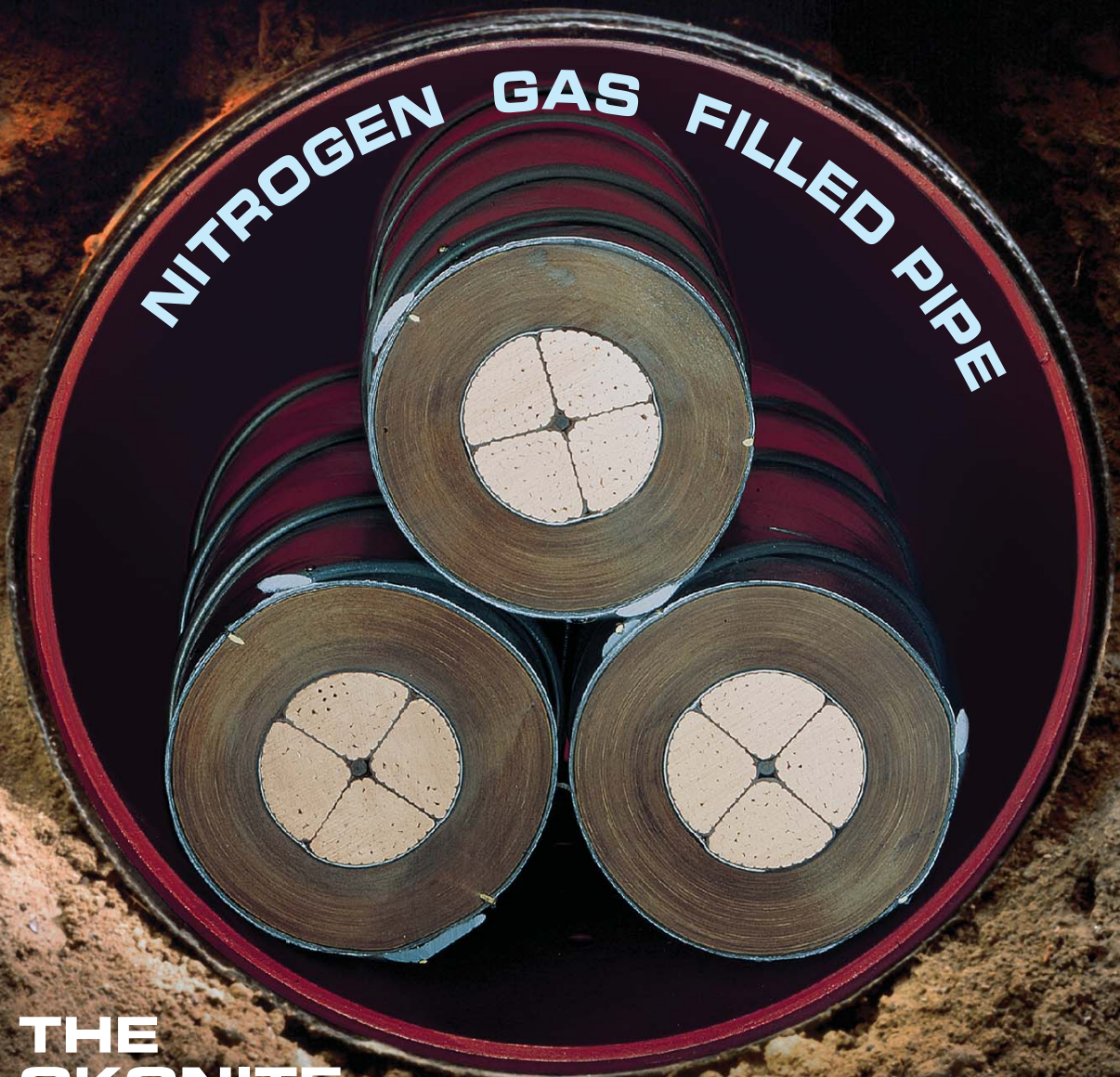
# OKONITE H.P.G.F

## HIGH PRESSURE GAS FILLED CABLES

### 69 kV - 115 kV - 138 kV

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# Introduction

The information in this booklet is provided to assist engineers faced with the need to design and install high reliability 69kV, 115kV and 138kV transmission circuits.

Section 1 contains information on the pioneering development by Okonite of the pipe type cable system, along with the improvements and variations over the last eighty (80) years.

The features and advantages of using a High Pressure Gas Filled (HPGF) pipe type cable system for new installations are covered in Section 2.

In Section 3, a listing of the many HPGF jobs supplied by Okonite since 1951 is provided. The total footage of Okonite HPGF cable installed and in service to date is over two million feet.

Section 4 contains ampacity tables for single circuit and double circuit installations, utilizing both copper and aluminum conductors.

A typical specifying standard for a 138kV HPGF cable and all other system components is provided in Section 5.

Section 6 provides dimensions and weights of copper and aluminum conductors plus mechanical and physical properties of the conductor materials.

Section 7 includes miscellaneous electrical formulas and information.

Section 8 contains a listing of Okonite locations, for obtaining additional information on HPGF cables.

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# Background

The pipe type cable system was developed by Okonite in 1931. This system was patented and our Oilostatic® trademark became a well known and respected trademark in the industry.

The first experimental Oilostatic® system was 2000 feet long and put in service at 69kV in 1932 at the Plymouth Meeting Substation of the Philadelphia Electric Company.

This was followed by the first commercial circuit in 1935 at 138kV for the Pennsylvania Railroad in Baltimore, Maryland. This circuit was three (3) miles long.

These early circuits were filled with an insulating liquid and pressurized at 200 psig. They later became generically known as HPOF (High Pressure Oil Filled) and more recently known as HPFF (High Pressure Fluid Filled) pipe type cable systems.

These Oilostatic® type systems quickly gained acceptance and became the primary method of transmitting bulk power underground at high voltage levels.

In 1955, the first Oilostatic® system at the 230kV level was supplied by Okonite to the Sao Paulo Light & Power Company Limited and placed in service at the Cubatao Power Plant in Brazil.

In 1963 these Oilostatic® type cables were supplied by Okonite and other manufacturers to Consolidated Edison Company of New York, Inc. for their underground large capacity 345kV transmission system. Okonite supplied by far the major portion of these 345kV cables.

Up until 1987, all these cables were manufactured with insulation consisting of impregnated paper tapes. In 1987 Okonite supplied the first commercial pipe type cable circuit insulated with impregnated laminated paper polypropylene (LPP) tapes to Boston Edison Company.

High Pressure Gas Filled (HPGF) pipe type cable systems were first introduced to the industry in 1941. These systems utilize nitrogen gas pressurized at 200 psig instead of an insulating liquid to fill the pipe. Since the dielectric properties of gas are lower than those of insulating liquid, the HPGF system is currently used only at three (3) voltages - 69kV, 115kV and 138kV.

HPGF cables are very similar in design to HPFF cables except:

(a) The insulation thicknesses are greater as shown in the table below due to the lower electrical strength of gas as compared to fluid.

**Paper Insulation Thicknesses**

| Voltage | HPGF | HPFF |
|---|---|---|
| 69kV | .300" | .270" |
| 115kV | .485" | .375" |
| 138kV | .585" | .440" |

(B) The cable impregnant used in HPGF cables is a far more viscous fluid, to minimize drainage of the impregnant from the insulating tapes.

The HPGF cables have been included in all editions of the industry AEIC pipe type cable specification going all the way back to the 1st edition dated September, 1951. The insulation wall thickness for HPGF cables has never changed from the earliest 1951 specification edition to the current edition, which is indicative of the stability and reliability of this design.

# Features & Advantages

The High Pressure Gas Filled (HPGF) pipe type cable system has many clearly desirable features and advantages. These are:

(1) Provides a highly reliable, simple, trouble-free system with proven long track record for new bulk power transmission circuits in the 69kV-115kV-138kV range, as an alternative to solid dielectric cables.

(2) Provides the ruggedness and high reliability of a pipe type cable system but without a liquid in the pipe, which eliminates environmental concerns.

(3) Provides extremely low magnetic field (1 to 2 milligausses) as confirmed by industry tests and data. This is about 50 times lower than 1/C solid dielectric cables installed in duct banks or direct buried.

(4) Multiple layers of insulating tapes produce a uniform laminated insulation wall, minimizing effects of any abnormalities in the insulation wall, as compared to an extruded insulation solid dielectric cable.

(5) Cable can be manufactured and installed in long lengths of 4000 feet and longer which minimizes the number of manholes, splices and cost.

(6) No metallic type moisture barrier or sheath is required over the insulation of each 1/C cable as is required for extruded solid dielectric cables.

(7) No special bulky sheath cross-bonding arrangements are required as on 1/C solid dielectric cables. No sheath sectionalizing joints, bonding leads, link boxes or sheath voltage limiters are required. No standing sheath voltages to ground are present.

(8) Eliminates need for disconnecting bonding connections and periodic testing of sheath insulation as on 1/C solid dielectric cables. This disconnecting and testing is done on 1/C solid dielectric cables to assure that no unintended grounds have occurred in service, which could cause considerable sheath currents to flow with resultant higher losses and overheating of cables.

(9) Nitrogen pressurization of 200 psig prevents ionization in service under normal and emergency operating conditions.

