15 times one conductor diameter between each triangular configuration group.

NOTE 7—Cable runs where segments with different thermal conditions exist will require separate derating considerations. The lowest ampacity calculated for any 3 m (10 ft) section in the cable run would determine the cable size.

NOTE 8—Conductor selection should be coordinated with circuit and system overcurrent and short-circuit protection to avoid cable damage during through-fault conditions. Refer to ICEA P-32-382 for short-circuit withstand capabilities of conductors and to ICEA P-45-482 for short-circuit withstand capabilities of metallic shields and sheaths.

NOTE 9—The ampacities in the tables are based on various maximum conductor temperatures. If the ampacity at a different maximum conductor temperature is required, then Equation (1) (extracted from IEEE Std 835) should be used to calculate the ampacity:

$$I' = \sqrt{\left(\frac{T_c' - T_a - \Delta T_d'}{T_c - T_a - \Delta T_d}\right) \times \left(\frac{\tau_c + T_c}{\tau_c + T_c'}\right)} \times I \qquad (1)$$

where

T_c is the maximum conductor temperature used in tables, °C
T_a is the ambient temperature used in the tables, °C
ΔT_d is the temperature rise due to dielectric loss, °C
T_c' is the new maximum conductor temperature, °C
$\Delta T_d'$ is the new temperature rise due to dielectric loss, °C
τ_c is the inferred temperature of zero electrical resistance (−234 °C per NBS 100 for copper conductors), °C
I is the ampacity shown in tables for T_c, T_a, and ΔT_d, A
I' is the new ampacity, A

[a] Current ratings in Table 1 are for 60 Hz ac and dc voltage through 646 kcmil, but ac only from 750 kcmil to 2000 kcmil. See Table 2 for dc voltage ratings for 750 kcmil to 2000 kcmil.

Table 2—Ampacities for Type P marine shipboard single-conductor distribution cables, 2000 V or less dc only, copper conductors, single-banked (single-layered), maximum current-carrying capacity based on 45 °C (113 °F) ambient

AWG or kcmil		Single-conductor cable			
kcmil	mm²	75 °C	90 °C	100 °C	110 °C
750	380.0	617	738	802	859
1000	506.7	747	896	964	1033
1250	633.3	865	1038	1126	1206
1500	760.0	980	1177	1276	1367
2000	1013.0	1195	1435	1557	1636

NOTE 1—See Table 1 for 60 Hz ac ampacities for sizes 750 kcmil to 2000 kcmil.

NOTE 2—The current-carrying capacities are for single-banked cables with maintained spacing of less than one cable diameter between adjacent cables and are 85% of the calculated free air values from IEEE Std 835. Ampacity values are for a given maximum conductor temperature based on an ambient temperature of 45 °C, no solar heat, and no wind. For those instances where cables are double-banked, the current-carrying capacities shall be decreased by multiplying the value shown by 0.8.

NOTE 3—For cables with maintained spacing of at least one cable diameter apart, the ampacities may be increased by dividing the values shown by 0.85.

NOTE 4—Current-carrying capacity of four-conductor cables where one conductor is not a current-carrying phase conductor (e.g., neutral or grounding conductor) is the same as three-conductor cables.

NOTE 5—For more than three conductors in a cable with no load diversity, see ampacity adjustment factors in Table 3.

NOTE 6—If ambient temperatures differ from 45 °C (113 °F), cable ampacities should be multiplied by the factors in Table 4.

NOTE 7—Cable runs where segments with different thermal conditions exist will require separate derating considerations. The lowest ampacity calculated for any 3 m (10 ft) section in the cable run would determine the cable size.

NOTE 8—Conductor selection should be coordinated with circuit and system overcurrent and short-circuit protection to avoid cable damage during through-fault conditions. Refer to ICEA P-32-382 for short-circuit withstand capabilities of conductors and to ICEA P-45-482 for short-circuit withstand capabilities of metallic shields and sheaths.

NOTE 9—The ampacities in the tables are based on various maximum conductor temperatures. If the ampacity at a different maximum conductor temperature is required, then Equation (2) (extracted from IEEE Std 835) should be used to calculate the ampacity:

$$I' = \sqrt{\left(\frac{T_c' - T_a - \Delta T_d'}{T_c - T_a - \Delta T_d}\right) \times \left(\frac{\tau_c + T_c}{\tau_c + T_c'}\right)} \times I \tag{2}$$

where

T_c is the maximum conductor temperature used in tables, °C

T_a is the ambient temperature used in the tables, °C

ΔT_d is the temperature rise due to dielectric loss, °C

T_c' is the new maximum conductor temperature, °C

$\Delta T_d'$ is the new temperature rise due to dielectric loss, °C

τ_c is the inferred temperature of zero electrical resistance (−234 °C per NBS 100 for copper conductors), °C

I is the ampacity shown in tables for T_c, T_a, and ΔT_d, A

I' is the new ampacity, A

Table 3—Ampacity adjustment factors for more than three conductors in a cable with no load diversity for Table 1 and Table 2

Number of conductors	Ampacity adjustment factor of three-conductor cable
4 through 6	0.80
7 through 9	0.70
10 through 20	0.50
21 through 30	0.45
31 through 40	0.40
41 through 60	0.35

NOTE—If there are more than three current-carrying conductors in a cable, then cable ampacities should be multiplied by these factors.

Table 4—Ampacity adjustment factors for ambient temperatures different from 45 °C (113 °F)

Ambient temperature	30 °C (86 °F)	40 °C (104 °F)	50 °C (122 °F)	55 °C (131 °F)	60 °C (140 °F)	70 °C (158 °F)
75 °C rated cables	1.22	1.08	0.91	0.81	0.71	—
90 °C rated cables	1.15	1.05	0.94	0.88	0.82	0.67
100 °C rated cables	1.13	1.04	0.95	0.90	0.85	0.74
110 °C rated cables	1.11	1.04	0.96	0.92	0.88	0.78

NOTE 1—If ambient temperatures differ from 45 °C (113 °F), cable ampacities should be multiplied by these factors.

NOTE 2—Equation (3) (extracted from IEEE Std 835) should be used to calculate ampacity at an ambient temperature not specified in Table 4.

$$I' = \sqrt{\left(\frac{T_c - T_a'}{T_c - T_a}\right)} \times I \qquad (3)$$

where

T_c is the maximum conductor temperature used in tables

T_a is the ambient temperature used in the tables

T_a' is the new ambient temperature

I is the ampacity shown in tables for *Tc* and *Ta*

I' is the new ampacity

6. Wiring methods

6.1 General

The purpose of this section is to provide practical guidance to the unique conditions encountered in wiring oil and gas land drilling rigs. This section should be used in conjunction with API RP 500 and API RP 505, which provide recommendations for hazardous location classification on oil and gas land drilling rigs. Wiring methods for areas classified by API RP 500 and API RP 505 on oil and gas land drilling rigs are listed in 0 below.

Because of the flexibility required by oil and gas land drilling rigs and the temporary nature of the installation where IEEE 1580 Type P cable systems are used to interconnect equipment, the following may be considered when applying sound engineering judgment that includes an evaluation of site circumstances and the risks.

When an unarmored IEEE 1580 Type P cable is routed from an unclassified location into a Class I, Division 2 or Zone 2 location, it is permitted to cross into an adjacent Class I, Division 1 or Zone 1 location in order to be terminated on a motor terminal box or other utilization equipment as long as the cable is supported and continuously protected against physical damage by location or a suitable guard and the cable is terminated with a cable gland, plug, or receptacle NRTL approved for use in a Division 1 or Zone 1 location, respectively.

Table 5—Wiring methods for hazardous (classified) locations

	Division 1 and Zone 1	Division 2 and Zone 2
Type P marine shipboard cable—armored and sheathed	X[a]	X[a]
Type P marine shipboard cable—unarmored	X[a, f]	X[a]
TC-ER-HL cable	X[b, c]	X[b, c]
Extra-hard usage flexible cord	X[d]	X[d]
Type MV (medium voltage) cable	—	X[e]
Application-specific cables that satisfy mechanical requirements of IEEE Std 1580	—	X
NOTE 1— X = Acceptable.		
NOTE 2— See Clause 4, Clause 5, Clause 6, and Clause 7 for explanations and qualifications.		

[a] Type P marine shipboard cable in accordance with IEEE Std 1580 using tinned copper conductors and flexible stranding.

[b] See NEC-2020 Article 501.10 or 505.15 for specific requirements.

[c] TC-ER-HL cable is an industrial cable and is not typically manufactured with tinned copper flexible stranded conductors or tested for exposure to drilling fluids. However, some Type P cables are NRTL approved as both marine shipboard cable and Type TC-ER-HL cable.

[d] See NEC-2020 Article 501.10 and 501.140 or 505.15 and 505.17, and 6.6 of this guide for specific requirements for use in specific flexible connections.

[e] See 6.7 for additional recommendations on the use of Type MV cable.

[f] See 6.1.

6.2 Power and lighting systems

Wiring methods recommended for hazardous (classified) locations should be in accordance with Table 5.

6.3 Instrumentation, control, and communication systems wiring

Wiring methods recommended for hazardous (classified) locations should be in accordance with Table 5 and are applicable for remote-control, signaling, and communications circuits for Division 1, Zone 1, Division 2 and Zone 2 locations.

Intrinsically safe system wiring in Division 1 and Zone 1 or Division 2 and Zone 2 locations may utilize any method acceptable for wiring in unclassified locations provided that the wiring method is suitable for the environment, meets the requirements of the IEEE Std 1202™ flammability test, and is installed in accordance with NEC Article 504. In addition, some installation situations may require sealing (gas-blocking–type seal) of the cable and cable cores at area classification boundaries to minimize the passage of gases from one area to another, or to a non-hazardous area.

