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RECLAIMING AND ENHANCING THE AGED AND FRESH TRANSFORMER OIL WITH ACTIVATED BENTONITE AND ANTIOXIDANTS

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ABSTRACT: This work focuses on reclaiming and enhancing critical characteristics of aged mineral oil and fresh transformer oil using activated bentonite and antioxidants. The reclamation is carried by treating aged mineral oil with activated bentonite 5 g quantity. Then the treated sample is mixed with different combinations of natural and synthetic antioxidants. The enhancement of fresh transformer oil is carried by adding multiple combinations of antioxidants with different mechanisms like free radical scavenging, metal chelating and synergism. The critical parameters like breakdown voltage, viscosity, flash point and fire point of the samples are calculated using ASTM and IEC specifications before and after adding antioxidants.
Index Terms: Power Transformer, transformer oil, antioxidants, dielectric, critical parameters.

I. INTRODUCTION

The transformer life mainly depends on the insulating medium used. Traditionally two dielectric mediums used in transformer are solid (kraft paper and press board) and liquid (mineral oil). Among them the liquid dielectric medium dominates due to its dynamic functions like insulation and cooling. The increasing population of transformers from post world war-II use mineral oil as dielectric. Because of the service life of transformer is expected to be at least 20 years, the ageing has negative effects on the dielectric properties of the insulating oil, thus causing deceleration in the transformer efficiency [1, 2]. This profuse use of mineral oil leads to shrinking of petroleum reserve. The increasing record of transformer accidents like explosion, harmful disposal and oil leak are governing a new dimension in liquid dielectric research. The conventional disposal method (incineration) available in literature is harmful to environment [3]. The demand forecast of the present and the future requirement is maintaining a non-equilibrium condition. However the potential consequence of transformer failure is complained majorly on the liquid insulation used in transformer, which is about 75% [4, 5]. The end of transformer life is defined by the condition of tensile strength of solid insulation about 50% [6]-[8]. Furthermore the key limitation of mineral oil is when disposed it cause risk to human life and ecosystem [9]. In many of the special applications synthetic liquids like silicone and perchloroethylene are used in transformer systems, but which are costlier and use of these oils are restricted to some degrees in special transformer applications [10]. The transformer life can be possibly improved by using recent versions of high grade dielectric fluids such as R-Temp®, Envirotemp® FR3™ and Beta fluid® [11, 12]. The insulation system of power transformer degrades constantly at normal operating condition, more specifically at higher temperature, higher moisture and oxidation. The residual life of a transformer is notably influenced by the condition of solid insulation. A serious failure of large power transformer due to liquid insulation breakdown can generate substantial costs for repair and economic losses [13]. Therefore most power utilities highly prefer to access the actual condition of the liquid insulation of the power transformer [14]. The aging process in the oil, cellulose insulation system under thermal stress and their measurable effects are due to chemical alteration in structures of dielectric. The temperature of the oil is the critical aging parameter to cause enough change in the mechanical and electrical properties of the liquid dielectric material. Apart from high temperatures, other important parameters affecting the aging of solid and liquid insulation includes the presence of water and oxygen in the system [15]. The commercial insulating oil after refining process usually contains small quantity of oxidation inhibitor, which comprise of DBP (2,6-di-tertiary-butylphenol) or DBPC (2,6, ditertary-butyl-para-cresol). The usage rate of oxidation inhibitor in the insulating oil depends upon the population of oxygen species in the transformer tank, catalytic mediators and impurities present in oil. In the modern transformer, the construction is themed in sealing the interior from the outer to prevent atmospheric oxygen contacting the oil. Practical statement of oxidation process is the chemical response between the oil and oxygen or metallic mediators. This could result in the formation of oil byproduct such as acids and sludges; which could be a menace to the dielectric properties of insulating oil. Regeneration processes carried using activated carbon and clay treatment can remove contaminants like sludges, metals and acids. But this could likely decrease the amount of oxidation inhibitor present in the oil. In order to overcome this condition, the natural inhibitor present in fresh oil is usually maintained in the range of 0.25 to 0.35 %. According to ASTM standard, the percentage of oxidation inhibitors in new insulating oil is labeled as Type I: contains about 0.08 % and Type II: contains about 0.3 %. For in-service units the oxidation inhibitor is 0.02 % and greater. The percentage concentration of natural inhibitor should be periodically tested and maintained at least every two years. The calculated loss percentage is remunerated by adding required oxidation inhibitors to oil [16]. Bentonite has been a promising adsorbent available in low-cost, which is extensively used for the removing toxic (contaminant) metal ions from waste water [17]. Bentonite consists predominately of smectite, a 2:1 clay mineral containing an octahedral sheet between two tetrahedral sheets. Adsorption properties of bentonite are a direct function of the montmorillonite content and interlayer cations. In order to remove impurities and various exchangeable cations, bentonite was modified with acid. Collection of aged oil and waste oil is a noticeable environment and economic reason. Adsorption processes with bentonite clay could constitute a simple economical alternative to conventional regeneration process. As far as adsorptive properties are concerned, bentonite has been used to remove a number of chemical elements [18]. The adsorption capacity of natural and acid-activated bentonite is high when compared to the conventional adsorbent such as activated carbon. Such research on enhancement of critical characteristics of aged transformer oil using natural bentonite clay has been reported with 5 g composition [19]. The bleaching capacity of bentonites is greatly increased by activation treatment. To improve the adsorptive properties of bentonite clay, it can be acid activated. This involves all the cations present in the bentonite (typically Ca2+, Na2+ and Al3+) being replaced by H+ by the addition of either sulphuric or hydrochloric acid. This bentonite clay is naturally a good bleaching compound, but should be treated with acid to increase the adsorption capacity of bentonite [20]-[22]. The comparison of performance of additives like semi conductive nanoparticles and antioxidants confirms the use of antioxidant is economic and effective [23]. The use of various natural and synthetic antioxidants like Butylated Hydroxy Toluene (BHT), Butylated Hydroxy Anisole (BHA), Ascorbic Acid (AA), Citric Acid (CA), Propyl Gallate (PG), Alpha Tocopherol (α-Tocopherol) are effective when used in single and combinatorial form [24]. In this paper, we aim to develop a new methodology to enhance and reuse the aged transformer oil with available compounds like activated bentonite and antioxidant. Also to investigate the critical properties of subjected samples and highlight the antioxidant behavior in regenerated oil samples.

