ASSESSMENT OF PERFORMANCE PARAMETERS BASED ON OIL AND PAPER CONDITION

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Abstract

This paper examines the influence of the oil insulation system on the solid insulation system for three types of transformers—nitrogen blanketed, membrane, and open conservator. Degree of polymerization (DP) test results for paper samples obtained from transformers are also grouped for two types of oil preservation systems (open conservator and nitrogen-gas blanket).

Introduction

It is generally recognized that the condition of the cellulose insulation affects the performance and life expectancy of power transformers. Interestingly, we have found that the chemical condition of the insulating oil in power transformers influences the condition of the cellulose insulation. Also, the condition of the insulating oil is greatly influenced by the extent of oxidation that has occurred. Oxidation of the oil produces organic acids; oxidation of the cellulose produces water. Both of these products increase the rate of degradation of the solid insulation system and consequently contribute to the transformer's loss of life.

Power Transformers Studied

The interfacial tension (IFT) and the neutralization number (NN) test results of the oils from 180 power transformers belonging to CPFL were analyzed in order to assess the influence of different oil preservation systems on the preservation of the oil itself. These units were fitted with three types of oil preservation system — nitrogen blanketed, membrane, and open conservator. Out of the 180 power transformers, 30 have an open conservator, 113 have a membrane, and 37 have a nitrogen-gas blanket. Out of the 37 units with a nitrogen-gas blanket, four of them had previously open conservators, but a bladder filled with dry nitrogen at approximately atmospheric pressure was fitted to their conservators a few years ago.

The IFT and the NN test results of each transformer were carefully analyzed before plotting them. In the case of the units with open conservators, several of them had their oil reclaimed several times over the years. In such cases, all of the test results obtained after the first reclamation were discarded to prevent a biased assessment of the influence of the oil preservation system on the transformer insulation preservation condition.

Figure 1 and 2 show the NN and IFT test results for the three types of oil preservation system. The NN of the oils of the transformers with open conservators are typically very high as compared to the data obtained for the other two types of preservation systems. Interestingly the data show that the NN of the oils of several transformers fitted with a membrane system reached values higher than 0.15 mg KOH/g even before 10 years in service (Figure 1-B). Several test results ranging from 0.15 – 0.35 KOH/g can be seen in the oils of units with membrane. Such an observation is very important because membrane systems are typically used in Brazil as an improved oil preservation system as compared to open conservators. However, the service performance of the oils of transformers with membrane systems is not significantly better as compared to that of the oils of units with open conservators. In several cases, membranes rupture and allow the contact of the oil with atmospheric air.

A very good long-term service performance was observed for the oils of transformers with nitrogen-gas blanket. Figures 1-C and 2-C present the NN and IFT test results of the oils of units in service for more than 30 years (360 months). Only after 30 years, some oils presented NN test results ranging from 0.10 – 0.15 KOH/g. This occurred because a few units leaked nitrogen, and atmospheric oxygen contaminated the oil. Figures 3 and 4 show the NN and IFT test results of three single phase transformers, rated 138/69 kV, 15 MVA, of the same vintage (7580, 7581 and 7582 company numbers). While units 7581 and 7582 presented no leaks, unit 7580 leaked for a few years. Consequently, the service performance of its oil was greatly impaired.

A comparison of the average performance of the three types of the oil preservation systems discussed here can be seen in Figure 5 for the NN. As can be seen in the figure, the service performance of the oil of transformers with nitrogen-gas blanket is very superior as compared to the other two types of oil preservation system. Such a good performance encouraged some of us to develop a bladder system filled with dry nitrogen at atmospheric pressure to be installed in open-conservator and membrane transformers. To install the bladder system, the silica gel canister is removed, and the bladder is connected to the pipe of the oil expansion tank. After the system is installed, the oil contamination with both oxygen and moisture from atmosphere is greatly minimized. Open-conservator and membrane transformers cannot operate under pressurized nitrogen to prevent gas bubble formation. In order to comply with a such a requirement, the nitrogen gas in the bladder is maintained at atmospheric pressure. As the oil temperature increases or diminishes, the bladder is allowed to inflate or to deflate, respectively.

