High Voltage Fluidic Interface (HVFI) Test Report

Introduction

Since the late 1980s it has been standard practice in fluid rejuvenation to connect dielectric tubing, typically nylon or polyethylene, to energized cables with the unsustained pressure rejuvenation (UPR) paradigm. In fact, over 80 million feet have been injected in this way. In typical underground residential distribution UPR applications, tubing is connected to a feed end of a cable and an outlet end. These two tubes are connected to a feed bottle and receiving bottle respectively. Both bottles are primarily plastic dielectric with some metal fittings. The tubing and connected bottles are termed "potentially energized," as it is at least theoretically possible that they are not at ground potential. In practice they would almost always be very close to ground potential. On the inlet side, dielectric fluid flows into a dielectric tube and the possibility that the tubing/fluid system will conduct electricity is generally small. The exception is when a feed bottle is left connected for a long period of time in what is called a "soak period." During the soak period the flow of fluid into the cable is very close to zero and may flow backwards as the connected cable cycles in temperature from a cycling load. More problematic is the outlet side that begins the injection process as a course vacuum. Typically within 24 hours the vacuum decays and the gas phase transitions to a liquid. In the worst case the liquid could be water displaced from the strand interstices, but is more likely dielectric enhancement fluid or a desiccant fluid. The outlet fluids also transport conductive particles such as carbon black and ions. The tubing and the connected tanks are allowed to float electrically and for the sake of safety are handled by line personnel as though they are energized. With over two decades of experience the author is unaware of any incident where there were any injuries. None-the-less, Novinium has taken steps to further mitigate the risk of potentially energized equipment by introducing a new injection paradigm called sustained pressure rejuvenation (SPR), which entirely eliminates the risk for most URD-length cables and introducing an improved UPR approach, which eliminates the soak period. The later improvement eliminates the multi-month soak periods and hence reduces the exposure of the equipment over 60-fold.

The SPR process eliminates the issue by injecting normal length cables while they are deenergized. However, for cables with longer lengths, it is not always practical to leave a cable out of service during the entirety of the injection process. It is for this last case, that the HVFI was designed and the balance of this test report focuses. To learn more about the risks summarized above, the interested reader is referred to "A Comparison of Rejuvenation Hazards" for EDIST 2009, Markham, Ontario, January 15, 2009 available at:

http://www.novinium.com/pdf/papers/EDIST_Rejuvenation_Hazards_Analysis.pdf

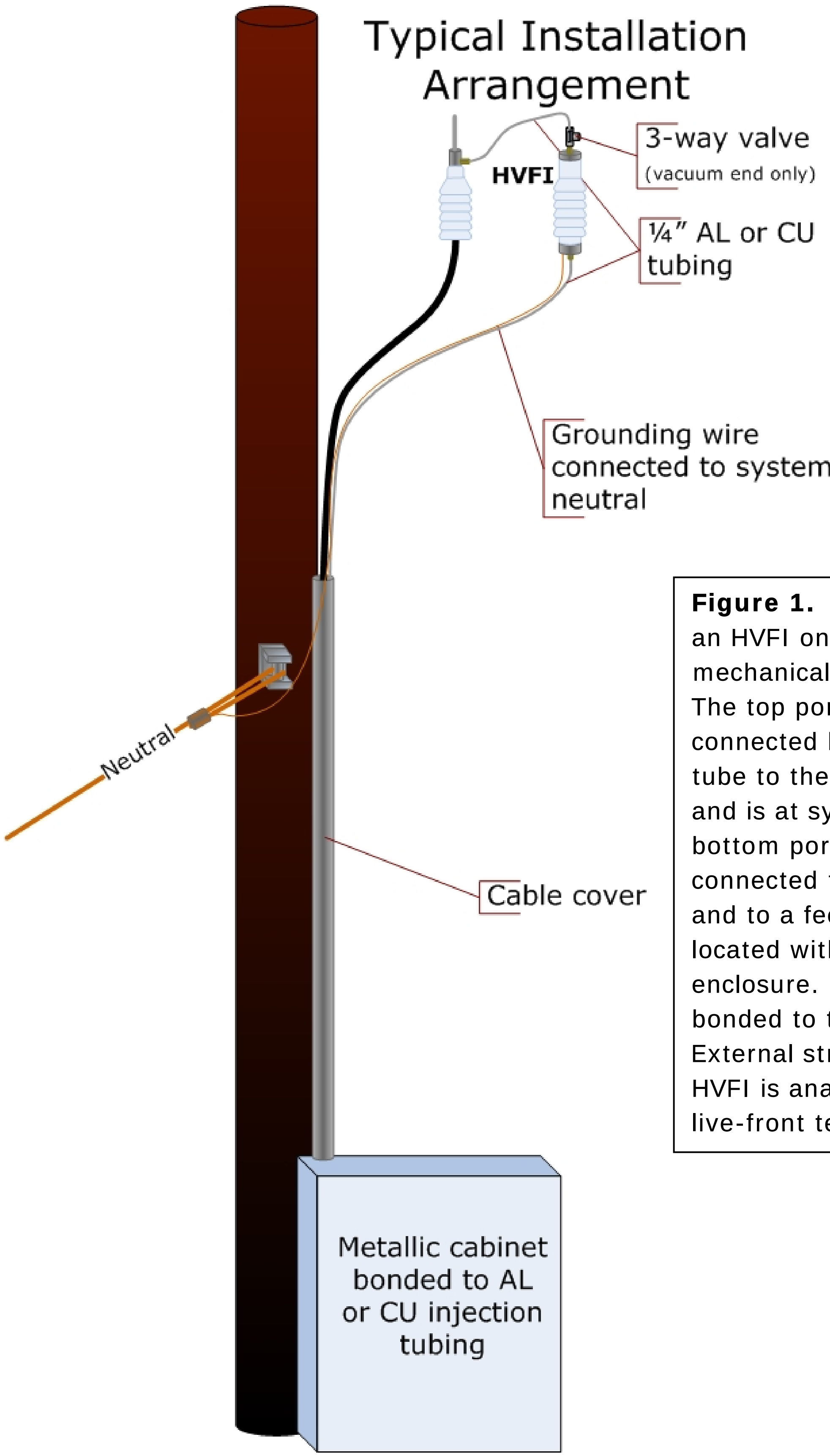


Figure 1. Typical arrangement of an HVFI on a pole excluding mechanical support hardware. The top portion of the HVFI is connected by a conductive metal tube to the cable injection adapter and is at system voltage. The bottom portion of the HVFI is connected to the system ground and to a feed or receiving tank located within a metallic enclosure. The enclosure is bonded to the system neutral. External stress control on the HVFI is analogous to that of a live-front termination.

