Improving Post-treatment Reliability:
Eliminating Fluid-Component Compatibility Issues

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Abstract**: For the past two decades fluid injection technology has almost always put the treatment fluid in direct contact with rubber termination and splice components. The incompatibility of the treatment fluids with silicone rubber components has been well known for most of this time. This paper discusses two other compatibility issues which affect the post-treatment performance of rejuvenation when fluid comes in direct contact with EPDM and EPR components. A robust solution which eliminates the issues and improves post-treatment reliability is introduced.**

THE PROBLEMS

The incompatibility of the widely deployed injection approach of the previous two decades referred to herein as ‘841 (described in detail in [1] and [2]) with silicone has been well know for some time. The author(s) of [3] wrote:

> *“… silicone rubber swells substantially in contact with … [‘841] silicone fluids.”*

Even at room temperature the swell is well over 50% and sustained contact will result in component failure. This is a problem for circuit owners, since it largely precludes the use of silicone cold-shrink splice technology for circuits which the circuit owner may wish to treat one day or which had been previously treated with ‘841.

Of more concern because of its Trojan horse implications, however, is the routine contact of the ‘841 fluids with EPDM and EPR rubber in both dead-front elbow terminations described in [4] and in molded and cold-shrink splices. Here a long record of adequate field performance at first suggests that there may be no incompatibility issues. However, a closer look indicates two heretofore unrecognized implications.

The first issue is swell at high temperatures and has been documented in the literature by end-users. Greg Sheil of London Hydro [5], for example, provided a photograph of just such an elbow and wrote:

> *“A recent development involves the possible swelling of an injection port. The history of this event is the cable section was being silicone injected. When the site was re-inspected, the injection cap had dislodged and silicone was leaking down the cable. It was physically impossible to re-insert the injection cap so the injection bottles were removed and an attempt was made to re-install the insulating cap. The insulating cap also would not fit back on; it is believed that the cap is swollen.”*

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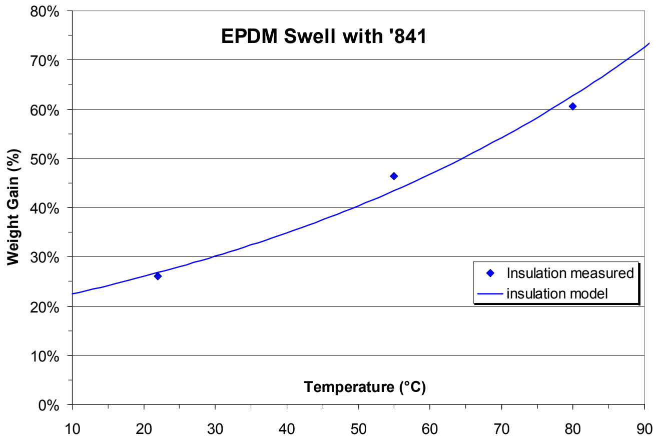

Figure 1. EPDM swells to electro-mechanical failure well before the rated temperature of XLPE cables.

Figure 1 demonstrates the swell of both insulating and semi-conductive EPDM rubber as a function of temperature in contact with the ‘841 fluid. There is a point where the mechanical swell will cause failure of the component. Possible failures causes include loss of interfaces at the injection port and mechanical cracking of the component. While detailed studies have not been done by this author, there is reason to believe that reliability is likely to be compromised well before 55°C.

If the circuit owner is assured that the cable will operate well below the design temperature of the cable and in fact well below 55°C, the failure rate is likely to be small. Although less obvious than catastrophic failure from gross swelling, a second effect is potentially more damaging. The issue arises from the direct contact of treatment fluid with rubber components and yields a performance penalty on the adjacent cable.

The under-treatment of small conductor cables (7-strand and 19-strand cables which are the bulk of cables circuit owners desire to rehabilitate) inherent in the ‘841 method chronicled in [6] and [7], is exacerbated by the direct contact of the ‘841 fluids with rubber terminations and splices. The direct contact diverts fluid intended to treat the cable to the rubber components.

Figure 2 shows the extent of this fluid loss for common 7-strand and 19-strand 15kV cases. Figure 2 assumes a 300 foot length with standard-length elbows and no splices. The situation worsens if longer elbow lengths (e.g. repair or extended-length elbows) are used, the cable length decreases, and for higher voltage classes.