Figure 6 and 7 show the NN and IFT test results of the oils from four originally open-conservator units. The test results were obtained after bladder systems had been installed on these transformers.

The influence of the type of oil preservation system can also be seen on the service performance of the insulating Kraft paper. Figure 8 presents the degree of polymerization (DP) test results obtained from paper samples collected from the windings of both open-conservator and nitrogen-gas blanketed power transformers. As can be seen in the figure, the DP test results for paper samples obtained from nitrogen-gas blanketed transformers are much higher than the results obtained from open conservator units. The DP test results of the nitrogen-gas blanketed units were obtained from the literature published by Griffin et al. [1-3]. All of the open-conservator units referred to in the figure belong to CPFL power system.

Conclusion

The data presented in this paper show that the service performance of insulating oils in power transformers is greatly influenced by the type of the oil preservation system used. The oil in nitrogen-blanketed has improved service performance, while the oils in membrane units is only slightly better than that of those with open conservators. Degree of polymerization (DP) test results for paper samples obtained from nitrogen-gas blanketed transformers are much higher than the results obtained from open conservator units.

The important consequences of this study concern the relationships between oil and paper condition assessment and strategic decisions related to the maintenance and operation of power transformers. The impact of these decisions on loading capabilities, life expectancy, and asset valuation has also to be taken into consideration.

References

1. P.J. Griffin, “Measurement of Cellulose Insulation Degradation: a Study of Service-Aged Transformers”, Paper 10-4.1, presented at the Fifty-Nineth Annual International conference of Doble Clients, Boston, MA (April 1992).

2. P.J. Griffin, and L.R. Lewand, “Measurement of Cellulosic Insulation Degradation Compounds in Oil”, Paper 10-3.1, presented at the Sixtieth Annual International conference of Doble Clients, Boston, MA (April 1993).

3. P.J. Griffin, “Paper Degradation By-Products Generated under Incipient-Fault Conditions”, Paper 10-5.1, presented at the Sixtieth-First Annual International conference of Doble Clients, Boston, MA (April 1994).

Biographies

Jose Mak

Mr. Jose Mak is the president of Bassetto & Mak Engineering Services that provides consulting and maintenance services to improve the service performance of high-voltage power apparatuses. For 22 years, Jose worked for CPFL, where he was involved both in several research studies involving the aging of both Kraft paper and electrical insulating oils, and in developing new maintenance techniques for high-voltage power apparatuses.

Mr. Mak obtained his BSEE from the Federal University of Juiz de Fora, Brazil.

Armando Bassetto F., PhD

Dr. Armando Bassetto is the president of Bassetto & Mak High-Voltage Technologies that develops technologies to improve the service performance of high-voltage power apparatuses. For 22 years, Armando worked for CPFL, a Brazilian Power distribution utility, where he was responsible for several research studies involving the aging of both Kraft paper and electrical insulating oils.

Dr. Bassetto obtained his PhD degrre from the University of Sao Paulo (USP), Brazil.

Ted J. Haupert, PhD

Dr. Ted Haupert is Professor Emeritus of Analytical Chemistry at California State University-Sacramento. He is an owner of TJ/H2b Analytical Services, Incorporated that specializes in chemical analyses exclusively for the electric power industry. He is involved with the development of testing methods related to dielectric materials (liquid, solids, and gases) that can provide for the assessment of the condition of electrical equipment.

Dr. Haupert is a graduate of the University of Wisconsin-Madison and since 1972 he worked in the area of developing analytical methods related to insulating materials. He is a member of the American Chemical Society, the Society of Sigma Xi, the Association of Official Analytical Chemists, the Insulating Fluids Subcommittee of the IEEE, and the Insulating Liquids and Gases Committee of the ASTM.

David L. Hanson, MS

Dave Hanson has a master's degree in chemistry and is the general manager of TJ/H2b Analytical Services, Inc. He has been active in the field of insulating materials testing since 1978. He has been involved with the development of test methods and diagnostic criteria for high-voltage electric equipment. His involvement extents to transformers, tap changers as well as gas- and oil-filled circuit breakers.

Marcelo De Moraes

Mr. Marcelo De Moraes is an engineer of the Engineering Department at CPFL. For 10 years, Marcelo worked at CPFL Insulating Oil Laboratory. He is presently responsible for assessing maintenance performance parameters of high-voltage power apparatuses on CPFL’s substations.