A high voltage fluidic interface or HVFI is a device which electrically isolates the necessarily high voltage injection devices utilized with live-front terminations such as an injection adaptor, which must be in contact with the conductor, from those injection tanks and tubes which must be hydraulically connected. In other words the HVFI allows hydraulic communication, but interrupts electrical communication between the cable's injection interface and the bottles to which they are connected. Figure 1 is a schematic overview of a typical HVFI installation. Up-to-date instructions for the installation and operation of HVFI devices are available online at:

http://www.novinium.com/pdf/instructions/low/NRI%2069-N-Rex_v.pdf

Figure 2 provides HVFI design details. The external design is a 35kV life-front cable termination (3M QT-III-7686-S-8 skirted termination), which meets or exceeds the IEEE 48-2009 standards. The internal components begin with 6.7 meters (22 ft) of 1/8" OD nylon tubing and a 0.073" ID with a total volume of about 18.1 ml. The tubing enters the top of the HVFI, is wound in a descending outer helix, then an ascending inner helix, and finally down the axis to the bottom where it exits. The tubing is positioned on a polyethylene board with over 120 tube positioning cutouts alternating between the inner helix and the outer helix. The board is secured to the two aluminum end pieces and within a high density polyethylene tube. The volume outside of the 1/8" tubing and inside of the 2.5" body tube is filled with degassed dimethyl silicone RTV liquid, which sets to a permanent non-flowing gel. The aluminum end caps include dedicated electrical connections to the system voltage at the top and to the system ground at the bottom. The end caps include securing hardware so that the HVFI may be installed in a manner similar to a post insulator. Unlike a post insulator, the hardware needs only to support the HVFI. Hydraulic/pneumatic swage-type connections are also on each end cap and mate with ¼" aluminum or copper tubing. The tube at the top of the HVFI is connected to the injection adaptor. The tube at the bottom of the HVFI is attached to a feed bottle on the inlet cable end and to a receiving bottle on the outlet cable end. On the outlet cable end a three-way ball valve is attached to the top of the HVFI as shown in Figure 1, so that a side stream of fluid can be introduced into the HVFI.

During operation on the inlet cable end the fluid flow is initiated prior to the cable being re-energized. On the inlet side the tubing is filled with dielectric fluid 100% of the time. On the outlet cable end there are two stages of operation with the cable is energized. Prior to the cable being energized a course vacuum (about 25 in Hg) is applied to the receiving tank, which is connected to the HVFI, associated tubing, and the cable. The majority of the air is removed from the system. At least 50 ml of low volatility, low viscosity, low surface energy, dielectric fluid (Ultrinium™ 732 fluid) is introduced into the top of the HVFI at the three-way valve shown in Figure 1. The fluid flushes through the 6.7 meters of tubing.

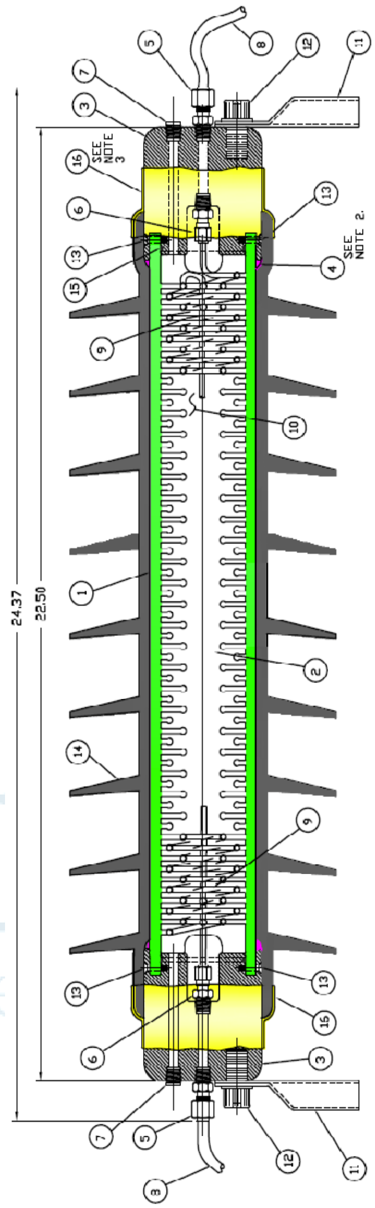


Figure 2. HVFI component assembly view.