Application-specific data and communication cables shall be constructed in accordance with their applicable standards using flexible copper conductors and meet the flammability requirements of IEEE Std 1202.

The use of fiber-optic cable systems for instrumentation, control, and communication applications on oil and gas well land drilling rigs has become common. The fiber-optic cable shall be rugged and flexible. A tightly buffered cable, as opposed to loose-tube constructed cable, should be considered. The advantages of using tightly buffered fiber-optic cables include crush resistance, tight bend radius capability, ease of termination, numerous available configurations (distribution, breakout, and tactical), and the ability to package easily in composite cables.

For Division 1, Zone 1, Division 2, and Zone 2 hazardous (classified) locations on oil and gas drilling land rigs there are two ignition-prevention protection concepts that are typically used for fiber-optic cables and cable systems. One of the protection methods is *protected optical fiber cable*, which is designated as *Type op pr*. The other protection method is *inherently safe optical radiation*, which is designated as *Type op is*. These two protection methods are defined in UL 60079-28. In addition, ANSI/ISA TR 12.21.01 provides information on these protection methods and their application in Class I hazardous (classified) locations. A summary of these two protection methods relative to oil and gas land drilling rigs is as follows:

— Protected optical fiber cable (op pr): Using this protection method, the fiber-optic cable is mechanically protected against damage that would result in the release of optical radiation in excess of Type op is energy levels, as defined in UL 60079-28, into the atmosphere during normal operation and foreseeable malfunctions by using flexible armored and sheathed fiber-optic cable, cable tray, or raceways. In addition, for fiber-optic cable systems that have plugs and receptacles attached to the fiber-optic cable ends, the connectors should be NRTL approved for the hazardous (classified) location they will be used in.

— Inherently safe optical radiation (op is): Using this protection method, the optical devices (to which the fiber-optic cable systems are connected) limit the visible or infrared radiation so that it is incapable of supplying enough energy under normal or specified fault conditions to ignite a specific explosive atmosphere. With this protection method there is not a requirement for armored and sheathed fiber-optic cables, and the cables can be connectorized with general purpose fiber-optic plugs and receptacles. However, engineering consideration should still be given to the additional mechanical protection that the armor and sheath provide relative to the cable routing on the rig and the potential for damage during drilling operations as well as rig-up and rig-down.

In addition to these ignition-prevention protection methods for fiber-optic cable systems, the fiber-optic cables installed in the hazardous (classified) locations shall also be resistant to the spread of fire and at a minimum pass the vertical-tray fire-propagation test in UL 1685 described in the NEC for Types OFN and OFC general purpose fiber-optic cables. Some installation applications may also require sealing (gas-blocking–type seal) of the fiber-optic cable and cable cores using a potted cable gland to minimize the passage of gases through the inside of the fiber-optic cable from the hazardous (classified) location to a non-hazardous location. Article 501.10 and 505.15 in NEC-2020 also provide specific requirements for the application of fiber-optic cables in hazardous (classified) locations.

IEEE Std 45.8™ and IEEE Std 1242™ provide additional guidance on the selection and use of fiber-optic cable systems. Transmission characteristics of commonly used fiber-optic cables are shown in Table 6.

Table 6—Multi-mode capabilities of optical-fiber cables

Category	Minimum modal bandwidth 850 nm/1310 nm, MHz·km	100 Mb Ethernet 100BASE, m (FX)	1 Gb (1000 Mb) Ethernet 1000BASE, m (SX)	10 Gb Ethernet 10GBASE, m (SR)	40 Gb Ethernet, m	100 Gb Ethernet, m
OM1 (62.5/125)	200/500	up to 2000	275	33	Not supported	Not supported
OM2 (50/125)	500/ –	up to 2000	550	82	Not supported	Not supported
OM3 (50/125) laser optimized	1500/2000	up to 2000	550	300	100 330 QSFP+eSR4	100
OM4 (50/125) laser optimized	3500/4700	up to 2000	1000	400	150 550 QSFP+eSR4	150

6.4 Armor grounding

All armor or other metal coverings of the cable shall be electrically continuous throughout their entire length and shall be effectively grounded. All cable glands shall use NRTL-approved, grounding-type terminators.

When utilizing Type P marine shipboard cables, which do not inherently provide a grounding means, an equipment grounding path shall be provided. The armor of Type P marine shipboard cable shall be grounded, but cannot be used as the grounding conductor. Thus, an appropriately sized grounding conductor shall be included within each cable, or other adequate grounding means provided to comply with NEC Article 250.

6.5 Motor cables for variable frequency drive (VFD) applications

Motor cables for VFD applications require special consideration because of harmonics, electromagnetic interference (EMI), reflected wave voltages, common mode current, and induced voltages in adjacent cables. Cable should be selected to minimize net induced ground currents into the system ground, to minimize common-mode current, to minimize motor-frame-standing voltage (minimize potential bearing currents), and to minimize cross-talk between adjacent cables.

Depending on the nominal voltage rating and the reflected voltage (which can be up to three times nominal voltage), over-insulated conductor ratings should be considered. Selection of the insulation thickness will also depend on the switching frequency, length of cable installed, and life expectancy of the installation. Reducing the capacitance of the cable reduces common mode current. It is recommended that the insulation used on these cables be a thermoset material with a dielectric constant less than 3.0 to reduce cable capacitance. To reduce voltage imbalances, the cable should have sectioned grounding conductors, one in each interstice. Motor cables for certain VFD manufacturers' applications should have an overall copper or aluminum braid plus tape shield or armor with a recommended minimum coverage of 100%. The VFD manufacturer should be consulted concerning this shielding or armor coverage requirement. The purpose of this overall shield or armor is to provide a low impedance ground path close to the cable core and contain EMI emissions.

The large motor applications described in 5.6 will require the use of conductor sizes above 262 kcmil. The use of traditional multi-conductor VFD cables may not be feasible due to size and weight limitations of those cables. For example, a typical 750 kcmil three-conductor VFD cable weighs about 14.88 kg/m (10 lb/ft) with an outside diameter of 71 mm (2.8 in). Such large multi-conductor VFD cables are often impractical to handle for rig-up and rig-down activities. Although connectors may be available for some of these large multi-conductor VFD cables, how and where to ground the connectors becomes problematic. The VFD manufacturers typically require grounding the connectors only at the VFD and motor, yet on a land drilling rig there are often intermediate connectors which also require grounding for safety reasons. For even larger conductor sizes, the cables and suitable connectors may not even be available. One solution which the industry has been practicing is to use non-shielded single-conductor cables arranged in a triangular configuration with ground wire(s); this cable bundle is segregated from other cables to avoid the effect of EMI. The grounding conductor size, cable routing, and segregation distance require sound engineering judgment, considering the VFD switching frequency, any output filters, and the EMI susceptibility of nearby cables, devices, and transducers. Motor bearing fluting and erosion may occur even if EMI issues have been minimized. Another possible solution is to use shielded single-conductor cables arranged in a triangular configuration with ground wire(s); this would reduce EMI, but sound engineering judgment would be required to address the intermediate connectors. Note that cables and connectors for large motor VFD applications are still being developed; other solutions using newer technologies could be applied using sound engineering judgment.

Voltage drop calculations for motor cables for VFD applications require special consideration for loads with transients related to high starting torques.

6.6 Extra-hard usage flexible cord

In Division 1, Division 2, Zone 1, and Zone 2 locations, flexible cord designated for extra-hard usage by the NEC and containing an equipment grounding conductor may be used in accordance with NEC-2020 Articles 501.10 and 501.140 or 505.15 and 505.17. It is recommended that flexible cords be NRTL approved per UL 62 and rated VW-1 in accordance with UL 2556, with an oil-resistant or water-resistant jacket where required.

Extra-hard usage cord may be used on rig lights when their mounting method allows them to be unplugged from the fixed portion of their supply circuit and moved during rig-up and rig-down operations, or unplugged and moved to facilitate maintenance.

6.7 Medium voltage cable (2001 V to 15 kV)

Medium-voltage cables in the NEC are designated as Type MV cables and are allowed by the NEC to be used in Class I, Division 2 and Zone 2 hazardous (classified) locations when approved by an NRTL as a Type MV cable manufactured per UL 1072. The use of medium-voltage power cables on oil and gas land drilling rigs is not common, and when used are typically not installed in the hazardous (classified) locations of the land rig operation.

When there is a need for medium-voltage power cables on oil and gas land drilling rigs, the land rig industry will typically use medium-voltage cables with flexible tinned copper conductors, flexible helical tinned copper wire or braided shields, and flexible insulation. These cables will also have rugged jackets and in some applications are designed to be used on cable reeling systems. These flexible medium-voltage power cables will typically be manufactured to ICEA S-75-381 (mining cables) or to IEEE Std 1580 (marine shipboard cables).

It is recognized that not all flexible, medium-voltage, mining cable constructions built under ICEA S-75-381 that are suitable for certain oil and gas drilling land rig applications are compliant with UL 1072. In addition, not all flexible medium-voltage power cable constructions built under ICEA S-75-381 or IEEE Std 1580 that are compliant with UL 1072 may be readily available in the market with a NRTL approval as a Type MV cable. In each of these cases, sound engineering judgment must be used in selecting the cable. These cables should be routed in such a way that they are protected from physical damage by their surrounding location or protected using a suitable mechanical guard.

For medium-voltage cables, ampacities at various conductor temperatures are given in Table 7, Table 8, and Table 9 with adjustments in Table 10 and Table 11.

