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US EXPERIENCE ON CONDITION ASSESSMENT OF VARIOUS TYPES OF TAPED CABLE SYSTEMS BY DISSOLVED GAS ANALYSIS BASED ON A NOVEL SAMPLING AND ANALYSIS TECHNIQUE

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ABSTRACT

The Dissolved Gas Analysis (DGA) technique, which has been successfully applied to transformers, is being increasingly considered for laminar dielectric cable systems. To enhance the effectiveness of the DGA technique to such cable systems, however, proper sampling, analysis and interpretation methods have to be developed taking into account not only the markedly differing field conditions but also the distinct characteristics of the fluids and constructions involved in the two products.

This paper describes a novel sampling and analysis method and its extensive application to the US underground transmission system. The system is characterized by easy-to- use, light, inexpensive disposable vial that serves both as the sampling and analysis vessel.

KEYWORDS

Dissolved-gas-analysis, disposable-sampling-analysis - vial, field-data, underground-transmission-cable.

INTRODUCTION

Laminar dielectric underground transmission cables, which are an integral part of the electric power system, represent considerable utility investment. It is imperative to protect this investment through proper maintenance to avoid unscheduled outages. Following the successful transformer practice, the Dissolved Gas Analysis (DGA) technique, is being increasingly considered for taped transmission cables.

The majority of the US underground transmission circuits are based on HPFF (high pressure fluid filled) cable systems, with a modest representation of HPGF (high pressure gas filled) and SCFF (self contained fluid filled) cable systems. The earliest cable systems installed in the 1920s were SCFF at 138 kV. The HPFF cable systems, introduced in the 1930s, became the predominant choice in the subsequent decades. The HPGF cable systems, which were introduced in the early 1940s, have received recent renewed interest due the absence of free dielectric fluid. Unlike HPFF and SCFF cable systems, the HPGF cable systems are limited to 138 kV level because the gaseous pressurizing medium (Nitrogen) does not provide sufficient dielectric strength at voltages above 138 kV, as compared to the liquid dielectric. It is estimated that the present total circuit lengths of installed HPFF, HPGF and SCFF cables respectively are 4,250, 300 and 400 miles. It should be noted that about 45% of US HPFF cable systems are over 35 years old.

While predictive and preventive maintenance have always been recognized, the present-day utility business climate brought about by increasing competition and deregulation calls for the maximum trouble-free utilization of such assets. It is essential to protect this large investment, amounting to tens of billion of dollars, through proper maintenance to avoid any unscheduled outages, all the more as a significant percentage of these cables is advancing in age. DGA is universally applied to power transformers and has proved quite effective in the condition monitoring of such equipment. While the transformer DGA experience is quite useful, particular attention to cable DGA with respect to sampling, analysis and interpretation has to be paid due to inherent differences in the design, materials and operating conditions relating to the two types of equipment. These differences include type of fluids and their viscosities, cellulosic materials, thermal and electrical stresses as well as operating pressures. Accordingly, the DGA behavior of cables is different from that of transformers and this also holds amongst various types of cables and their accessories.

DGA relates to the analysis of various gases – lower and higher hydrocarbons, hydrogen and carbon oxides – that are generated under electrical and thermal stresses experienced by an operating cable. These gases remain dissolved in the dielectric fluid (unless the saturation level is exceeded) in a liquid state, loosing all semblances to a gas, hence the name “dissolved” gases. The type, distribution and concentration of such gases are governed by the specific nature of the electrical, thermal or mechanical problems faced by a cable, giving cues to the condition of an in-service cable. The success of DGA depends on sampling, analysis and interpretation. The collected sample should faithfully represent what is within the cable and no gases should escape or add to the sample during handling, transportation and analysis. Gases with low solubility such as hydrogen and carbon monoxide tend to escape. The high concentration of nitrogen from pumping plant can lead to bubble formation as the pressure is significantly reduced in the sample that is invariably taken in a glass syringe. Such bubbles present difficulties in the analysis, further compounded by the escape of low solubility gases into these bubbles. The relatively high viscosity of dielectric fluids associated with HPFF cables further add difficulties in sampling, all the more in winter months. The handling of the collected sample involving the extraction of gases and subsequent transferring to chemical instrumentation, can lead to errors.

