PACIFIC CREST
TRANSFORMERS

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Dissolved Gas Analysis of Liquid Filled Transformers

Hydrocarbon or mineral-based oils and silicones are used as insulation fluids in transformers because of their high dielectric strength, heat transfer properties and chemical stability. These fluids are also considered the "lifeblood" of the transformer. Just as a blood sample can provide a doctor with insight as to the health of his patient, dissolved gas analysis (DGA) of a transformer's insulating fluid provides an indication as to the general health of the transformer.

DGA has become a standard in the utility industry throughout the world and is considered to be the most important oil test for insulating liquids in transformers and other electrical apparatus. More importantly, an oil sample can be taken at anytime in most cases without having to take the equipment out of service. The ability to access the general condition of the liquid filled transformer through DGA represents a significant advantage over dry type transformers. Monitoring the dissolved gas contents over time provides the opportunity to enact preventative measures to minimize the potential of failure.

The following excerpt from the PCT web site provides a technical explanation of the process:

> *Dissolved gas-in-oil analysis, performed in accordance with ASTM D3612 or IEC 60567, is by far the most frequently requested diagnostic test and the single most important test performed on transformer oil. As the insulating materials of a transformer, break down from excessive thermal or electrical stress, gaseous byproducts form. The byproducts are characteristic of the type of incipient-fault condition, the materials involved and the severity of the condition. It is the ability to detect such a variety of problems that makes this test such a powerful tool for detecting incipient-fault conditions and for root-cause investigations after failures have occurred. Dissolved gases are detectable in low concentrations (parts per million or ppm level), which usually permit early intervention before failure of the electrical apparatus occurs, and allow for planned maintenance.*
>
> *The DGA technique involves extracting or stripping the gases from the oil and injecting them into a gas chromatograph (GC). Detection of gas concentrations*

Pacific Crest Transformers
300 West Antelope Road - Medford, Oregon 97503
Tel : (541) 826 - 2113 Fax : (541) 826 - 8847

usually involves the use of a flame ionization detector (FID) and a thermal conductivity detector (TCD). Most systems also employ a methanizer, which converts any carbon monoxide and carbon dioxide present into methane so that it can be burned and detected on the FID, a very sensitive sensor.

Syringe used for oil sampling

The primary gases that are generated by mineral oil/cellulose insulated transformers are:

- Hydrogen H2
- Methane CH4
- Ethane C2H6
- Ethylene C2H4
- Acetylene C2H2
- Carbon Dioxide CO2
- Carbon Monoxide CO

The presence of solid insulation decomposition by-products in the oil is an indication of thermal faults. The solid insulation is usually composed of cellulose material which naturally breaks down over time but the rate increases with an increase in temperature. During an electrical fault, energy is released that breaks the chemical bonds of the insulating fluid in which the fault gases are formed. The rate at which the gases are generated are different for each which when properly analyzed, can be used to determine the type of fault activity.

Interpreting oil sample dissolved gas results is an exact science. With the proper knowledge and experience the results of a DGA test can be used to produce a detailed and accurate profile of the overall condition of the insulation system. This

is made possible by the fact that different conditions within a transformer give rise to different quantities and types of gas.

When a transformer is overloaded, the temperature rises which can result in the deterioration of the cellulose insulation which leads to a build-up of carbon monoxide and carbon dioxide in the oil.

If the insulating fluid is overheated, it can lead to a breakdown of the fluid resulting in the development of thermal gases (methane, ethane, and ethylene).

Corona (partial discharge) within the transformer leads to elevated hydrogen gas levels.

Arcing within the transformer is the most severe condition and is determined by the presence of acetylene.