Table 7—Ampacities for three-conductor medium-voltage power cable, 2001 V to 15 kV copper conductor single-banked (single-layered), maximum current-carrying capacity based on 45 °C (113 °F)

AWG or kcmil	mm^2	Circular mils, cm	Three-conductor cable			
			Up to 8 kV shielded		8001 V to 15 kV shielded	
			90 °C	105 °C	90 °C	105 °C
6	13.30	26 240	75	85	—	—
4	21.15	41 740	99	112	—	—
2	33.62	66 360	129	146	133	150
1	42.40	83 690	149	168	151	170
1/0	53.50	105 600	171	193	174	196
2/0	67.44	133 100	197	222	199	225
3/0	85.02	167 800	226	255	229	259
4/0	107.20	211 600	260	294	263	297
250	126.70	250 000	287	324	291	329
263	133.10	262 600	296	334	299	338
313	158.60	313 100	328	370	331	374
350	177.30	350 000	352	397	355	401
373	189.30	373 700	365	412	367	414
444	225.20	444 400	387	437	388	438
500	253.30	500 000	434	490	434	490
535	271.20	535 300	449	507	449	507
646	327.50	646 400	496	560	497	561
750	380.00	750 000	541	611	542	612
777	394.00	777 700	550	621	550	621
1000	506.70	1000 000	622	702	623	703
NOTE—See Table 10 and Table 11 for adjustment factors.						

Table 8—Ampacities for medium-voltage power cable, 2001 V to 15 kV, copper conductor single-conductor in triplexed or triangular configuration, maximum current-carrying capacity based on 45 °C (113 °F)

AWG or kcmil	mm^2	Circular mils, cm	Single-conductor cable (in triplexed or triangular configuration)			
			Up to 8 kV shielded		8001 V to 15 kV shielded	
			90 °C	105 °C	90 °C	105 °C
6	13.30	26 240	92	106	—	—
4	21.15	41 740	121	135	—	—
2	33.62	66 360	159	187	164	187
1	42.40	83 690	184	216	189	216
1/0	53.50	105 600	212	245	217	242
2/0	67.44	133 100	244	284	250	284
3/0	85.02	167 800	281	327	288	327
4/0	107.20	211 600	325	375	332	375
250	126.70	250 000	360	413	366	413
263	133.10	262 600	371	425	377	425
313	158.60	313 100	413	473	418	471
350	177.30	350 000	444	508	448	505
373	189.30	373 700	460	526	464	523
444	225.20	444 400	510	581	514	580
500	253.30	500 000	549	625	554	625
535	271.20	535 300	570	648	574	648
646	327.50	646 400	635	720	638	720
750	380.00	750 000	697	788	697	788
777	394.00	777 700	709	802	709	802
1000	506.70	1000 000	805	913	808	913
NOTE—See Table 10 and Table 11 for adjustment factors.						

Table 9—Ampacities for single-conductor medium-voltage power cable, 2001 V to 15 kV, copper conductor single-banked (single-layered), maximum current-carrying capacity based on 45 °C (113 °F) ambient, shields grounded on one end (open-circuited shields)

AWG or kcmil	mm^2	Circular mils, cm	Single-conductor cable (in triplexed or triangular configuration)			
			Up to 8 kV shielded		8001 V to 15 kV shielded	
			90 °C	105 °C	90 °C	105 °C
6	13.30	26 240	91	103	—	—
4	21.15	41 740	120	135	—	—
2	33.62	66 360	158	178	158	178
1	42.40	83 690	182	205	182	205
1/0	53.50	105 600	210	237	210	237
2/0	67.44	133 100	242	273	241	272
3/0	85.02	167 800	279	315	278	314
4/0	107.20	211 600	324	366	321	362
250	126.70	250 000	359	405	356	402
263	133.10	262 600	370	418	366	413
313	158.60	313 100	413	466	409	462
350	177.30	350 000	444	501	440	497
373	189.30	373 700	462	522	456	515
444	225.20	444 400	515	581	508	573
500	253.30	500 000	561	629	549	620
535	271.20	535 300	580	655	571	645
646	327.50	646 400	652	736	641	724
750	380.00	750 000	720	813	706	797
777	394.00	777 700	735	830	721	814
1000	506.70	1000 000	859	970	842	951
NOTE—See Table 10 and Table 11 for adjustment factors.						

Table 10—Medium-voltage power cable, 2001 V to 15 kV adjustments for Table 7, Table 8, and Table 9. If ambient temperatures differ from 45 °C (113 °F), cable ampacities should be multiplied by the following factors

Conductor temperature	Ambient temperature					
	30 °C (86 °F)	40 °C (104 °F)	50 °C (122 °F)	55 °C (131 °F)	60 °C (140 °F)	70 °C (158 °F)
90 °C	1.10	1.05	0.94	0.88	0.82	—
105 °C	1.08	1.04	0.96	0.92	0.86	0.76

NOTE 1—Double-banking of medium-voltage cables is not recommended.

NOTE 2—The current-carrying capacities in Table 7 and Table 9 are for single-banked cables with maintained spacing of less than one cable diameter between adjacent cables and are 85% of the calculated free air values.

NOTE 3—For cables with maintained spacing of at least one cable diameter apart, the ampacities in Table 7 and Table 9 may be increased by dividing the values shown by 0.85.

NOTE 4—Specific for Table 8 above:

1) Each triplexed or triangular configuration of single-conductor cable shall consist of phases A, B, and C.
2) Ampacities given are based on operation with open-circuited shields.
3) Cable lengths should be limited to maintain a shield voltage below 25 V.
4) More than three conductors without maintained spacing require additional derating. For four to six conductors, multiply the value in the table by 0.8. For seven to nine conductors, multiply the value in the table by 0.7. Ten or more conductors require special calculation for derating.
5) It is recommended that single conductors be installed in a triplexed or triangular configuration, each to reduce electrical losses and may allow for grounding of the shield on both ends without significant cable derating due to circulating current in the shield.

Table 11—Medium-voltage power cable, 2001 V to 15 kV adjustments for Table 7, Table 8, and Table 9 for cables wound on a reel, ampacities should be multiplied by the following factors (from ICEA S-75-38)

Number of layers	Multiplying factor
1	0.85
2	0.65
3	0.45
4	0.35

7. General wiring considerations

7.1 Cable systems

Cables, including portable cords, shall be provided with a flame retardant, sunlight- and oil-resistant thermoset outer jacket, sheath, or integral insulation/jacket that provides superior resistance to the environment present in oil and gas land drilling locations. All cables shall have stranded conductors to provide superior flexibility and resistance to fatigue. Where armored cables are subject to repeated flexing or high vibration, cables with flexible stranded conductors and braid armor should be used. Cable glands shall be selected and installed to provide positive armor/metallic sheath grounding, watertight sealing, and mechanical anchoring.

Special attention should be devoted to applications involving festooning, or where exposed to high vibration, repeated flexing, excessive movement, or twisting. Cables that utilize flexible or extra-flexible conductor stranding, braided armors, or braided shields should be considered for such applications.

Unarmored single-conductor Type P cables, 18 AWG and larger, rated 2 kV or less, that are not installed within equipment or an enclosure should have a jacket as specified in IEEE Std 1580. However, a jacket is optional for single-conductor IEEE 1580 Type P cables, sizes 4/0 and larger, with heavy-duty (HD) insulation. The HD insulation wall serves as an integral insulation/jacket. Single-conductor IEEE 1580

Type P cables, sizes 4/0 AWG and larger, with HD insulation are permitted for applications as cable external to equipment or enclosures for interconnection purposes. Unarmored single-conductor IEEE 1580 Type P cables with HD insulation thicknesses should be considered for applications where installations and service conditions are such that the additional mechanical protection is considered necessary.

Consider low smoke, halogen-free cables for areas containing sensitive electronic equipment that can be damaged by corrosive acid gasses emitted during a fire. Cables with Type LSX or LSE insulation and Type L jacket per IEEE Std 1580 are recommended.

Where a cable can be immersed in liquid or exposed to vapor continuously or for lengthy periods, the cable shall be of a type suitable for such conditions or shall be appropriately protected (such as a metallic pipe) capable of withstanding the liquid or vapor.

Where cables are exposed to drilling fluids, including drilling mud, the cable sheath, jacket, or integral insulation/jacket should be resistant to the fluids. Reference IEEE Std 1580 or IEC 60092-360 for guidance.

7.2 Color coding and identification of cables

IEEE 1580 Type P marine shipboard cables typically use color codes to identify the conductors in distribution and control cables. The color codes are specified in Table 22 and Table 23 of IEEE Std 1580. Where conductors in distribution and control cables all have the same single solid-colored insulation, conductor identification can be printed with alphanumeric characters on the solid-colored insulation. Example: "1-ONE," "2-TWO," etc., or "1-BLACK," "2-WHITE," etc., per the color code in IEEE Std 1580. The legend is repeated at intervals not exceeding 8 cm (3 in). The color code utilized in the rig should be documented and be consistent throughout the rig and/or be clearly identified by conductor identification. Some users may adopt a variation of the IEEE Std 1580 color code. For example, the color "WHITE" may be used exclusively for neutral conductors in ac circuits. The use of suitably colored heat-shrink tubing or other acceptable means of marking at both ends of a conductor is recommended when changing the color of each conductor from the standard IEEE Std 1580 color code.

An insulated conductor functioning as a grounding conductor (normally not a current-carrying conductor) in a distribution system is colored green or green with yellow stripe.

Conductor identification of signal cable is as follows:

- Pairs contain one black insulated conductor and one white (or red) insulated conductor. The pair number is identified on the pair. Pair numbering is sequential.
- Triads contain one black insulated conductor, one white insulated conductor, and one red insulated conductor. The triad number is identified on the triad. Triad numbering is sequential.
- Quads contain one black insulated conductor, one white insulated conductor, one red insulated conductor, and one green (or blue) insulated conductor. The quad number is identified on the quad. Quad numbering is sequential.

7.3 Cable retention

When cable systems are subject to vibration or other unwanted movement (including differential movement between modules, transportation accelerations, etc.), the cables should be appropriately restrained to prevent chafing and fatigue. Additionally, for cables that may be subject to short-circuit magnetic forces (including temporary feeder cables, generator cables, and grid connection cables) the forces should be calculated prior to determining the installation method. During short circuits, cables experience cyclical mechanical shock loads that stress the retaining devices. The cable installation method, including the cable-retaining devices, should be suitable for the potential static and dynamic forces to protect the cables and terminations.