1. HDPE tubing 2.5” OD
2. UHMWPE board (2”x ¼”x16.5”)
3. Aluminum end cap
4. Stress control compound (3M HiK)
5. ¼”-1/8” tube connector
6. 1/8”-1/8” tube connector
7. Pipe plug, brass
8. 1/8” nylon tubing, 6.7 m (22 ft)
9. ¼” AL or CU tubing
10. Silicone dielectric potting gel
11. 1-hole lug, 4/0
12. Cap screw
13. Set screw
14. Skirted termination, 3M QT-III, 35kV
15. O-ring, EPDM
16. Self-fusing silicone rubber tape (3M Scotch 70)

The majority of the 50 ml of fluid introduced flushes through the entire HVFI as the total volume within the tubing is about 18 ml. The HVFI traps several ml of the fluid in the tubing coils with two mechanisms. First, because of the low surface energy of the fluid it coats the tubing walls. Second, in the ascending inner coil fluid is drawn upward by weak shear forces as the low pressure air slowly flows toward the vacuum source, but gravity exerts a downward force on the fluid. An equilibrium is established where fluid flows upward in the coil near the tube axis, but flows downward in the coil near the inside diameter of the tube. The perpetual presence of the dielectric fluid blocks the path of any electrical field resisting ionization and repairs any microscopic damage that might occur if there were partial discharges. The shear length of tubing and thickness of the insulation layers including both the thickness of the nylon tubing and the surrounding dimethyl silicone gel make the HVFI tolerant of partial discharge.

The cable can now be energized and Stage I begins. In this stage the tubing is filled with a mixture of air at 25 in Hg vacuum and dielectric fluid. In the first ever application of a HVFI at Desolation Sound in British Columbia, Stage I lasted for about 100 days and the HVFI performed without issue. Stage II begins when dielectric fluid reaches the HVFI and the tubing becomes filled with dielectric fluid.

Standards

There are no industry standards for high voltage fluidic interfaces. Some guidance on qualification testing can be found by reviewing appropriate standards for devices that include similar functions as the HVFI. Appropriate engineering judgment is required for the application of these other standards as many dimensions of those standards will not be relevant to the design and operation of a HVFI.

IEEE 48 – IEEE Standard for Test procedures and Requirements fir Alternating-Current Cable Terminations Used on Shielded Cables Having … Extruded Insulation Rated 2.5kV through 500 kV

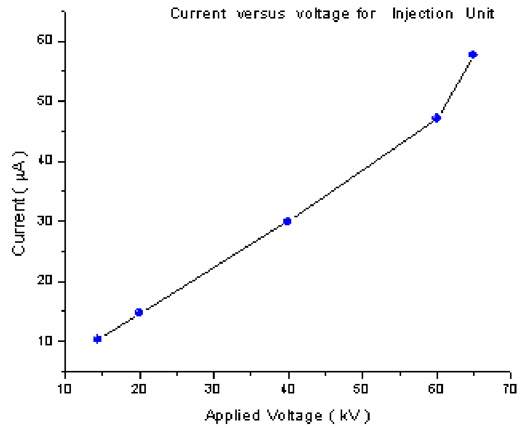
As implied by the title, the scope of IEEE 48 includes only cable terminations and hence does not apply to an HVFI, which does not terminate a cable. However, the performance of the exterior of the HVFI is analogous to the exterior of a termination. In fact the exterior of the HVFI is an IEEE 48 complaint terminator. It is a 3M QT-III-7686-S-8 and has passed all of the IEEE 48 requirements as per 3M's attached product data sheet, "3M™ Cold Shrink Silicone Rubber Termination Kit QT-III, 7620-S, 7680-S and 7690-S Series 5 - 34.5 kV. Test requirements include dielectric (7.1.1) and pressure leak tests (7.1.2).

Testing

In addition to the design testing performed for IEEE 48 of the HVFI external components, additional testing was undertaken at Powertech Laboratories by John Vandermaar (Manger, High Voltage Laboratory) and Kal Abdolall (Senior Research Physicist) at the behest of BC Hydro and in cooperation with Novinium on the HVFI assembly. The researchers concluded, "In our opinion this unit is suitable for this application." The results were transmitted by email on October 12, 2007. The email is attached to this test report. The measurements and tests undertaken were done in accordance with the requirements of IEEE Std. 48-1996 for 25 kV insulation class equipment are outlined below:

- The HVFI passed the AC dry withstand test at 65 kV for one minute.
- The HVFI passed the AC wet withstand test at 60 kV for 10 seconds.
- The HVFI passed the impulse withstand test at 150 kV (3 positive and 3 negative impulse waveforms).
- The HVFI was energized at 14.4 kV for 6.75 hours. There was no measurable increase in temperature above ambient on the surface of the HVFI.

- The HVFI tan delta is 3.75 and does not seem to affect the performance of the unit, as reflected by the low leakage current (see figure nearby) and no measurable rise of temperature after 6.75 hrs at 14.4 kV.



Practice

Two HVFI units were placed in service on a crossing of Desolation Sound in British Columbia on October 15, 2007. Both terminations are within 100 meters of an ocean sound subject to high winds and salt spray. The “Pollution Severity Level” is “Heavy.” (i.e. Areas generally close to the coast and exposed to coastal spray or to strong winds carrying sand and salt, and subjected to regular condensation.) It took approximately 100 days for fluid to flow from the inlet side HVFI to the outlet side HVFI. The HVFI units have remained in continuous use to the day of this writing, November 11, 2010, which is over three years with perfect performance. The Desolation Sound crossing is a worst case scenario in that typical deployments of the HVFI would be of much shorter duration.

Summary

There are no industry standards for HVFI devices. The HVFI design incorporates an IEEE 48 35 kV standard termination, which is overdesigned for the application. Additional testing modeled after IEEE 48 was carried out on the HVFI assembly to confirm that internal components did not compromise the IEEE 48 performance. The testing confirmed that there was no performance degradation. Two HVFI devices have stood the rigorous test of time in a rugged field environment for over three years, which is much longer than typical deployments. The HVFI provides a safe and reliable fluid interface for fluid injection into energized live-front terminators.

Validation

This report was written by Glen Bertini, P.E. of Novinium. 3M provided the IEEE 48 test results for the termination kit, which is integral with the HVFI. Powertech has made measurements, which are a part of this test report. I have reviewed the HVFI design and the data and concur that the HVFI is suitable for the application of fluid injection into energized live-front terminators.