To overcome some of these difficulties, a previous sampling and analysis approach, called the EPOSS (EPRI Pressurized Oil Sampling System) method, was specifically developed for taped cables by Detroit Edison under EPRI (Electric Power research Institute) sponsorship in the mid-

1985 [1, 2]. The EPOSS technique was based on the headspace principle and it lent to automation, with a commercially available headspace analyzer. It is noteworthy that the sampling and analysis operations were performed in the same cell in the EPOSS method. The question of undesirable bubble formation in the cable fluid sample does not arise with the headspace process.

While the EPOSS method served well, its sampling cell was large, expensive, heavy, and required time-consuming assembly, disassembly and cleaning for re-use, increasing the cost of analysis. These shortcomings have been eliminated by a modified version called EDOSS (EPRI Disposable Oil Sampling System) method [3], which is covered in this paper along with field applications, including data generated on various cable systems [4,5,6].

A Novel Sampling and Analysis Method

The importance of accurate sampling and subsequent determination of individual gas concentrations cannot be overemphasized. Field conditions are not most conducive to sampling for cable systems that offer a wide variety of locations such as splices, terminations, risers and spreaders/trifurcators. Moreover, these locations are not as readily accessible as transformers, for which the DGA sampling devices such as glass syringes and steel cylinders were introduced and deemed appropriate for transformer oils with relatively low viscosity and absence of any potential problems relating to the conditions specific to cable systems.

The EDOSS method, based on the same headspace principle as its predecessor EPOSS, significantly augments the many diverse advantages offered by EPOSS, without compromising accuracy and precision. The theory, accuracy and precision have already been discussed in the EPRI report [1, 3]. The additional advantages provided by EDOSS include: small sample size, light-weight and inexpensive glass sampling vial, long-shelf life, ease of vial shipment and the disposable vials, hence the name EPRI Disposable Oil Sampling System (EDOSS). As true for EPOSS, the sampling and analysis are carried out in the same very cell for EDOSS – the only known systems where the sampling vessel also serves as the analysis vessel. The small sample size renders EDOSS suitable for low fluid volume apparatus such as extruded cable terminations and transformer bushings.

The EDOSS technique consists of three components, namely, sampling vial, quick-connect vial holder, and the sampling tool comprised of a metallic housing with a hollow needle and 3-way valve. Each is briefly addressed below.

Sampling Vial: The sampling vial consists of a disposable evacuated crimp-top 22mm x 75mm glass cell with a nominal capacity of 20 cm^3. However, only about 6 cc of fluid sample is needed. The vial is sealed with a suitable elastomeric plug, which is secured with a metallic crimp cap, Figure 1.

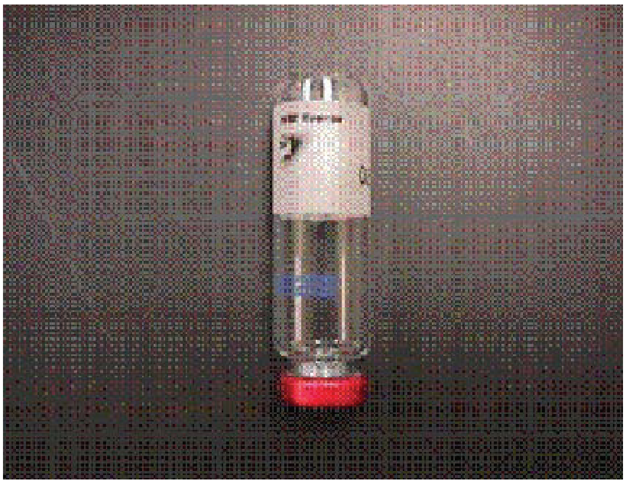

Figure 1: Disposable Glass Vial with a Crimp-Top

Quick-Connect Vial Holder: This is made up of a quick-connect coupler modified to hold the disposable crimp-top vial. Figure 2 shows two views of the quick-connect vial holder. An additional rubber septum is incorporated into the quick-connect coupler, shown lower in Figure 2. This septum not only provides a platform for the crimped-top vial but also improves the overall needle penetration process, avoiding any contamination.

