Survey on the Advancements of Dielectric Fluids and Experiment Studies for Distribution Power Transformers

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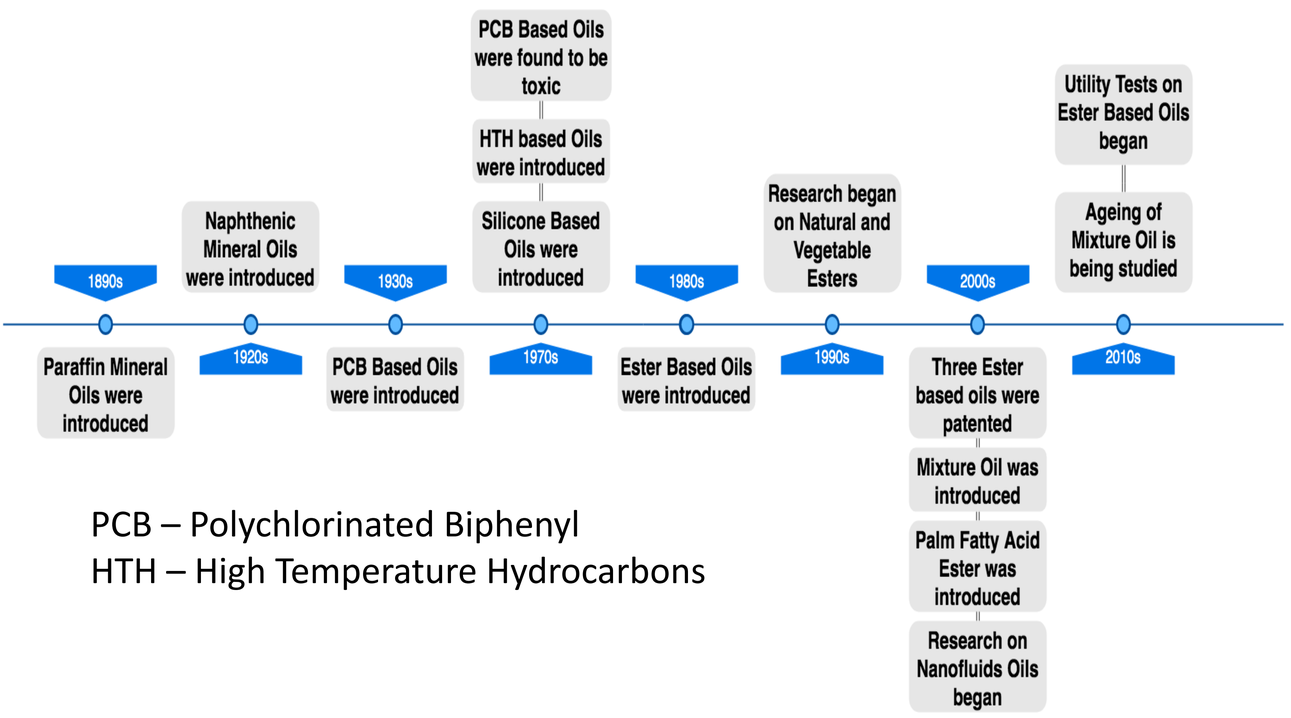
This work summarises the most used dielectric fluids used in the Distribution Power Transformers (DPT) and it surveys new solutions readily available in the market and in development to be the next generation of the DPT dielectric fluid.

In the end, the work compares the performance of the new dielectric Natural Ester Fluids against Mineral Oils, assessing the ageing of Ester fluids and advance how to calculate their health indexes throughout their expected life span.

Brief History of Dielectric Fluids:



PCB – Polychlorinated Biphenyl
HTH – High Temperature Hydrocarbons

Table 1: DPTs Dielectric Fluids: Advantages and Disadvantages

	Availability	Price	Pour Point	Flash/Fire Point	Origin	Toxicity	Viscosity	Chemical Stability	Biodegradability
Paraffin	✓	✓	X	X	X	X			X
Naphthenic	✓	✓	✓	X	X	X			X
PCBs				✓	X	X			X
HTHs				✓			X		
Silicone Oils		X		✓		✓		✓	
Synthetic Esters				✓			✓	✓	✓
Natural Esters				✓			✓/X	X	✓

[✓] It is an advantage ; [X] It is an Disadvantage.