Signed: Glen J. Bertini, PE

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November 24, 2010

To Whom It May Concern:

We have read the paper “High Voltage Fluid Interface (HVFI) Test Report” by Mr. Glen Bertini and also a letter from K. Abdolall, Ph.D. dated Friday, October 12, 2007. If the values obtained during tests are those mentioned, then the HVFI device meets with the requirements of the IEEE Standard 48-1996 for 25 kV terminations.

Sincerely,

Carlos Katz
Chief Research Engineer

3M™ Cold Shrink Silicone Rubber Termination Kit QT-III,

7620-S, 7680-S and 7690-S Series 5 - 34.5 kV

Data Sheet **August 2008**

Product Description

3M™ Cold Shrink Silicone Rubber Termination Kit QT-III, 7620-S, 7680-S and 7690-S Series contain one-piece, skirted, silicone rubber terminations, qualified as IEEE Standard 48-1996 Class 1 for outdoor weather-exposed applications. The termination assemblies consist of a skirted insulator, high-dielectric constant (Hi-K) stress control tube*, conformable Hi-K stress controlling compound and built-in silicone top seal. The insulator is made of a dark gray silicone rubber with excellent tracking resistance and hydrophobic properties.

***7620-S and 7621-S designed and assembled with stress controlling compound only.**

The complete assembly is pre-stretched and loaded onto a removable core. The disposable core can be recycled. The kits are designed for terminating solid dielectric shielded power cables rated 5 through 34.5 kV, with tape shield, wire shield and UniShield® constructions.

Kit Contents

- 3 Hi-K, tracking resistant, silicone rubber terminations
- 3 Pre-formed ground braids
- 3 Constant force springs
- 6 strips sealing mastic
- 1 Cable preparation kit
- 1 Instruction sheet

Features

- Conforms to the IEEE Standard 48-1990 Class 1 requirements for 5, 8.7, 15 25/28 and 34.5 kV terminations
- One-piece versatile design, allowing quick installation and accommodating a wide range of cable sizes
- Cold Shrink delivery system for easy installation: simply place termination over prepared cable and unwind core to shrink into place (no force fit required)
- Hi-K stress control: specially formulated high dielectric constant material minimizes surfaces stress by more uniformly distributing the electrical field over the entire surface of the insulator
- Compact design provides for easier installation in restricted spaces
- Silicone rubber insulators, EPDM stress control tubes, stress controlling compound and silicone sealing compound are compatible with all common solid dielectric insulations, such as polyethylene (PE), cross-linked polyethylene (XLPE) and ethylene propylene rubber (EPR)

Stress Control

The QT-III termination controls the electric field stress distribution with special Hi-K materials, which are an integral part of the termination. The Hi-K materials, with a dielectric constant (K) of greater than 15, capacitively distributes the field that surrounds the termination.

The stress concentrations in a continuous length of shielded cable are typically 50 V/mil adjacent to the shield to about 70 V/mil at the conductor. The QT-III reduces the cable stresses at the termination to less that those in the continuous shielded portion of the cable.

Electrical flux is refracted to distribute the voltage stress in a controlled manner along the entire termination length extending beyond the cable shield cutoff. By controlling the electric field, the stress concentrations on the termination insulator surface are kept below 15 V/mil at rated voltage. This stress distribution permits high power frequency performance and impulse performance with a compact termination design.

Figure 1 below illustrates an actual computerized stress plot of the QT-III termination.

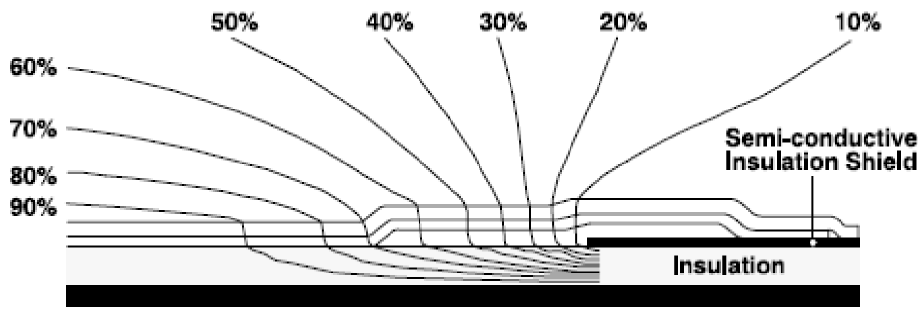


Figure 1

Applications

3M™ Cold Shrink Silicone Rubber Termination Kit QT-III, 7620-S, 7680-S and 7690-S Series are used to terminate tape shield, wire shield and UniShield® power cable rated 5 – 34.5 kV, having extruded solid dielectric insulation as follows:

- Polyethylene (high and low density), cross-linked polyethylene (XLP) and ethylene propylene rubber 9EPR)
- The terminations are light weight for either free-hanging or bracket-mounting arrangements.
- They can be used in both protected and weather-exposed contaminated areas

The amount of airborne contamination determines the operating environment. Operating environments are described as areas having varying degrees of airborne contaminant or pollution severity that may, or may not affect the long-term performance of terminations. These operating environments are defined as light, medium, heavy and extremely heavy variations of pollution severity. The appropriate termination selection depends on the system voltage and operating environment *(see tables below)*.

Recommended Application Guide

Termination Kit	System Voltage	Operating Environment			
		Light	Medium	Heavy	Extremely Heavy
(2 skirt) 7620-S-2 – 76-21-S-2	5 & 8 kV	✓	✓	✓	
(2 Skirt) 7622-S-2	15 kV	✓	✓	✓	
(4 Skirt) 7692-S-4 – 7696-S-4	15 kV	✓	✓	✓	✓
(8 Skirt) 7683-S-8 – 7686-S-8	15 kV	✓	✓	✓	✓
(4 Skirt) 7692-S-4 – 7696-S-4	25/28 kV	✓	✓	✓	
(8 Skirt) 7683-S-8 – 7686-S-8	25/28 kV	✓	✓	✓	✓
(8 Skirt) 7683-S-8 – 7686-S-8	34.5 kV	✓	✓	✓	*

Recommended operation environments are marked with a check (✓).
*Consult 3M sales representative.