II. MOTIVATION OF THE WORK

The scope of this study is based on present technologies that are currently under practice to regenerate and enhance liquid insulation used in power transformer. The use of low-cost, less-hazardous and high performance compounds like activated bentonite and antioxidants are employed in this research. The illustrated technique is a pulsating tool for economically reusing the aged transformer oil and enhancing the fresh transformer oil for the optimized functions of power transformer.

III. SAMPLE DESCRIPTIONS

3.1 Transformer Oil Samples

In this research aged transformer oil (under service for 8 years) has been collected from regional substation. The fresh transformer oil is purchased from transformer manufacturing company. The aged oil sample thus collected shows poor performance and sludge deposits, which can directly influence the dielectric performance of the insulation systems of transformer. The specification about the transformer from which the oil sample is collected is particularized in Table1.

Table 1. Specification of transformer.

CONTENT	AGED TRANSFORMER OILS
Source	Sethur Substation, Tamilnadu, India
Transformer Type	Step down
KVA rating	150 KVA
Voltage rating	11 kV / 433 V
Age of oil and status	8 years In-service

3.2 Properties of Base fluids (Aged transformer oil and fresh transformer oil)

The aged and fresh transformer oil is taken as base fluid 1and 2 respectively, which are subjected throughout the investigation process. The base fluid 1 and 2 are initially heated to 100 OC to remove the moisture content in the oil. Then the base fluids are naturally cooled until it reaches room temperature and the critical characteristics of the base fluids are measured according to ASTM and IEC specifications, which are given in Table 2. The result shows that the regeneration and enhancement of the aged oil is required for reusing it in power transformer.

Table 2. Critical properties of base fluids.