(10) System is pressurized with low cost nitrogen, utilizing a simple “Gas Control Unit” placed at one end of the circuit. This unit contains only three pressure switches for Hi-Low-Emergency alarms, one nitrogen pressure regulator and two nitrogen cylinders. There are no moving parts and no maintenance is required. The unit can be installed at a remote unattended terminal station.

(11) Pipe system is totally welded from one end to the other. No gaskets are used in the entire pipe circuit run except in the terminators at each end of the circuit, which are also filled with nitrogen, same as the pipe section of the circuit.

# Features & Advantages

(12) The system is subjected to a simple, fool-proof series of vacuum and pressure tests during installation. The circuit is filled and pressurized with "one lot" of nitrogen gas during installation, which provides the pressurization throughout the life of the system. The "locked in" nitrogen gas pressure fluctuates slightly during everyday normal load cycling and ambient temperature changes. No nitrogen is added to the system and no nitrogen is vented from the system in everyday operation.

(13) Nitrogen gas is physiologically inert, non-toxic, non-flammable, non-corrosive, colorless and odorless.

(14) Nitrogen leaks, which are extremely rare, can be readily detected by introducing a small quantity of tracer gas into the system and using a "sniffer" detector. Any leaks are minute and readily dissipate into the atmosphere without any hazard or environmental damage (the atmosphere we breathe is composed of 78% nitrogen, 21% oxygen and 1% trace elements).

(15) Manufactured in the U.S.A. in the largest capacity, most modern paper cable plant at Paterson, New Jersey. Engineering, installation and technical assistance are always readily available.

(16) Provides a low cost, highly reliable alternative pipe type cable system, especially for short cable runs of one-half mile or so by eliminating the need for a liquid pressure control center (pumping plant).

(17) High overload capabilities in emergency type situations.

(18) Cable insulation materials and manufacturing processes have been fine-tuned to a high degree of quality and reliability over eight (8) decades.

(19) Pipe type cable splices and terminators have proven over many years of service to be exceptionally reliable and trouble-free, as compared to the more volatile track record of splices and terminators on alternate type cable systems at these voltage levels.

(20) Splicing vaults (manholes) for HPGF pipe type cables are much smaller, less costly and occupy less space in congested underground areas.

(21) For dual circuit installations, both HPGF pipe type cable circuits are spliced in one common vault. For solid dielectric cables, two separate side by side vaults are required.

(22) Capable of easy future voltage and MVA uprating by reconductoring the existing pipe or converting to an HPFF system.

(23) Cable can be overinsulated to allow future operation at a higher 230kV level with fluid filling of the pipe. Initial operation would be with nitrogen gas filling at the lower 69/115/138kV level.

(24) There are over 4500 circuit miles of underground high voltage transmission cable in service in the U.S.A. Over 75% of this total is HPFF and HPGF pipe type cable. With three conductors per circuit foot, this equates to over 53 million feet of single conductor pipe type cable currently in service in the U.S.A.

# Features & Advantages

(25) Impregnated paper insulated cables have proven to be almost ageless in service life. No pipe type cable systems have been decommissioned due to age or problems with the impregnated paper dielectric. Many circuits are now over 50 years old. This long term operating experience plus evaluation and testing of removed cable samples whenever they become available, (such as reconductoring for upgrading the MVA, etc.) have shown very little aging has occurred.

(26) We may well be looking at a 100 year service life for these cables.

# Experience Record

## HIGH PRESSURE GAS FILLED (HPGF)
## PIPE-TYPE CABLES

| Year | Customer | kV | kcmil Size | Insulation Thickness, Inches | Cable Footage |
|---|---|---|---|---|---|
| 1951 | Detroit Edison | 138 | 1500 | .600 | 22,500 |
| 1955 | Con Edison of New York | 69 | 350, 1000, 1250 | .315 | 31,800 |
| 1957 | Gulf States Utilities | 69 | 1750 | .315 | 900 |
| 1957 | Jacksonville Electric Association | 69 | 600 | .285 | 3,400 |
| 1957 | Con Edison of New York | 69 | 1250 | .315 | 16,500 |
| 1957 | Con Edison of New York | 69 | 1500 | .315 | 17,000 |
| 1959 | Con Edison of New York | 69 | 2000 | .315 | 51,600 |
| 1959 | Con Edison of New York | 69 | 2500 | .315 | 26,000 |
| 1959 | Con Edison of New York | 69 | 2000 | .315 | 2,100 |
| 1959 | Con Edison of New York | 69 | 2500 | .315 | 750 |
| 1960 | Con Edison of New York | 69 | 2000 | .315 | 27,600 |
| 1960 | Con Edison of New York | 69 | 2500 | .315 | 21,000 |
| 1960 | Con Edison of New York | 138 | 2000 | .600 | 24,000 |
| 1960 | Con Edison of New York | 138 | 2500 | .600 | 4,500 |
| 1961 | Pacific Gas & Electric | 120 | 1250 | .500 | 10,900 |
| 1961 | Con Edison of New York | 69 | 2000 | .315 | 29,300 |
| 1961 | Con Edison of New York | 69 | 2500 | .315 | 12,300 |
| 1963 | Puerto Rico Water Resources Auth. | 115 | 1250 | .480 | 2,700 |
| 1965 | United Illuminating | 120 | 2500 | .550 | 85,200 |
| 1968 | Public Service Electric & Gas | 138 | 1250 | .600 | 17,400 |
| 1968 | Pacific Gas & Electric | 120 | 1250 | .500 | 27,600 |
| 1971 | Pacific Gas & Electric | 69 | 800 (Alum.) | .315 | 12,600 |
| 1972 | Detroit Edison | 138 | 600 | .600 | 12,600 |
| 1974 | Detroit Edison | 138 | 2250 (Alum.) | .600 | 19,900 |
| 1976 | United Illuminating | 120 | 2500 | .550 | 4,900 |
| 1977 | Aramco | 115 | 500 | .500 | 33,200 |
| 1977 | Pacific Gas & Electric | 115 | 500 (Alum.) | .500 | 15,600 |
| 1977 | Public Service Electric & Gas | 138 | 1250 | .600 | 2,700 |

# Experience Record

## HIGH PRESSURE GAS FILLED (HPGF)
## PIPE-TYPE CABLES

| Year | Customer | kV | kcmil Size | Insulation Thickness, Inches | Cable Footage |
|---|---|---|---|---|---|
| 1978 | Pacific Gas & Electric | 115 | 1250 | .500 | 15,500 |
| 1978 | Central Electric Power | 115 | 1250 | .500 | 8,500 |
| 1978 | Detroit Edison | 138 | 1500 | .600 | 6,900 |
| 1979 | Delmarva Power & Light | 138 | 2750 (Alum.) | .600 | 19,800 |
| 1980 | Pacific Gas & Electric | 69 | 2000 (Alum.) | .315 | 10,200 |
| 1981 | Detroit Edison | 138 | 1500 | .600 | 4,500 |
| 1986 | Pacific Gas & Electric | 115 | 500 | .485 | 12,300 |
| 1987 | Detroit Edison | 138 | 1500 | .620 | 6.900 |
| 1988 | Pacific Gas & Electric | 115 | 3000 (Alum.) | .485 | 46,200 |
| 1989 | South Carolina Electric & Gas | 115 | 1750 | .485 | 15,200 |
| 1990 | Long Island Lighting | 69 | 1500 | .300 | 203,000 |
| 1991 | Santee Cooper | 115 | 3000 | .485 | 64,500 |
| 1991 | United Illuminating | 115 | 1500 | .485 | 54,100 |
| 1992 | Public Service Electric & Gas | 138 | 2500 | .585 | 84,000 |
| 1992 | South Carolina Electric & Gas | 115 | 1750 | .485 | 18,400 |
| 1993 | Colorado Springs Utilities | 115 | 2000 (Alum.) | .485 | 62,300 |
| 1994 | Pacific Gas & Electric | 115 | 3000 | .485 | 38,700 |
| 1995 | Brooklyn Navy Yard Cogeneration Partners LP | 138 | 1750 | .615 | 19,800 |
| 1996 | Vermont Electric | 115 | 1750 | .680 | 32,900 |
| 1996 | Detroit Edison | 138 | 2250 (Alum.) | .605 | 20,000 |
| 1997 | NASA Langley Research Center | 115 | 1000 | .485 | 7,100 |
| 1997 | Louisville Gas & Electric | 138 | 2000 | .635 | 29,200 |
| 1998 | AES/Warrior Run | 138 | 1500 | .585 | 15,600 |
| 1999 | South Carolina Electric & Gas | 115 | 1750 | .485 | 22,200 |
| 1999 | New England Electric Service | 115 | 750 | .485 | 108,600 |
| 1999 | South Carolina Electric & Gas | 115 | 1750 | .485 | 22,600 |
| 2001 | Pacific Gas & Electric | 115 | 3000 | .485 | 11,300 |

