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# EXTENDING THE LIFE OF SECONDARY SERVICE CABLE THROUGH SILICONE GEL-INJECTION

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## ABSTRACT

*Secondary service cables form the last link in the power grid by interconnecting the distribution transformer to the end user's service meter. For many utilities with underground services, failures on this class of cable account for over half of their total cable-failure count and are on the rise. Utilities would traditionally be faced with a decision to continue to make ad-hoc repairs or create a replacement program. This paper introduces silicone-gel injection as a third option for utilities to consider. The injection of silicone gel purges water from the conductor and forms a physical barrier that protects against water intrusion and corrosion. Silicone-gel injection is a non-invasive solution that causes minimal disruption to neighborhood homes and businesses.*


## I. INTRODUCTION

Secondary service cables form the last link in the power grid by interconnecting the distribution transformer to the end user's service meter. For many utilities with underground services, failures on this type of cable are on the rise and account for over half of their total failure count on their underground system [1], [2] and [3]. Utilities would traditionally be faced with a decision to either create a replacement program utilizing modern cable and installation practice [4] and [5] or continue making ad-hoc repairs on their aging system. Both options bring disruption to the neighborhood using heavy equipment and extended outages.

Silicone-gel injection is introduced by this paper and becomes a third option for utilities to consider. The injection of silicone gel reinsulates the cable and protects it against corrosion and failures. The process is minimally invasive and can restore reliability to more cable in less time than the conventional alternatives.

## II. BACKGROUND

Secondary service cables installed in underground residential distributions (URD) systems typically fail in service due to either the full or partial loss of ampacity of the conductor due to corrosion. Corrosion commonly occurs when water contacts the aluminum conductor strands for an extended period. Cables installed in manholes that contain heat sources like steam pipes may also undergo thermal degradation and oxidation of the polymeric insulation.

### *Corrosion Mechanism in Aluminum Conductors*

Small surface irregularities of the conductor combined with oxygen, water, and electrolytes to result in pitting corrosion and the formation of aluminum hydroxide. Due to the higher specific volume of the corrosion products compared to pure aluminum, swelling and deformation of the cable can occur as shown in Figure 1. Corrosion of the conductor leads to the potential failure of the segment through high resistance and a reduction of the cable's ampacity. The fundamental equations for the corrosion mechanism are provided in below in (1) and (2) and have been well documented in literature [3] and [6].

$$4Al + 3O_2 \rightarrow 2Al_2O_3 \quad (1)$$

$$2Al + 6H_2O \rightarrow 2Al(OH)_3 + 3H_2 \quad (2)$$

*Fig. 1. Full loss of ampacity of a secondary service cable due to corrosion of the aluminum conductor.*

### *B. Sources of Water Ingress*

Water ingress into the conductor of secondary cables can be due to many factors including; installation practice, external damage and chemical or thermal exposure.

#### *1) Installation Practices*

Installation practices have a huge impact on the cable reliability. Cables that have been stretched during installation may develop stress cracks and other breaks in the insulation that serve as entry points for water. During home construction, cables may be left unterminated with the conductors exposed to rain for weeks or months prior to the completion of craftwork. Poor craftsmanship at the splices and terminations may also allow water to enter the conductor.

*2) External Damage*

Secondary service cables are typically installed in compliance with national and local standards at a cable depth of 24 inches [7]. This depth can leave cables vulnerable to incidental damage caused by home and garden projects or the installation and maintenance of neighboring utilities such as water, natural gas, fiber optic and other telecommunications where accurate locates were not performed prior to the start of work. Yet another source of damage may be caused by rodents and insects that prefer the taste polymeric insulations like polyethylene.

*3) Chemical & Thermal Exposure*

The material properties of the polymeric insulation can be degraded by several factors including chemical, thermal and UV exposure. Over-heating of the conductor can cause common plasticizers to migrate out of the insulation, resulting in cracking. Fertilizers and corrosive soil can damage the insulation leading to degradation of the insulation. Cables running through pull boxes, ducts or manhole systems can be exposed to petrochemicals that may deteriorate the polymeric jacket.

*C. Cable Rejuvenation*

Cable rejuvenation with di alkoxysilane fluid has been an alternative to the replacement of aged and failing medium and high-voltage power cables for the past 30 years. The chemistry, process, efficacy and case studies of cable rejuvenation have been well documented and summarized in literature [8]. However, the chemistry of the di alkoxysilane fluid only benefits the solid-dielectric cable that suffers from water trees, brought about by the relatively high electrical stresses at which these cable systems operate. This paper describes a new process of silicone-gel injection that addresses the unique causes of secondary service cable failure operating at less than 600V. The process described is quick, non-invasive and causes minimum disruption to the end user.