Critical Parameters	Base Fluid 1	Base Fluid 2
	Aged Mineral Oil	Fresh Mineral Oil
Breakdown Voltage (kV)	20	28
Viscosity (cSt)	45	27
Flash Point (^{O}C)	145	150
Fire Point (^{O}C)	150	160

3.3 BLEACHING CLAYS AND ACID ACTIVATION

Bentonite clay is commonly referred to as "green" healing clay. It occurs in naturally form by the combination of volcanic ash minerals called montmorillonite and ocean water. Bentonite occurs in natural form as clays which hold commercial importance for bleaching of oils and fats [25]. The bentonite ($Al_2O_34SiO_2H_2O$) occurring in natural form called as hydrated aluminum silicate, which is packed with potassium, calcium, and sodium; depends upon the source of occurrence. The wet form of bentonite expands like a sponge, which absorb toxins present in the mixture to which it is added. This process of expansion and attraction is called as adsorption [19]. The adsorption characteristic of bentonite is due to the presence of positive and negative charges on its edges and surfaces. During the expansion state of bentonite, the toxins are attracted like a magnet and placed inside the small pores (spaces) where the toxins are bonded with the chemicals of the clay [26]. Acid activation of the bentonite carried with 7N concentrated sulphuric acid (H_2SO_4), which yields an adsorbent material of higher bleaching efficiency when used in the oil; function better than the commercial bleaching products [22]. The literature survey shows the ability of Activated Bentonite compound in absorption of impurities, suspended matters, sediment and removal of contaminants such as ash content, carbon content in aged transformer oil.

3.4 ANTIOXIDANT

Antioxidants are a compound that eliminates the oxidation process [27]. The antioxidant performs electron scavenging mechanism by trapping free radicals or free electrons present in the solution. Thus completely purging the chain reaction, the amount of free radicals is kept to minimum quantity; it can avoid oxidation of oil and peroxide formation. The main functional mechanisms of antioxidant are free electron scavenging, metal chelation and synergism [28], [29]. The performances of antioxidant under normal temperature and higher temperature conditions, but to some extend the diminution of antioxidant composition decreases when compared to its original quantity. The function of antioxidant is high when used in combinations of three and more, but sloppy when singly used. The different combinations of antioxidants used for the investigation are presented in Table 3. Antioxidants can increase the oxidative stability of oil in the presence of metal contaminants, sludges and other foreign substances present in the oil [30]-[32]. The antioxidants are generally categorized into three types based on their mechanism and source; they are natural antioxidants, secondary antioxidants and synergists. The primary antioxidants like BHT, BHA and PG are synthetic type, which performs mechanisms like free radical scavenging and metal chelation, while α-T comes under natural type, which performs synergist mechanism. Similarly the secondary antioxidants like AA and CA are from natural source, which performs the synergist mechanism.

Table 3. Critical properties of base fluids.

Model	Antioxidant combination			Antioxidants Mechanisms		
	1	2	3	1	2	3
A1	BHA	AA	α-T	Free Radical Scavenger	Synergist	Regenerators of Scavengers
A2	BHT	CA	α-T	Free Radical Scavenger	Synergist	Regenerators of Scavengers
A3	BHA	BHT	CA	Free Radical Scavenger	Free Radical Scavenger	Synergist
A4	BHA	CA	α-T	Free Radical Scavenger	Synergist	Regenerators of Scavengers
A5	BHT	PG	α-T	Free Radical Scavenger	Metal chelators	Regenerators of Scavengers
A6	PG	CA	α-T	Metal chelators	Free Radical Scavenger	Regenerators of Scavengers

Similarly the secondary antioxidants like AA and CA are from natural source, which performs the synergist mechanism. The antioxidants like Butylated Hydroxy Toluene (BHT), Butylated Hydroxy Anisole (BHA), Citric Acid (CA), Ascorbic Acid (AA), Alpha Tocopherol (α-T) and Propyl Gallate (PG) are used for this investigation. For consistency of this work, the effective concentration is taken into consideration while selecting antioxidants [30]-[32].

3.5 PREPARATION OF SAMPLE

The regeneration process is carried by taking 5 g of activated bentonite for 500 ml of base fluid 1 (aged transformer oil). The activated bentonite is mixed with base fluid 1 vibrantly by using magnetic stirrer under 750 rotations per minute (RPM) (sonication can also be used). For fine mixing of the activated bentonite compound in the base fluid 1, the oil is heated upto a temperature of 80 OC before mixing. The mixture is then filtered using Whatman filter paper no. 42 until the bentonite is completely removed. The sample of reclaimed base fluid 1 and the filter paper before and after removal of activated bentonite compound is shown in Figure 1 and 2 respectively. Then the critical characteristics of the reclaimed base fluid 1 is measured and publicized in Table 5. The reclaimed samples show some percentage of improvement in its critical characteristics. The reclaimed base fluid 1 (aged transformer oil) and base fluid 2 (fresh transformer oil) are then mixed with the selected high performance antioxidants (A1 – A6), which are given in Table 4. The antioxidant combinations 1, 2 and 3 are taken in the ratio of 1 g : 1 g : 1 g and mixed using magnetic stirrer unit for 20 to 30 minutes under 750 RPM and melting point temperature of the antioxidant. The critical characteristics of the samples thus prepared using antioxidants are measured according to ASTM and IEC specification.