Some cable restraints, such as cable ties, may not be suitable for the dynamic forces delivered during fault conditions.

When three-phase single-conductor or direct current single-conductor cable systems are employed, it is recommended they are securely bound in circuit groups (e.g., bundled in triangular or triplex formation, or single-banked in flat formation) to prevent excessive movement due to fault current magnetic forces.

The cable-retaining devices utilized should be suitable for the cable size and available fault current and capable of withstanding the maximum mechanical forces delivered during a fault. After exposure to fault current, there should be no failure to the cable-retaining devices that will affect the intended function of holding the cables in place. Similarly, the cable-retaining devices should be intact with no missing parts and there should be no cuts or damage visible to the outer sheath of the cable caused by the cable-retaining devices.

One method of demonstrating the performance of the cable-retaining devices is by testing in accordance with IEC 61914.

Cables subject to fault current magnetic forces may deflect violently during fault conditions due to the alternating attractive and repulsive magnetic fields. Adequate space should be provided between those cables subject to fault current magnetic forces and any adjacent cables.

One method to mitigate cable damage is to provide at least 2.15 cable diameters of clear space adjacent to securely bound triangular and triplex circuit groups, and at least one cable diameter of clear space adjacent to each securely bound single-banked cable, to accommodate cable deflection.

During short-circuit conditions, the current magnitude in one or more of the phases can exceed √2 times the rms current value and can theoretically be as great as 2√2 times the rms current value. The electrodynamic mechanical force between two conductors during a short circuit is a function of the current magnitude in each conductor and the center-to-center spacing between the conductors. The distributed mechanical forces can be calculated as shown in Equation (4).

$$F / l = \frac{\mu_0 \times i_1 \times i_2}{2 \times \pi \times S} \tag{4}$$

where

F/l	is the distributed force on conductor per unit length (Newtons/meter)
μ_0	is the magnetic permeability of air = $4\pi \times 10^{-7}$ N/A^2 (Newtons per ampere squared)
i_1	is the instantaneous current magnitude in the first conductor (amperes)
i_2	is the instantaneous current magnitude in the second conductor (amperes)
S	is the center-to-center spacing between conductors (meters)

To calculate the distributed force between conductors, first compute the time-dependent distributed force vectors at each conductor due to each of the other conductors; then sum the vector components to determine the resultant distributed force acting on each conductor. The calculations should consider the symmetrical, asymmetrical, and the unidirectional aperiodic current (i.e., dc offset) components of the short-circuit waveform. The point of maximum force may not correspond to the peak amplitude of a waveform. Therefore, it will be necessary to perform multiple calculations. The calculations should be iterated in order to evaluate the forces through the duration of the short circuit, beginning with the initiation of the fault and considering an adequate sampling of data points.

To calculate the maximum mechanical force applied to a cable-retaining device, multiply the resultant distributed force by the lineal cable-retaining device spacing. For example, given a maximum distributed repulsive force between two conductors of 20 000 N/m and a cable-retaining device lineal spacing of 0.305 m, the force transmitted to the cable-retaining device calculates to 6100 N. For additional guidance on calculating the maximum mechanical force on a cable-retaining device, reference IEEE Std 1185™.

7.4 Cable-bending radius

The bend radius of a cable shall not be less than the minimum as defined by IEEE Std 45.8 (for Type P marine shipboard cable), ICEA S-75-381 (for mining and portable power feeder cables), or NFPA 70 (for NEC cable types and wiring methods), as applicable.

7.5 DC conductor insulation

Conductors used for dc service above approximately 40 V dc in wet locations shall have a thermosetting insulation material such as ethylene propylene rubber (EPR), crosslinked polyethylene (XLPE), crosslinked polyolefin (XLPO), or other insulation suitable for the application. In wet locations, thermoplastic insulation such as polyvinyl chloride (PVC) can be adversely affected by dc voltages. This deleterious effect is caused by a phenomenon known as *electro-osmosis, electroendosmosis,* or *electrical endosmosis*.

8. AC and DC top drive power service loops

An ac or dc top drive power service loop is either a special type of umbilical or drag chain assembly that operates in a rigorous and physically abusive environment and yet fits into a very limited envelope of space. The power service loop connects between the top drive and the derrick and hangs freely in the air between these two mounting points in a pronounced U-shaped catenary configuration. It feeds electrical power to the top drive drill motor as the top drive is hoisted up and lowered down along a track in the derrick during drilling operations. The uniqueness of the application, due to the environment on a drilling rig that the power service loop operates in, dictates that special considerations shall be made relative to its mechanical and electrical design criteria.

The power service loop cable size shall have a continuous current-carrying capacity determined by multiplying the 0.80 duty factor times the continuous current rating of the top drive drill motor. The power service loop cable size shall be selected such that the cable temperature does not exceed the emergency overload temperature rating of the cable (reference ANSI/NEMA WC 70/ICEA S-95-658, Appendix C; interpolation between published temperatures in the table is allowed) when the motor is operating at maximum continuous current rating of the top drive drill motor.

The top drive is a drilling machine that is constantly manned by an operator when in use. The top drive control system that the operator interfaces with monitors the temperature of the top drive drilling motor and the operational status of its external cooling system. The top drive control system also limits the amount of continuous and intermittent current that can be applied to the top drive drilling motor based on its continuous full load amp current rating during drilling, makeup, and breakout operations. Therefore, the practice of sizing motor branch circuit power cables based on 125% of the motor's full load amps for direct across the line (DOL) motor starter circuits and adjustable speed drive applications is not applicable to sizing the ampacity of the ac and dc top drive power service loop.

The cable bundle used to build the power service loop should be uniformly twisted and have a lay-length suitable for the application. The ampacity of a hose type umbilical service loop can be determined as follows:

a) When a power service loop design consists of a uniformly twisted cable bundle pulled into a hose and filled along its entire length with potting compound, the power service loop ampacity is determined using Table 1 values divided by 0.85 as the assembly is considered as a cable in free air. Reference Example 1 in Annex B for example calculations.

b) When it is desired to consider the specific thermal properties of the materials and components used to manufacture the power service loop as well as other parameters relative to the specific top drive application, the use of equations from IEC 60287-1-1 in conjunction with cable selected from Table 1 shall be allowed as an alternative method for calculating the cable size and ampacity.

c) When a power service loop design consists of a uniformly twisted cable bundle pulled into a hose with a short section (e.g., 2 ft to 4 ft) at each end of the hose potted so as to support and hold the twisted cable bundle in place within the hose and the remaining mid-section of the hose is not potted, the ampacity of the power service loop should be calculated by multiplying the free air ampacity of the cable selected from Table 1 by a factor of 0.80. Reference Example 3 in Annex B for an example calculation.

d) When multiple power service loops are installed on a top drive, a space of one service loop diameter between each service loop at both hang-off points is required to consider each power service loop assembly as cable in free air, otherwise the appropriate ampacity derating factor for conductors operating is parallel is required. See Example 2 in Annex B for example calculations.

When a power service loop consists of an assembly manufactured as a complete cable under one jacket in lieu of a cable bundle pulled into a hose, the power service loop ampacity is determined using Table 1 values divided by 0.85 as the assembly is considered as a cable in free air. Reference Example 1 and Example 2 in Annex B for example calculations.

A drag chain assembly is typically an articulated cable tray containing power cables which allows the equipment to be repositioned without disconnection of the cables. When a drag chain assembly in lieu of an umbilical-type power service loop is used to power the top drive drill motor, the power cables in the drag chain should be considered as cables in a cable tray using Table 1. See B.4 for an example of an ampacity calculation for this application.

The flying power leads that exit the top drive end of the power service loop should be mechanically protected by a non-magnetic metallic braided armor that is suitably grounded.

In variable frequency drive (VFD) applications, power service loops should be provided with enough shielding to minimize the potential for electromagnetic interference (EMI) and its impact on systems surrounding the power service loop performance. Braided bronze is not considered an adequate shield in this case due to its low conductivity (~ 20% or less) as compared to copper.

9. Cable glands Class I, Division 1 and Division 2

9.1 Overview

Cable seals are designed to withstand the potential internal pressures of the explosionproof enclosure by creating a seal to minimize the passage of vapors and gasses and to prevent flame propagation into the cable. Explosionproof cable glands that are NRTL approved to comply with ANSI/UL 2225 or UL 1203 meet this criterion. Cable glands and seals shall be installed in accordance with NEC-2020 Article 501.15 requirements.[1]

The cable gland type shall be selected based on the enclosure protection method and cable type. For example, the cable gland should be able to withstand the internal pressure of the explosionproof enclosure even when installed in a Division 2 location.

9.2 Class I, Division 1

Cables shall be sealed at the point of entry with a sealing-type cable gland. In multi-conductor cable the jacket and any other fillers or coverings shall be removed to allow the sealing material to surround each individual insulated conductor to minimize the passage of gases and vapors.

Exception: Shielded cables and twisted pair cables shall not require the removal of the shielding material or separation of the twisted pairs, provided that the termination is sealed by an approved means to minimize the passage of gases and vapors and to prevent flame propagation into the cable core.

9.3 Class I, Division 2

Cables entering enclosures that are required to be explosionproof shall be sealed in accordance with 9.2.

Cables entering enclosures that are not explosionproof shall be terminated with cable gland fittings approved by an NRTL for the cable type and protection method of the enclosure.