# Experience Record

## HIGH PRESSURE GAS FILLED (HPGF)
## PIPE-TYPE CABLES

| Year | Customer | kV | kcmil Size | Insulation Thickness, Inches | Cable Footage |
|---|---|---|---|---|---|
| 2002 | Con Edison of New York | 69 | 1000 | .300 | 1,000 |
| 2002 | South Carolina Electric & Gas | 115 | 1750 | .485 | 14,800 |
| 2002 | Pacific Gas & Electric | 115 | 3000 | .485 | 11,400 |
| 2003 | Keyspan | 69 | 1500 | .300 | 12,600 |
| 2003 | Detroit Edison | 138 | 2250 (Alum.) | .605 | 4,200 |
| 2003 | South Carolina Electric & Gas | 115 | 1750 | .485 | 14,800 |
| 2004 | Pacific Gas & Electric | 69 | 800 (Alum.) | .300 | 2,400 |
| 2004 | South Carolina Electric & Gas | 115 | 2250 | .485 | 33,000 |
| 2004 | Con Edison of New York` | 138 | 2500 | .585 | 79,400 |
| 2005 | Con Edison of New York | 138 | 1000 | .585 | 7,200 |
| 2005 | Con Edison of New York | 138 | 2500 | .585 | 7,400 |
| 2005 | Con Edison of New York | 138 | 1000 | .585 | 26,300 |
| 2005 | Con Edison of New York | 138 | 2500 | .585 | 115,800 |
| 2006 | South Carolina Electric & Gas | 115 | 2250 | .485 | 16,300 |
| 2006 | Con Edison of New York | 138 | 500 | .585 | 2,100 |
| 2007 | Con Edison of New York | 138 | 1000 | .585 | 2,200 |
| 2007 | Louisville Gas & Electric | 138 | 2000 | .585 | 7,800 |
| 2007 | Con Edison of New York | 69 | 2000 | .300 | 2,100 |
| 2007 | Con Edison of New York | 138 | 2500 | .585 | 2,100 |
| 2008 | South Carolina Electric & Gas | 115 | 2250 | .485 | 64,400 |
| 2008 | Florida Power & Light | 138 | 3000 | .585 | 56,500 |
| 2008 | Louisville Gas & Electric | 69 | 2000 | .300 | 29,900 |
| 2009 | Pacific Gas & Electric | 115 | 2000 | .385(LPP) | 89,000 |
| 2009 | Santee Cooper | 115 | 1500 | .485 | 8,500 |
| 2009 | Con Edison of New York | 138 | 2500 | .585 | 41,000 |
| 2010 | Pacific Gas & Electric | 115 | 2000 | .385(LPP) | 73,300 |
| 2011 | South Carolina Electric & Gas | 115 | 2250 | .485 | 85,000 |

# Ampacity Tables

The ampacity tables in this section are for installation conditions most commonly encountered and for applications where the thermal conditions are generally known.

The values in the tables are based on data from the IEEE Standard 835-1994 “IEEE Standard Power Cable Ampacity Tables”. The complete publication can be obtained from the Institute of Electrical and Electronic Engineers, 445 Hoes Lane, Piscataway, N.J. 08855-1331.

Load factors of 75 and 100 percent are shown. By definition the load factor of a circuit is the ratio of average hourly load to the maximum hourly load for a given period, usually 24 hours. These load factors apply for pipe type cables in conventional underground installations, since there is a time lag between the temperature rise of the cable and the temperature rise of the pipe and surrounding earth. This heat-time lag characteristic permits assigning higher current ratings for pipe type cables which do not carry full load continuously (100 percent load factor).

Ampacities for both copper and aluminum conductors are provided since both have been used in HPGF pipe type cable systems. Aluminum conductor systems can possibly provide a cost savings when compared to an equivalent MVA copper conductor system. Both copper and aluminum conductor cables should be considered in the early design stages of a circuit.

# Ampacity Tables

## 69kV

### COPPER CONDUCTORS

Buried Circuit - One or Two Pipes

Load Factor - 75% or 100%

Conductor Temperature - 85°C

Earth Ambient Temperature - 25°C

Earth Thermal Resistivity - 90 RHO

Depth of Burial - 36 inches

| Conductor Size kcmil | Pipe I.D. Inches | One Pipe Circuit 75 LF | One Pipe Circuit 100 LF | Two Pipes 24" Spacing 75 LF | Two Pipes 24" Spacing 100 LF | Two Pipes 36" Spacing 75 LF | Two Pipes 36" Spacing 100 LF |
|---|---|---|---|---|---|---|---|
| **COMPACT ROUND STRAND** | | | | | | | |
| 3/0 AWG | 4.026 | 298 | 274 | 281 | 254 | 286 | 259 |
| 4/0 AWG | 4.026 | 340 | 311 | 320 | 287 | 325 | 294 |
| 350 | 4.026 | 449 | 409 | 420 | 375 | 429 | 384 |
| 500 | 5.047 | 556 | 501 | 517 | 456 | 528 | 468 |
| 750 | 5.047 | 683 | 610 | 631 | 552 | 645 | 568 |
| 1000 | 5.047 | 779 | 692 | 716 | 623 | 733 | 642 |
| 1250 | 5.047 | 851 | 752 | 780 | 675 | 799 | 696 |
| **COMPACT SEGMENTAL STRAND** | | | | | | | |
| 1000 | 5.047 | 818 | 725 | 750 | 651 | 769 | 671 |
| 1250 | 6.125 | 927 | 812 | 843 | 725 | 867 | 748 |
| 1500 | 6.125 | 1003 | 876 | 910 | 779 | 936 | 805 |
| 1750 | 6.125 | 1068 | 928 | 966 | 823 | 994 | 851 |
| 2000 | 6.125 | 1121 | 972 | 1012 | 860 | 1042 | 890 |
| 2250 | 6.125 | 1164 | 1006 | 1048 | 889 | 1079 | 920 |
| 2500 | 8.125 | 1244 | 1058 | 1107 | 925 | 1144 | 960 |
| 2750 | 8.125 | 1280 | 1085 | 1136 | 947 | 1174 | 983 |
| 3000 | 8.125 | 1307 | 1106 | 1158 | 964 | 1198 | 1001 |

# Ampacity Tables

## 69kV

### ALUMINUM CONDUCTORS

Buried Circuit - One or Two Pipes

Load Factor - 75% or 100%

Conductor Temperature - 85°C

Earth Ambient Temperature - 25°C

Earth Thermal Resistivity - 90 RHO

Depth of Burial - 36 inches

| Conductor Size kcmil | Pipe I.D. Inches | One Pipe Circuit 75 LF | One Pipe Circuit 100 LF | Two Pipes 24" Spacing 75 LF | Two Pipes 24" Spacing 100 LF | Two Pipes 36" Spacing 75 LF | Two Pipes 36" Spacing 100 LF |
|---|---|---|---|---|---|---|---|
| **COMPACT ROUND STRAND** | | | | | | | |
| 3/0 AWG | 4.026 | 233 | 214 | 220 | 198 | 224 | 203 |
| 4/0 AWG | 4.026 | 266 | 244 | 250 | 225 | 255 | 230 |
| 350 | 4.026 | 353 | 322 | 331 | 295 | 337 | 302 |
| 500 | 5.047 | 441 | 397 | 410 | 362 | 418 | 372 |
| 750 | 5.047 | 550 | 492 | 508 | 446 | 520 | 458 |
| 1000 | 5.047 | 639 | 569 | 588 | 513 | 603 | 528 |
| 1250 | 5.047 | 713 | 632 | 654 | 568 | 671 | 585 |
| **COMPACT SEGMENTAL STRAND** | | | | | | | |
| 1000 | 5.047 | 656 | 583 | 603 | 524 | 618 | 540 |
| 1250 | 6.125 | 754 | 662 | 687 | 592 | 706 | 611 |
| 1500 | 6.125 | 827 | 724 | 752 | 645 | 772 | 666 |
| 1750 | 6.125 | 892 | 778 | 808 | 691 | 831 | 714 |
| 2000 | 6.125 | 949 | 825 | 859 | 732 | 883 | 757 |
| 2250 | 6.125 | 998 | 865 | 900 | 766 | 927 | 792 |
| 2500 | 8.125 | 1082 | 924 | 966 | 810 | 997 | 840 |
| 2750 | 8.125 | 1127 | 959 | 1003 | 839 | 1036 | 870 |
| 3000 | 8.125 | 1162 | 987 | 1032 | 862 | 1067 | 895 |
| 3250 | 8.125 | 1198 | 1015 | 1062 | 885 | 1098 | 919 |
| 3500 | 8.125 | 1232 | 1041 | 1089 | 906 | 1128 | 941 |
| 3750 | 8.125 | 1261 | 1063 | 1113 | 924 | 1153 | 960 |
| 4000 | 8.125 | 1288 | 1084 | 1135 | 941 | 1176 | 978 |

# Ampacity Tables

## 115kV

### COPPER CONDUCTORS

Buried Circuit - One or Two Pipes

Load Factor - 75% or 100%

Conductor Temperature - 85°C

Earth Ambient Temperature - 25°C

Earth Thermal Resistivity - 90 RHO

Depth of Burial - 36 inches

| Conductor Size kcmil | Pipe I.D. Inches | One Pipe Circuit 75 LF | One Pipe Circuit 100 LF | Two Pipes 24" Spacing 75 LF | Two Pipes 24" Spacing 100 LF | Two Pipes 36" Spacing 75 LF | Two Pipes 36" Spacing 100 LF |
|---|---|---|---|---|---|---|---|
| **COMPACT ROUND STRAND** | | | | | | | |
| 350 | 5.047 | 439 | 400 | 411 | 367 | 419 | 376 |
| 500 | 5.047 | 536 | 485 | 498 | 442 | 509 | 454 |
| 750 | 6.125 | 672 | 600 | 619 | 542 | 633 | 558 |
| 1000 | 6.125 | 767 | 682 | 703 | 612 | 721 | 631 |
| 1250 | 6.125 | 840 | 743 | 767 | 665 | 788 | 686 |
| **COMPACT SEGMENTAL STRAND** | | | | | | | |
| 1000 | 6.125 | 804 | 713 | 736 | 638 | 755 | 658 |
| 1250 | 6.125 | 894 | 788 | 814 | 703 | 836 | 726 |
| 1500 | 8.125 | 1003 | 870 | 903 | 768 | 930 | 796 |
| 1750 | 8.125 | 1069 | 924 | 959 | 813 | 989 | 842 |
| 2000 | 8.125 | 1125 | 968 | 1005 | 850 | 1038 | 881 |
| 2250 | 8.125 | 1170 | 1003 | 1042 | 878 | 1077 | 911 |
| 2500 | 8.125 | 1210 | 1035 | 1076 | 904 | 1112 | 939 |
| 2750 | 8.125 | 1246 | 1063 | 1105 | 926 | 1143 | 962 |
| 3000 | 8.125 | 1275 | 1084 | 1128 | 943 | 1167 | 980 |