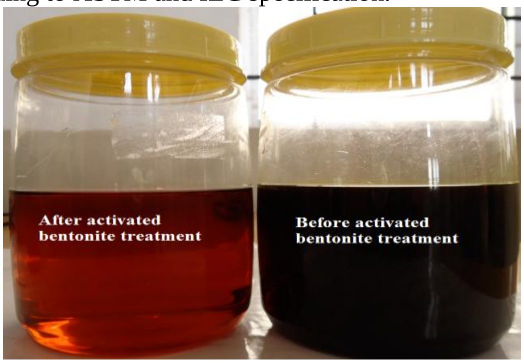

Figure 1. Base fluid 1 before and after treatment with activated bentonite.

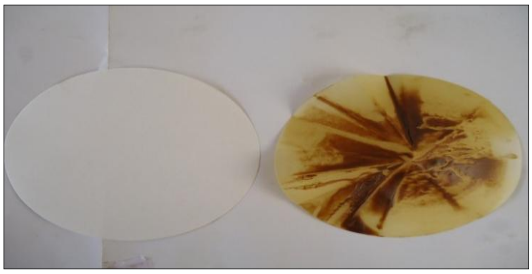

Figure 2. Sample of filter paper before and after filtration.

IV. EXPERIMENTAL PROCEDURES

4.1 BREAKDOWN VOLTAGE MEASUREMENT

In assessing the condition of oil's insulating properties; the breakdown voltage measurement plays an important role. The important factors that determine the breakdown voltage of the oil are moisture, air bubbles, suspended solid matters and acidity of fluid [33, 34]. The breakdown voltage of the sample is measured using breakdown voltage test kit which has a measuring capacity of 60 kV as per the specification of IEC 60156 [35].

Samples prepared using base fluid 1		Samples prepared using base fluid 2	
Sample 1	Base Fluid 1 + A1	Sample 7	Base Fluid 2 + A1
Sample 2	Base Fluid 1 + A2	Sample 8	Base Fluid 2 + A2
Sample 3	Base Fluid 1 + A3	Sample 9	Base Fluid 2 + A3
Sample 4	Base Fluid 1 + A4	Sample 10	Base Fluid 2 + A4
Sample 5	Base Fluid 1 + A5	Sample 11	Base Fluid 2 + A5
Sample 6	Base Fluid 1 + A6	Sample 12	Base Fluid 2 + A6

Table 4. Samples prepared from reclaimed base fluid 1 and base fluid 2 with antioxidants A1 - A9.

Critical Parameters	**Base Fluid 1**		**% reclaimed**	**Base Fluid 2**
	Before reclamation	**After reclamation**		**Fresh Mineral Oil**
Breakdown Voltage (kV)	20	25	25	28
Viscosity (cSt)	45	37	-17.8	27
Flashpoint (°C)	145	147	1.4	150
Firepoint (°C)	150	153	2	160

Table 5. Comparisons of critical characteristics of reclaimed base fluid 1 and base fluid 2.

The test sample is filled in the test cup to required level (40 mm above the electrode surface). The test kit contains two spherical electrodes of standard diameter and inter-spacing of 2.5 mm. Application of voltage is started after ensuring no air bubbles. The linear voltage rise of 2 kV/s by using the control knob. Five successive measurements of breakdown voltages are taken by giving time delay of one or two minute between each successive measurement. The time delay is given in order to disperse the byproducts to expel before next consecutive measurements are conducted. The average of five values is taken as breakdown voltage of the test sample [36].

4.2 FLASH POINT AND FIRE POINT MEASUREMENT

The flash point of the sample is measured using Pensky Martin Flash point equipment at room temperature and pressure as per the specifications of ASTM D 93 [37]. The flash point is recorded when a temporary test flame stimulated on the oil's surface. The vapour formed inside the test cup mix with atmospheric air to kindle a temporary fire on the oil surface less than one second. The Pensky Martin Flash point apparatus includes a closed brass test cup where the test sample is filled and the temperature of oil sample is increased by energy regulator. Similarly, the fire point is recorded when persistent fire on the oil's surface; when a small test flame is introduced to the test sample [33, 34].

