

Dielectric Oil Regeneration

The four functions of transformer oil

- Oil provides dielectric strength and acts as a dielectric and insulating medium
- Oil provides heat transfer - acts as a cooling medium
- Oil protects solid insulation - acts as a barrier between paper and the damaging effects of oxygen and moisture
- The oil can be tested to give an indication of conditions inside the equipment - it acts as a diagnostic tool to assess solid insulation

Purification of dielectric oil

Oil purification is an important part of regular transformer preventive maintenance. In the purification process, water and contaminants such as solid particles and gases are removed from transformer oil.



UVM-6/7 MOBILE DEGASSING UNIT

- Meets international standards for transformer oil purification quality
- Water removal to 3 ppm
- Gases removed to 0.1% by volume
- Dirt and particles removed to 0.2 micron
- Stationary or mobile plants
- Very effective and simple to operate

Dielectric oil regeneration

- There are different international regulations pertaining to the regeneration process.
- IEC 60422-2013.
- IEEE C57.637-2015



The importance of oil regeneration



Oil regeneration

- IEEE Std C57.106-2015
- Defines regeneration is the removal of contaminants and decomposition products, such as polar, acidic or colloid materials from electrical insulation fluids with the help of chemical or adsorbing materials. Regeneration commonly includes treatment with clay or other adsorbents.



Oil treatment methods

Table 4—Oil-purification practices

Oil-purification practices	Types of contamination removed					
	Solids	Free water	Soluble water	Air and gas	Volatile acids	Other
(1) Vacuum dehydrator	No	Yes	Yes	Yes	Most	No
(2) Mechanical filter (blotter or filter press)	Yes	Partial	Partial	No	No	No
(3) Centrifuge	Yes	Yes	No	No	No	No
(4) Coalescing filter	Yes	Yes	No	No	No	No
(5) Precipitation settling	Yes	Yes	No	No	No	No
(6) Contact process	Yes	Yes	Yes	No	Yes	Yes
(7) Percolation by gravity	Yes	Yes	Partial	No	Yes	Yes
(8) Percolation by pressure	Yes	Yes	Partial	No	Yes	Yes
(9) Activated carbon sodium silicate process	Yes	No	No	No	Yes	Yes
(10) Trisodium phosphate process	Yes	No	No	No	Yes	Yes

IEEE Std C57.637-2015

IEEE Guide for the Reclamation of Mineral Insulating Oil and Criteria for Its Use

To change or to regenerate?

Table 1—Suggested limits for oil to be reconditioned or reclaimed

ASTM test property	Group I	Group II	ASTM test method
Acid number maximum, mg KOH/g	0.2	0.5	D974
Interfacial tension, minimum, mN/m	24	16	D971

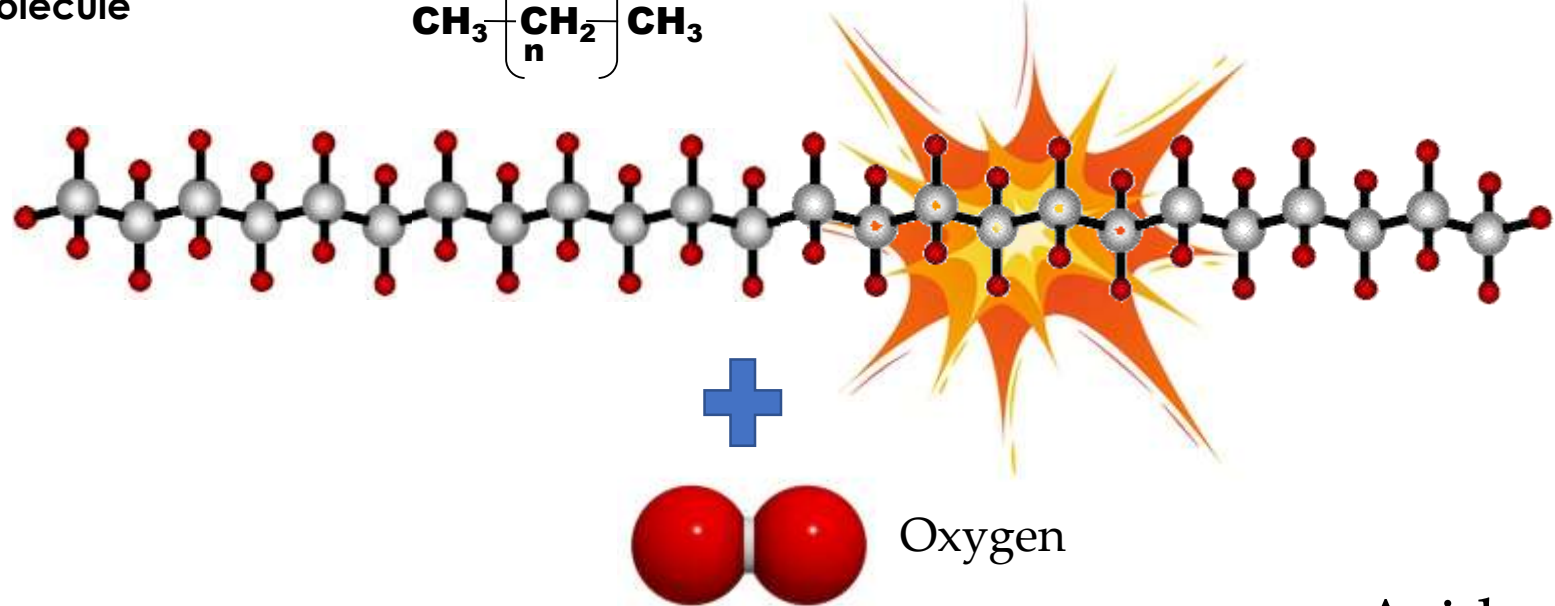
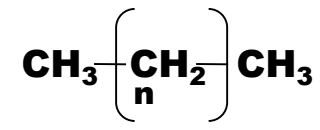
Oil Acidity.