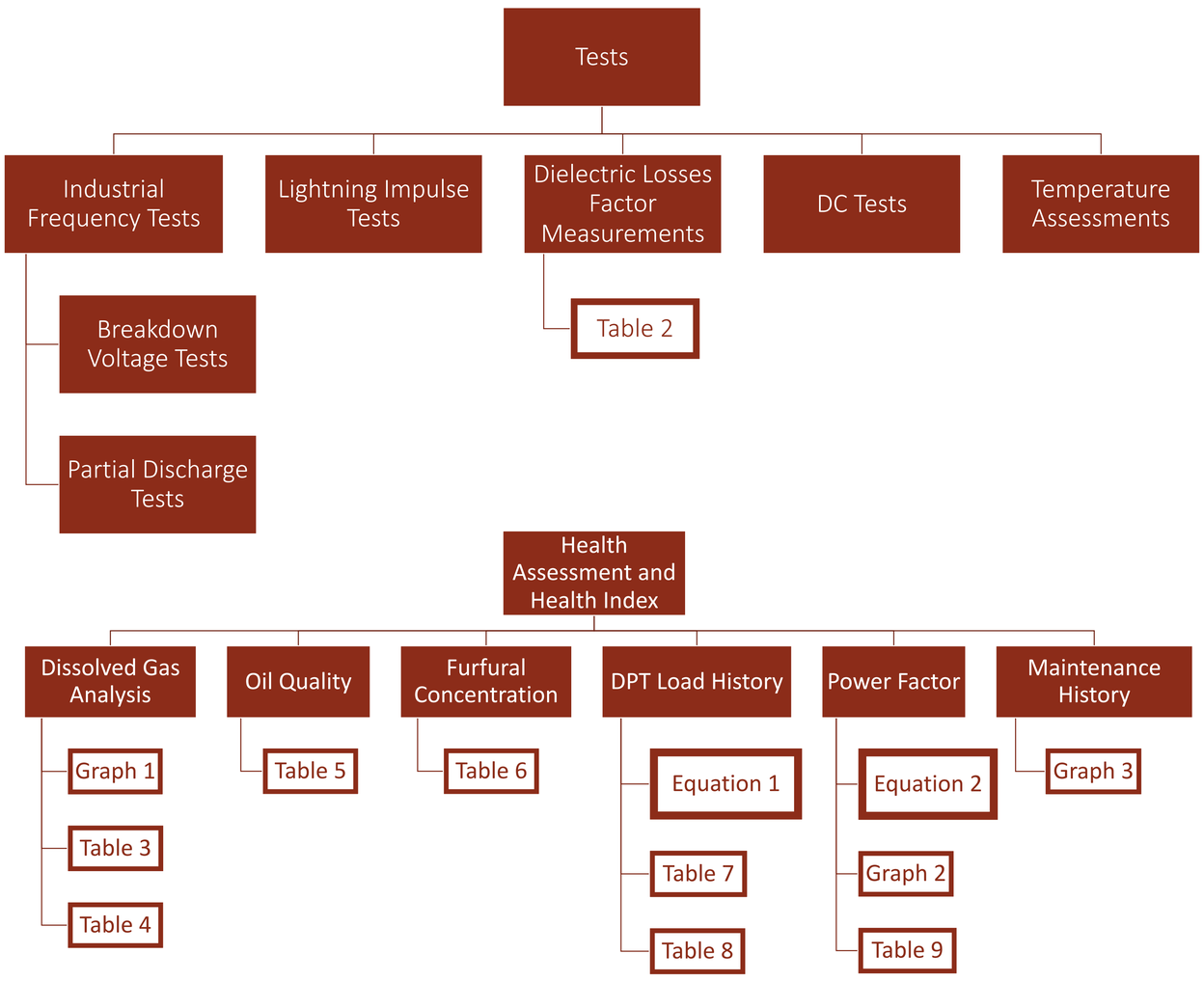


Table 2 – Oil Grade Guide for test

Power Factor at 20ºC	Condition
< 0,5%	Satisfactory for Service
[0,5% - 2%]	Doubtful Condition
> 2%	Reconditioning/Replacement

Graph 1 – Fault type by relative gas concentration

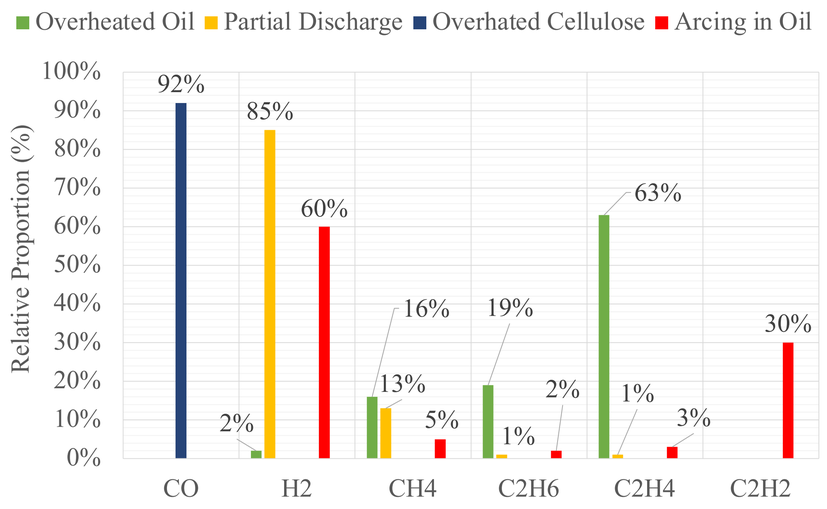


Figure 1 – Power Distribution transformer housing interior

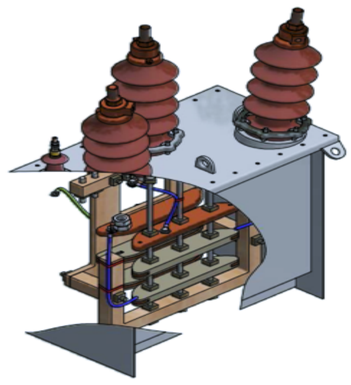


Table 3 – Score S_i for Gas Levels [ppm]