## III. CHEMISTRY OF SILICONE GEL

Silicone gel is a two-part formulation that is field-mixed prior to injection. The two components undergo the hydrosilation reaction detailed in Figure 2. Part A of this mixture contains the vinyl and hydrido silanes shown below along with a cross-linking agent. Part B of this mixture containing the catalyst and silane-bound antioxidant that protect the polymer from oxidation brought on by heat, steam or UV exposure.

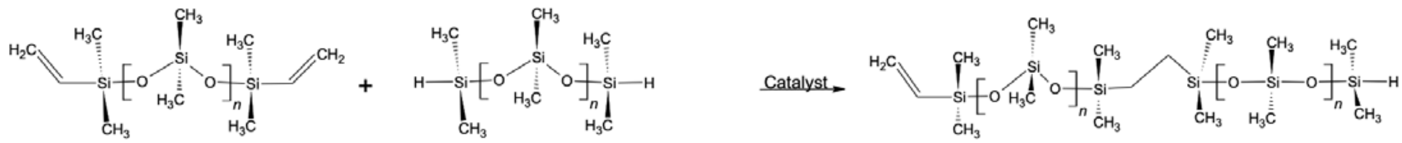

*Fig. 2. Hydrosilation reaction of waterblocking silicone gel.*

The catalyzed reaction transforms the fluid from a easy-flowing mixture with a viscosity of 5cS into a non-flowable gel in approximately 48 hours (Figure 3). The low viscosity allows for an average injection time of less than one hour. This silicone gel is hydrophobic and protects the cable against corrosion by first flushing standing water from the cable conductor. Once the silicone gel has cured, the gel will protect the conductor from water ingress through any opening that occurs in the jacket.


*Fig. 3. Silicone gel is a unique two-part material that transforms from a easy-flowing mixture into a non-flowable gel in approximately 48 hours.*

## IV. SILICONE-GEL INJECTION PROCESS

In a typical project, the 6 or more services that initiate from a single transformer may be simultaneously injected. A brief outage is taken to complete the craftwork and full service is typically restored to the meters in under 3 hours. Transformer and mid-span junction like a pull box or pedestal are used to sectionalize the system and serve as injection points.

*A. Injection Connector*

Injection connectors are proprietary devices installed at the cable ends (Figure 4). They provide controlled fluid access to the conductor while creating the electrical connection that joins the cable's conductor to the secondary buss. At the meter, the injection connectors are reconnected to the supply side of the of the buss (Figure 5). The flexible tubes from the injection connectors are routed to the collection tank, and the meter is reassembled and returned to service. At the transformer, the flexible tubes are routed to the pump that makes up the fluid delivery system discussed in the next section.

*Fig. 4. Injection connectors are installed at each cable end to create a fluid access point for injecting silicone gel into the cable's conductor.*

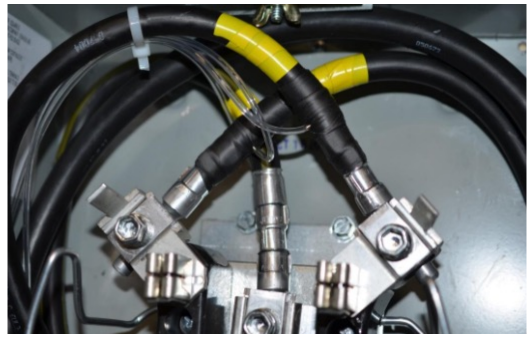

*Fig. 5. Injection connectors installed in a residential 200A meterbox. Tubes are routed to the temporary collection tank.*

*B. Fluid Delivery System*

The fluid delivery system consists of the pump typically positioned at the transformer as a centralized point of injection. Injection begins once all craftwork has been completed and the meters are returned to service.

A temporarily collection tank is hung from the meter base through one of the knock-out panels (Figure 6). The collection tank receives the silicone gel as it flows through the cable's conductor, providing a visual indication of when injection is complete. When fluid is received, the injection equipment including the collection tank can be removed from the circuit.

Once silicone gel is observed entering the collection tank, the pump is turned off and the flexible tubes feeding the cables are trimmed and capped (Figure 7). At the meter, the collection tank is removed, the flexible tubes are capped, and a permanent PVC end cap is cemented in place.