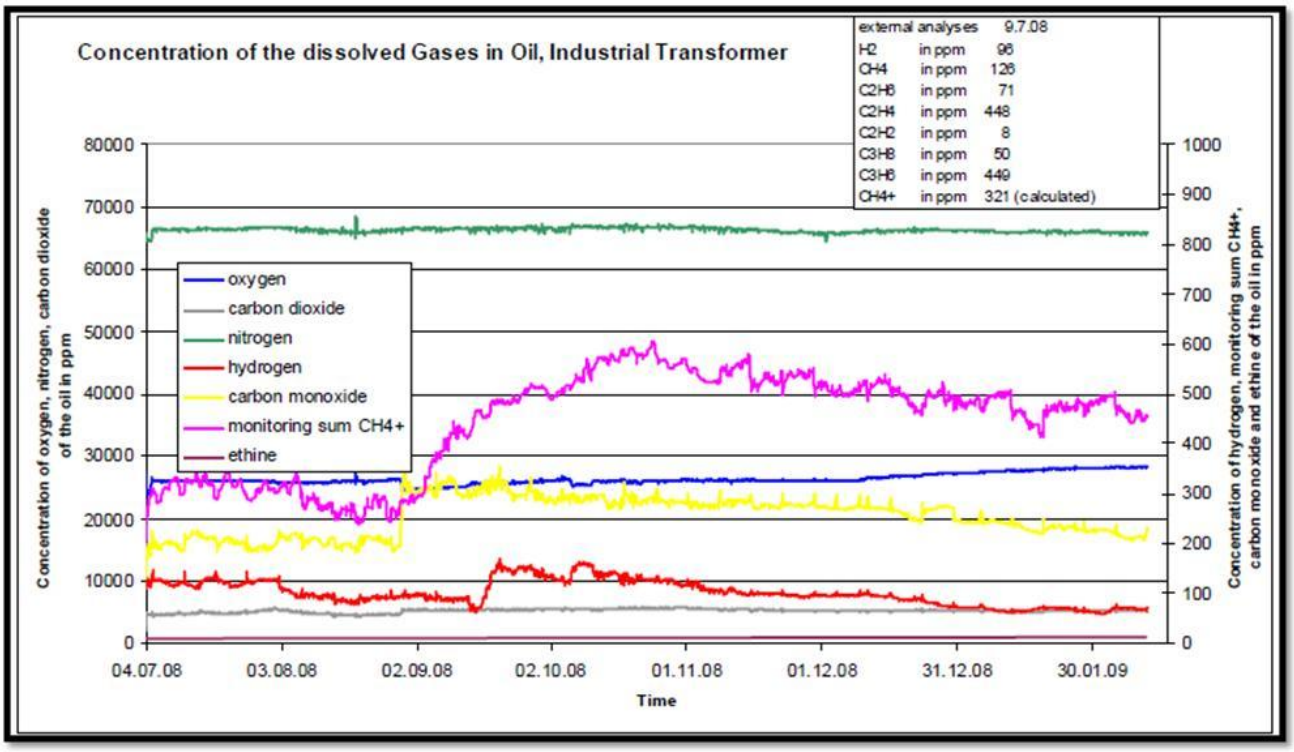
The following table is derived from information provided within ANSI/IEEE C57.104 providing a very *basic* guideline for interpretation of DGA test results.

Gas Description		Key Gas Concentration (in ppm)		
		Normal Limits* (<)	Action Limits** (>)	Potential Fault Type
Hydrogen	H_2	150	1,000	Corona, Arcing
Methane	CH_4	25	80	Sparking
Acetylene	C_2H_2	15	70	Arcing
Ethylene	C_2H_4	20	150	Severe overheating
Ethane	C_2H_6	10	35	Local Overheating
Carbon monoxide	CO	500	1,000	Severe overheating
Carbon dioxide	CO_2	10,000	15,000	Severe overheating
Total Combustibles	TDCG	720	4,630	

* As the value exceeds this limit, sample frequency should be increased with consideration given to planned outage in near term for further evaluation.

** As value exceeds this limit, removal of transformer from service should be considered.

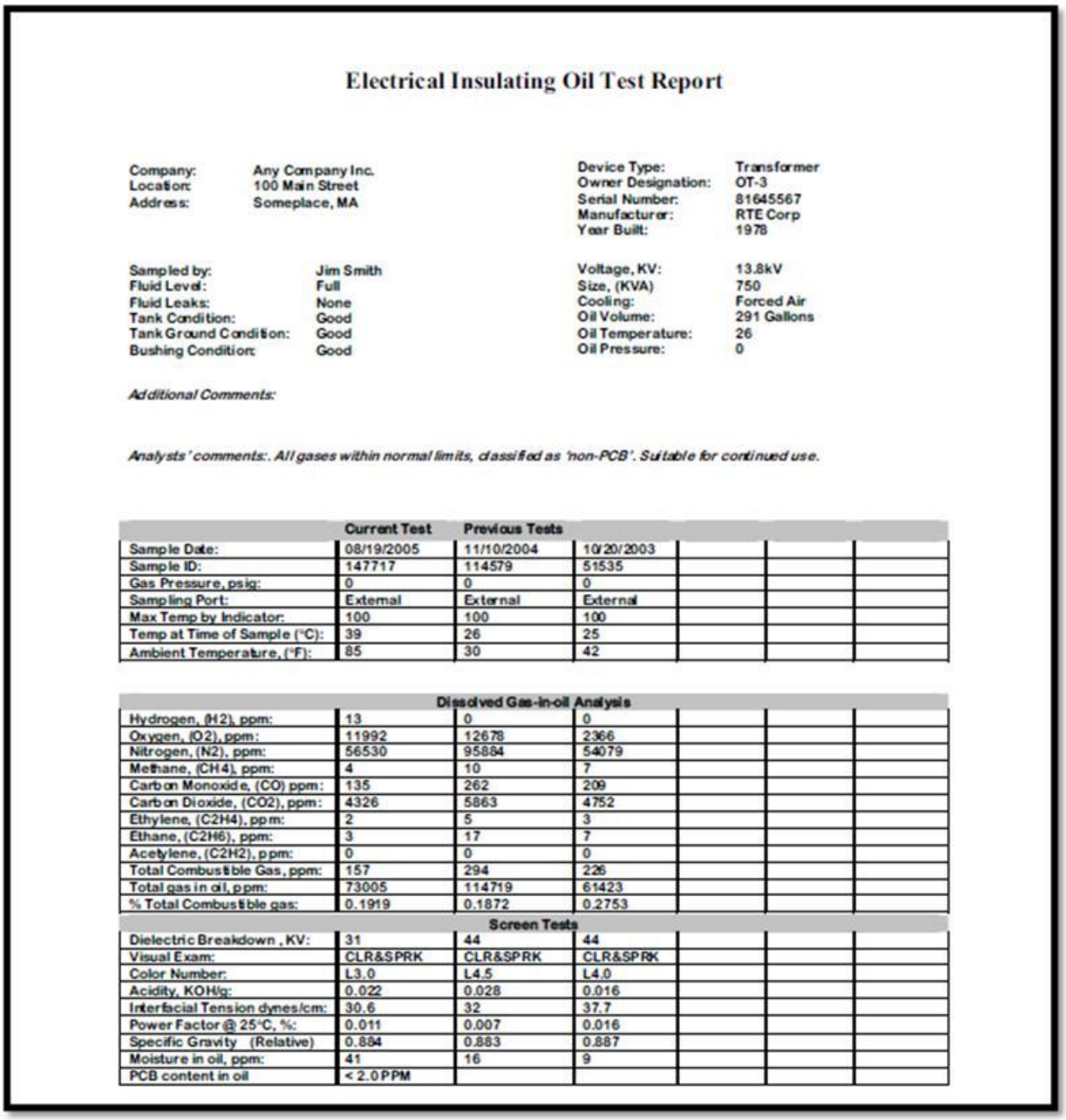
Recommended test frequency depends on a number of factors including transformer loading and the critical need for uninterrupted power. This could translate to daily testing if the initial results reveal abnormalities. If initial DGA results are “normal”, the frequency could be reduced to once per quarter or perhaps annually. Multiple testing allows one to graph the changes as depicted below.