S_i =>	1	2	3	4	5	6
H_2	< 100	100 -200	200 - 300	300 -500	500 - 700	> 700
CH_4	< 75	75 - 125	125 - 200	200 - 400	400 - 600	> 600
C_2H_6	< 65	65 - 80	80 - 100	100 - 120	120 - 150	> 150
C_2H_4	< 50	50 - 80	80 - 100	100 -150	150 - 200	> 200
C_2H_2	< 3	3 - 7	7 - 35	35 - 50	50 - 80	> 80
CO	< 350	350 - 700	700 - 900	900 - 1100	1100 - 1400	> 1400

Table 4 [Left] – Power Distribution Transformer Rating based on DGA
Table 5 [Right] – Assess Parameters for Oil Quality

Rating	Condition	DGA Scoring
A	Good	< 1.2
B	Acceptable	1.2 – 1.5
C	Need Caution	1.5 – 2
D	Poor	2 – 3
E	Very Poor	> 3

Parameter	ASTM Norm	IEC Norm
DBV (1)	D877 & D1816	60156
Water Content	D1533	60814
Dissipation Factor	D924	60247
Interfacial Tension	D971	ISO 6295
Acidity Test	D644 & D974	62021
Color	D1500	ISO 2049

Table 6 – Furfural Test Rating or Age Rating when Test Results are not available

Rating Code	Furaldehyde [ppm]	Age in years
A	0 – 0.1	< 20
B	0.1 – 0.25	20 – 40
C	0.25 – 0.5	40 – 60
D	0.5 – 1	> 60
E	> 1	

Equation 1

$$LF = \frac{\sum_{i=0}^{4}(1-i).N_i}{N_i}$$

Equation 2

$$PF = \cos(\theta) = \frac{I_{reactive}}{I}$$

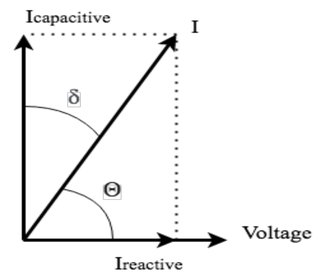
Table 7 [Left] – IEC 354 N_i value
Table 8 [Centre]– Load Factor Rating Code
Table 9 [Right] – Highest PF measured Rating

N_i	Peak Load / Rated Load
N_0	$S_i/S_B < 0.6$
N_1	$0.6 < S_i/S_B < 1$
N_2	$1 < S_i/S_B < 1.3$
N_3	$1.3 < S_i/S_B < 1.5$
N_4	$1.5 < S_i/S_B$

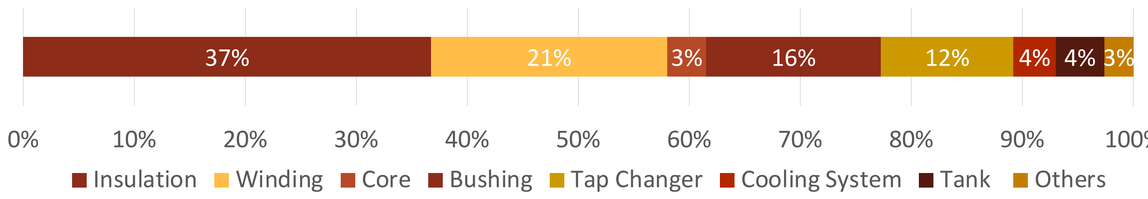
Rating Code	Load Factor
A	> 3.5
B	2.5 – 3.5
C	1.5 – 2.5
D	0.5 – 1.5
E	< 0.5

Rating Code	Maximum PF [%]
A	< 0.5 %
B	0.5 – 1 %
C	1 – 1.5 %
D	1.5 – 2 %
E	> 2 %

Graph 2 – Test Current Components



Graph 3 – *Power transformer component failures in the period 2003–2013*



This work advances the power distribution transformers health index most commonly used to assess the condition of the transformer.

Literature review shows there is extensive information, norms and standards regarding testing and assessments of mineral oil used as a dielectric fluid in Distribution Power Transformers – DPT – and other electrical equipment.

However, regarding the dielectric Ester Fluids (either natural or synthetic) there is lack of information regarding the use of norms and standards on Ester Fluid Testing.

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