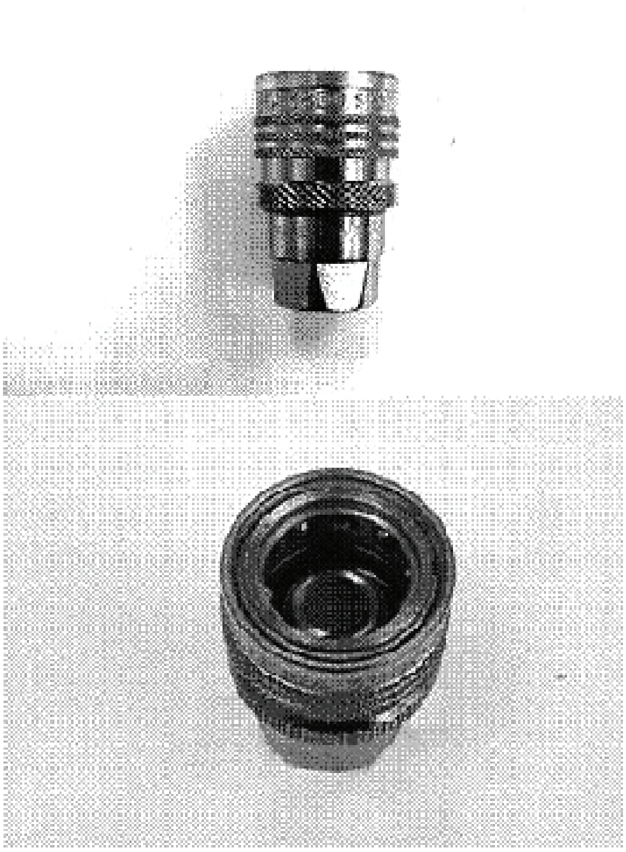

Figure 2: Horizontal and Top Views of the Quick-Connect Vial Holder

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Metallic Housing with Needle and 3-way Valve: This arrangement is shown in Figure 3, and represents the adapter incorporating a hollow needle through which the fluid is admitted into the vial by means of a 3-way valve. The metallic housing protects the needle.

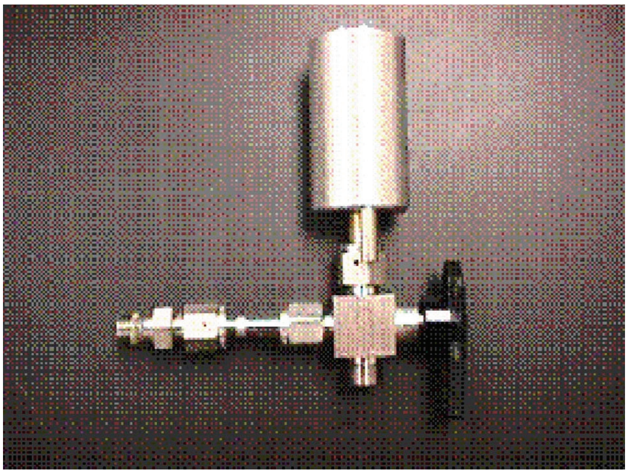

Figure 3: 3-way Valve with Protected Hollow Needle

EDOSS Sampling Procedure:

A schematic diagram of the key components of the EDOSS system, as they are put together in sequence of sampling, is illustrated in Figure 4. With the aid of this sequential schematic diagram, the sampling procedure is described as follows:

The EDOSS sampling vial is under vacuum, with a shelf life of about 8 weeks from the date of preparation. The date of preparation is inscribed on the vial and is represented by the left most 4 digits, with two digits for a month, and two digits for the day.