# Ampacity Tables

## 115kV

### ALUMINUM CONDUCTORS

Buried Circuit - One or Two Pipes

Load Factor - 75% or 100%

Conductor Temperature - 85°C

Earth Ambient Temperature - 25°C

Earth Thermal Resistivity - 90 RHO

Depth of Burial - 36 inches

| Conductor Size kcmil | Pipe I.D. Inches | One Pipe Circuit 75 LF | One Pipe Circuit 100 LF | Two Pipes 24" Spacing 75 LF | Two Pipes 24" Spacing 100 LF | Two Pipes 36" Spacing 75 LF | Two Pipes 36" Spacing 100 LF |
|---|---|---|---|---|---|---|---|
| | | | COMPACT ROUND STRAND | | | | |
| 350 | 5.047 | 345 | 315 | 323 | 289 | 329 | 296 |
| 500 | 5.047 | 424 | 384 | 394 | 350 | 403 | 360 |
| 750 | 6.125 | 539 | 483 | 497 | 436 | 509 | 449 |
| 1000 | 6.125 | 627 | 559 | 576 | 502 | 590 | 518 |
| 1250 | 6.125 | 700 | 621 | 641 | 556 | 657 | 574 |
| | | | COMPACT SEGMENTAL STRAND | | | | |
| 1000 | 6.125 | 644 | 572 | 590 | 513 | 605 | 529 |
| 1250 | 6.125 | 723 | 639 | 660 | 572 | 678 | 590 |
| 1500 | 8.125 | 822 | 716 | 742 | 634 | 764 | 656 |
| 1750 | 8.125 | 887 | 770 | 798 | 680 | 823 | 704 |
| 2000 | 8.125 | 945 | 817 | 848 | 719 | 874 | 746 |
| 2250 | 8.125 | 994 | 857 | 889 | 752 | 918 | 780 |
| 2500 | 8.125 | 1041 | 894 | 929 | 783 | 959 | 813 |
| 2750 | 8.125 | 1084 | 929 | 965 | 812 | 997 | 843 |
| 3000 | 8.125 | 1119 | 957 | 994 | 834 | 1028 | 867 |
| 3250 | 8.125 | 1155 | 984 | 1023 | 857 | 1059 | 891 |
| 3500 | 8.125 | 1188 | 1010 | 1050 | 877 | 1087 | 912 |
| 3750 | 8.125 | 1217 | 1032 | 1073 | 896 | 1112 | 932 |
| 4000 | 10.25 | 1279 | 1068 | 1114 | 918 | 1158 | 957 |

# Ampacity Tables

## 138kV

### COPPER CONDUCTORS

Buried Circuit - One or Two Pipes

Load Factor - 75% or 100%

Conductor Temperature - 85°C

Earth Ambient Temperature - 25°C

Earth Thermal Resistivity - 90 RHO

Depth of Burial - 36 inches

| Conductor Size kcmil | Pipe I.D. Inches | One Pipe Circuit 75 LF | One Pipe Circuit 100 LF | Two Pipes 24" Spacing 75 LF | Two Pipes 24" Spacing 100 LF | Two Pipes 36" Spacing 75 LF | Two Pipes 36" Spacing 100 LF |
|---|---|---|---|---|---|---|---|
| **COMPACT ROUND STRAND** | | | | | | | |
| 500 | 6.125 | 530 | 480 | 493 | 437 | 503 | 449 |
| 750 | 6.125 | 659 | 591 | 607 | 533 | 621 | 549 |
| 1000 | 6.125 | 753 | 671 | 691 | 602 | 708 | 621 |
| 1250 | 8.125 | 853 | 749 | 773 | 665 | 795 | 688 |
| **COMPACT SEGMENTAL STRAND** | | | | | | | |
| 1000 | 8.125 | 815 | 717 | 740 | 638 | 761 | 659 |
| 1250 | 8.125 | 906 | 793 | 819 | 703 | 843 | 727 |
| 1500 | 8.125 | 984 | 857 | 886 | 756 | 913 | 783 |
| 1750 | 8.125 | 1050 | 910 | 941 | 800 | 971 | 830 |
| 2000 | 8.125 | 1106 | 954 | 988 | 837 | 1020 | 868 |
| 2250 | 8.125 | 1150 | 990 | 1025 | 865 | 1059 | 898 |
| 2500 | 8.125 | 1191 | 1022 | 1059 | 892 | 1095 | 926 |
| 2750 | 8.125 | 1228 | 1050 | 1088 | 914 | 1126 | 950 |
| 3000 | 8.125 | 1256 | 1071 | 1110 | 931 | 1150 | 968 |

# Ampacity Tables

## 138kV

### ALUMINUM CONDUCTORS

Buried Circuit - One or Two Pipes
Load Factor - 75% or 100%
Conductor Temperature - 85°C
Earth Ambient Temperature - 25°C
Earth Thermal Resistivity - 90 RHO
Depth of Burial - 36 inches

| Conductor Size kcmil | Pipe I.D. Inches | One Pipe Circuit 75 LF | One Pipe Circuit 100 LF | Two Pipes 24" Spacing 75 LF | Two Pipes 24" Spacing 100 LF | Two Pipes 36" Spacing 75 LF | Two Pipes 36" Spacing 100 LF |
|---|---|---|---|---|---|---|---|
| | | | COMPACT ROUND STRAND | | | | |
| 350 | 5.047 | 345 | 315 | 323 | 289 | 329 | 296 |
| 500 | 5.047 | 424 | 384 | 394 | 350 | 403 | 360 |
| 750 | 6.125 | 539 | 483 | 497 | 436 | 509 | 449 |
| 1000 | 6.125 | 627 | 559 | 576 | 502 | 590 | 518 |
| 1250 | 6.125 | 700 | 621 | 641 | 556 | 657 | 574 |
| | | | COMPACT SEGMENTAL STRAND | | | | |
| 1000 | 6.125 | 644 | 572 | 590 | 513 | 605 | 529 |
| 1250 | 6.125 | 723 | 639 | 660 | 572 | 678 | 590 |
| 1500 | 8.125 | 822 | 716 | 742 | 634 | 764 | 656 |
| 1750 | 8.125 | 887 | 770 | 798 | 680 | 823 | 704 |
| 2000 | 8.125 | 945 | 817 | 848 | 719 | 874 | 746 |
| 2250 | 8.125 | 994 | 857 | 889 | 752 | 918 | 780 |
| 2500 | 8.125 | 1041 | 894 | 929 | 783 | 959 | 813 |
| 2750 | 8.125 | 1084 | 929 | 965 | 812 | 997 | 843 |
| 3000 | 8.125 | 1119 | 957 | 994 | 834 | 1028 | 867 |
| 3250 | 8.125 | 1155 | 984 | 1023 | 857 | 1059 | 891 |
| 3500 | 8.125 | 1188 | 1010 | 1050 | 877 | 1087 | 912 |
| 3750 | 8.125 | 1217 | 1032 | 1073 | 896 | 1112 | 932 |
| 4000 | 10.25 | 1279 | 1068 | 1114 | 918 | 1158 | 957 |

# Specifying Standard (Typical)

## MATERIAL REQUIREMENTS FOR 138kV HIGH PRESSURE GAS FILLED (HPGF) PIPE TYPE CABLE SYSTEM

### GENERAL

The following specification outlines requirements for the materials to be furnished for a 138kV HPGF pipe type cable system. Manufacturers shall include information in their proposal relative to their previous experience record on high pressure gas filled pipe type cable systems, including 138kV voltage level.

### PIPE

Pipe shall be 8.625" O.D. x .250" wall electric resistance welded Grade A steel in accordance with ASTM A-523 Specification, latest edition. Double random lengths shall be furnished. No “jointers” shall be furnished. Ends shall be beveled for welding.

The exterior surface of the pipe shall be thoroughly cleaned, dried, primed, and coated with 10 mils adhesive and 60 mils of high density polyethylene.

The interior surface of the pipe shall be thoroughly cleaned and coated with a 1.5 mil dry film thickness of Endcor 745 epoxy.

Pipe ends shall be flared at both ends for use with Wedge Products type P-421 or equal chill rings. After flaring, the ends shall be of uniform thickness.

The exterior coating shall be in-line tested with a 15,000 volt Holiday Detector to assure that a completely satisfactory coating is obtained. Pipe ends shall be suitably capped to prevent the entry of dirt during shipment and storage.