- Acidity of used oil is caused by the formation of oxidation products.
- Acids and other products of oxidation, as well as water and other impurities, influence the dielectric properties of oil.
- Acids have an impact on cellulose degradation and may cause corrosion of transformer metal parts.



How does transformer oil oxidize?

Oil chain molecule

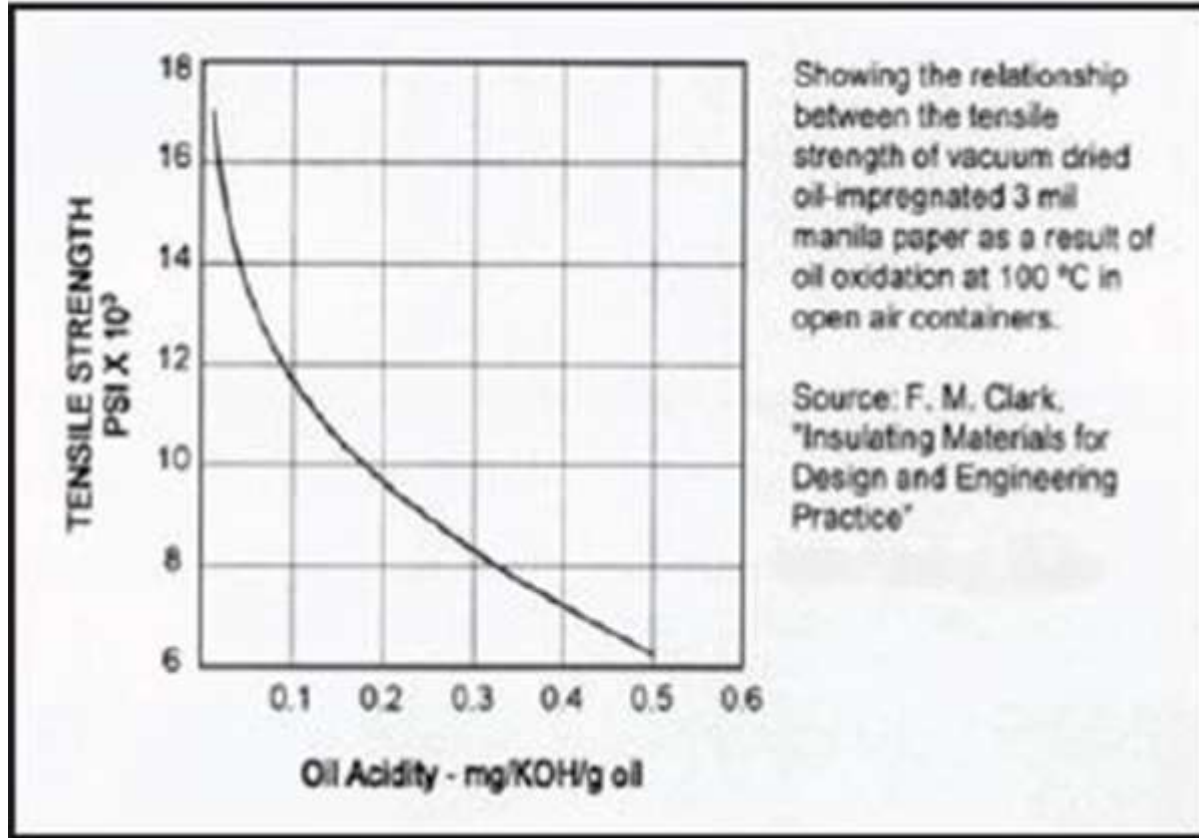


- Thermic and electrical stress
- Cellulose decomposition
- Chemical reactions due to impurities

↓
**Chain breaks
+
Molecular regrouping**

- Acids
Peroxides
Alcohols
Soap
Cetone
Aldehydes
Epoxy.

Oil acidity.



IEEE C57-106 Limits			
Voltage Class	≤ 69 kV	> 69 kV, < 230 kV	≥ 230 kV