Mr. De Moraes obtained his BSEE from the Engineering College of Sorocaba, Brazil.

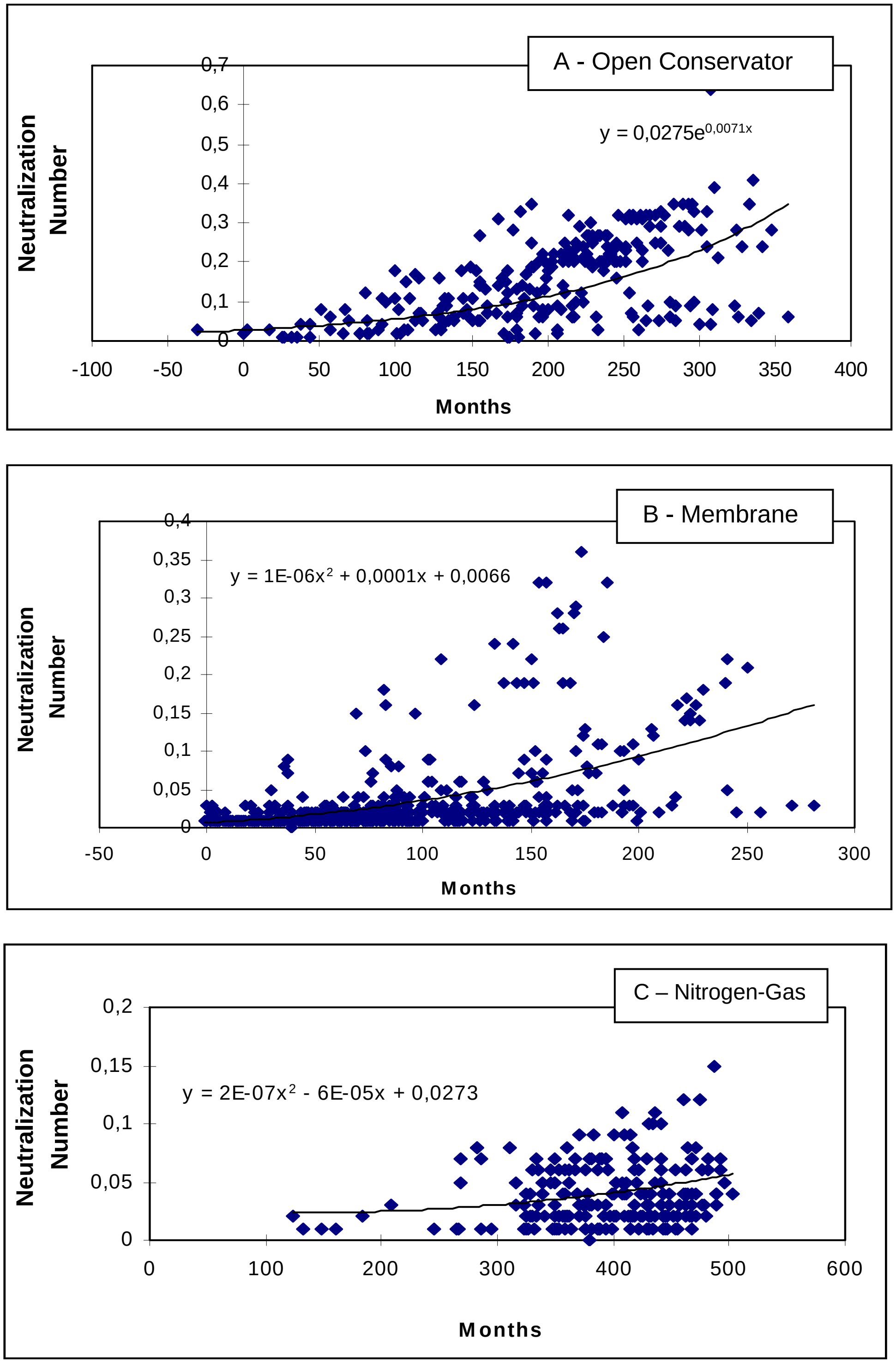

Figure 1
Comparison of NN (mg KOH/g) Test Results of Oils from Open-Conservator, Membrane and Nitrogen-Gas Blanketed Power Transformers