4.3 VISCOSITY MEASUREMENT

Viscosity is the measure of resistance offered by a fluid due to shear stress. The factors that determine the viscosity of the sample are temperature of oil and fluid resistance offered by the oil [33, 34]. For cooling, the free circulation of oil in the transformer tank should have the moderate viscosity. Viscosity of the oil is inversely proportional to the temperature of oil. The viscosity of the sample is measured using Redwood Viscometer equipment at room temperature and pressure as per the specification of ASTM D 445 [38]. The equipment contains a silver plated oil cup with orifice.

V. 5. RESULTS AND DISCUSSION

5.1 Effect of ANTIOXIDANT on the Properties of base fluid 1 and base fluid 2 (aged AND FRESH Transformer Oil)

The base fluid 1 after treatment with activated bentonite compound shows less percentage of reclamation of oils critical properties, which can be observed from the Table 5.
base fluid 1 for potential reuse in power transformer application, these oil should be enhanced with low cost high performance natural and synthetic antioxidants. The base fluid 1 and 2 mixed with antioxidant combinations (A1 – A6) shows enhanced critical characteristics, which are publicized in Table 6. The critical characteristics of base fluid 1 and 2 before and adding antioxidants are discussed here.

5.2 BREAKDOWN VOLTAGE

The breakdown strength of the samples from Table 6 shows, the potential strength of antioxidant used in combinations. The breakdown strength of base fluid 1 after treatment with antioxidant is less compared to base fluid 2 after adding antioxidants. The breakdown voltage enhancement percentage of base fluid 1 and 2 after added with antioxidants (A1 – A6) are given in Table 7 and are characterized in Figure 3. At normal room temperature and pressure (RTP) and elevated temperature (70°C) all the samples prepared from base fluid 1 shows good percentage of enhancement, especially with A2, A4 and A6. The efficiency of antioxidant at elevated temperature is not affected by the diminution of antioxidants in very less percentage.
The samples with A2, A4 and A6 contain predominantly of Citric Acid (CA) and α-Tocopherol (α-T) combination. The significant property of CA and α-T is its parallel mechanisms such as synergism and regeneration of scavengers. The breakdown voltage of sample with A6 combination place highest in enhancement property due to the presence of Propyl Gallate (PG), which act as metal chelators. Similarly the enhancement percentage in breakdown voltage of samples prepared from base fluid 2 and antioxidants (A2, A4 and A6) is high when compared to other antioxidant combinations (A1, A3 and A5).

Antioxidant Combination	Breakdown Voltage (kV) at RTP		Breakdown Voltage (kV) at 70°C		Viscosity (cSt)		Flashpoint (°C)		Firepoint (°C)	
	Base Fluid 1	Base Fluid 2	Base Fluid 1	Base Fluid 2	Base Fluid 1	Base Fluid 2	Base Fluid 1	Base Fluid 2	Base Fluid 1	Base Fluid 2
A1	27	33	33	41	39	29	147	154	149	162
A2	39	52	48	57	37	34	151	152	162	170
A3	28	36	30	38	39	29	146	158	153	165
A4	41	49	51	56	40	28	155	160	159	167
A5	34	39	37	45	39	30	145	159	153	165
A6	45	52	60	60	35	32	152	155	160	168

Table 6. Critical characteristics of reclaimed base fluid 1 and 2 with antioxidants.

Though this reclaimed values of base fluid 1 does not govern any equivalent status of base fluid 2 (fresh transformer oil), the removal of sludges, suspended particles and clearance of oil are observed. The BHT being used as an oxidation inhibitor with fresh transformer oil by oil manufacturers, the introduction of BHA, AA, CA, α-T and PG in combinations holds recorded outstanding performance, in particular only few combinations show high degree of enhancement.

Antioxidant Combination	Breakdown Voltage (kV) at RTP		Breakdown Voltage (kV) at RTP	
	Base Fluid 1 with antioxidants	% enhancement	Base Fluid 2 with antioxidants	% enhancement
A1	27	8	33	18
A2	39	56	52	86
A3	28	12	36	29
A4	41	64	49	75
A5	34	36	39	39
A6	45	80	52	86

Table 7. Percentage Enhancement of breakdown voltage of reclaimed base fluid 1 and base fluid 2 with antioxidants (A1 – A6).