10. Cable glands Class I, Zone 1 and Zone 2

10.1 Overview

Cable seals are designed to withstand the potential internal pressures of the flameproof enclosure by creating a seal to minimize the passage of vapors and gasses and to prevent flame propagation into the cable. Flameproof cable glands that are NRTL approved to comply with ANSI/UL 2225 meet this criterion. Cable glands and seals shall be installed in accordance with NEC-2020 Article 505.16 requirements. The cable gland type shall be selected based on the enclosure protection method and cable type. For example, the cable gland should be able to withstand the internal pressure of the flameproof enclosure even when installed in a Zone 2 location. There are national differences in the testing requirements for cable glands and cable gland fittings. Cable glands NRTL approved "only" to the IEC 60079 series, such as UL 60079-1 (Flameproof Ex d) or UL 60079-0 (Increased Safety Ex e), are NOT permitted in AEx d or AEx e equipment, respectively.

10.2 Class I, Zone 1

Cables entering AEx d (flameproof) protected enclosures shall be sealed with cable gland fittings approved by an NRTL for the cable type and protection method AEx d and in accordance with Clause 10.

[1] Large Class B standard conductors (> 35 mm^2 [2 AWG]), temperature extremes, highly corrosive liquids and vapors, and small differences in pressure (76 mmH_2O [3 inH_2O]) across the seal may result in the passage of gas or vapor through a seal and through conductors passing through the seal.

Exception: Where the enclosure having type of protection AEx d is marked to indicate that a seal is not required.

Note: NRTL approved, explosionproof cable glands for Class I, Division 1 are a permitted cable termination method into AEx d protected equipment.

Cables entering AEx e (increased safety) protected enclosures shall be terminated with cable gland fittings approved by an NRTL for the cable type and protection method AEx e.

Note: NRTL-approved fittings to ANSI/UL514B are a permitted termination method into AEx e protected equipment, provided the equipment ingress level is maintained.

10.3 Class I, Zone 2

Cables entering enclosures that are required to be flameproof shall be sealed in accordance with the Zone 1 requirements.

Cables entering enclosures in Class I, Zone 2 locations shall be terminated with cable gland fittings approved by an NRTL for the cable type, location, and equipment-protection method.

10.4 Boundaries

There are additional protection methods in NEC Article 505 for Zone 0 or Zone 1 equipment that do not require seals that are required for explosionproof equipment. Therefore, additional seals are needed to prevent migration of flammable gases from Zone 0 or 1 locations into Zone 2 or an unclassified location.

Cables shall be sealed at the first point of termination after entry into a Zone 0 location to prevent migration of flammable gases into Zone 1, 2, or an unclassified location.

Cables shall be sealed at the Zone 1 termination point when leaving a Zone 1 location to prevent migration of flammable gases into Zone 2 or unclassified location.

Cables with a gas-/vapor-tight continuous sheath, such as Type P cable, are not required to be sealed based on the cable leaving a Zone 2 boundary.

For additional information on seals for hazardous (classified) location boundaries, refer to NEC-2020 Article 505.16.

11. Reciprocity of division and zone equipment in hazardous (classified) locations

11.1 Use of divisional rated equipment in zone classified locations

Equipment complying to Class I, Division 1 intrinsically safe requirements for hazardous (classified) locations may be used in Class I, Zone 0 locations for the same gas and with a suitable temperature rating.

NRTL-approved equipment marked in accordance with Class I, Division 1 requirements for hazardous (classified) locations may be used in Class I, Zone 1 or Zone 2 locations for the same gas and with a suitable temperature rating.

NRTL-approved equipment or suitable for Division 2 per NEC Article 501 may be used in Class I, Zone 2 locations for the same gas and with a suitable temperature rating.

Note: Equipment not approved by an NRTL for Division 2 is subject to authority having jurisdiction (AHJ) approval. A common example would be a NEMA 4X enclosure with suitable terminal blocks.

11.2 Use of zone-rated equipment in divisional classified locations

NRTL-approved equipment marked in accordance with Class I, Zone 0 requirements for hazardous (classified) locations may be used in Class I, Division 1 locations for the same gas and with a suitable temperature rating.

NRTL-approved equipment marked in accordance with Class I, Zone 0, 1, or 2 requirements for hazardous (classified) locations may be used in Class I, Division 2 locations for the same gas and with a suitable temperature rating.

Annex A

(informative)

Bibliography

Bibliographical references are resources that provide additional or helpful material but do not need to be understood or used to implement this standard. Reference to these resources is made for informational use only.

[B1] API RP 14F, Recommended Practice for Design, Installation, and Maintenance of Electrical Systems on Fixed and Floating Offshore Petroleum Facilities for Unclassified and Class I, Division 1, and Division 2 Locations.[2]

[B2] API RP 14FZ, Recommended Practice for Design, Installation, and Maintenance of Electrical Systems for Fixed and Floating Offshore Petroleum Facilities for Unclassified and Class I, Zone 0, Zone 1, and Zone 2 Locations.

[B3] IEC 60079-2, Explosive Atmospheres—Part 2: Equipment Protection by Pressurized Enclosure "p."[3]

[B4] IEC 60079-13, Explosive Atmospheres—Part 13: Equipment Protection by Pressurized Room "p" and Artificially Ventilated Room "v."

[B5] IEC 60092-360, Electrical Installations in Ships—Part 360: Insulating and Sheathing Materials for Shipboard and Offshore Units, Power, Control, Instrumentation and Communication Cables.

[B6] IEC 61914, Cable Cleats for Electrical Installations.

[B7] IEEE Std 1185™, IEEE Recommended Practice for Cable Installation in Generating Stations and Industrial Facilities.[4,5]

[B8] IEEE Std 1202™, IEEE Standard for Flame-Propagation Testing of Wire and Cable.

[B9] IEEE Std 1242™, IEEE Guide for Specifying and Selecting Power, Control, and Special-Purpose Cable for Petroleum and Chemical Plants.

[B10] IEEE Std 1580™, IEEE Recommended Practice for Marine Cable for Use on Shipboard and Fixed or Floating Facilities.

[B11] ISA 60079-15, Explosive Atmospheres—Part 15: Equipment Protection by Type of Protection "n."

[B12] NFPA 496, Standard for Purged and Pressurized Enclosures for Electrical Equipment.[6]

[B13] UL 62, Flexible Cords and Cables.[7]

[B14] UL 913, Standard for Intrinsically Safe Apparatus and Associated Apparatus for Use in Class I, II, and III, Division 1, Hazardous (Classified) Locations.

[B15] UL 1072, Medium-Voltage Power Cables.

[B16] UL 1203, Explosion-Proof and Dust-Ignition-Proof Electrical Equipment for Use in Hazardous (Classified) Locations.

[B17] UL 1309, Standard for Marine Shipboard Cable.

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[2] API publications are available from the American Petroleum Institute (https://www.api.org/).
[3] IEC publications are available from the International Electrotechnical Commission (https://www.iec.ch) and the American National Standards Institute (https://www.ansi.org/).
[4] The IEEE standards or products referred to in Annex A are trademarks owned by The Institute of Electrical and Electronics Engineers, Incorporated.
[5] IEEE publications are available from The Institute of Electrical and Electronics Engineers (https://standards.ieee.org/).
[6] NFPA publications are published by the National Fire Protection Association (http:// www.nfpa.org/).
[7] UL publications are available from Underwriters Laboratories (https://www.ul.com/).

[B18] UL 2225, Cables and Cable-Fittings for Use in Hazardous (Classified) Locations.

[B19] UL 2556, Wire and Cable Test Methods.

[B20] UL 60079-1, Standard for Explosive Atmospheres—Part 1: Equipment Protection by Flameproof Enclosures.

[B21] UL 60079-5, Standard for Explosive Atmospheres–Part 5: Equipment Protection by Powder Filling "q."

[B22] UL 60079-6, Standard for Explosive Atmospheres—Part 6: Equipment Protection by Oil Immersion "o."

[B23] UL 60079-7, Standard for Explosive Atmospheres—Part 7: Equipment Protection by Increased Safety "e."

[B24] UL 60079-11, Standard for Explosive Atmospheres—Part 11: Equipment Protection by Intrinsic Safety "i."

[B25] UL 60079-13, Standard for Explosive Atmospheres—Part 13: Equipment Protection by Pressurized Room "p" and Artificially Ventilated Room "v."

[B26] UL 60079-15, Standard for Explosive Atmospheres—Part 15: Equipment Protection by Type of Protection.

[B27] UL 60079-18, Standard for Explosive Atmospheres—Part 18: Equipment Protection by Encapsulation "m."

Annex B

(informative)

Example ac top drive power service loop ampacity calculations

B.1 Example 1

A top drive that is designed to operate in a 45 °C (113 °F) ambient temperature is powered with one ac drill motor. The drill motor has a maximum continuous current rating of 700 A. Per the specific top drive design and as illustrated in Figure B.1, the top drive drill motor is powered with one power service loop consisting of either a uniformly twisted three-conductor cable bundle pulled into a hose that is potted along its entire length, or a complete multiconductor cable under a common jacket that is designed for service loop applications.