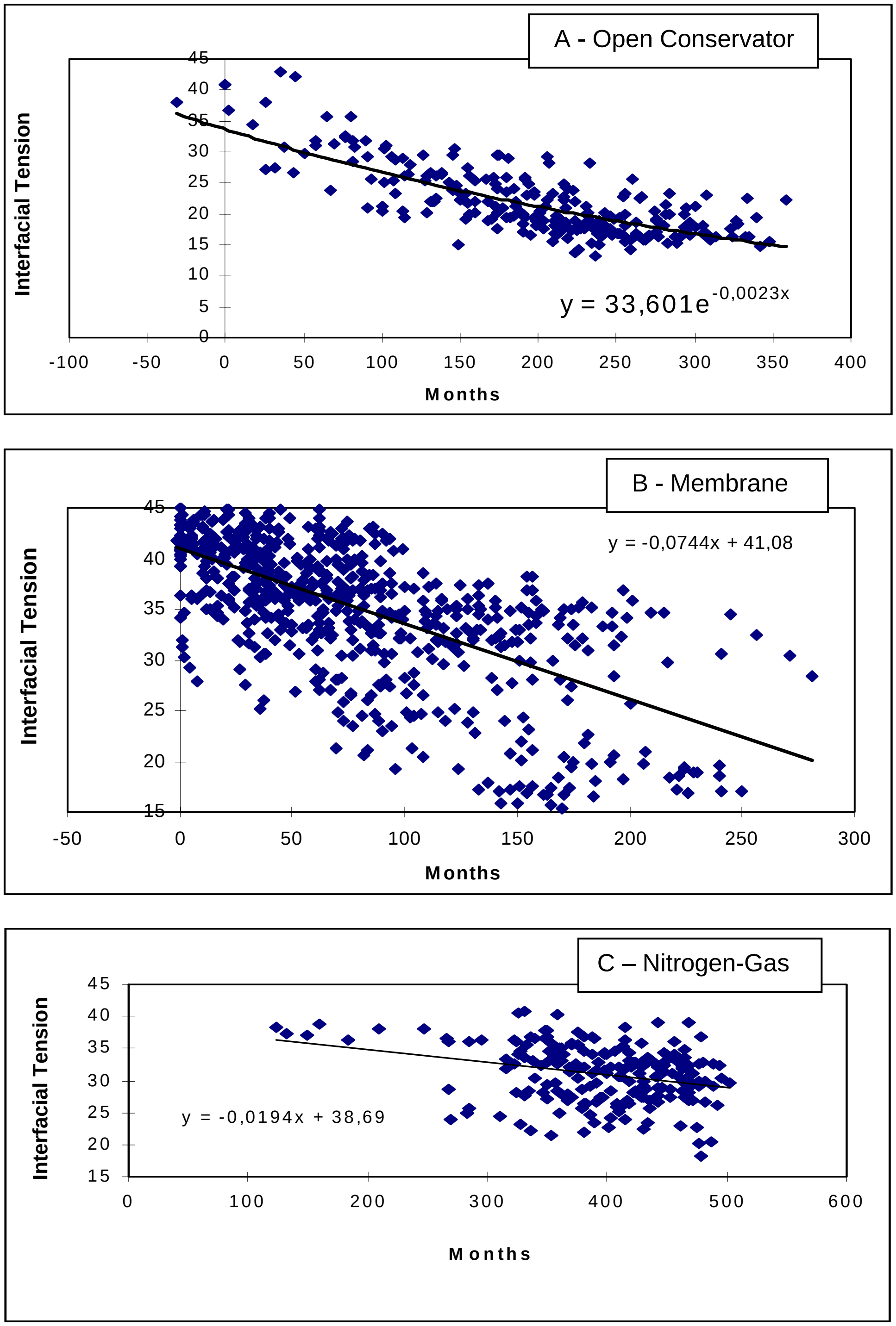

Figure 2
Comparison of IFT (dyne/cm) Test Results of Oils from Open-Conservator, Membrane and Nitrogen-Gas Blanketed Power Transformers