A sufficient quantity of heat shrinkable sleeves and chill rings shall be furnished for the pipe welds.

### CABLE

The cable shall be 2500 kcmil compact segmental copper with 585 mils insulation thickness exclusive of shielding tapes, stainless steel shielding tape, 100 x 200 mil stainless steel skid wires, 138kV rated.

The cable shall comply fully with the AEIC Specification CS2-97 for Impregnated Paper and Laminated Paper Polypropylene Insulated Cable - High Pressure Pipe Type, 6th edition, or latest revision.

Cable shall be impregnated with a 100% polybutene impregnant having a viscosity of 3000 SUS at 210°F, to provide the most stable cable and greatest possible resistance to the effects of heat and oxidation over its long life. Cable manufacturer shall have had at least 10 years experience with this impregnant and supplied this continuously for at least 10 years as their standard impregnant for 69kV to 138kV high pressure gas filled pipe type cables. A list of previous cables impregnated with this polybutene impregnant over the last 10 years shall be included in the bidder's

# Specifying Standard (Typical)

proposal. The list shall include customer's name, voltage, conductor size, year of manufacture and footage.

Each length of cable shall be shipped on a sealed steel reel under nitrogen atmosphere and have a pulling bolt on the outer end.

## TERMINATION ASSEMBLIES

Each termination assembly shall be furnished complete with the following materials:

- Trifurcator - Horizontal Style
- 4.50" O.D. x .120" wall Type 304 stainless steel riser pipes, factory bent to fit the termination structure
- Type 304 stainless steel weld-type couplings
- Anchor plate

## TERMINATORS

Terminators furnished shall be 138kV rated high pressure type suitable for 200 psig gas-filled normal operation. Terminators shall be manufactured and tested in accordance with the latest revision of IEEE Standard 48, and shall have a guaranteed test pressure of 500 psig for one hour.

Each terminator shall be furnished complete with baseplate assembly, stainless steel riser pipe stub, baseplate insulators, stress cone build-up kit and aerial lug. Complete installation instruction manuals shall be provided prior to shipment of the terminators.

## NORMAL JOINTS

Each normal joint shall be complete with joint sleeves, reducers, compression style connectors, splicing materials, support spiders, and other components for a normal installation. Complete installation instruction manuals shall be provided prior to shipment of the normal joints.

## NITROGEN GAS CONTROL UNIT

One outdoor type nitrogen gas control unit suitable for 200 psig operating pressure shall be provided for each circuit. Each unit shall contain:

- All components housed in a free-standing NEMA-Type 3R enclosure fabricated from stainless steel.
- Three 0-300 psig pressure switches for High, Low, Emergency Alarms.
- One 4½" diameter, 0-400 psig pressure gauge.
- A manifold with pressure regulator suitable for connection to two (2) nitrogen cylinders.
- Two (2) nitrogen cylinders.
- Instrument maintenance valves.
- Heater and thermostat (Cold climate installations only).
- A 3/4" insulated flange outlet for connection to circuit.

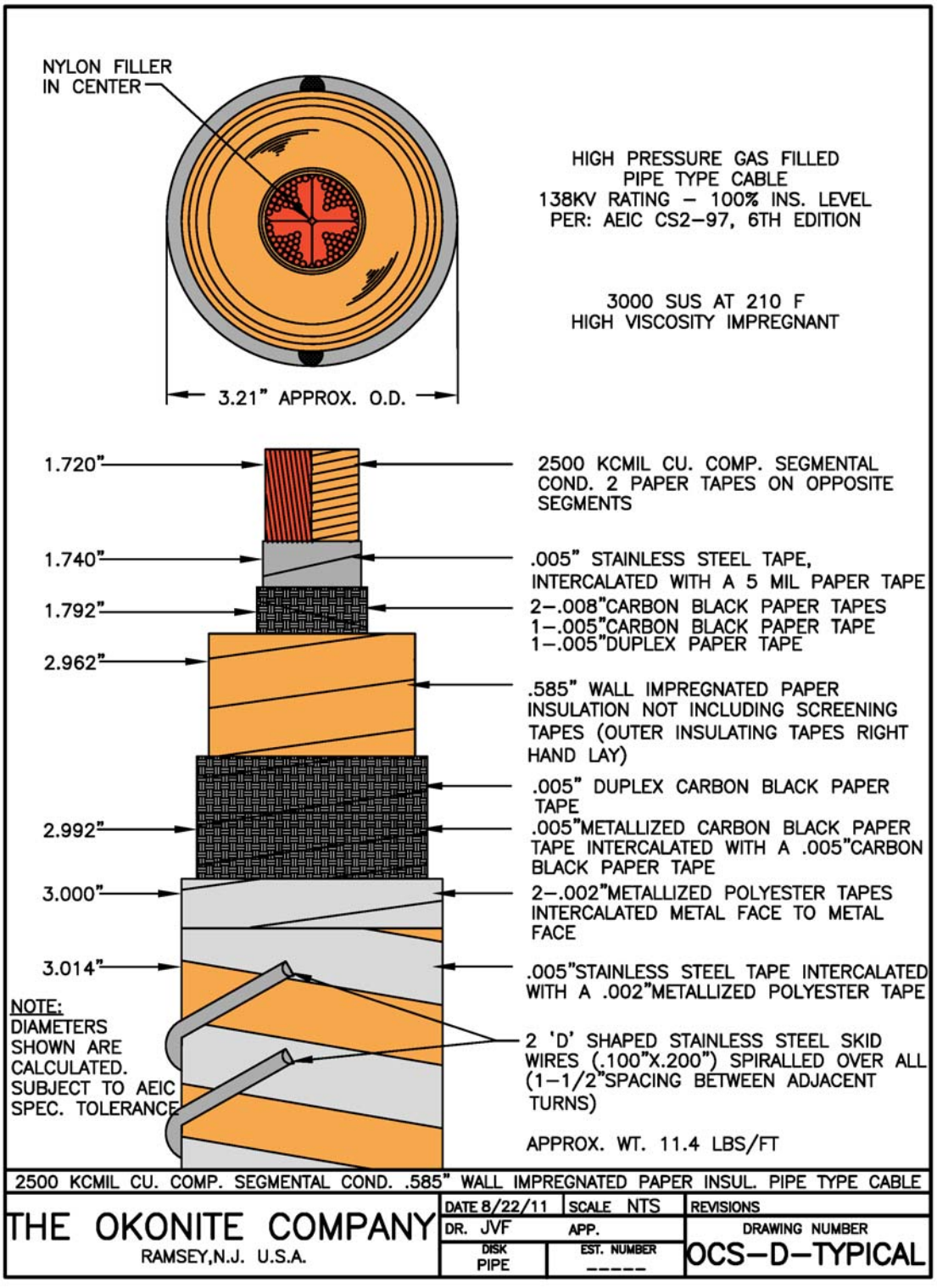
# Specifying Standard (Typical)

## CATHODIC PROTECTION MATERIALS

A solid state isolator/surge protector (ISP) suitable for up to 30,000 amperes and outdoor installation shall be provided for each end of each circuit. This is for grounding the pipe circuit at each end.

Cathodic protection rectifier, anodes and connecting wiring will be provided by others to coordinate with other cathodic protection systems in the area.

# Cross-Sectional Drawing (Typical)



# Specifying Standard

## NITROGEN GAS SPECIFICATION

### PURPOSE

**1.**

To specify the various requirements for the nitrogen gas used during installation and for filling of a High Pressure Gas Filled (HPGF) pipe-type cable system.

### REQUIREMENTS

**2.**

The nitrogen gas shall be Type III, produced from air by the liquefaction process, and shall comply with ASTM Standard Specification for Nitrogen Gas as an Electrical Insulating Material D-1933, latest edition and as listed in Table I.

TABLE I

| | |
|---|---|
| Nitrogen, % by volume, min. | 99.993 |
| Hydrogen, % by volume, max. | 0.005 |
| Oxygen, % by volume, max. | 0.002 |
| Dew Point, °F, max. | -75 |

**3.**

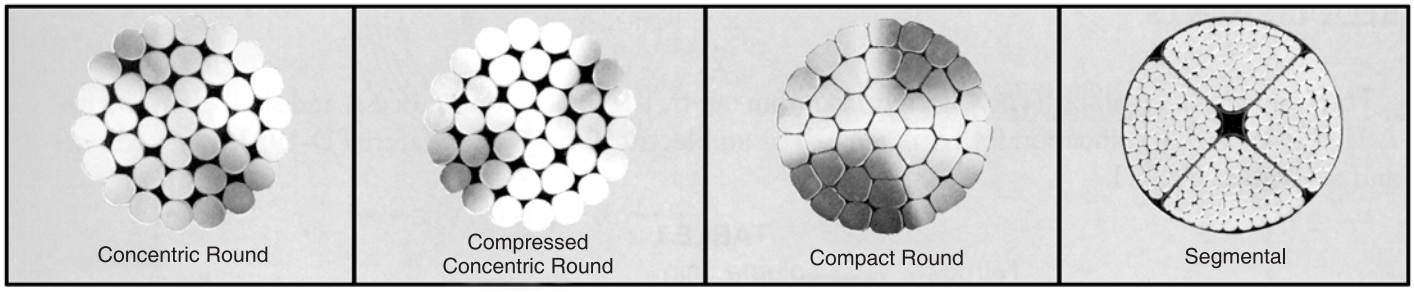
Cylinders shall be charged with a pressure of 2200 psig at 70°F. Under these conditions, the cylinders shall contain 224 cubic feet of free nitrogen at atmospheric pressure. In case the cylinders are delivered at a temperature above or below 70°F, the gauge pressure shall be in accordance with Table II.