- Attach the sampling tool to the equipment being sampled utilizing proper reduction fittings.
- With the valve handle pointing toward the ground, open the equipment valve to flush about one quart of fluid. This operation cleans all the connecting fittings and pipes.
- Point the valve handle toward the needle by rotating it 180° and allowing a few cc of fluid to flush through the hollow needle.
- While fluid slowly drains out of the needle, install a glass vial in the vial holder. This is accomplished by pulling down the outer ring of the vial holder with a spring-loaded mechanism, inserting the vial and then releasing the outer ring. The spring-loaded mechanism should close by itself and hold the vial firmly in place.
- Push the vial holding unit with the secured vial into the needle housing as shown in Figure 4. Fluid will rush into the vial as soon as the needle passes through the rubber stopper.
- Allow fluid to reach the center blue line as shown in Figure 4 at e and pull from the glass vial until it is released from the vial holder. You can leave the valve open until the next sample, or close the valve as the proper level of fluid is reached.
- Two samples should be taken at every location.

The EDOSS sampling set-up for a HPFF cable is shown in Figure 5.

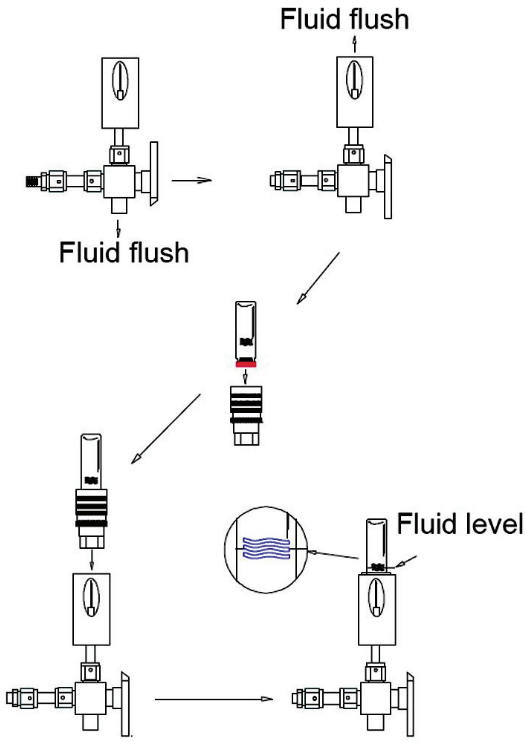

Figure 4: A Sequential Schematic Diagram of EDOSS

Figure 5: Sampling of a HPFF Cable by EDOSS

DGA Data on Field Cable Systems by EDOSS

It is now increasingly recognized that DGA offers an effective means to assess the condition and life of an operating laminar dielectric cable system, and the US experience provides ample support.

DGA has many unique features: (a) High measurement accuracy; (b) High sensitivity to electrical/thermal stresses, distinguishing each stress; (c) Low detection limits with readily available, relatively low cost equipment; (d) Apparently higher sensitivity than PD measurements; at any rate, exceedingly more economical approach; (e) Once formed, dissolved gases stay in place -accumulative process - not intermittent like corona activity; (f) Can locate a problem source through fluid movement; (g) Potential for rough remaining life assessment via carbon oxides; (h) Sampling on energized HPFF/HPGF cables, but not terminations and SCFF cables; however, the bottom of 230 and 345 kV HPFF terminations can be sampled, albeit with due care - done on several occasions.

The sampled cable systems include HPFF, HPGF and SCFF cables and their accessories. Since the vast majority of the US underground transmission is comprised of HPFF cable systems, the bulk of data generated by EDOSS/EPOSS methods are based on HPFF cable systems, with a good representation of HPGF and SCFF systems – the latter data include some non-US systems.