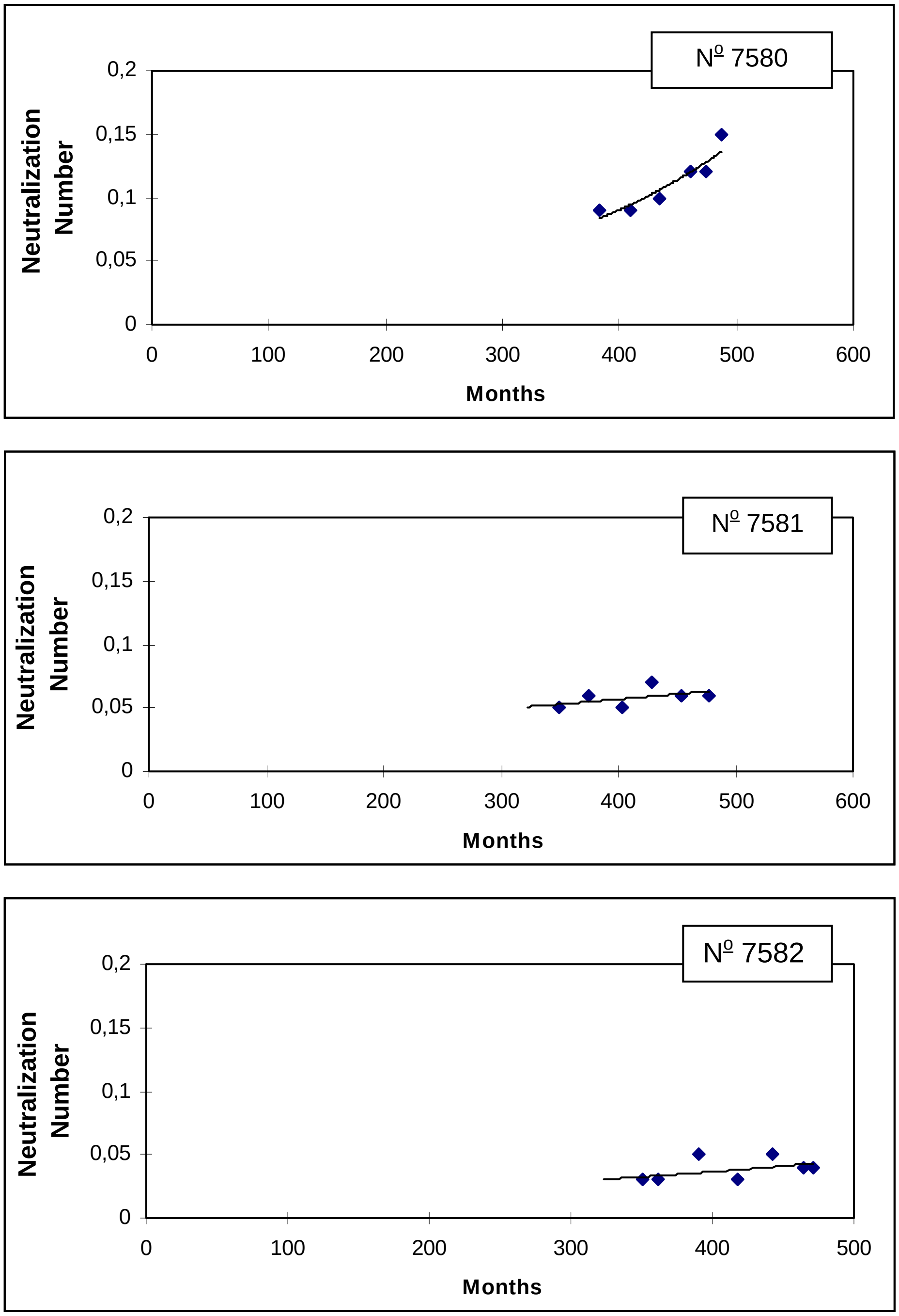

Figure 3
NN (mg KOH/g) Test Results of Nitrogen-Gas Blanketed Power Transformers (138/69 kV, 1 phase, 15 MVA)