Pollution Severity Level Guide

Light	Heavy
• Areas without industry and with low-density housing • Areas subjected to frequent winds and/or rainfall with low-density industry and housing • Agricultural areas ✯ • Mountainous areas All of these regions should be situated at least 7 miles from the coast and should not be exposed to coastal winds.*	• High-density industrial areas and some urban areas with high-density housing, especially those with infrequent rainfall • Areas subjected to a moderate concentration of conductive dust, particularly industrial smoke-producing deposits • Areas generally close to the coast and exposed to coastal spray or to strong winds carrying sand and salt, and subjected to regular condensation
Medium	**Extremely Heavy**
• Non-polluting industrial areas subject to infrequent rainfall and with average-density housing • Areas subject to frequent winds and/or rainfall with high-density industry and housing • Areas exposed to wind from the coast, but generally over two miles from the coast	• Usually very limited areas having extremely heavy pollutants from industrial sites, especially those located near oceans and subjected to prevailing winds from the sea • Very small isolated areas where terminations are located immediately adjacent to a pollutant source, especially downwind (cement plants, paper mills, etc.)

✯Use of fertilizers by spraying or the burning of crop residues, can lead to a higher pollution level due to dispersal by wind.
* Distances from coast depend on the topography of the coastal area and on the extreme wind conditions.

Environmental Classification

When airborne contaminants are deposited on a termination surface, destructive leakage currents can be initiated when the surface becomes wet. Fog and drizzle are worse than rain. Rain tends to wash the pollutants off the termination while fog will wet the pollutants, making the surface conductive to varying degrees, promoting leakage current formation. This is most typical of hydrophilic surfaces typified by porcelain *(Figure2)*.

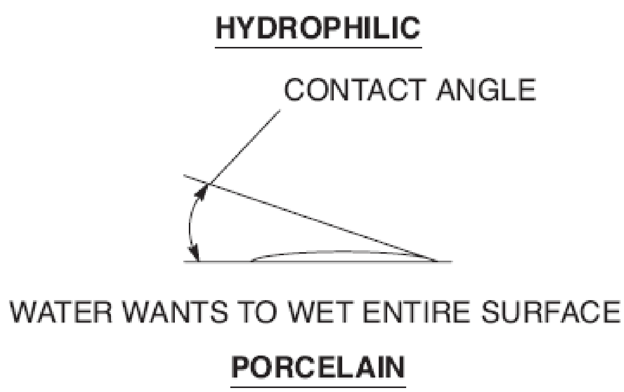


Figure 2

The surface of the QT-III silicone insulator is hydrophobic, which makes it less likely to erode or track because the surface does not wet readily *(Figure 3)*. This either prevents or minimizes leakage current formation. On occasion severe environmental conditions can be sustained for long time periods and cause any polymeric surface to lose its hydrophobicity. However, the silicone insulator surface will re-establish its hydrophobic surface within 24 hours. This prevents the surface from becoming increasingly hydrophilic with time, which would result in premature failure of the flashover. This unique ability of the QT-III silicone is a major factor to insure long service life.

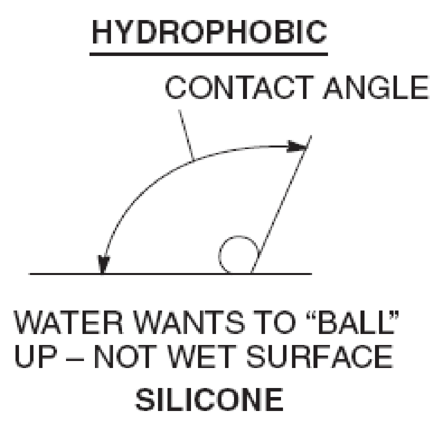
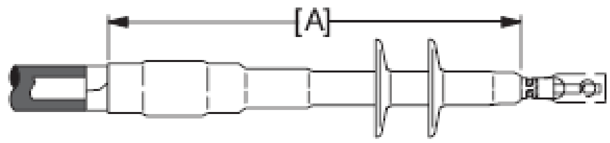


Figure 3

Physical and Electrical Properties

3M™ Cold Shrink Silicone Rubber Termination Kit QT-III, 7620-S, 7680-S and 7690-S Series can be used on cables with a rated maximum operating temperature of 105° C and an overload rating of 140° C. 7620-S, 7680-S and 7690-S Series terminations meet all requirements of IEEE Standard 48-1996, "IEEE Standard Test Procedures and Requirements for High-Voltage Alternating-Current Cable Terminations", and are designated Class 1 for outdoor weather-exposed locations. The current rating of these terminations meets or exceeds the current rating of the cables on which they are installed.

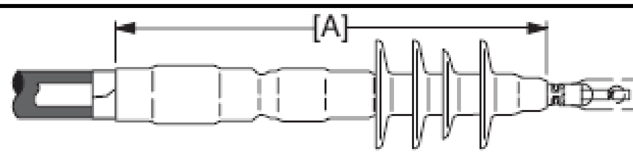
Typical Dimensions



Kit Number	Dimension [A] (Max.)	Wet Creepage Distance (Max.)	Arcing Distance Max.
7620-S-2	10.5" (267 mm)	14.0" (356 mm)	10.5" (267 mm)
7621-S-2	10.5" (267 mm)	14.0" (356 mm)	10.5" (267 mm)
7622-S-2	9.8" (249 mm)	13.3" (338 mm)	9.8" (249 mm)