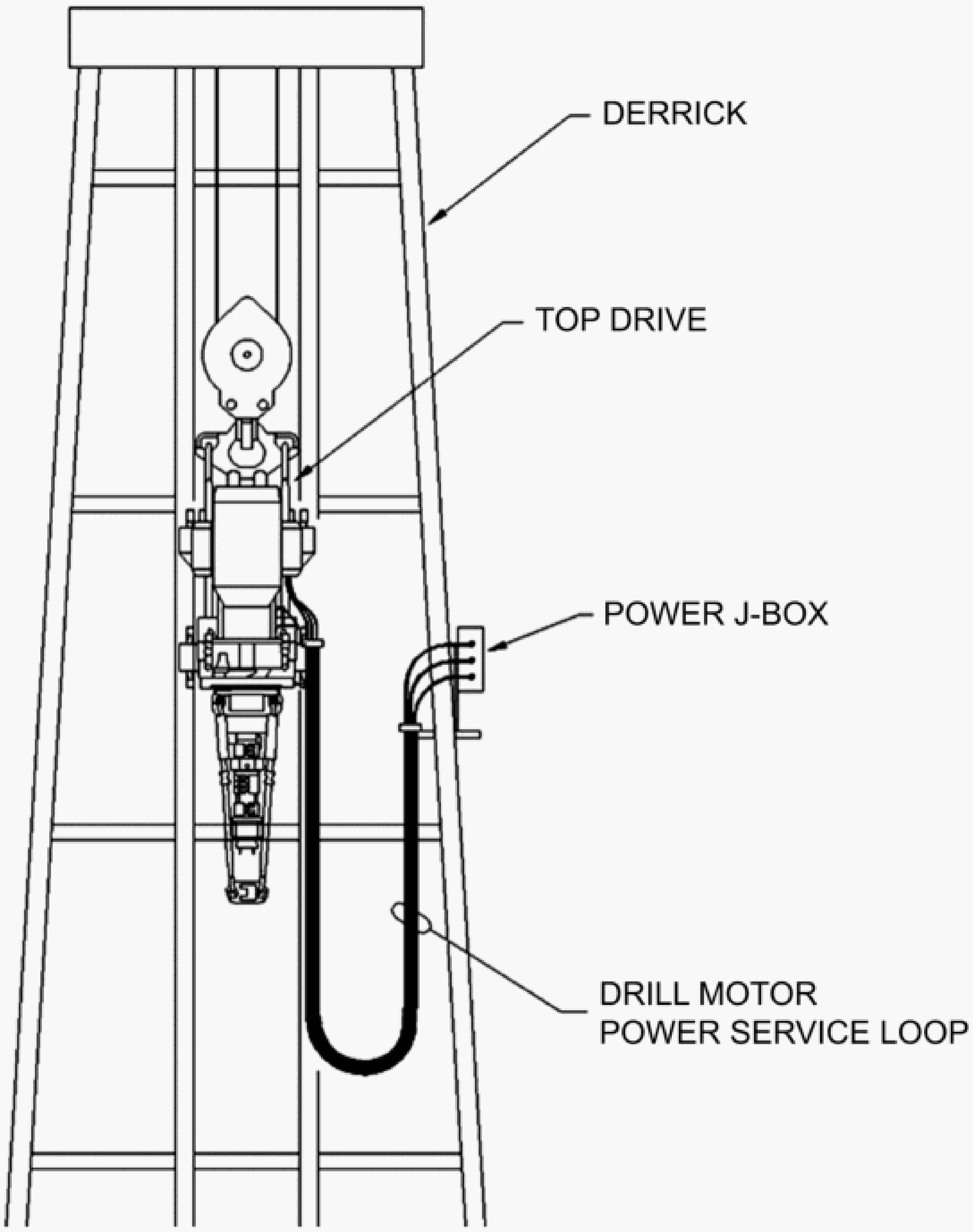

Figure B.1—Top drive installed in derrick with power service loop potted entire length

The power service loop cable size and ampacity calculation begins by applying the 0.80 duty factor to the top drive drill motor, which results in the following:

$$I_{\text{TD Drill Motor}} = 0.80 \times 700\text{ A} = 560\text{ A} \tag{B.1}$$

The ac top drive power service loop is manufactured with IEEE 1580 Type P power cables that are approved by an NRTL for a maximum conductor temperature of 110 °C. Therefore, this power service loop is considered as a three-conductor power cable rated for a 110 °C conductor temperature.

An inspection of Table 1 is performed and a 646 kcmil three-conductor power cable with an ampacity of 553 A at a conductor temperature rating of 110 °C is selected. It is noted that the tabulated ampacities specified in Table 1 are based on a 45 °C (113 °F) ambient temperature.

NOTE 1 and NOTE 2 of Table 1 state that the ampacity values shown are for single-banked cables, and that for cables in free air with one cable diameter spacing between them, the ampacities may be increased by dividing values shown by 0.85.

This power service loop is considered as a three-conductor power cable hanging in free air between the top drive and derrick as illustrated in Figure B.1. Therefore, the ampacity from Table 1 for a 646 kcmil ac top drive power service loop is determined as follows:

$$I_{\text{646 kcmil SL}} = \frac{553\text{ A}}{0.85} = 651\text{ A} \tag{B.2}$$

Based on these results, the inequality below shows that for an ambient temperature of 45 °C (113 °F), a single 646 kcmil ac top drive power service loop connected to the top drive drill motor is enough to power the drill motor:

$$I_{\text{646 kcmil SL}} = 651\text{ A} > 560\text{ A} = I_{\text{TD Drill Motor}} \tag{B.3}$$

B.2 Example 2

A top drive that is designed to operate in a 55 °C (131 °F) ambient temperature is powered with two ac drill motors. Each drill motor has a maximum continuous current rating of 1250 A. Per the specific top drive design and as illustrated in Figure B.2, each top drive drill motor is powered with two power service loops connected to it in parallel. Each of the four power service loops consists of either a uniformly twisted three-conductor cable bundle pulled into a hose that is potted along its entire length, or a complete multiconductor cable under a common jacket that is designed for service loop applications. The service loops are installed such that there is one service loop diameter spacing between each service loop at both hang-off points. The main body of each service loop is hanging independently, allowing free air circulation around each service loop. Therefore, ampacity derating is not required.

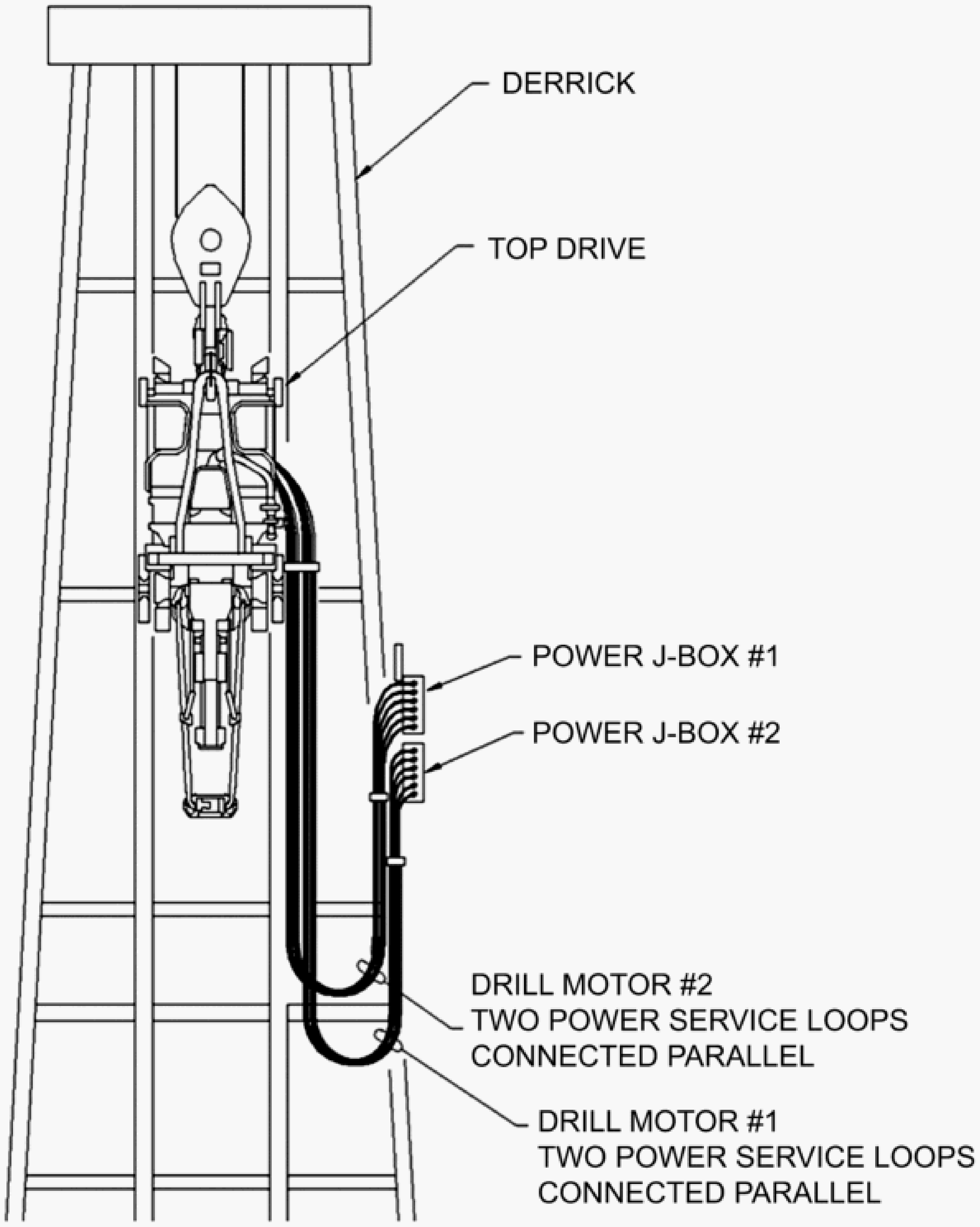

Figure B.2—Top drive installed in derrick with power service loops potted entire length

The power service loop cable size and ampacity calculation begins by applying the 0.80 duty factor to each of the top drive drill motors, which results in the following:

$$I_{\text{TD Drill Motor}} = 0.80 \times 1250\ \text{A} = 1000\ \text{A} \qquad \text{(B.4)}$$

The ac top drive power service loops are manufactured with IEEE 1580 Type P power cables that are approved by a NRTL for a maximum conductor temperature of 110 °C. Therefore, these power service loops are each considered as three-conductor power cables rated for a 110 °C conductor temperature.

An inspection of Table 1 is performed and a single 646 kcmil three-conductor power cable with an ampacity of 553 A at a conductor temperature rating of 110 °C is selected. It is noted that the tabulated ampacities specified in Table 1 are based on a 45 °C (113 °F) ambient temperature.

