# DGA (Dissolved Gas Analysis) Diagnostic Method Reveals Internal Carbonization in Oil-Filled High Voltage Extruded Cable Terminations

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## *ABSTRACT*

*The widespread use of transmission extruded cable systems has placed increasing focus on effective diagnostics. DGA is one such emerging method for fluid-filled extruded cable terminations. This paper covers the successful application of DGA, as validated by the relationship of dissolved gases, to the tracking or carbonization pattern observed at the transition between the cable insulation and cable insulation semi-conductive screen of a 37 years old 115 kV termination. It was due to the poor preparation of the transition at the end of the cable insulation semi-conducting screen, as shown by dissection. This investigation demonstrates that DGA holds potential as a diagnostic tool for extruded cable terminations*

## *KEYWORDS*

Dissolved Gas Analysis (DGA), diagnostics, fluid-filled extruded terminations, revealed tracking/carbonization, XLPE gassing

## INTRODUCTION

Two 1250 MCM, aluminum conductor, 115 kV cross-linked polyethylene (XLPE) 800 mil steam-cured insulation wall cable circuits, each 2.8 mile and 2.9 mile long, manufactured in 1975, were placed in service in 1976 connecting two substations at the Lincoln Electric System (LES), Nebraska, USA. Although a third party dig-in was experienced in 2007, the service was resumed after due repairs and an examination of the cable insulation. The observations with respect to contaminants, water-trees cloudy areas containing micro-voids in the insulation along with some conductor shield imperfections were generally expected in a XLPE cable of this vintage, and were deemed not to be of concern at this voltage level. This cable, with 93 hand-taped splices, was the longest XLPE circuit at that time in the US. The utility decided to retire the cable system in 2013, primarily based on age – a life exceeding 35 years was considered sufficient by the user. This retirement after 37 years of service offered an additional opportunity to address the condition of the cable and its accessories made thus physically available.

This paper covers only the condition assessment of the terminations through DGA and some additional testing of dielectric fluid. Following the successful application of DGA to power transformers dating back to the mid-1960s – it is hard to imagine a large power transformer in the world, where DGA is not regularly employed as a diagnostic tool. DGA has been extended to high voltage fluid-paper cable systems since the early 1980s in the US, with success – thanks to the early EPRI support. The DGA is particularly effective and highly economical for pipe-type cable terminations, over 12,500 of which have been installed in the US over the last 8 decades. The limited and captive amount of the dielectric fluid in such terminations further helps toward condition assessment by DGA, accentuating the DGA sensitivity. The success rate of DGA application for all types of taped fluid-filled terminations is extremely high compared to splices/cables per se. All this goes to show that, whenever a dielectric fluid exposed to thermal and electrical stresses, including any chemical stresses, can be accessed, DGA and fluid testing has a legitimate place in the diagnostic tool box. Accordingly, DGA can well serve as a diagnostic method for extruded cable terminations containing a fluid, as holds for transformers, Load Tap Changers and oil-paper cables, where the dielectric fluid can be readily accessed.

Basically, DGA consists of fluid sampling from the equipment and its subsequent analysis to quantify lower and higher hydrocarbons, hydrogen and carbon oxides that are generated under electrical and thermal stresses over time. Depending on the prevailing conditions, gas evolution can accelerate. The sampled fluid should faithfully represent the fluid in the equipment, and nothing should be added or lost during sampling, storage and transportation of the sample. Thus proper sampling and its preservation are very important, all the more for fluid-filled extruded cable terminations where highly viscous dielectric liquids are employed compared to other fluid-filled apparatus, challenging the sampling process without a proper technique. An appropriate sampling and analysis technique for viscous fluids was employed. In addition to sampling, the gas quantification and interpretation are of vital importance. The success of DGA depends on these 3 elements. Viscous fluids are chemically more stable than thinner fluids and are more insensitive to conducting, polar and non-polar materials.

The interpretation of fluid-filled extruded cable terminations is markedly different from their paper counterparts, where considerable experience already exists. The gassing from the universal chemical cross-linking process by peroxide can also raise an important factor, if due and prolonged cable heating is compromised during the manufacturing cycle for high voltage cables. However, this potential issue can be resolved with better understanding of the overall DGA technique, and the masking effects can be overcome; they are practically inconsequential. Moreover, certain key diagnostic gases cannot be caused by the peroxide cross-linking process. Incidentally, DGA can provide an assessment and extent of the crosslinking gases – a unique advantage that is also economical

The gas generation is largely a thermodynamic