Armed with multiple DGA test data, one can access the need for remedial action. If the test results show continued overheating due to overloading, transferring a portion of the total load to another transformer may be necessary. On the other hand, if a test report reveals the likelihood of internal arcing, a shutdown may be scheduled to allow for an internal inspection of the core/coil assembly to reveal the source.

Following corrective action, reprocessing of the oil can be performed in the field to remove the dissolved gasses from the oil. Any moisture that may have been accumulated can also be done thereby “resetting” the oil to its’ original state. In most cases the reprocessing can be done while the transformer is energized.

The following is an example of a full DGA test report.



Electrical Insulating Oil Test Report

Company:	Any Company Inc.	Device Type:	Transformer
Location:	100 Main Street	Owner Designation:	OT-3
Address:	Someplace, MA	Serial Number:	81645567
		Manufacturer:	RTE Corp
		Year Built:	1978
Sampled by:	Jim Smith	Voltage, KV:	13.8kV
Fluid Level:	Full	Size, (KVA)	750
Fluid Leaks:	None	Cooling:	Forced Air
Tank Condition:	Good	Oil Volume:	291 Gallons
Tank Ground Condition:	Good	Oil Temperature:	26
Bushing Condition:	Good	Oil Pressure:	0

Additional Comments:

Analysts' comments:. All gases within normal limits, classified as 'non-PCB'. Suitable for continued use.

	Current Test	Previous Tests				
Sample Date:	08/19/2005	11/10/2004	10/20/2003			
Sample ID:	147717	114579	51535			
Gas Pressure, psig:	0	0	0			
Sampling Port:	External	External	External			
Max Temp by Indicator:	100	100	100			
Temp at Time of Sample (°C):	39	26	25			
Ambient Temperature, (°F):	85	30	42			
Dissolved Gas-in-oil Analysis						
Hydrogen, (H2), ppm:	13	0	0			
Oxygen, (O2), ppm:	11992	12678	2366			
Nitrogen, (N2), ppm:	56530	95884	54079			
Methane, (CH4), ppm:	4	10	7			
Carbon Monoxide, (CO) ppm:	135	262	209			
Carbon Dioxide, (CO2), ppm:	4326	5863	4752			
Ethylene, (C2H4), ppm:	2	5	3			
Ethane, (C2H6), ppm:	3	17	7			
Acetylene, (C2H2), ppm:	0	0	0			
Total Combustible Gas, ppm:	157	294	226			
Total gas in oil, ppm:	73005	114719	61423			
% Total Combustible gas:	0.1919	0.1872	0.2753			
Screen Tests						
Dielectric Breakdown , KV:	31	44	44			
Visual Exam:	CLR&SPRK	CLR&SPRK	CLR&SPRK			
Color Number:	L3.0	L4.5	L4.0			
Acidity, KOH/g:	0.022	0.028	0.016			
Interfacial Tension dynes/cm:	30.6	32	37.7			
Power Factor @ 25°C, %:	0.011	0.007	0.016			
Specific Gravity (Relative)	0.884	0.883	0.887			
Moisture in oil, ppm:	41	16	9			
PCB content in oil	< 2.0 PPM					

As stated early on, dissolved gas analysis of liquid filled transformers provides a significant advantage over dry types in that it can reveal potential problems in a manner that allows corrective action to alleviate field failures.