TABLE II

| Temperature, °F | Gauge Pressure, psig |
|---|---|
| 0 | 1910 |
| 10 | 1950 |
| 20 | 1990 |
| 30 | 2035 |
| 40 | 2080 |
| 50 | 2120 |
| 60 | 2160 |
| 70 | 2200 |
| 80 | 2240 |
| 90 | 2280 |
| 100 | 2320 |

# Conductors

Copper or aluminum conductors may be furnished in Okonite HPGF cables. Concentric round, compressed concentric round, compact round, or compact segmental designs are available. The standard design for each size is shown in the dimensional tables.




## CONCENTRIC STRANDED
## CLASS B
## ALUMINUM and COPPER CONDUCTORS

| SIZE | | NUMBER OF WIRES | APPROXIMATE OUTSIDE DIAMETER | | APPROXIMATE WEIGHT ALUMINUM | | APPROXIMATE WEIGHT COPPER | |
|---|---|---|---|---|---|---|---|---|
| kcmil | mm $^2$ | | inches | mm | Lbs/mft | kg/km | Lbs/mft | kg/km |
| 3/0 AWG | 85.0 | 19 | 0.470 | 11.9 | 157 | 234 | 518 | 771 |
| 4/0 AWG | 107.2 | 19 | 0.528 | 13.4 | 199 | 296 | 653 | 972 |
| 250 | 127 | 37 | 0.575 | 14.6 | 235 | 349 | 772 | 1150 |
| 300 | 152 | 37 | 0.630 | 16.0 | 282 | 419 | 925 | 1380 |
| 350 | 177 | 37 | 0.681 | 17.3 | 329 | 489 | 1080 | 1610 |
| 400 | 203 | 37 | 0.728 | 18.5 | 376 | 559 | 1236 | 1840 |
| 450 | 228 | 37 | 0.772 | 19.6 | 422 | 629 | 1390 | 2070 |
| 500 | 253 | 37 | 0.813 | 20.7 | 469 | 699 | 1542 | 2300 |
| 550 | 279 | 61 | 0.855 | 21.7 | 517 | 768 | 1700 | 2530 |
| 600 | 304 | 61 | 0.893 | 22.7 | 559 | 838 | 1850 | 2760 |
| 650 | 329 | 61 | 0.929 | 23.6 | 610 | 908 | 2006 | 2990 |
| 700 | 355 | 61 | 0.964 | 24.5 | 657 | 978 | 2160 | 3220 |
| 750 | 380 | 61 | 0.998 | 25.3 | 704 | 1050 | 2316 | 3450 |
| 800 | 405 | 61 | 1.031 | 26.2 | 751 | 1120 | 2469 | 3680 |
| 900 | 456 | 61 | 1.094 | 27.8 | 845 | 1260 | 2780 | 4140 |
| 1000 | 507 | 61 | 1.152 | 29.3 | 939 | 1400 | 3086 | 4590 |
| 1250 | 633 | 91 | 1.289 | 32.7 | 1173 | 1750 | 3859 | 5740 |
| 1500 | 760 | 91 | 1.412 | 35.9 | 1408 | 2100 | 4632 | 6890 |
| 1750 | 887 | 127 | 1.526 | 38.8 | 1643 | 2440 | 5403 | 8040 |
| 2000 | 1010 | 127 | 1.632 | 41.5 | 1877 | 2790 | 6176 | 9190 |

# Conductors

## COMPRESSED CONCENTRIC STRANDED CLASS B ALUMINUM and COPPER CONDUCTORS

| SIZE | | NUMBER OF WIRES | APPROXIMATE OUTSIDE DIAMETER | | APPROXIMATE WEIGHT ALUMINUM | | APPROXIMATE WEIGHT COPPER | |
|---|---|---|---|---|---|---|---|---|
| kcmil | $mm^2$ | | inches | mm | Lbs/mft | kg/km | Lbs/mft | kg/km |
| 3/0 AWG | 85.0 | 19 | 0.458 | 11.6 | 157 | 234 | 518 | 771 |
| 4/0 AWG | 107.2 | 19 | 0.515 | 13.1 | 199 | 296 | 653 | 972 |
| 250 | 127 | 37 | 0.560 | 14.2 | 235 | 349 | 772 | 1150 |
| 300 | 152 | 37 | 0.614 | 15.6 | 282 | 419 | 925 | 1380 |
| 350 | 177 | 37 | 0.664 | 16.9 | 329 | 489 | 1080 | 1610 |
| 400 | 203 | 37 | 0.710 | 18.0 | 376 | 559 | 1236 | 1840 |
| 450 | 228 | 37 | 0.753 | 19.1 | 422 | 629 | 1390 | 2070 |
| 500 | 253 | 37 | 0.793 | 20.1 | 469 | 699 | 1542 | 2300 |
| 600 | 304 | 61 | 0.871 | 22.1 | 559 | 838 | 1850 | 2760 |
| 700 | 355 | 61 | 0.940 | 23.9 | 657 | 978 | 2160 | 3220 |
| 750 | 380 | 61 | 0.973 | 24.7 | 704 | 1050 | 2316 | 3450 |
| 800 | 405 | 61 | 1.005 | 25.5 | 751 | 1120 | 2469 | 3680 |
| 900 | 456 | 61 | 1.067 | 27.1 | 845 | 1260 | 2780 | 4140 |
| 1000 | 507 | 61 | 1.123 | 28.5 | 939 | 1400 | 3086 | 4590 |

# Conductors

## COMPACT ROUND
## ALUMINUM and COPPER CONDUCTORS

| SIZE | | NUMBER OF WIRES | APPROXIMATE OUTSIDE DIAMETER | | APPROXIMATE WEIGHT ALUMINUM | | APPROXIMATE WEIGHT COPPER | |
|---|---|---|---|---|---|---|---|---|
| kcmil | $mm^2$ | | inches | mm | Lbs/mft | kg/km | Lbs/mft | kg/km |
| 3/0 AWG | 85.0 | 19 | 0.423 | 10.7 | 157 | 234 | 518 | 771 |
| 4/0 AWG | 107.2 | 19 | 0.475 | 12.1 | 199 | 296 | 653 | 972 |
| 250 | 127 | 37 | 0.520 | 13.2 | 235 | 349 | 772 | 1150 |
| 300 | 152 | 37 | 0.570 | 14.5 | 282 | 419 | 925 | 1380 |
| 350 | 177 | 37 | 0.616 | 15.6 | 329 | 489 | 1080 | 1610 |
| 400 | 203 | 37 | 0.659 | 16.7 | 376 | 559 | 1236 | 1840 |
| 500 | 253 | 37 | 0.736 | 18.7 | 469 | 699 | 1542 | 2300 |
| 600 | 304 | 61 | 0.813 | 20.7 | 559 | 838 | 1850 | 2760 |
| 650 | 329 | 61 | 0.845 | 21.5 | 610 | 908 | 2006 | 2990 |
| 750 | 380 | 61 | 0.908 | 23.1 | 704 | 1050 | 2316 | 3450 |
| 800 | 405 | 61 | 0.938 | 23.8 | 751 | 1120 | 2469 | 3680 |
| 900 | 456 | 61 | 0.999 | 25.4 | 845 | 1260 | 2780 | 4140 |
| 1000 | 507 | 61 | 1.060 | 26.9 | 939 | 1400 | 3086 | 4590 |

# Conductors

## SEGMENTAL
## ALUMINUM and COPPER CONDUCTORS

| SIZE | | NUMBER OF WIRES | APPROXIMATE OUTSIDE DIAMETER * | | APPROXIMATE WEIGHT ALUMINUM | | APPROXIMATE WEIGHT COPPER | |
|---|---|---|---|---|---|---|---|---|
| kcmil | $mm^2$ | | inches | mm | Lbs/mft | kg/km | Lbs/mft | kg/km |
| 1000 | 507 | 148 | 1.140 | 29.0 | 939 | 1400 | 3086 | 4590 |
| 1250 | 633 | 148 | 1.260 | 32.0 | 1173 | 1750 | 3859 | 5740 |
| 1500 | 760 | 148 | 1.375 | 34.9 | 1408 | 2100 | 4632 | 6890 |
| 1750 | 887 | 244 | 1.480 | 37.6 | 1643 | 2440 | 5403 | 8040 |
| 2000 | 1013 | 244 | 1.570 | 39.9 | 1877 | 2790 | 6176 | 9190 |
| 2250 | 1140 | 244 | 1.665 | 42.3 | 2104 | 3131 | 6945 | 10334 |
| 2500 | 1267 | 244 | 1.740 | 44.2 | 2338 | 3479 | 7718 | 11485 |
| 2750 | 1393 | 244 | 1.830 | 46.5 | 2570 | 3824 | 8483 | 12623 |
| 3000 | 1520 | 364 | 1.910 | 48.5 | 2804 | 4172 | 9256 | 13773 |
| 3250 | 1647 | 364 | 1.985 | 50.4 | 3037 | 4519 | 10027 | 14920 |
| 3500 | 1773 | 364 | 2.060 | 52.3 | 3271 | 4867 | 10798 | 16068 |
| 3750 | 1990 | 364 | 2.125 | 54.0 | 3504 | 5214 | 11568 | 17213 |
| 4000 | 2027 | 364 | 2.195 | 55.8 | 3738 | 5562 | 12341 | 18364 |

*Diameters of segmental conductors are over the metal binder tape.