Acid	≤ 0.20	≤ 0.15	≤ 0.10

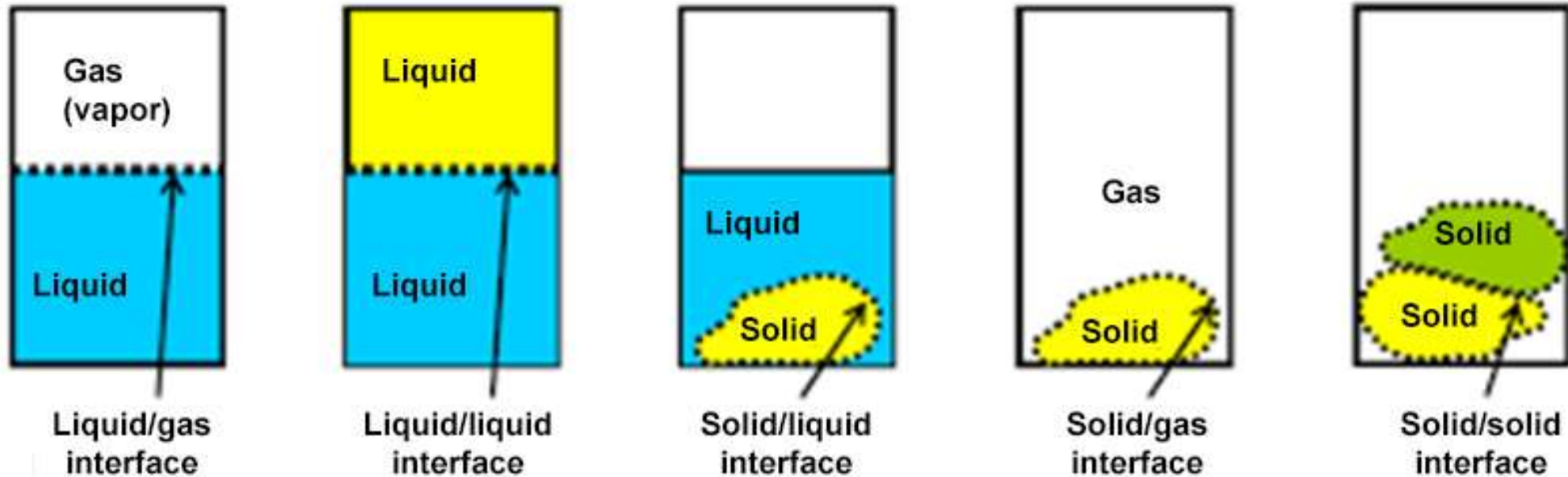
Oil oxidation

Experiment	Catalyst	Water	Hours	Acid number
Control	None	Low	3500+	0,17
Humidity	None	High	3500+	0,9
Iron	Iron	Low	3500+	0,65
Humidity and iron	Iron	High	400	8,1
Copper	Copper	Low	3000	0,89
Humidity and copper	Copper	High	100	11,2

The tests ended when they saw the first sign of sludge

Source: Dobbie Laboratories

Interfacial tension ASTM 971



- The interfacial tension between oil and water provides a means of detecting soluble polar impurities and decomposition products. This parameter changes quite rapidly in the early stages of aging, but stabilizes while the deterioration is still moderate.