Table 1

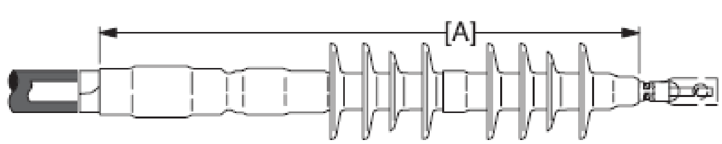
Typical Dimensions



Kit Number	Dimension [A] (Max.)	Wet Creepage Distance (Max.)	Arcing Distance Max.
7692-S-4	12.25" (311 mm)	18.5" (470 mm)	12.25" (311 mm)
7693-S-4	12.25" (311 mm)	18.5" (470 mm)	12.25" (311 mm)
7694-S-4	12.25" (311 mm)	18.5" (470 mm)	12.25" (311 mm)
7695-S-4	12.25" (311 mm)	18.5" (470 mm)	12.25" (311 mm)
7696-S-4	13.25" (337 mm)	19.5" (495 mm)	13.25" (337 mm)

Table 2

Typical Dimensions



Kit Number	Dimension [A] (Max.)	Wet Creepage Distance (Max.)	Arcing Distance Max.
7683-S-8	20.50" (521 mm)	33.00" (838 mm)	20.50" (521 mm)
7684-S-8	20.50" (521 mm)	33.00" (838 mm)	20.50" (521 mm)
7685-S-8	20.50" (521 mm)	33.00" (838 mm)	20.50" (521 mm)
7686-S-8	21.50" (546 mm)	34.00" (864 mm)	21.50" (546 mm)

Table 3

Physical and Electrical Properties

Hi-K Stress Control Tube

Physical Properties (Test Method) (ASTM D150 unless noted)	Value
Tensile Strength **(ASTM D412 Test Method)**	1500 psi
Modulus @ 100% Elongation	160 psi
Modulus @ 300% Elongation	500 psi
Electrical Properties (Test Method) (ASTM D150 unless noted)	**Value**
Dielectric Constant (K() 60 Hz; @ 1000 V; 73° F (23° C), 50% RH	22
Dissipation Factor 60 Hz; @ 1000V; 73° F (23° C), 50% RH	0.10

Hi-K Stress Controlling Compound

Electrical Properties (Test Method) (ASTM D150 unless noted)	Value
Dielectric Constant 60 Hz; @ 1000 V; 73° F (23° C), 50% RH 100 mil (2,54 mm) thickness	25
Dissipation Factor 60 Hz; @ 1000 V; 73° F (23° C), 50% RH 100 mil (2,54 mm) thickness	0.90

Silicone Sealing Compound

Electrical Properties Test Method ASTM D149	Value
Dielectric Strength 75 mil (1,90 mm) thickness	300 V/mil

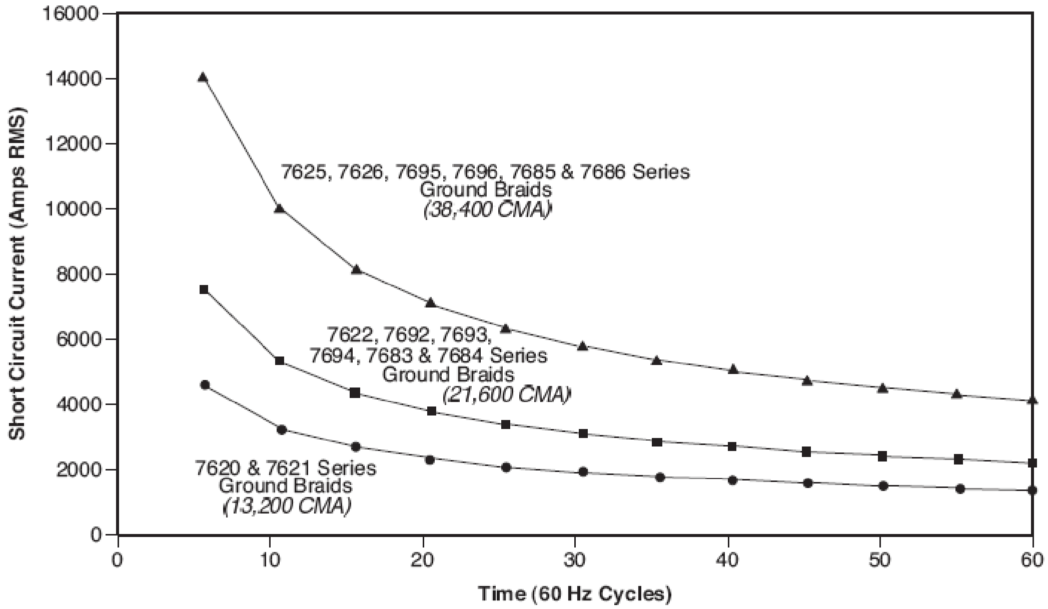
Silicone Rubber Insulator

Physical Properties (Test Method)	Value
Color	Dark Gray
Tensile Strength (ASTM D412)	850 psi
Modulus @ 100% Elongation	130 psi
Modulus @ 300% Elongation	400 psi
Hydrophobic Recovery **(3M Test Method No. 406)** >90° Contact Angle	5.0 hrs
Electrical Properties (Test Method) (ASTM D150 unless noted)	**Value**
Dielectric Constant (S.I.C.) 60 Hz; @ 1000 V; 73° F (23° C), 50% RH	3.6
Dissipation Factor 60 Hz; @ 1000V; 73° F (23° C), 50% RH	0.003
Dielectric Strength (ASTM D149) 75 mil (1,90 mm) thickness	500 V/mil
Track Resistance (ASTM 2303) 3.5 kV	5.0 hrs.