## MECHANICAL & PHYSICAL PROPERTIES
## of CONDUCTOR MATERIALS (AVERAGE VALUES)

| | COPPER | ALUMINUM |
|---|---|---|
| Melting Point °F<br>Melting Point °C | 1981<br>1083 | 1215<br>657 |
| Density, lb/cu. in.<br>Tensile Strength, mlbs/sq.in. | 0.323<br>35 | 0.0977<br>15 |
| Thermal Conductivity at 68°F<br>Btu/sq. ft./ft./hr./°F | 224 | 135 |
| Electrical Resistivity at 68°F<br>ohm-cir mil/ft. | 10.37 | 16.96 |
| Linear Coefficient of Expansion<br>(68-212°F) micro in/°F | 9.4 | 13.1 |
| Specific Heat<br>Btu/lb/°F | 0.092 | 0.215 |

# Miscellaneous Information

## Electrical formulas for determining amperes, kilowatts and kilovolt-amperes

| DESIRED DATA | ALTERNATING CURRENT THREE PHASE |
|---|---|
| Amperes when kva is shown | $\frac{\text{kva} \times 1000}{1.73 \times E}$ |
| Amperes when kilowatts are shown | $\frac{\text{kw} \times 1000}{1.73 \times E \times pf}$ |
| Kilovolt - Amperes | $\frac{I \times E \times 1.73}{1000}$ |
| Kilowatts | $\frac{I \times E \times 1.73 \times pf}{1000}$ |
| E = volts ∅ to ∅ <br> pf = power factor in decimals <br> kva = kilovolt-amperes | I = amperes <br> kw = kilowatts |

### Capacitance of Cables

The Capacitance of a one conductor shielded cable is given by the formula:

$$C = \frac{7.35\,(SIC)}{\log \frac{D}{d}}$$

Where: C = capacitance of cable in picofarads per foot
SIC = dielectric constant of the insulation (3.5 for HPGF Paper Insulated Cables)
D = diameter over insulation
d = diameter under insulation

### Charging Current

The charging current of a single conductor insulated power cable can be obtained as follows:

$$I = 2\pi f C e$$

Where: I = charging current in microamperes per 1000 feet
C = capacitance, picofarads per foot
e = Voltage, conductor to neutral, kilovolts
f = frequency, Hz

# Miscellaneous Information

## Inches & Millimeters Conversion

| Fractional Inches | Decimal Inches | Millimeters |
|---|---|---|
| 1/64 | 0.015625 | 0.39687 |
| 1/32 | 0.031250 | 0.79375 |
| 3/64 | 0.046875 | 1.19061 |
| 1/16 | 0.062500 | 1.58750 |
| 5/64 | 0.078125 | 1.98437 |
| 3/32 | 0.093750 | 2.38125 |
| 7/64 | 0.109375 | 2.77813 |
| 1/8 | 0.125000 | 3.17500 |
| 9/64 | 0.140625 | 3.57187 |
| 5/32 | 0.156250 | 3.96875 |
| 11/64 | 0.171875 | 4.36563 |
| 3/16 | 0.187500 | 4.76250 |
| 13/64 | 0.203125 | 5.15937 |
| 7/32 | 0.218750 | 5.55625 |
| 15/64 | 0.234375 | 5.95313 |
| 1/4 | 0.250000 | 6.35000 |
| 17/64 | 0.265625 | 6.74687 |
| 9/32 | 0.281250 | 7.14375 |
| 19/64 | 0.296875 | 7.54063 |
| 5/16 | 0.312500 | 7.93750 |
| 21/64 | 0.328125 | 8.33437 |
| 11/32 | 0.343750 | 8.73125 |
| 23/64 | 0.359375 | 9.12813 |
| 3/8 | 0.375000 | 9.52500 |
| 25/64 | 0.390625 | 9.92187 |
| 13/32 | 0.406250 | 10.31875 |
| 27/64 | 0.421875 | 10.71563 |
| 7/16 | 0.437500 | 11.11250 |
| 29/64 | 0.453125 | 11.50938 |
| 15/32 | 0.468750 | 11.90625 |
| 31/64 | 0.484375 | 12.30313 |
| 1/2 | 0.500000 | 12.70000 |
| 33/64 | 0.515625 | 13.09687 |
| 17/32 | 0.531250 | 13.49375 |
| 35/64 | 0.546875 | 13.89063 |
| 9/16 | 0.562500 | 14.28750 |
| 37/64 | 0.578125 | 14.68437 |
| 19/32 | 0.593750 | 15.08125 |
| 39/64 | 0.609375 | 15.47813 |
| 5/8 | 0.625000 | 15.87500 |
| 41/64 | 0.640625 | 16.27187 |
| 21/32 | 0.656250 | 16.66875 |
| 43/64 | 0.671875 | 17.06563 |
| 11/16 | 0.687500 | 17.46250 |
| 45/64 | 0.703125 | 17.85937 |
| 23/32 | 0.718750 | 18.25625 |
| 47/64 | 0.734375 | 18.65313 |
| 3/4 | 0.750000 | 19.05000 |
| 49/64 | 0.765625 | 19.44687 |
| 25/32 | 0.781250 | 19.84375 |
| 51/64 | 0.796875 | 20.24063 |
| 13/16 | 0.812500 | 20.63750 |
| 53/64 | 0.828125 | 21.03437 |
| 27/32 | 0.843750 | 21.43125 |
| 55/64 | 0.859375 | 21.82813 |
| 7/8 | 0.875000 | 22.22500 |
| 57/64 | 0.890625 | 22.62187 |
| 29/32 | 0.906250 | 23.01875 |
| 59/64 | 0.921875 | 23.41563 |
| 15/16 | 0.937500 | 23.81250 |
| 61/64 | 0.953125 | 24.20937 |
| 31/32 | 0.968750 | 24.60625 |
| 63/64 | 0.984375 | 25.00313 |
| 1 | 1 | 25.40000 |

| MM | | INCHES | MM | | INCHES |
|---|---|---|---|---|---|
| 0.1 | — | .0039 | 46.0 | — | 1.8110 |
| 0.2 | — | .0079 | 47.0 | — | 1.8504 |
| 0.3 | — | .0118 | 48.0 | — | 1.8898 |
| 0.4 | — | .0157 | 49.0 | — | 1.9291 |
| 0.5 | — | .0197 | 50.0 | — | 1.9685 |
| 0.6 | — | .0236 | 51.0 | — | 2.0079 |
| 0.7 | — | .0276 | 52.0 | — | 2.0472 |
| 0.8 | — | .0315 | 53.0 | — | 2.0866 |
| 0.9 | — | .0354 | 54.0 | — | 2.1260 |
| 1.0 | — | .0394 | 55.0 | — | 2.1654 |
| 2.0 | — | .0787 | 56.0 | — | 2.2047 |
| 3.0 | — | .1181 | 57.0 | — | 2.2441 |
| 4.0 | — | .1575 | 58.0 | — | 2.2835 |
| 5.0 | — | .1969 | 59.0 | — | 2.3228 |
| 6.0 | — | .2362 | 60.0 | — | 2.3622 |
| 7.0 | — | .2756 | 61.0 | — | 2.4016 |
| 8.0 | — | .3150 | 62.0 | — | 2.4409 |
| 9.0 | — | .3543 | 63.0 | — | 2.4803 |
| 10.0 | — | .3937 | 64.0 | — | 2.5197 |
| 11.0 | — | .4331 | 65.0 | — | 2.5591 |
| 12.0 | — | .4724 | 66.0 | — | 2.5984 |
| 13.0 | — | .5118 | 67.0 | — | 2.6378 |
| 14.0 | — | .5512 | 68.0 | — | 2.6772 |
| 15.0 | — | .5906 | 69.0 | — | 2.7165 |
| 16.0 | — | .6299 | 70.0 | — | 2.7559 |
| 17.0 | — | .6693 | 71.0 | — | 2.7953 |
| 18.0 | — | .7087 | 72.0 | — | 2.8346 |
| 19.0 | — | .7480 | 73.0 | — | 2.8740 |
| 20.0 | — | .7874 | 74.0 | — | 2.9134 |
| 21.0 | — | .8268 | 75.0 | — | 2.9528 |
| 22.0 | — | .8661 | 76.0 | — | 2.9921 |
| 23.0 | — | .9055 | 77.0 | — | 3.0315 |
| 24.0 | — | .9449 | 78.0 | — | 3.0709 |
| 25.0 | — | .9843 | 79.0 | — | 3.1102 |
| 26.0 | — | 1.0236 | 80.0 | — | 3.1496 |
| 27.0 | — | 1.0630 | 81.0 | — | 3.1890 |
| 28.0 | — | 1.1024 | 82.0 | — | 3.2283 |
| 29.0 | — | 1.1417 | 83.0 | — | 3.2677 |
| 30.0 | — | 1.1811 | 84.0 | — | 3.3071 |
| 31.0 | — | 1.2205 | 85.0 | — | 3.3465 |
| 32.0 | — | 1.2598 | 86.0 | — | 3.3858 |
| 33.0 | — | 1.2992 | 87.0 | — | 3.4252 |
| 34.0 | — | 1.3386 | 88.0 | — | 3.4646 |
| 35.0 | — | 1.3780 | 89.0 | — | 3.5039 |
| 36.0 | — | 1.4173 | 90.0 | — | 3.5433 |
| 37.0 | — | 1.4567 | 91.0 | — | 3.5827 |
| 38.0 | — | 1.4961 | 92.0 | — | 3.6220 |
| 39.0 | — | 1.5354 | 93.0 | — | 3.6614 |
| 40.0 | — | 1.5748 | 94.0 | — | 3.7008 |
| 41.0 | — | 1.6142 | 95.0 | — | 3.7402 |
| 42.0 | — | 1.6535 | 96.0 | — | 3.7795 |
| 43.0 | — | 1.6929 | 97.0 | — | 3.8189 |
| 44.0 | — | 1.7323 | 98.0 | — | 3.8583 |
| 45.0 | — | 1.7717 | 99.0 | — | 3.8976 |
| | | | 100.0 | — | 3.9370 |