## V. DISCUSSION

Compared to the alternatives of cable replacement and repair, silicone-gel injection offers many advantages. Both alternatives require heavy equipment for excavation or drilling on a home-owner's property that can lead to expensive landscaping costs. In comparison, silicone-gel injection is a non-invasive solution and, in most cases, requires only foot access to the transformer, pull box and meter base.

Silicone-gel injection can be implemented by electric utilities either as a stand-alone service or integrated into reliability improvement programs that may consist of rejuvenation of URD cables, neutral corrosion assessment or turnkey services like transformer changeouts, cable replacement, splice replacement, and other electrical craftwork.

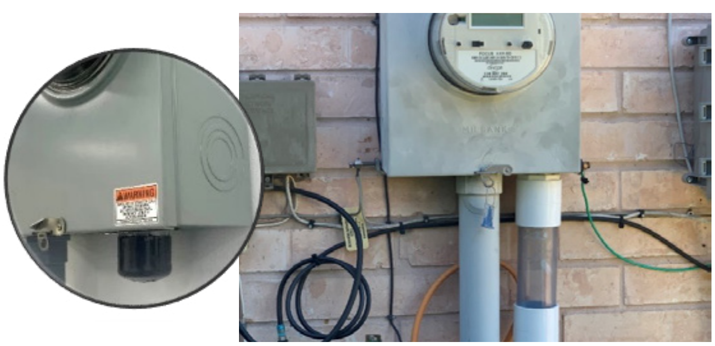

*Fig. 6. Meter returned to service with collection tank temporarily installed through the knock-out panel. Insert shows a permanent cap installed where the collection tank hung following the successful injection.*

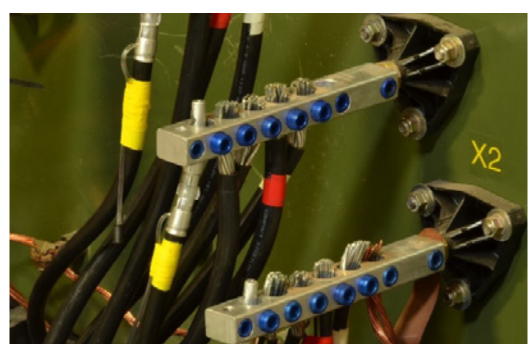


*Fig. 7. Injection connectors installed in a transformer. Tubes have been trimmed and capped following a successful injection.*

## VI. CONCLUSIONS

Silicone-gel injection increases the reliability of the aged secondary-service cables that connect the distribution transformer to the meter. The injection of silicone-gel purges water from the cable and forms a physical barrier that protects the aluminum conductor from corrosion. The silicone gel is a unique two-part mixture that transforms from a easy-flowing mixture into a non-flowable gel in approximately 48 hours. Compared to the alternatives of cable replacement and repair, silicone-gel injection is non-invasive and does not require heavy construction equipment on property. Silicone-gel injection is cost effective solution for protecting the last link of the power transmission and distribution system.

## VII. REFERENCES

[1] R. Harp, "Secondary Cable Failure Statistics at TXU Electric Delivery Company", ICC Education Program Panel Session, St. Petersburg Beach, FL, April 20, 2005.

[2] J. Hans, "History of Secondary Cable Designs" ICC Education Section, St. Petersburg Beach, FL April 20, 2005.

[3] A. van Deursen, B. Kruizinga, P.A.A.F. Wouters, E.F. Steennis, "Impact of Corrosion on the Reliability of Low Voltage Cables with Aluminium Conductors," 52nd International Universities' Power Engineering Conference, paper no. 150.

[4] Reese, et al, "Electrical Cable Having A Self-Sealing Agent and Method for Preventing Water From Contacting the Conductor", U.S. Patent 6,184,473, Feb. 6, 2001.

[5] ANSI/ICEA S-105-692-2011, Standard for 600 Volt Single Layer Thermoset Insulated Utility Underground Distribution Cable, 2011.

[6] S. Pelissou, J. Cote, R. Savage, S. St-Antoine, "Influence of corroded conductors on the performance of MV extruded cables", Jicable, 2003.

[7] NFPA 70, National Electric Code (NEC), 2017.

[8] Banerjee, et al, "Cable Rejuvenation Practices", CEATI Report No. T154700-50/129, November 2017.