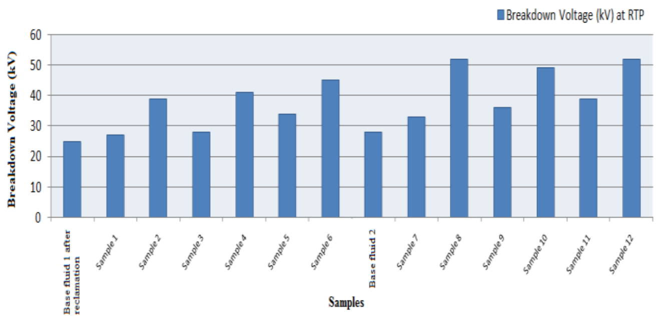

Figure 3. Breakdown voltage characteristics of samples treated with antioxidants (A1-A6).

5.3 VISCOSITY

The addition of antioxidants should not increase the viscosities of the samples prepared from base fluid 1 and 2 with antioxidants. Since the increase in viscosity of oil may decrease the heat convection rate; possibly it could increase the electrostatic forces on the metal parts. The viscosity gets altered while on temperature increase, but keeping the value of viscosity less than the base value is mandatory.

The viscosity of samples from Table 6 shows the antioxidant used in combinations has positive and negative impact on viscosity value. The percentage increase and decrease of viscosities of the samples are shown in Table 8 and depicted in Figure 4. The viscosity of base fluid 1 and 2 after treatment with antioxidant (A1 – A5) is more or less equal when compared to antioxidant combination A6. The viscosity enhancement percentage of base fluid 1 and 2 added with antioxidant A6 prove to be effective and less than the base viscosity value.

Antioxidant Combination	Viscosity (cSt)			
	Base Fluid 1 with antioxidants	% decrement	Base Fluid 2 with antioxidants	% decrement
A1	39	-5	29	-7
A2	37	0	34	-26
A3	39	-5	29	-7
A4	40	-8	28	-4
A5	39	-5	30	-11
A6	35	5	32	-19

Table 8. Percentage Enhancement of viscosity of reclaimed base fluid 1 and base fluid 2 with antioxidants (A1-A6).

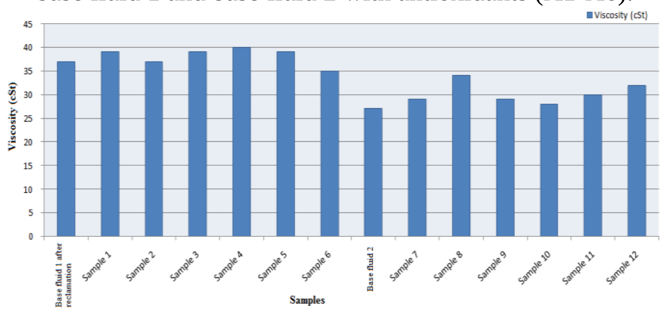

Figure 4. Viscosity characteristics of samples treated with antioxidants (A1-A6).

5.4 flash and fire point

The flash and fire point being an important parameter in accessing the performance of liquid dielectric. The base fluid 1 and 2 recorded after adding antioxidants (A1 – A6) shows good enhancement, which are shown in Table 9 and 10 and characteristics are depicted in Figure 5 and 6.

Antioxidant Combination	Flashpoint (°C)			
	Base Fluid 1 with antioxidants	% enhancement	Base Fluid 2 with antioxidants	% enhancement
A1	147	0	154	3
A2	151	3	152	1
A3	146	-1	158	5
A4	155	5	160	7
A5	145	-1	159	6
A6	152	3	155	3

Table 9. Percentage Enhancement of flash point reclaimed base fluid 1 and base fluid 2 with antioxidants(A1-A6).