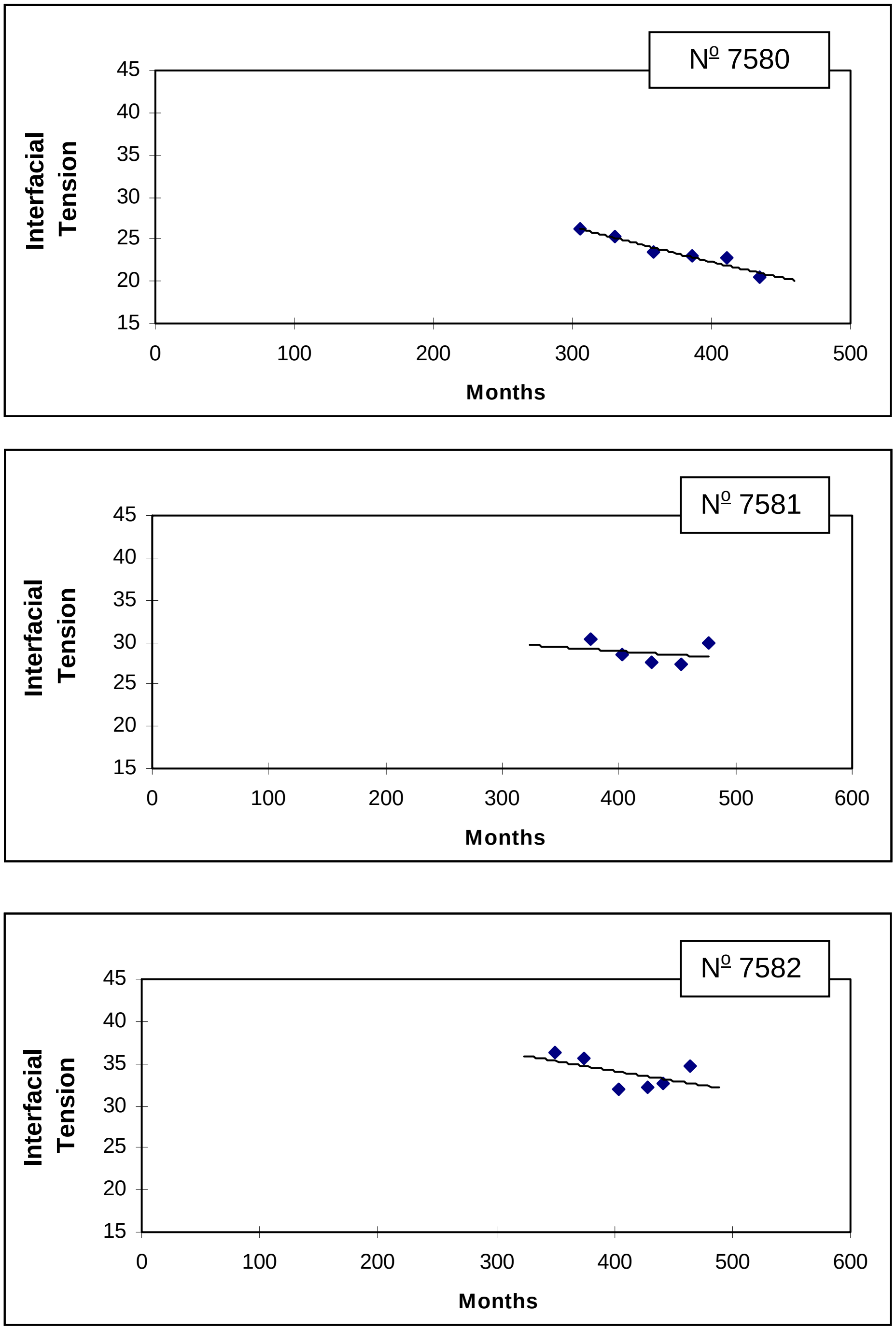

Figure 4
IFT (Dyne/cm) Test Results of Nitrogen-Gas Blanketed Power Transformers
(138/69 kV, 1 phase, 15 MVA)

