DISCUSSION OF THE PAUL J. GRIFFIN PAPER,

"MEASUREMENT OF CELLULOSE INSULATION DEGRADATION:
A STUDY OF SERVICE-AGED TRANSFORMERS"

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I wish to commend Paul Griffin for a very interesting paper, which contains much useful data. When tabulating these data (Table 30), Mr. Griffin included several important parameters for a better assessment of the aging conditions of each case individually. This discussion will concentrate on analyzing the cases where the paper samples were collected from the windings, and the information on the estimated water and oxygen contents, oil condition, type of paper and load were all available. Out of the 28 cases presented in the paper, 13 of them had all of these parameters supplied. However, one of them (Case 1) was not included here because it was the only shell type unit.

The first distinction made between the 13 cases analyzed was the type of paper. The units containing thermally upgraded Kraft paper were tabulated in Table I of this discussion. Those transformers insulated with regular Kraft paper were included in Table II. To facilitate the comparison between the units, they were listed in order of their service age.

The comparisons in Table I were made to try to assess the influence of oxygen and water on the aging of thermally upgraded Kraft paper under service condition. Cases 16 and 20 were aged nine years in service under estimated similar conditions, except for the oxygen content of their oils. As can be seen, the estimated high oxygen content of Case 20 did not accelerate paper aging as compared with that of Case 16. Probably as paper ages, a more significant effect will be noticed. In Case 7, for example, the unit also contained an estimated high oxygen content, and a very intense aging was noticed despite the estimated low loading. In accord with Mr. Griffin's statement, the difference in aging between the 11 paper wraps around the conductors of this unit (Table 8 of the paper) may be attributed to oxygen.

A more intriguing fact can be seen when analyzing Cases 5, 13, and 15. All the three cases were at an approximately similar service age, ranging 19-23 years. Though the unit of Case 5 was low loaded, those of Cases 13 and 15 were high loaded. The three units also had estimated low oxygen content and ou contamination. The main difference between them was that the water content of the oil of Case 15 was moderate, while the other two had a low water content. The aging recorded for Case 15 was very significant. Probably the high loading and the moderate water contamination have acted in conjunction to accelerate paper aging. In accord with a laboratory study, Shroff and Stannett[1] stated that thermally upgraded paper would be much less affected by water and oxygen than Kraft paper. Based on the service data shown, it would be very encouraging to analyze several other similar cases to assess more precisely how such a statement applies to service-aged Upgraded paper. It may be possible that water has an important influence on the aging of upgraded paper under service condition.

The marked influence of water and oxygen on Kraft paper aging can be seen in Table II. When analyzing Cases 8 and 18, it is not difficult to conclude that oxygen may have accelerated the paper aging of Case 8 as compared with that of Case 18. The analysis of the three following cases is even more conclusive concerning the effect of both water and oxygen. Though the unit of Case 12 had an ou in good condition and its oxygen and water contents were low, it was loaded to nameplate. Even so, its paper was much less aged than those of Cases 4 and 17, which were moderately loaded, but contained high oxygen and water contents,

As well as a contaminated oil. Concerning Case 3, its low loading may have had a positive influence for obtaining a long service life since all the other parameters were in a poor condition.

Figures 3 and 4 show a great dispersion in the DP test results. If there were more data available, it would be more interesting to plot in the same graph only the data from transformers aged under comparable condition such as loading, oxygen and water contents, oil contamination, and paper type. Obviously, this will require much more data and time to obtain meaningful information from the several graphs to be plotted, but it will be easier to study the influence of the different parameters on paper aging separately. A distinction between the paper types and the service conditions should also be made when plotting the DP test results in Conjunction with the furan rneasurements to be made.

REFERENCE

1. Shroff, D. H. and Stannett, A. W. “A Review of Paper Aging in Power Transformers,” IEE Proceedings, v. 132, n. 6, Nov. 1985, pp. 312-19.

TABLE I

COMPARISON OF DATA FROM TRANSFORMERS

INSULATED WITH THERMALLY UPGRADED KRAFT PAPER

Service Age (Years)	Case	Lowest Winding DP_v	Average Winding DP_v	Estimated Water Content	Estimated Oxygen Content	Estimated Oil Condition	Estimated Load
9	16	895	985	L	L	L	M
9	20	785	997	L	H	L	L-M
13	7	507	672	L	H	L	L
19	5	757	815	L	L	L	L
20	15	442	474	M	L	L	H
23	13	787	849	L	L	L	H

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TABLE II

COMPARISON OF DATA FROM TRANSFORMERS INSULATED WITH KRAFT PAPER

Service Age (Years)	Case	Lowest Winding DP_v	Average Winding DP_v	Estimated Water Content	Estimated Oxygen Content	Estimated Oil Condition	Estimated Load
31	8	274	469	L	H	L	L
32	18	370	627	L	L	M	M
36	12	447	512	L	L	L	H
37	4	200	212	H	H	H	M
40	17	206	252	M-H	H	M	M
48	3	205	206	H	H	H	L