Physical and Electrical Properties

Ground Braid

Rated Ground Fault Current Limit



Termination Selection Guide

Kit Number	Cable Insulation O.D. Range	Conductor Size Range (AWG and kcmil)				
		5 kV 100 % 133 %	8.7 kV 100% 133%	15 kV 100% 133%	25/28 kV 100% 33%	35 kV 100% 33%
7620-S-2	0.32 – 0.59” (8,2 – 15,0 mm)	8 – 4 --	8 – 6 --	-- --	-- --	-- --
7621-S-2	0.49 – 0.89” (12,1 – 22,7 mm)	2 – 3/0 --	4 – 2/0 --	-- --	-- --	-- --
7622-S-2	0.64 – 1.08” ((16,3 – 27,4 mm)	4/0 – 400 --	3/0 – 300 --	2 – 4/0 (35 – 120 mm^2)	-- --	-- --
7692-S-4	.064 – 1.08 (16,3 – 27,4 mm	4/0 – 400 --	3/0 – 300 --	2 – 4/0 (35 – 120 mm^2)	2 – 1/0 (35 – 50 mm^2)	-- --
7693-S-4	0.72 – 1.29” (18.3 – 32,8 mm)	300 – 500 --	250 – 500 --	2/0 – 300 (70 – 150 mm^2)	2 – 4/0 (35 – 120 mm^2)	-- --
7694-S-4	0.83 – 1.53” (21,1 – 38,9 mm)	500 - 750 --	350 - 700 --	4/0 – 500 (120 – 240 mm^2)	2/0 – 250 (70 – 150 mm^2)	-- --
7695-S-4	1.05 – 1.80” (26,7 – 45,7 mm)	700 - 1500 --	600 - 1250 --	500 – 1000 (240 – 500 mm^2)	250 – 800 (125 – 400 mm^2)	-- --
7696-S-4	1.53 – 2.32” (38,9 – 58,9 mm)	1750 – 2000 --	1500 – 2000 --	1250 – 2000 (625 – 1000 mm^2)	900 – 1750 (500 – 800 m^2)	-- --
7683-S-8	0.72 – 1.29” (18.3 – 32,8 mm)	300 – 500 --	250 – 500 --	2/0 – 300 (70 – 150 mm^2)	2 – 4/0 (35 – 120 mm^2)	2 – 2/0 (35 – 70 mm^2)
7684-S-8	0.83 – 1.53” (21,1 – 38,9 mm)	500 - 750 --	350 - 700 --	4/0 – 500 (120 – 240 mm^2)	2/0 – 250 (70 – 150 mm^2)	2 – 4/0 (35 – 120 mm^2)
7685-S-8	1.05 – 1.80” (26,7 – 45,7 mm)	700 - 1500 --	600 - 1250 --	500 – 1000 (240 – 500 mm^2)	250 – 800 (125 – 400 mm^2)	3/0 – 600 (95 - 325 mm^2)
7686-S-8	1.53 – 2.32” (38,9 – 58,9 mm)	1750 – 2000 --	1500 – 2000 --	1250 – 2000 (625 – 1000 mm^2)	900 – 1750 (500 – 800 m^2)	700 – 1500 (400 – 725 mm^2)

Product Specifications

The cable termination must have a voltage class rating equal to or greater than the cable being terminated. The rating shall be 5, 8.7, 15, 25/28 kV or 34.5 kV as an IEEE Standard 48-1996 Class 1 termination. It must have a maximum continuous operating temperature rating of 105° C, with an emergency overload rating of 140° C. The termination stress control shall be capacitive and constructed of a Hi-K EPDM rubber tube. The installation procedure shall not require using silicone grease. The termination insulator shall be of a skirted design, constructed of tracking resistant silicone rubber, dark gray in color. The termination must be of a pre-stretched Cold Shrink design, installed without the application of a heat source. The termination kit shall include all materials required (except lug and vinyl tape) and shall accommodate tape (ribbon), wire, or UniShield® shielded cables.

The Class 1 termination kits shall be used with listed copper or aluminum compression lugs.

Engineering/ Architectural Specifications

Terminating of all 5, 8.7, 15, 25/28 and 34.5kV shielded power cables, indoors and in weather-protected equipment shall be performed in accordance with instructions included in the 3M™ Cold Shrink Silicone Rubber Termination Kit QT-III 7620-S,7680-S and 7690-S Series. This shall include all outdoor weather-exposed areas for tape (ribbon), wire or UniShield® shielded cables. The termination kits shall be used in conjunction with 3M™ Scotchlok™ Connector 3000 or 4000 Series or 3M™ Stem Connectors SC Series.

Performance Tests

Typical Results, IEEE Standard 48 Short-Term Test Sequence

Insulation Class Test	5 / 8.7 kV (2 Skirt)		15/25 kV (4 Skirt)		34.5 kV (8 Skirt)	
	Require-ments	Results	Require-ments	Results	Require-ments	Results
Partial Discharge Extinction voltage @ 3 pC	7.5 kV	Passed	13 / 21,5 kV	Passed	30 kV	Passed
Power Frequency Voltage 1 min. Dry Withstand	35 kV	Passed	50 / 65 kV	Passed	90 kV	Passed
Power Frequency Voltage 10 sec, Wet Withstand	30 kV	Passed	45 / 60 kV	Passed	80 kV	Passed
Power Frequency Voltage 6 hr. Dry Withstand	25 kV	Passed	35 / 55 kV	Passed	76 kV	Passed
Direct Voltage 15 min. Dry Withstand	65 kV	Passed	75 / 105 kV	Passed	140 kV	Passed
Lightning Impulse Voltage Withstand (BIL)	95 kV	Passed	110 / 150 kV	Passed	200 kV	Passed
Partial Discharge Extinction Voltage @ 3 pC	7.5 kV	Passed	13 / 21.5 kV	Passed	30 kV	Passed

