Summary of Oil Tests and the Test Objective

ASTM Test Method	Test Type	Test Significance
D 791	(IFT) Interfacial Tension	The IFT test measures the presence of soluble contaminants and oxidation products. A decreasing value indicates an increase in contaminants and/or oxidation products within the oil.
D 974	Acid Number	The acid neutralization number is a measure of the amount of acid materials present in the oil. As the transformer ages, the oil will oxidize and increase in acidity. The acid value can also increase from contamination of other foreign material such as paint, varnish, etc...
D 1533	Oil Moisture	The Karl Fisher Moisture Test measures water ppm within the transformer oil. ** Note it does not measure the water content in the paper insulation.
D 924	Power Factor	The power factor test measures the dielectric losses of the oil, or energy that is dissipated as heat. A low value indicates low losses. It is a useful test for measuring changes within the oil resulting from contamination or deterioration.
D 877 / D 1816	Dielectric Breakdown Voltage	The dielectric test measures the ability of the oil to withstand electric stress without failure. The higher the value, the lower the presence of contaminants such as water, dirt, or other conductive particles.
D 3612	(DGA) Dissolved Gas Analysis	The DGA test measures various gas ppm levels that are present. Different gasses will dissolve in the oil that indicate various types of thermal and electrical stress occurring within the transformer.
D 1500	Oil Color	The color test is a simple test that indicates oil quality. The higher the color number is, the higher the probability of contamination or deterioration of the oil.
EPA 8082	PCB	Test the PCB ppm level of the oil

OIL ANALYSIS

Although it is important to test the oil in transformers, it is more important to know how to interpret the data from the results. No one test can be used independently to determine the oil condition. Rather, all of the results should be reviewed simultaneously to give a full understanding about what is occurring in both the oil and the transformer. This will allow you to review the options and make a decision as to how to treat the oil.

The *IEEE Guide for reclamation of Insulating Oil and Criteria for Its Use* (IEE Std 637-1985) has four group classifications for oil evaluation.

Group I: Oils that are in satisfactory condition for continued use.
Group II: Oils that required only reconditioning for further service.
Group III: Oil in poor condition. Such oil should be reclaimed or diposed of depending upon economic considerations
Group IV: Oil in such poor condition that it is technically advisable to dispose of it.

Suggested Limits for In-Service Oils Group I by Voltage Class

Test	Voltage			ASTM Test Method
	<69KV	69KV-288KV	>345KV	
Dielectric Breakdown Voltage, 60Hz, 0.100 gap (min)	26	26	26	D-877
Neutralization Number, mg KOH/g (max)	0.20	0.20	0.10	D-974
Interfacial tension, mN/m (min)	24	26	30	D-971
Water ppm (max)	35	25	20	D-1533

For oil that does not meet the recommended thresholds above, there are two options. One,the oil can be utilized in a lower voltage application, assuming it was utilized above a 69KV application. Two, the oil can be reconditioned or reclaimed to meet the Group I classification. Listed below are the thresholds for oil treatment.

Suggested Limits for in-Service oils Group II & Group III

Test	Group II	Group III	ASTM Test Method
Neutralization Number Mg KOH/g (max)	0.20	0.50	D 974
Interfacial Tension, mN/m (min)	24	16	D-971

In terms of what is actually occurring in the transformer, listed below is a sample table that provides a general summary of what's happening in the transformer based on the neutralization number and the interfacial tension value.

TRANSFORMER OIL RESULTS ANALYSIS

Oil Color	Acid (NN)	IFT	Oil Status	Transformer Condition
Water White	0.03-0.10	30-45	Excellent	Good
Yellow Tint	0.05-0.10	27-30	Good	Sludge dissolved in oil
Yellow Solution	0.11-0.15	24-27	Marginal	Acid coating insulation, sludge ready to deposit in transformer
Orange	0.16-0.40	18-24	Bad	Sludge in radiators, core & coil
Reddish-Brown	0.41-0.65	14-18	Very Bad	Sludge hardening & layering, insulation is shinking & weakening
Brown	0.66-1.5	9-14	Extremely Bad	Radiators blocked with bad sludge, increased operating temperture
Black	Over 1.5	Below 9	High Risk	Transformer failure is likely

Although the acid test determines conditions under which sludge may form, it does not necessarily indicate that sludging condition exist. The IFT test is a good indicator of the sludging characteristics of transformer oil because it correlates to the concentration of polar molecules in suspension and in the solution in the oil. Thus, the IFT test serves as an early warning to the beginning stages of deterioration.

It is Important to not just consider these two test as indicators as to whether or not oil treatment is necessary. Other oil quality results should be reviewed as well as dissolved gas analysis (DGA) results should also be considered.

Dissolved Gas Analysis

Disolved gas analysis (DGA) and the information it can provide are particulary important in analyzing the health of the transformer and determining whether oil treatment is necessary. The rate of insulation decomposition will increase significantly in the presence of faults. By drawing a sample and having the gas composition analyzed, it's possible to distinguish between different fault types.

Although transformer oil testing is important, the results will be of no use if you don't know how to interpret them. If the oil doesn't meet the recommended level base on the *IEEE Guide for Reclamation of Insulating Oil* , then it should be reconditioned, reclaimed or disposed of based on the test results.

Dissolved Gas Concentrations Limits (ppm)

Status	H_2	CH_2	C_2H_2	C_2H_4	C_2H_6	CO	CO_2	TDCG
Condition 1	100	120	35	50	65	350	2500	720
Condition 2	101-700	121-400	36-50	51-100	66-100	351-570	2501-4000	721-1920
Condition 3	701-1800	401-1000	51-80	101-200	101-150	571-1400	4001-10000	1921-4630
Condition 4	>1800	>1000	>80	>200	>150	>1400	>10000	>4630
	Hydrogen	Methane	Acetylene	Ethylene	Ethane	Carbon Monoxide	Carbon Dioxide	Total Dissloved Combustible Gas

Condition 1 - TDCG below this level indicates the transformer is operating satisfactorily
Condition 2 - TDCG within this range indicatesgreater than normal combustible levels & should prompt additional investigation. (any gas exceeding specified levels)

Condition 3 - TDCG within this range indicates high level of decomposition (additional investigation required)
Condition 4 - TDCG within this range indicates excessive decomposition. Continued operation could result in failure of the transformer