Per NOTE 5 of Table 1, the ampacity is adjusted as follows for a 55 °C (131 °F) ambient temperature:

$$I_{\text{646 kcmil SL}} = 553\ \text{A} \times 0.92 = 509\ \text{A} \qquad \text{(B.5)}$$

NOTE 6 and NOTE 7 of Table 1 state that the ampacity values shown are for single-banked cables, and that for cables in free air with one cable diameter spacing between them the ampacities may be increased by dividing values shown by 0.85.

These four power service loops are considered as three-conductor power cables hanging in free air between the top drive and derrick as illustrated in Figure B.2. Therefore, the ampacity from Table 1 for a single three-conductor 646 kcmil ac top drive power service loop is increased as follows:

$$I_{646\text{ kcmil SL}} = \frac{509\text{ A}}{0.85} = 599\text{ A} \tag{B.6}$$

Two 646 kcmil power service loops connected in parallel (2 per phase [2/ph]) to the top drive drill motor results in the following:

$$I_{2/\text{ph }646\text{ kcmil SL}} = 2 \times 599\text{ A} = 1198\text{ A} \tag{B.7}$$

Based on these results, the inequality below shows that for an ambient temperature of 55 °C (131 °F), two 646 kcmil ac top drive power service loops connected in parallel to each top drive drill motor are sufficient to power the drill motors:

$$I_{2/\text{ph }646\text{ kcmil SL}} = 1198\text{ A} > 1000\text{ A} = I_{\text{TD Drill Motor}} \tag{B.8}$$

B.3 Example 3

A top drive that is designed to operate in a 45 °C (113 °F) ambient temperature is powered with one ac drill motor. The drill motor has a maximum continuous current rating of 575 A. Per the specific top drive design and as illustrated in Figure B.3, the top drive drill motor is powered with one power service loop. The power service loop design consists of a uniformly twisted three-conductor cable bundle pulled into a hose with a short 1 m (3 ft) section at each end of the hose potted to support and hold the cable bundle within the hose. The remaining center section of the power service loop hose is not potted.

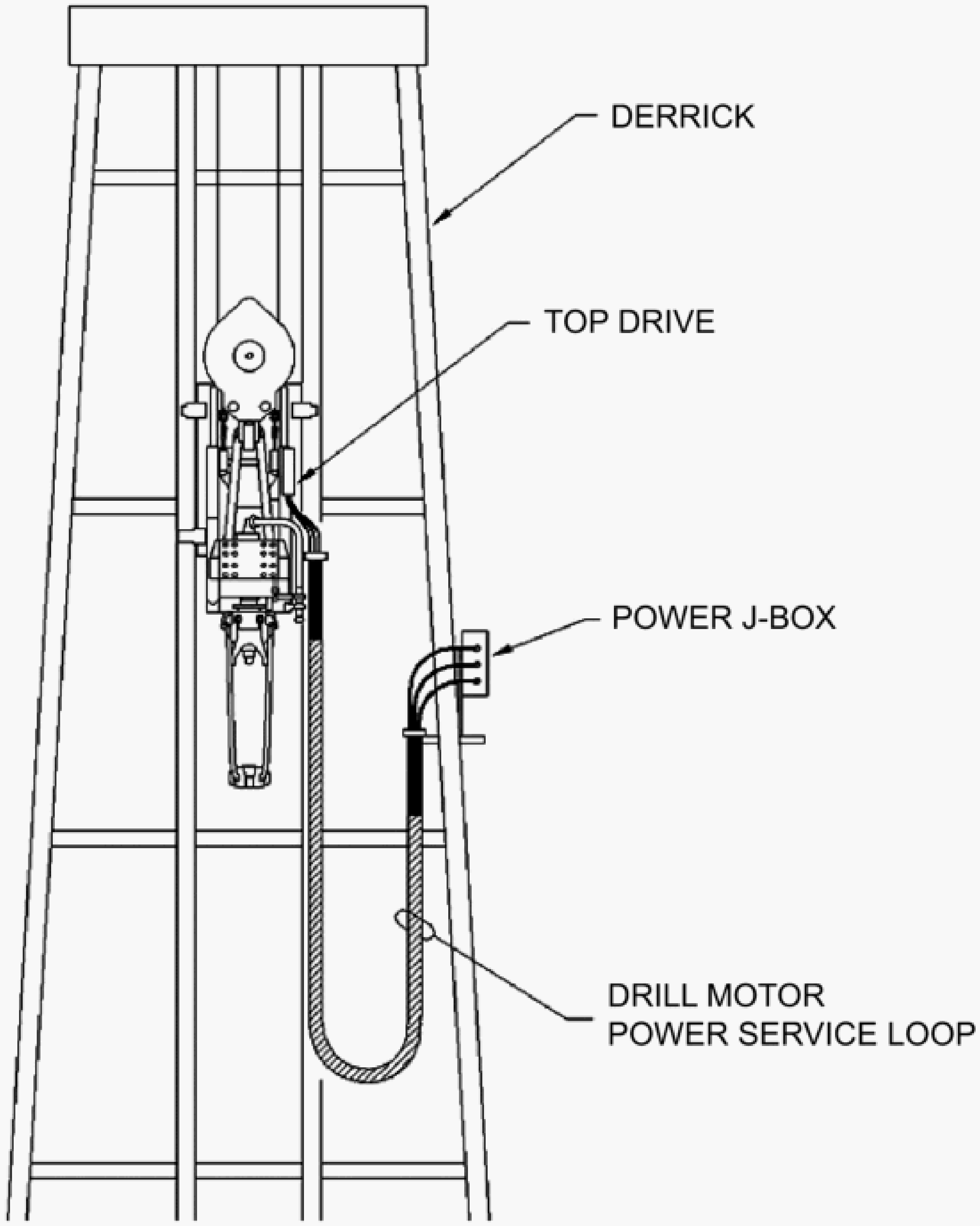

Figure B.3—Top drive installed in derrick with power service loop potted at each end only

The power service loop cable size and ampacity calculation begins by applying the 0.80 duty factor to the top drive drill motor, which results in the following:

$$I_{\text{TD Drill Motor}} = 0.80 \times 575\ \text{A} = 460\ \text{A} \tag{B.9}$$

The ac top drive power service loop is manufactured with IEEE 1580 Type P power cables that are approved by an NRTL for a maximum conductor temperature of 110 °C. Since these conductors are installed in a hose that is potted at each end only with the remaining center section of the hose being unpotted, the ampacities shall be derated in accordance with item c) in Clause 8.

An inspection of Table 1 is performed and a 646 kcmil three-conductor power cable with an ampacity of 553 A at a conductor temperature rating of 110 °C is selected. It is noted that the tabulated ampacities specified in Table 1 are based on a 45 °C (113 °F) ambient temperature.

NOTE 6 and NOTE 7 of Table 1 state that the ampacity values shown are for single-banked cables, and that for cables in free air with one cable diameter spacing between them the ampacities may be increased by dividing values shown by 0.85.

The 646 kcmil three-conductor power cable ampacity is adjusted for a cable in free air.

$$I_{646\text{ kcmil 3C}} = \frac{553\text{ A}}{0.85} = 651\text{ A} \tag{B.10}$$

Since the power service loop is only potted at each end and the center section is not potted, the ampacity of the 646 kcmil power service loop is calculated as follows:

$$I_{646\text{ kcmil SL}} = 0.80 \times 651\text{ A} = 521\text{ A} \tag{B.11}$$

Based on these results, the inequality below shows that for an ambient temperature of 45 °C (113 °F), a single 646 kcmil ac top drive power service loop of this design connected to the top drive drill motor is sufficient to power the top drive:

$$I_{646\text{ kcmil SL}} = 521\text{ A} > 460\text{ A} = I_{\text{TD Drill Motor}} \tag{B.12}$$

B.4 Example 4

A top drive that is designed to operate in a 45 °C (113 °F) ambient temperature is powered with one ac drill motor. The drill motor has a maximum continuous current rating of 750 A. Per the specific top drive design and as illustrated in Figure B.4, the top drive drill motor is powered with three separate single-conductor power cables that are routed through a drag-chain attached between the top drive and derrick. Spacing between the three single-conductor power cables is equal to one cable diameter.

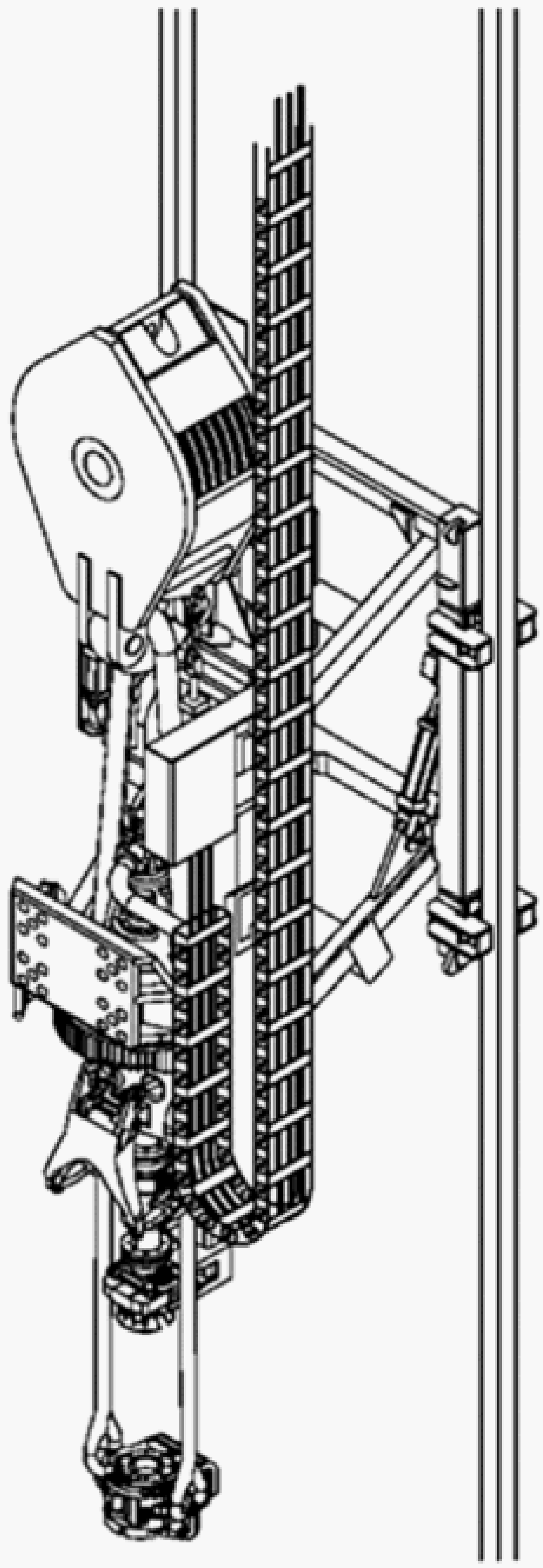

Figure B.4—Top drive installed in derrick drill motor power cables routed through drag-chain