Under normal and sometimes unusual electrical and thermal stresses to which in-service cables are subjected, lower and higher hydrocarbon gases (acetylene, ethylene, ethane, methane, propane, propylene, and isomers of butane), hydrogen and carbon oxides are evolved. Depending on the severity of the problem, the type, distribution and concentration of these gases vary, thereby offering clues as to the condition of the cable system. The satisfactorily operating cable systems have a minimal gas content, despite long service, unless the original fluid came with some gases. This has been observed for several HPFF cable systems, but never in their SCFF counterparts, where due attention is paid to the gas content of the fluid along with other dielectric properties such as dissipation factor, breakdown and moisture.

Of all gases, acetylene is the single, most important gas, and is related to strong electrical activity involving an electric arc, howsoever, feeble. The other gases of importance include hydrogen, ethylene, ethane, methane, isobutylene (particularly for polybutene fluids, the starting material of which is the isobutylene gas), and carbon oxides. While the individual gas levels are important, one has to look at the entire gas pattern as a whole to draw sound conclusions. This is due to the fact that the generation of several gases is interrelated. For example, acetylene is almost invariably accompanied by hydrogen and ethylene, although the levels of the latter two gases vary, depending on the nature of the problem. It is not sufficient to address only the gas ratios, which are independent of individual concentration levels.

The DGA experience of other cables is useful, however, focus on the specific cable system and its operating history with respect to any failure, rework, DGA history, and degassing is essential. The establishment of gas generation trends is valuable. The periodic monitoring allows to determine whether or not an existing problem has become more severe, dormant, less severe or a new problem has cropped up.

The DGA behavior of terminations is strikingly different from that of splices, cable per se and risers. The gas limits, gas types, and gas distributions relating to terminations are markedly different from that of cables and splices. This is a direct consequence of the field configuration involved and the limited volume of fluid in the terminations; the small amount of fluid accentuates the concentration of the observed gases. The confined nature of the small fluid volume in the long annular space between the termination housing and limited mixing with the cable fluid requires a different sampling procedure to cover the entire termination length. This is due to the fact that, once formed, the dissolved gases tend to stay in place, and move only when the fluid moves or is made to move. The sampling procedure consists of draining a few small instalments of fluid relative to the total volume as DGA is performed to account for the entire termination length. Both top and bottom valves, when available, should be utilized for sampling. If the latter is not available, three from the top port will suffice. For satisfactory terminations, the DGA data corresponding to the entire length are essentially the same.

The field DGA data generated by EDOSS/EPOSS are discussed for each type of cable and its accessories.

HPFF Cable Systems

HPFF cable systems have an excellent track record in the US. Because of the extensive applications in the 138 kV through 345 kV levels and advancing age, such cable systems have received the most DGA attention. HPFF cables lend themselves well to DGA, which can be performed on energized cables and splices. The ready ability of pipe fluid movement serves as an enabler to locate potential problems in the pipe section, splices, and risers. The availability of spreader heads/trifurcators further aid in the DGA focus on cable sections and risers, as valves are not always provided on the risers. Compared to the 230 kV and 345 kV terminations, the 138 kV level counterparts have experienced more problems. Cable problems at 138 kV have been rather rare, despite some very old systems. However, 345 kV splices and probably cables per se have encountered a larger share of problems compared to 345 kV HPFF terminations.

The following cases, designated as A through I in Table 1, demonstrate the value of DGA to HPFF cable systems. More interesting cases were encountered for HPFF cable systems, probably because of their large U. S population. Each is briefly discussed, as follows:

Case A: This case represents a normal operation. The HPFF cable systems performing well should have a minimal gas content, unless the original fluid has been contaminated with some other gases and not properly degassed. The DGA data are based on a 230 KV cable operating only at 120 kV level for lack of demand since its installation in 1974. The absence of acetylene and very low levels of other gases should be noted.