Table 4

Performance Tests

Typical Results, IEEE Standard 48 Long-Term Test Sequence

Insulation Class Test	5 / 8.7 kV (2 Skirt)		15/25 kV (4 Skirt)		34.5 kV (8 Skirt)	
	Require-ments	Results	Require-ments	Results	Require-ments	Results
Partial Discharge Extinction voltage @ 3 pC	7.5 kV	Passed	13 / 21.5 kV	Passed	30 kV	Passed
Cycling Aging 30 days, 130° C cond. temp Power Frequency voltage Withstand	35 kV	Passed	26 / 43 kV	Passed	60 kV	Passed
Partial Discharge Extinction Voltage @ 3 pC	7.5 kV	Passed	13 / 21.5 kV	Passed	30 kV	Passed
Lightning Impulse Voltage Withstand (BIL)	95 kV	Passed	110 / 150 kV	Passed	200 kV	Passed

Table 5

Partial Discharge (Corona) Tests

The purpose of corona testing is to determine whether all properly installed terminations operate corona-free at a minimum of 150% of their operating voltage. For the test, an applied test voltage is gradually increased until discharges appear on the test set oscilloscope display. The voltage at which these discharges reach a magnitude of 3 picocoulombs is recorded as the corona starting voltage (CSV). The applied voltage is then lowered until the discharge level drops below 3 picocoulombs, and this is recorded as the corona extinction voltage (CEV).

Power Frequency (AC) Withstand Tests

All 3M™ Cold Shrink Silicone Rubber Termination Kit QT-III, 7620-S,7680-S and 7690-S Series exceed the IEEE Standard 48-1996 requirements for a Class 1 termination.

Lightning Impulse Tests

For these tests, a 1.2 x 50 microsecond voltage wave is applied to the termination lug. The testing consists of both positive and negative polarity surges per IEEE Standard 48-1996 BIL requirements. The termination kits exceed these BIL requirements.

Sealing Tests

Termination top and bottom seals are tested by applying 7 psi (0.05 MPa) to the cable conductor strands with the termination submerged in water. Both seals withstand this internal air pressure for 6 hours without leaking.

Installation Techniques

Detailed instructions are included in each kit to provide the installer with all information required to properly install the appropriately sized 3M™ Cold Shrink Silicone Rubber Termination Kit QT-III, 7620-S,7690-S and 7680-S Series. A brief summary of the installation steps for tape-shielded cable is outlined as follows:

1. Prepare cable according to standard procedure.

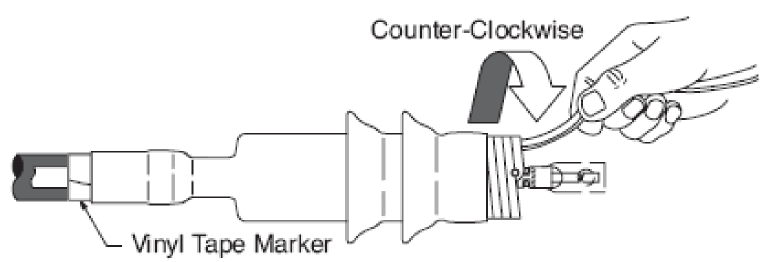
2. Apply bottom mastic seal. (*Figure 4*).

Figure 4

3. Install lug using a listed crimping tool and die.

4. Install termination onto cable and unwind core, allowing termination to shrink into place (*Figure 5*).

⚠ Caution
Working around energized high-voltage systems may cause serious injury or death. Installation should be performed by personnel familiar with good safety practice in handling high-voltage electrical equipment. De-energize and ground all electrical systems before installing product.



NOTE: The material being removed at this step is mixed polymers and can be recycled with other ***waste.***

Figure 5

Shelf Life & Storage	Maximum recommended storage temperature is 110° F (43° C). The termination assemblies are not affected by freezing storage temperatures. Normal stock rotation is recommended. As provided, in the expanded state, 3M™ Cold Shrink Silicone Rubber Termination Kit QT-II 7620-S, 7690-S and 7680-S Series terminations have an on-shelf storage life of three years from the date of manufacture.
Maintenance	**Surface Cleaning** – 3M QT-III terminations are not harmed by field surface cleaning. Established techniques for cleaning insulators and terminations in extremely contaminated areas such as high-pressure water and pulverized corn cobs are acceptable.
Availability	Please contact your local distributor; available from 3M.com/electrical [Where to Buy] or call 1-800-245-3573.
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78-8126-6167-2_B

From: Kal Abdolall [Kal.Abdolall@powertechlabs.com]
Sent: Friday, October 12, 2007 7:38 PM
To: dexter.tarampi@bchydro.com; joe.crozier@bchydro.com; russell.dobie@bchydro.com
Cc: John Vandermaar
Subject: FW: Dielectric Tests - Novinium Injection Interface

Gentlemen:

The unit passed all the dielectric tests (See John's e-mail) . We also measured Tan delta and the result obtained was 3.75 . This high value for Tan delta does not seem to affect the performance of the unit , as reflected by the low leakage current (see Figure 1) and no measurable rise of temperature after 6.75 hrs at 14.4 kV, by virtue of the long length of tubing coiled inside the unit

In our opinion this unit is suitable for this application .

Cheers

Kal

K. Abdolall, Ph.D.
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ole0.bmp

-----Original Message-----
From: John Vandermaar
Sent: Friday, October 12, 2007 6:39 PM
To: Kal Abdolall
Cc: May Wang
Subject: Dielectric Tests

We have completed the dielectric tests on the Novinium High Voltage Fluidic Interface, HVFI. The unit passed the AC dry withstand test at 65 kV for one minute, AC wet withstand test at 60 kV for 10 seconds and the impulse withstand test at 150 kV (3 positive and 3 negative impulse waveforms). The tests were done in accordance with the requirements of IEEE Std. 48-1996 for 25 kV insulation class equipment.

In addition the HVFI was energized at 14.4 kV for 6.75 hours. There was no measurable increase in temperature above ambient on the surface of the HVFI.

Regards,

John Vandermaar
Manager, High Voltage Laboratory
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