Appendix 1 DGA Analysis Based on IEC 599-1978

Range of ratios	Code			
	C2H2/C2H4	CH4/H2	C2H4/C2H6	
	R2	R1	R5	
<0.1	0	1	0	
0.1 to 1.0	1	0	0	
1.0 to 3.0	1	2	1	
>3.0	2	2	2	
Fault Types				Typical phenomena
Normal (No fault)	0	0	0	Normal aging.
Partial discharge of low energy density	0 (but not significant)	1	0	Discharge in gas filled cavities resulting from incomplete impregnation or super-saturation or cavitation or high humidity.
Partial discharge of high energy density	1	1	0	As above, but leading to tracking or perforation of solid insulation.
Discharge of low energy (see note 1)	1 to 2	0	1 to 2	Continuous sparking in oil between bad connections of different potential or to floating potential. Breakdown of oil between solid insulation.
Discharge of high energy	1	0	2	Discharges with power follow-through. Arcing-breakdown of oil between windings or coils or between coils to ground. Selector breaking current.
Thermal fault of low temperature <150°C (see note 2)	0	0	1	General insulation conductor overheating.
Thermal fault of low temperature range 150-300°C (see note 3)	0	2	0	Local overheating of the core due to concentration of flux. Increasing hot spot temperatures; varying from small hot spots in the core, shorting links in the core, overheating of copper due to eddy bad contacts/joints (pyrolytic carbon formation) up to core and tank circulating currents.
Thermal fault of medium temperature range 300-700°C	0	2	1	
Thermal fault of high temperature >700°C (see note 4)	0	2	2	

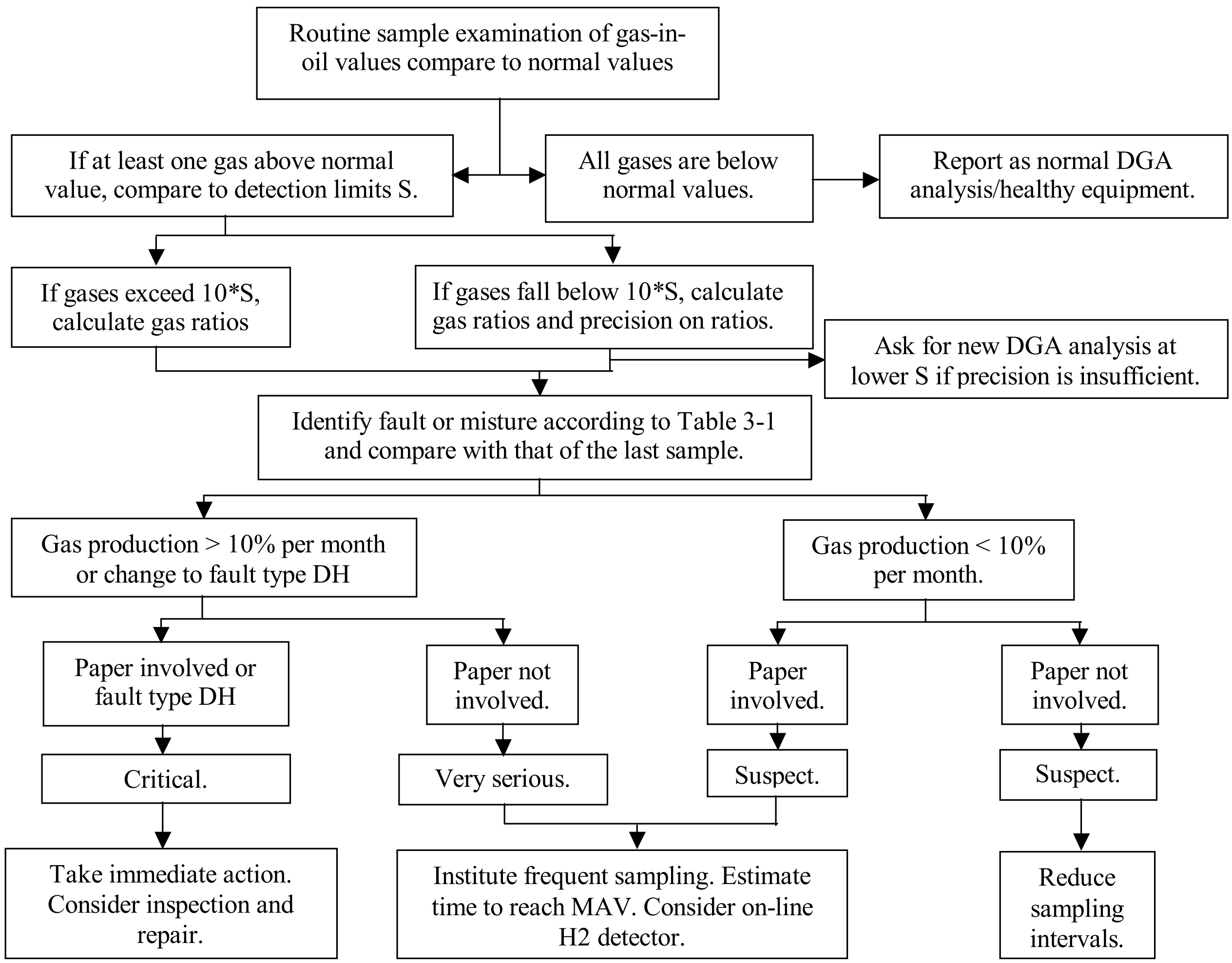
Note 1: For the purpose of this table, there will be a tendency for the ratio C2H2/C2h4 to rise from a value between 0.1 and 3.0 to above 3.0, and for the ratio C2H4/C2H6 from a value between 0.1 and 3.0 to above 3.0 as the spark develops in density.