Gases	A	B	C	D
Methane	17	52,895	266	802
Ethane	15	28,579	38	160
Ethylene	2	7.7	394	233
Acetylene	0	0	1,110	125
Propane	18	12,362	30	121
Propylene	3.2	30	108	104
Iso-butane	13	1,423	47	52
n-butane	6.6	2,103	15	54
Isobutylene	38	4,305	16	163
Hydrogen	138	271	2,527	2,081
C. Monoxide	25	25	61	299
C. Dioxide	98	360	403	911

Table 1: DGA case histories on HPFF Cable Systems

Case B: Of the over 600 different HPFF cables sampled by Detroit Edison since the early 1980s, several have shown very high levels of saturated gases such as methane, ethane, propane and butanes. Most of these cables were of the late 1960s to early 1970s vintage, when the importance of fluid shipment under high quality nitrogen blanket was not fully appreciated. Cable B, a 138 kV cable installed in 1971, falls into this category. While such a situation can complicate DGA to some extent, a careful review of the data based on other gases along with the vintage, type of fluid, and trending can allow proper assessment.

Case C: The DGA data corresponds to one of the 115 kV terminations of a 1953 HPFF cable. Based on a review of the data with a particular note of unusually excessive acetylene and relative levels of ethane and ethylene and that of propane and propylene, the termination was opened. Subsequent inspection, revealed stress cone movement and carbonization with classic dendritic formation, confirming that significant damage was present. Repairs involved removal of 10 cable paper tapes and installation of a new stress cone. The rest of the cable system was found to be normal, and continues to perform satisfactorily. The extra cable insulation (161 kV design being used at 115 kV) and the continued pressure prevented a serious event. Another 138 kV termination at a different utility with163 ppm acetylene was opened, and rebuilt as tracking was found on few outer cable tapes.

Case D: The data are elated to a 345 kV PPP SF6 termination. Based on the levels of acetylene and other lower hydrocarbon gases, the termination was opened. Extensive carbonized damage was observed on about 20 outer paper layers of the stress cone, with extensive holes at the end of the grounding copper mesh tapes. The stress cone was rebuilt. The other two terminations were also opened as their corresponding DGA levels, while lesser, were of concern. The observed reduced damage, as expected on the basis of DGA was much smaller, but enough to re-build the terminations.

Gases	E	F	G	H	I
CH4	137	354	1,810	739	542
C2H6	126	215	1,543	177	13,001
C2H4	5	243	2.1	11	141
C2H2	0	25	0	0	0
C3H8	263	169	1,226	319	21,157
C3H6	54	209	6.5	61	20
i-C4H10	698	70	235	707	1,133
n-C4H10	161	151	45	905	959
C4H8	1,881	981	17	1,980	2,568
H2	418	1,095	612,610	305,300	23,207
CO	114	999	21	99	11
CO2	655	514	333	507	99

Table 1 Continued

Cases E and F: These DGA data correspond to two splices each on two 345 kV HPFF cables at two different utilities; these cables manufactured by the same company were installed in 1973. Cable E has continued to operate well, with no problems. However, cable F suffered 7 splice failures over 1988-1997. The opening of the failed splices revealed strong TMB (Thermo-mechanical Bending) evidence. Unlike cable E, the pattern of gases in cable F was highly undesirable in terms of acetylene, carbon oxides, and the levels and ratios of ethane-to-ethylene and propane-to-propylene. The observed high concentration of carbon monoxide is extremely unusual for cables, and it suggests that the paper has been exposed to strong ionization activity. We have observed higher levels of carbon monoxide than carbon dioxide, when both dry and impregnated papers are subjected to strong ionization in laboratory investigations.