The drag chain power cable size and ampacity calculation begins by applying the 0.80 duty factor to the top drive drill motor, which results in the following:

$$I_{\text{TD Drill Motor}} = 0.80 \times 750\ \text{A} = 600\ \text{A} \quad \text{(B.13)}$$

The single-conductor power cables installed in the drag chain are IEEE 1580 Type P power cables that are approved by an NRTL for a maximum conductor temperature of 110 °C.

An inspection of Table 1 is performed and a 373 kcmil single-conductor power cable with an ampacity of 553 A at a conductor temperature rating of 110 °C is selected. It is noted that the tabulated ampacities specified in Table 1 are based on a 45 °C (113 °F) ambient temperature.

NOTE 6 and NOTE 7 of Table 1 state that the ampacity values shown are for single-banked cables, and that for cables in free air with one cable diameter spacing between them, the ampacities may be increased by dividing values shown by 0.85.

The three single-conductor power cables have one cable diameter spacing between them as they travel through the drag chain. Therefore, the ampacity is adjusted for a cable in free air.

$$I_{\text{373 kcmil 1C}} = \frac{553\ \text{A}}{0.85} = 650\ \text{A} \quad \text{(B.14)}$$

Based on these results the inequality below shows that for an ambient temperature of 45 °C (113 °F), one single-conductor 373 kcmil power cable connected to each phase of the top drive drill motor is enough to power the top drive drill motor:

$$I_{\text{373 kcmil 1C}} = 650 \text{ A} > 600 \text{ A} = I_{\text{TD Drill Motor}} \tag{B.15}$$

Annex C

(informative)

Protection techniques for Class I, Zone 0, Zone 1, or Zone 2 locations

C.1 General

Acceptance of protection techniques related to equipment approved for zones may vary between authorities having jurisdiction (AHJs). Specific requirements may have to be addressed for AHJ approvals.

Zone protection methods, in compliance with the NEC, are prefixed with the letter A, e.g., AE x d.

Although like IEC, equipment test methods for NEC Zone protection and IEC Zone protection are not the same.

C.2 Flameproof "d"

Flameproof is a type of protection of electrical equipment in which the enclosure will withstand an internal explosion of a flammable mixture that has penetrated the interior, without suffering damage and without causing ignition, through any joints or structural openings in the enclosure, of an external explosive atmosphere consisting of one or more of the gases or vapors for which it is designed. This protection technique is permitted for equipment in Class I, Zone 1 locations for which it is approved. For further information, see UL 60079-1 [B20].

C.3 Pressurization "p"

In some cases, hazards may be reduced or hazardous (classified) locations limited or eliminated by adequate positive-pressure ventilation from a source of clean air in conjunction with effective safeguards against ventilation failure. Pressurization "p" is a type of protection of electrical equipment that uses the technique of guarding against the ingress of the external atmosphere that may be explosive, into an enclosure by maintaining a protective gas therein at a pressure above that of the external atmosphere. This protection technique is permitted for equipment in those Class I, Zone 1 or Zone 2 locations for which it is approved. For further information, see IEC 60079-2 [B3], IEC 60079-13 [B4], and NFPA 496 [B12].

The types of "p" pressurization techniques are as follows:

- From Zone 1 to unclassified (Type px pressurization)
- From Zone 1 to Zone 2 (Type py pressurization)
- From Zone 2 to unclassified (Type pz pressurization)

C.4 Intrinsic safety "ia," "ib," and "ic"

Intrinsically safe circuits are incapable of releasing enough electrical or thermal energy under prescribed test conditions to cause ignition of a specific hazardous atmospheric mixture in its most easily ignitable concentration. Test conditions include both normal and abnormal operating conditions. Abnormal equipment conditions include accidental damage to or failure of the equipment, wiring, insulation, or other components and exposure to overvoltage. Normal conditions include periods of adjustment and maintenance. The most common applications are found in the fields of instrumentation and communications. Intrinsic safety is designated as Type "i" protection. Type "i" protection is subdivided into categories "ia," "ib," and "ic."

Intrinsic safety suitable for use in Zones 0, 1, and 2 locations is designated category "ia" by UL 60079-11 [B24].

Intrinsic safety suitable for use in Zones 1 and 2 locations is designated category "ib" by UL 60079-11 [B24].

Intrinsic safety suitable for use in Zone 2 locations is designated category "ic" by UL 60079-11 [B24].

For further information, see UL 913 [B14] and UL 60079-11 [B24].

Simple apparatus incorporated in intrinsically safe circuits is permitted in Class I, Zone 0 or Zone 1 locations, according to the category of the associated apparatus. Such apparatus need not be certified, or approved, provided that the associated apparatus is suitably certified or approved, and provided that neither the capacitance nor the inductance of the simple apparatus, considered together with the electrical parameters of the field cabling, exceeds the relevant limits given in the documentation or marking of the associated apparatus.

Intrinsically safe associated apparatus, designated by [ia], [ib], or [ic], is connected to intrinsically safe equipment ("a," "ib," or "ic," respectively), but is located outside the hazardous (classified) location unless also protected by another type of protection (such as flameproof).

C.5 Type of protection "n"

Type "n" protection is a type of protection applied to electrical equipment such that, in normal operation, the electrical equipment is not capable of igniting a surrounding explosive gas atmosphere and a fault capable of causing ignition is not likely to occur. This protection technique is permitted for equipment in Class I, Zone 2 locations for which it is approved. Type of protection "n" is further subdivided into "nA," "nC," "nL," and "nR." See Table 1 for the descriptions of subdivisions for type of protection "n." For further information, see UL 60079-15 [B26] and ISA 60079-15 [B11].

C.6 Oil (liquid) immersion "o"

Oil immersion is a type of protection in which the electrical equipment or parts of the electrical equipment are immersed in a protective liquid in such a way that an explosive atmosphere that may be above the liquid or outside the enclosure cannot be ignited. This protection technique is permitted for equipment in Class I, Zone 1 locations for which it is approved. For further information, see UL 60079-6 [B22].

C.7 Increased safety "e"

Increased safety is a type of protection applied to electrical equipment that does not produce arcs or sparks in normal service and under specified abnormal conditions, in which additional measures are applied to give increased security against the possibility of excessive temperatures and of the occurrence of arcs and sparks. This protection technique is permitted for equipment in Class I, Zone 1 locations for which it is approved. For further information, see UL 60079-7 [B23].

C.8 Encapsulation “ma” and “mb”

Encapsulation is a type of protection in which the parts that could ignite an explosive atmosphere by either sparking or heating are enclosed in a compound in such a way that this explosive atmosphere cannot be ignited. This protection technique is permitted for equipment in Class I, Zone 1 locations for which it is approved. For further information, see UL 60079-18 [B27]. Encapsulation suitable for use in Zones 0, 1, and 2 locations are designated category “ma.” Encapsulation suitable for use in Zones 1 and 2 locations is designated category “mb.”

C.9 Powder filling “q”

Powder filling is a type of protection in which the parts capable of igniting an explosive atmosphere are fixed in position and surrounded by filling material (glass or quartz powder) to prevent the ignition of an external explosive atmosphere.

This protection technique is permitted for equipment in Class I, Zone 1 locations for which it is approved. For further information, see UL 60079-5 [B21].

Table C.1—Summary of protection techniques

Designation	Technique	Zone[a]
D	Flameproof enclosure	1, 2
E	Increased safety	1, 2
Ia	Intrinsic safety	0, 1, 2
Ib	intrinsic safety	1, 2
Ic	Intrinsic safety	2
[ia][b]	Intrinsically safe associated apparatus	Non-hazardous
[ib][b]	Intrinsically safe associated apparatus	Non-hazardous
[ic][b]	Intrinsically safe associated apparatus	Non-hazardous
Ma	Encapsulation	0, 1, 2
Mb	Encapsulation	1, 2
nA	Non-sparking equipment	2
nC	Sparking equipment in which the contacts are suitably protected other than by restricted breathing enclosure	2
nL	Energy limited—limit the energy of sparks and surface temperatures	2
nR	Restricted breathing enclosure	2
O	Liquid immersion	1, 2
Px	Pressurization	1
Py	Pressurization	1
Pz	Pressurization	2[c]
Q	Powder-filled	1, 2

[a] Does not address use where a combination of techniques is used.

[b] See B.4.

[c] Depends on factors such as the provision of automatic shutdown, or alarm only on loss of pressurization, the arrangement for the exhaust of the protective gas, the inclusion of sparking/arcing, or high temperature devices within the enclosure, etc.

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