Note 2: In this case the gases come mainly from the decomposition of solid insulation. This explains the ratio C2H4/C2H6

Note 3: The fault condition is normally indicated by increasing gas concentrations. Ratio CH4/H2 is normally about 1.0; the actual value is dependent on many factors such as design of oil preservation system, actual level of temperature and oil quality.

Note 4: An increased value of C2H2 may indicate that the hot spot temperature is higher than 1000°C.

Appendix 2 DGA Analysis Flow Chart of IEC 599 Revision Draft



Appendix 3 Editing and Condensing Algorithms for NNR Classifiers

Editing algorithm (assume data set S is of N classes):

Step 1 Diffusion: make a random partition of the available data set S into N subsets S_1, S_2, …, S_N

Step 2 Classification: classify the samples in S_i using the 1-NNR (nearest neighbor rule) with $S_{(i+1) \bmod N}$ as a training set, $i = 1, \ldots, N$

Step 3 Editing: discard all the samples that were misclassified at Step 2

Step 4 Confusion: pool all the remaining data to constitute a new set S

Step 5 If the last N iterations produced no editing, exit with the final set S, else go to Step 1

Condensing algorithm:

Step 1 Initialization: place one sample in a bin called STORE, place all the other samples in a bin called GRABBAG. Assume n_k is the number of samples in GRABBAG whenever Step 2 is entered.

Step 2 Use the 1-NNR with the current contents of STORE to classify the i-th sample from GRABBAG. If classified correctly the sample is returned to GRABBAG, otherwise it is placed in STORE. Repeat this operation for $i = 1, \ldots, n_k$

Step 3 If one complete pass has been made through Step 2 with no transfer from GRABBAG to STORE or the GRABBAG is exhausted then terminate, otherwise go to Step 2

The final contents of STORE constitute the condensed subset. The contents in GRABBAG are discarded.

Appendix 4 Multivariate Gaussian Classifier

Assume the underlying feature distribution is multivariate normal and characterizes each class by its mean vector $\boldsymbol{\mu}_i$ and covariance matrix $\boldsymbol{R}_i$. The conditional probability density function (PDF) of i-th class is:

$$p(\boldsymbol{x}|c_i) = \frac{1}{(2\pi)^{M/2}\|\boldsymbol{R}_i\|^{1/2}} \exp\left[-\frac{1}{2}(\boldsymbol{x}-\boldsymbol{\mu}_i)^T \boldsymbol{R}_i (\boldsymbol{x}-\boldsymbol{\mu}_i)\right] \qquad \text{(A4-1)}$$

Where M is the feature dimension.

Classification index can be written as:

$$C(i) = \ln p(i) + \ln\frac{1}{(2\pi)^{M/2}\|\boldsymbol{R}_i\|^{1/2}} - \frac{1}{2}(\boldsymbol{x}-\boldsymbol{\mu}_i)^T \boldsymbol{R}_i (\boldsymbol{x}-\boldsymbol{\mu}_i) \qquad i = 1,\ldots,N \qquad \text{(A4-2)}$$

Where $p(i)$ is the priori probability of class i.

$\boldsymbol{x}$ is classified to class i if $C(i)$ is the largest among the N classification indices.