Cases G/H: The DGA data for Cable G relates to a 69 kV HPFF cable installed in 1966, while the DGA data for cable H corresponds to a 345 kV HPFF cable installed in 1974. The exceedingly large concentrations of hydrogen should be noted. Acetylene is absent, and the levels of other important gases are relatively quite small. Both cables are in service. In addition, we have encountered very high levels of hydrogen (25,000 -225,000 ppm) in a few other HPFF cable systems, 138 kV -230 kV. It must be pointed out that such high levels of hydrogen were true for less than 1% of the large sampled cable population; moreover, the high hydrogen was confined only to certain lengths of the affected cables. Unlike SCFF cables, the very geometry of a HPFF cable (skid wire, internal connections within the splice housing toward the header, outer shielding) can lead to hydrogen evolution, which is essentially confined to the fluid phase. To avoid any bubble formation, it is recommended to replace or degas this high hydrogen-bearing fluid.

Case I: This case represents DGA data on a sample taken from the pressurizing plant associated with a 35 years old 138 kV HPFF cable. A hydrogen concentration of 23,207 ppm is not at all expected in a reservoir fluid sample; a mass balance of its headspace hardly showed any hydrogen. While hydrogen generation is attributed to low level ionization, it can also evolve from the rusting of iron. A later-added valve with a 0.3 meter old pipe to the reservoir bottom raised some suspicion. Once a gallon of fluid was drained from this old piped-valve and another DGA sample taken, the hydrogen level reduced to about 3,000 ppm. This field case not only demonstrates the chemical generation of a high level of hydrogen but also the confinement of dissolved gases in the region, where formed. The high levels of saturated hydrocarbon gases (propane, ethane) came with the fluid and were observed in the cable.

The HPFF cable systems offer a convenient means to locate a potential problem by fluid drainage. To resolve a high level of hydrogen, with the virtual absence of all other gases, observed in a 1963, 230 HPFF cable, fluid was moved at the affected splice, as shown in Figure 6. As shown in this Figure, the hydrogen level first increased from 23,682 ppm to 24,225 ppm and then fell to 15,770 ppm, as the drained fluid volume reached about 160 gallons. A knowledge of cable geometry and direction of fluid flow indicated that the peak hydrogen level corresponded to near the end of the splice. Upon opening, TMB was observed with modest electrical activity. The splice was rebuilt.

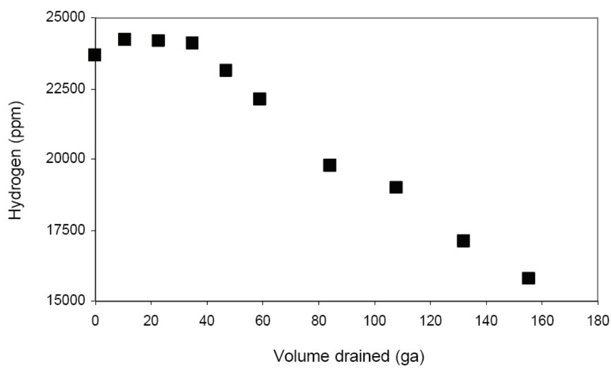

Figure 6: Hydrogen vs. Drained Fluid at a 230 kV HPFF Splice

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HPGF and SCFF Cable Systems

Table 2 shows the DGA data on these two types of cable systems. Unlike HPFF and SCFF cable systems, evidently, a gas sample from a HPGF cable system cannot be taken in a glass syringe or glass vial. The nitrogen gas sample was taken in a steel cylinder and then directly analyzed.

Gases	J	K	L	M
Methane	3.29	48.7	20	12
Ethane	1.063	1.5	5	7
Ethylene	2.564	8.9	4	6
Acetylene	0.016	14.4	3.3	0
Propane	0.757	0.2	5	6
Propylene	1.516	2.1	3	4
Iso-butane	0.367	0.6	1	1
n-butane	0.411	0.02	2	1
Isobutylene	4.29	6.6	2	3
Hydrogen	188.5	564.9	1,359	170
C. Monoxide	7.5	412.9	20	8
C. Dioxide	31.3	98.7	98	30

Table 2: DGA on HPGF and SCFF Cable Systems

Cases J/K: The GA (gas analysis rather than dissolved-gas analysis for a gas cable) for a 47-year 120 kV HPGF cable, taken at a splice, is shown for cable J. While the gas levels for HPGF cables are quite small, they follow the same principles are as their dielectric fluid counterparts.