## Temperature Conversion

| TO CONVERT DEGREES To C | F or C | To F |
|---|---|---|
| -65.0 | -85 | -121 |
| -62.22 | -80 | -112 |
| -59.45 | -75 | -103 |
| -56.67 | -70 | -94 |
| -53.89 | -65 | -85 |
| -51.11 | -60 | -76 |
| -48.34 | -55 | -67 |
| -45.56 | -50 | -58 |
| -42.78 | -45 | -49 |
| -40.0 | -40 | -40 |
| -37.22 | -35 | -31 |
| -34.44 | -30 | -22 |
| -31.67 | -25 | -13 |
| -28.89 | -20 | -4 |
| -26.11 | -15 | 5 |
| -23.33 | -10 | 14 |
| -20.56 | -5 | 23 |
| -17.78 | 0 | 32 |
| -15.0 | 5 | 41 |
| -12.22 | 10 | 50 |
| -9.44 | 15 | 59 |
| -6.67 | 20 | 68 |
| -3.89 | 25 | 77 |
| -1.11 | 30 | 86 |
| 1.67 | 35 | 95 |
| 4.44 | 40 | 104 |
| 7.22 | 45 | 113 |
| 10.0 | 50 | 122 |
| 12.78 | 55 | 131 |
| 15.56 | 60 | 140 |
| 18.33 | 65 | 149 |
| 21.11 | 70 | 158 |
| 23.89 | 75 | 167 |
| 26.67 | 80 | 176 |
| 29.44 | 85 | 185 |
| 32.22 | 90 | 194 |
| 35.0 | 95 | 203 |
| 37.78 | 100 | 212 |
| 40.56 | 105 | 221 |
| 43.33 | 110 | 230 |
| 46.11 | 115 | 239 |
| 48.89 | 120 | 248 |
| 51.67 | 125 | 257 |
| 54.44 | 130 | 266 |
| 57.22 | 135 | 275 |
| 60.0 | 140 | 284 |
| 62.78 | 145 | 293 |
| 65.56 | 150 | 302 |
| 68.33 | 155 | 311 |
| 71.11 | 160 | 320 |
| 73.89 | 165 | 329 |
| 76.67 | 170 | 338 |
| 79.44 | 175 | 347 |
| 82.22 | 180 | 356 |
| 85.0 | 185 | 365 |
| 87.78 | 190 | 374 |
| 90.56 | 195 | 383 |
| 93.33 | 200 | 392 |
| 96.11 | 205 | 401 |
| 98.89 | 210 | 410 |
| 101.67 | 215 | 419 |
| 104.44 | 220 | 428 |
| 107.22 | 225 | 437 |
| 110.0 | 230 | 446 |
| 112.78 | 235 | 455 |
| 115.56 | 240 | 464 |
| 118.33 | 245 | 473 |
| 121.11 | 250 | 482 |
| 123.89 | 255 | 491 |
| 126.67 | 260 | 500 |
| 129.44 | 265 | 509 |
| 132.22 | 270 | 518 |
| 135.0 | 275 | 527 |

# Okonite Locations

**Additonal information about Okonite H.P.G.F. Cables can be obtained by contacting the Okonite office nearest you.**

## OKONITE SERVICE CENTERS

Houston,Texas
Kansas City, Kansas
Los Angeles,California
New Orleans, Louisiana
Pittsburgh, Pennsylvania
Portland,Oregon

## OKONITE MANUFACTURING PLANTS

Ashton, Rhode Island
Paterson, New Jersey
Richmond, Kentucky
Santa Maria, California
Orangeburg, South Carolina (2)

## OKONITE DISTRICT SALES OFFICES

### Atlanta District Office
645 Molly Lane
Suite 120
Woodstock, GA 30189
(770) 928-9778
FAX: (770) 928-0913
E-Mail: atlanta@okonite.com

### Birmingham District Office
3516 Vann Road
Suite 112
Birmingham, AL 35235
(205) 655-0390
FAX: (205) 655-0393
E-Mail: birmingham@okonite.com

### Boston District Office
169 South River Road
Bedford, NH 03110
(603) 625-1900
(781) 749-3374
FAX: (603) 624-2252
E-Mail: boston@okonite.com

### Charlotte District Office
11111 Carmel Commons Blvd.
Suite 140
Charlotte, NC 28226
(704) 542-1572
FAX: (704) 541-6183
E-Mail: charlotte@okonite.com

### Chicago District Office
2280 White Oak Circle, Suite 106
Aurora, IL 60502
(630) 961-3100
FAX: (630) 961-3273
E-Mail: chicago@okonite.com

### Cincinnati District Office
11260 Chester Road, Suite 650
Cincinnati, OH 45246
(513) 771-2122
FAX: (513) 771-2126
E-Mail: cincinnati@okonite.com

### Cleveland District Office
3926 Clock Pointe Trail, Suite 101
Stow, OH 44224
(330) 926-9181
FAX: (330) 926-9183
E-Mail: cleveland@okonite.com

### Dallas District Office
2220 San Jacinto Blvd.
Suite #125
Denton, TX 76205
(940) 383-1967
FAX: (940) 383-8447
E-Mail: dallas@okonite.com

### Denver District Office
12000 N. Washington Street
Suite #260
Northglenn, CO 80241
(303) 255-5531
FAX: (303) 255-3128
E-Mail: denver@okonite.com

### Hartford District Office
169 South River Road
Bedford, NH 03110
(860) 258-1900
FAX: (860) 258-1903
E-Mail: hartford@okonite.com

### Houston District Office and Service Center
802 Century Plaza
Houston, TX 77073
(281) 821-5500
FAX: (281) 821-7855
E-Mail: houston@okonite.com

### Kansas City District Office and Service Center
2631 South 96th Street
Edwardsville, KS 66111
(913) 422-6958
FAX: (913) 422-1647
E-Mail: kansascity@okonite.com

### Los Angeles District Office and Service Center
14730 Northam Street
LaMirada, CA 90638
(714) 523-9390
FAX: (714) 523-1783
E-Mail: losangeles@okonite.com

### Minneapolis District Office
Suite 110
16795 Country Road 24
Plymouth, MN 55447
(763) 432-3818
FAX: (763) 432-3811
E-Mail: minneapolis@okonite.com

### New Orleans District Office and Service Center
101 Delta Drive, Suite J
St. Rose, LA 70087
(504) 467-1920
FAX: (504) 467-1926
E-Mail: neworleans@okonite.com

### New York District Office
Three Garret Mountain Plaza
West Paterson, NJ 07424
NJ (973) 742-8040 • NY (212) 239-0660
FAX: (973) 742-2156
E-Mail: newyork@okonite.com

### Philadelphia District Office
P.O. Box 335
Bellmawr, NJ 08099
(856) 931-0595 • (215) 567-5739
FAX: (856) 931-1193
E-Mail: philadelphia@okonite.com

### Phoenix District Office
633 E. Ray Road, Suite #117
Gilbert, Arizona 85296
(480) 838-8596
FAX: (480) 897-8924
E-Mail: phoenix@okonite.com

### Pittsburgh Service Center
120 Solar Drive
Imperial, PA 15126
(724) 899-4300
FAX: (724) 899-4320
E-Mail: pittsburgh@okonite.com

### Portland District Office and Service Center
6777 S.W. Bonita Road, Suite 150
Portland, OR 97224
(503) 598-0598
FAX: (503) 620-7447
E-Mail: portland@okonite.com

### Salt Lake District Office
5280 S. Commerce Dr. (320-W.)
Suite E-110, Cedar Park
Murray, UT 84107
(801) 262-1993
FAX: (801) 262-3167
E-Mail: saltlake@okonite.com

### San Francisco District Office
One Annabel Lane, Suite 212
San Ramon, CA 94583
(925) 830-0801
FAX: (925) 830-0954
E-Mail: sanfrancisco@okonite.com

### Tampa District Office
10002 Princess Palm Avenue
Suite 104
Tampa, FL 33619
(813) 627-9400
FAX: (813) 246-4705
E-Mail: tampa@okonite.com

### Washington District Office
7000 Infantry Ridge Rd., Suite #100A
Manassas, VA 20109
(703)
FAX: (703)
E-Mail: washington@okonite.com

### International Sales
Hilltop Road
P.O. Box 340
Ramsey, NJ 07446
(201) 825-0300 • FAX: (201) 825-9026
ramsey@okonite.com

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Okonite 9/2011