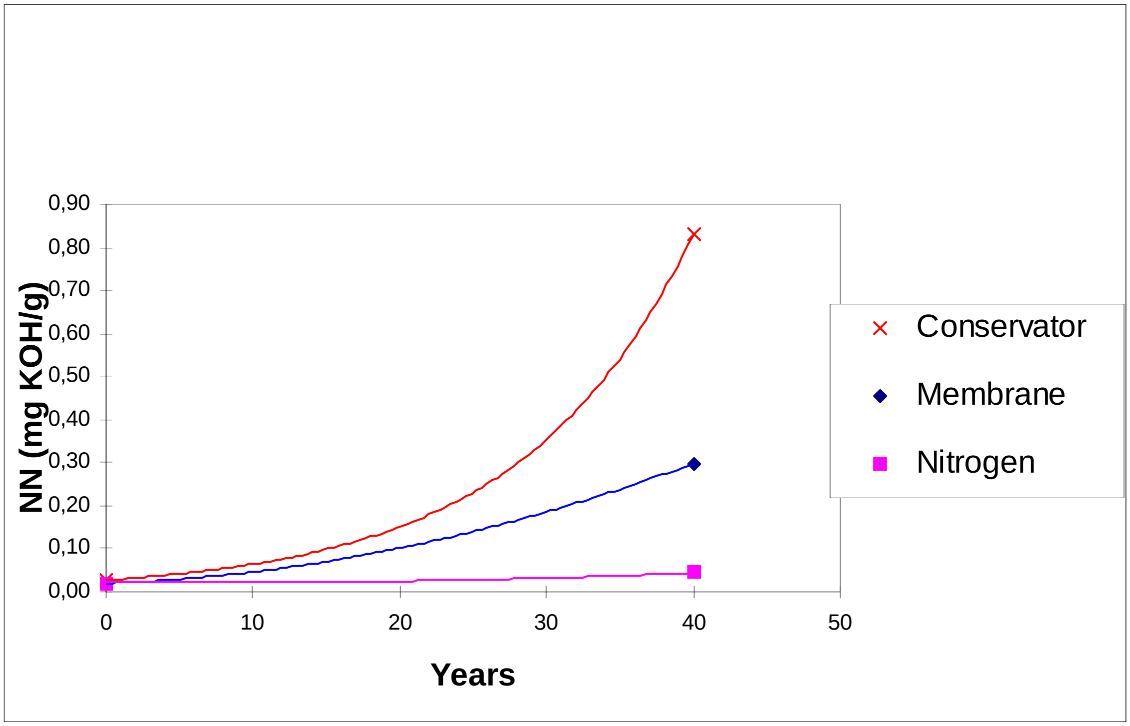

Figure 5
Comparison of Average NN of Oils from Open-Conservator, Membrane and Nitrogen-Gas Blanketed Power Transformers

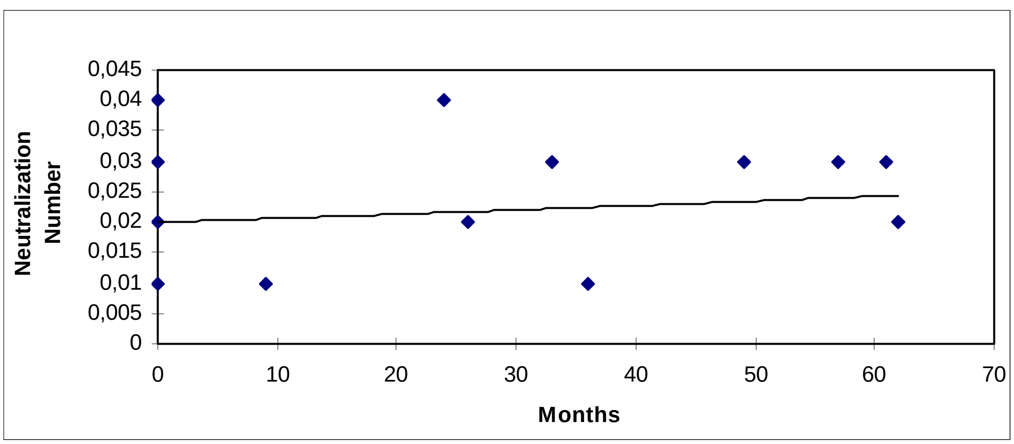

Figure 6
NN (mg KOH/g) Test Results of the Oil from a Power Transformer with Nitrogen-Gas Bladder System