This is further supported by the data for a 138 kV HPGF cable, K. Although the GA samples from cable K were taken after one-month of failure, nevertheless, they display the classic gas pattern of trouble. The relatively high levels of acetylene, and the levels of ethylene, ethane (and their reverse ratios compared to normal situations) together with such reverse ratios for propane and propylene as well as carbon dioxide and carbon monoxide reflect the circumstances. The magnitude of various gases must have also been affected, to some extent, by the effort in fault location.

The DGA data for a 138 kV SCFF case is shown as cable L in Table 2. Unfortunately, the pressurizing reservoirs unhinged because of serious water problems in one of the manholes. As a result, the cable experienced several problems after 18 years of service due ingress of some water. The data relate to a manhole that eventually encountered a failure. Because of poor service record, this cable was replaced.

The DGA data for one of the 230 kV phases of a 15-year old SCFF cable (M) is shown. The relatively low gas concentrations do not indicate any problems at all. However, it must be mentioned that the gas concentrations in SCFF cable systems are quite small, compared to HPFF cable systems. While the SCFF cables start with well degassed fluid, the relatively small fluid volumes associated with such cables, accentuate the effect of gases as is the case for HPFF terminations. The same amount of a gas in a large and a small volume of fluid, will result in higher ppm in the latter volume. It follows that the concern gas levels for a SCFF cable splice would be higher compared to a HPFF cable splice.

Conclusions

Based on the work presented in this paper, the following conclusions can be made:

A novel DGA method called EDOSS (EPRI Disposable Oil Sampling System) has been developed, specifically for laminar dielectric cables. The uniqueness of this method lies in the fact that the fluid sampling and subsequent analysis are performed in the same container – the only known such system. It is easy- to-use, light, inexpensive because of its disposable vial, lends to automation, and requires a small fluid volume – an advantage for low fluid volume equipment. It is based on headspace principle and fabricated out of commercially available components.

This method has been successfully applied to all types of laminar dielectric cables and their accessories. Depending on the cable type, the DGA behaviour varies significantly. This also holds for terminations versus the cables.

Acknowledgements:

The EPRI support is deeply appreciated along with that of several North American and foreign utilities, too numerous to mention. Special mention should be made of Dr. Reza Ghafurian of Consolidated Edison for his continued support and contributions.

References:

[1] Singh N., Morel O., Singh S.K., 1995, "*A Novel Method to Monitor the Condition of Fluid Filled Taped Cables Employed in Underground Transmission Through Dissolved Gas Analysis* ", EEIC Conference, Illinois.

[2] Singh N., Morel O., Butucel B. and Rochen M., 1991, "*Development of an Oil Deterioration Test Method to Monitor the Condition of High-Pressure Fluid-Filled Paper Cable",* EPRI Final Report, EL-7488-L, Research Project 77895-1.

[3] Singh N. and Morel O., 1998, "Dissolved Gas Analysis (DGA) by EPRI Disposable Oil Sampling (EDOSS)", EPRI Final Report, TR-111322.

[4] Singh N. and Morel O., 1999, "*Dissolved Gas Analysis (DGA) for Fluid Filled Terminations of Extruded Transmission Cables",* EPRI Report, TR-114197.

[5] INNOVATORS with EPRI Technology, 1992, "*Dissolved Gas Analysis Ensures Continued Operation of 115-kV High-Pressure Fluid-Filled Cable System",* IN-101579.

[6] INNOVATORS with EPRI Technology, 1992, "*Accurate Gas Analysis Reveals Damaged Cable Section",* IN-100114.