The potential strength of antioxidant used in combinations to increase the flash and fire point is overpowering. The flash and fire point of base fluid 1 and 2 after treatment with antioxidants is high after added with antioxidants (A1 – A6). This enhancement percentage is accounted for all the antioxidant combinations (A1 – A6). This is because, when antioxidant reacts with free radicals and retards the formation of peroxides, which are prone to chain oxidation. For Samples

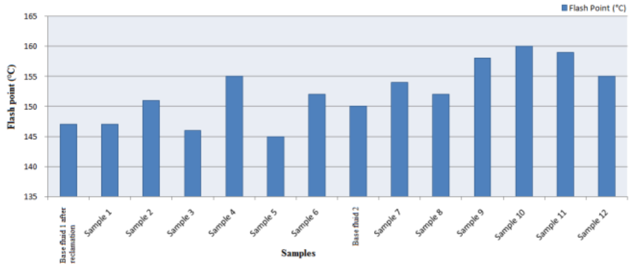

Figure 5. Flash point characteristics of samples treated with antioxidants (A1-A6).

Antioxidant Combination	Firepoint (°C)			
	Base Fluid 1 with antioxidants	% enhancement	Base Fluid 2 with antioxidants	% enhancement
A1	149	-3	162	1
A2	162	6	170	6
A3	153	0	165	3
A4	159	4	167	4
A5	153	0	165	3
A6	160	5	168	5

Table 10. Percentage Enhancement of fire point reclaimed base fluid 1 and base fluid 2 with antioxidants (A1 – A6).

prepared from base fluid 1 and 2 with A2, A4 and A6, these antioxidant combinations commonly contain Citric Acid (CA) and α-Tocopherol (α-T), which are stable during high temperature and the loss percentage of free radical scavengers can be compensated due to the presence of regenerators. Specifically for sample containing A2, the involvement of BHT adds additional momentum; which is thermally unstable with increasing ignition mixtures formed during experimentation. This enables the sample to posses' high thermal strength during operation.

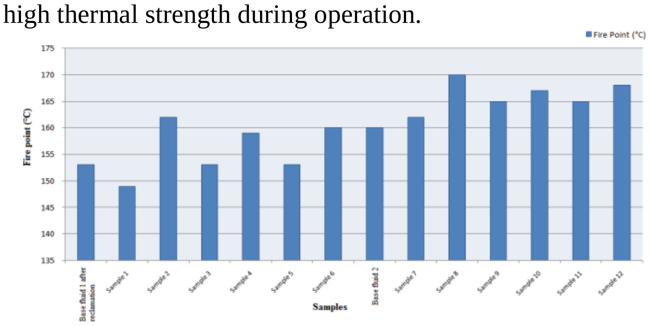

Figure 6. Fire point characteristics of samples treated with antioxidants (A1-A6).

VI. FUTURE SCOPE

The use of natural ester with antioxidants and mixed dielectric as insulating fluids in transformer system is the expected to replace the traditional transformer liquid insulation. The measurement of critical characteristics of natural ester with antioxidants shows potential strength of antioxidants to transform the natural ester to meet commercial standard, moreover the possibility of mixed dielectric are also reported in literature [24, 34]. But still there are limited published research works in these platforms of natural ester, mixed dielectric and cryogenic insulations. This novelty in transformation gives a different dimension in the research of liquid dielectric.

VII. CONCLUSION

The analysis is used to establish the reclamation of aged oil possible by treatment with activated bentonite. Moreover the combination of antioxidants is a proven technique for enhancing the reclaimed aged transformer oil and fresh transformer oil. The addition of natural and synthetic antioxidants (A1 – A6) with petroleum based transformer fluids (base fluid 1 and base fluid 2) enhances the critical properties of oil. More specifically the performance of enhanced base fluid 1 and 2 with antioxidants is stable at normal and elevated temperature. The important features of using antioxidants combination during experimentation apart from enhancement property are very less carbon content during breakdown and this constitute least percentage of dissolved gases. During experimentation of samples parallel mechanisms of antioxidants are observed. From inspection of results, combinatorial effect of high performance antioxidants is effective and less prone to chemical effects. Result offers a different dimension in estimating the performance of aged transformer oil and fresh transformer oil with antioxidants. Implementation of natural and synthetic antioxidants combination with different mechanisms with transformer oil suggest a new facet in the research of power transformers. This technique of reclamation and enhancement of aged mineral oil help to reuse the aged insulating fluids, in other words it helps to overcome oil shortages expected in the near future. This approach is also useful in avoiding harmful disposal of used transformer oil to environment. On the whole the analysis brings to a close conclusion, saying that the aged and fresh transformer oils enhanced using antioxidant is an apt solution for potential reuse in power transformer.

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