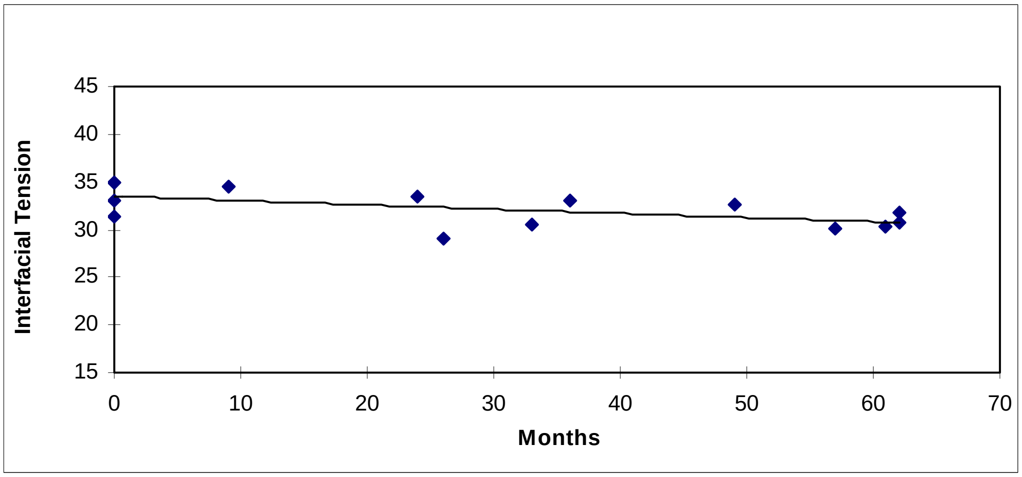

Figure 7
IFT (Dyne/cm) Test Results of the Oil from a Power Transformer with Nitrogen-Gas Bladder System

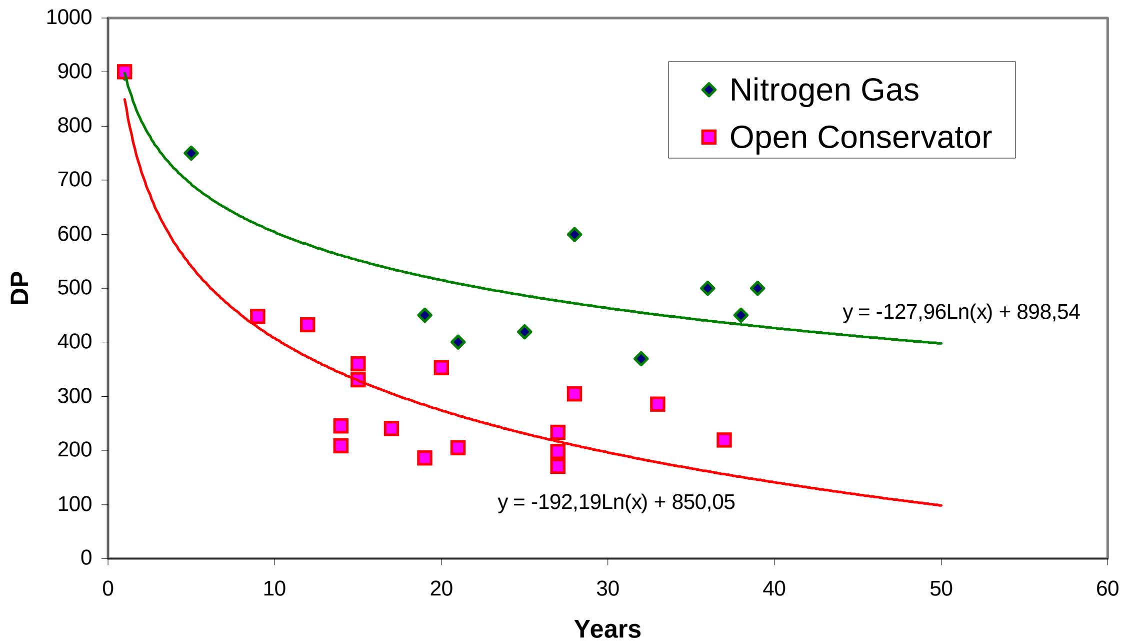

Figure 8
Comparison of DP Test Results from Nitrogen-Gas Blanketed and Open-Conservator Power Transformers