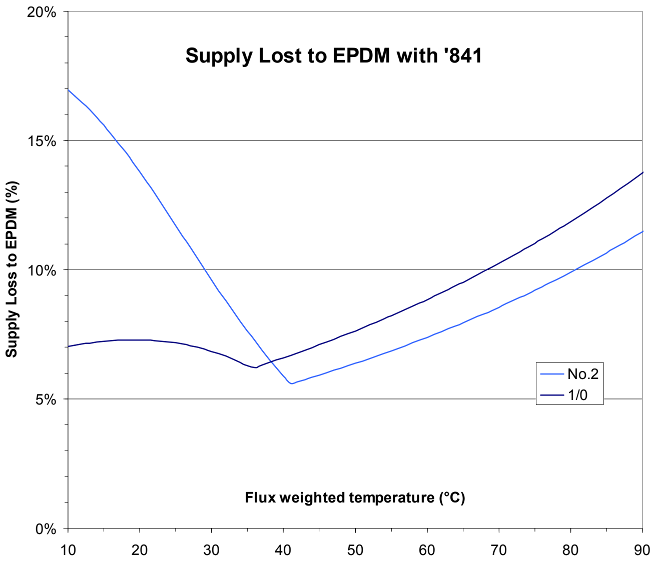

Figure 2. Fluid diverted from cable treatment by short EPDM elbows for 300 ft of 175 mil cable with no splices.

Depending on the cable geometry and the flux weighted operating temperature of the cable, between 5% and 15% of the fluid intended to extend the life of the cable is diverted into the elbow. The penalty for this diversion will manifest itself as reduced cable life extension.

The discontinuities for the two lines in Figure 2 are a result of the treatment methodology employed by the purveyors of the '841 injection method. This method relies on filling the interstitial voids in the cable and then leaving a soak bottle attached to the cable for approximately 60 days. If the flux weighted temperature is low the amount of fluid which permeates into the cable and components is lower than if the temperature were higher. The attached soak bottle is filled only with enough fluid to adequately treat the cable to avoid damaging over saturation. When that amount of fluid is exhausted, a valve closes and no more fluid is supplied. The discontinuities occur at about 40°C (flux weighted) where the valve closes within the prescribed 60-days.

THE SOLUTION

If high reliability is a circuit owner requirement, treatment fluid should not be allowed to contact components. A device, referred to as an injection adaptor or IA, to accomplish this goal is illustrated in Figures 3, 4, and 5. The device is swaged or circumferentially crimped onto both the crimp connector and the insulation. The design enjoys a tenacious seal tested to over 1000 psig at low temperatures and over 30 psig with hundreds of thermal cycles from ambient to over 90°C. The swage also has the advantage of superior ampacity relative to a multi-point crimp.

Using an injection adaptor any desired amount of fluid can be supplied to the cable with no risk of any being diverted to unproductive saturation of elbow and splice components.

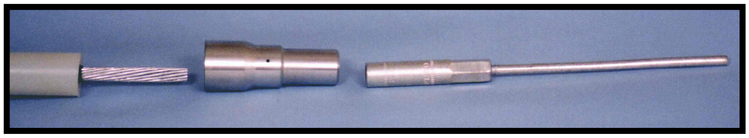

Figure 3. Prepared 1/0 cable end, IA with fluid access hole, and termination connector before installation.

Figure 4. IA and lug swaged to cable.

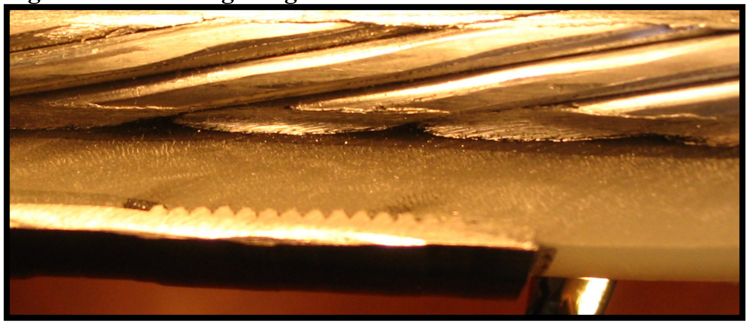

Figure 5. Cutaway of IA at insulation interface showing leak-proof tenacious seal.

SUMMARY

Traditional injection approaches used over the last two decades put cable components at risk of failure, particularly at higher temperatures. Even if the component survives exposure to the treatment chemical, valuable fluid meant to extend the life of the cable dielectric is unproductively diverted.

The patent pending injection adaptor [8] introduced here eliminates all of these issues. The design is robust and can be used to inject any desired amount of fluid into the strands, from the quantity provided by the legacy approach to the optimum quantity required for life times of 40 years or more.

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