Interfacial tension

ASTM 971

	Acceptable	Problematic	Unacceptable
mN/m	Over 32	Between 32 and 28	Below 28

- Presence of polar impurities has a direct effect on interfacial tension.

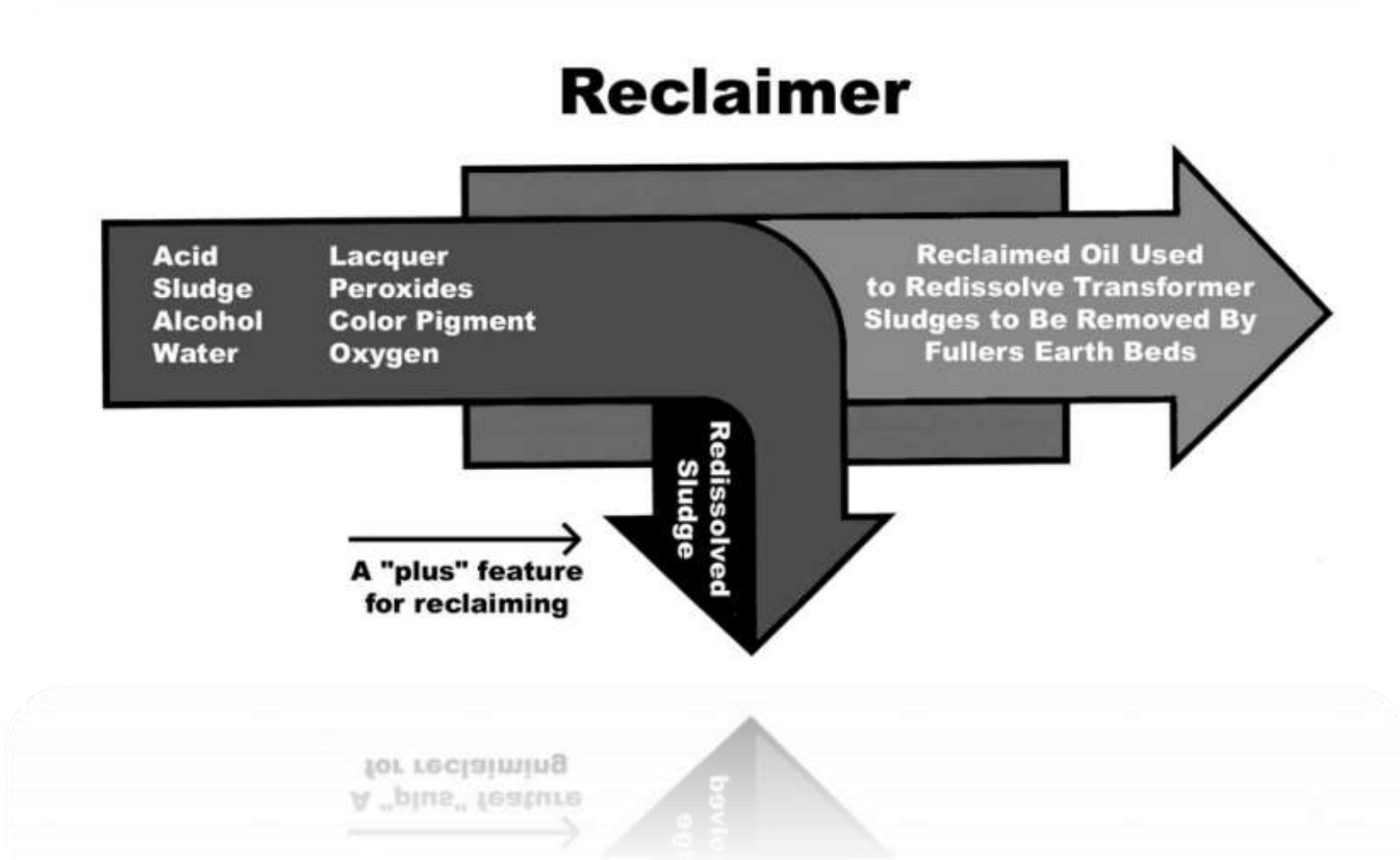
Interfacial tension

ASTM 971

- Polar contaminants dissolved in oil (not polar), increase its affiliation with water (polar substance).



Oil regeneration



Oxidation inhibitors

- The most common types of inhibitors used in transformer oils are of phenol type: 2,6-di-tert-butyl-paracresol (DBPC) and 2,6-di-tert-butyl phenol (DBP). The efficacy of the inhibitor depends on the chemical composition of the base oil.

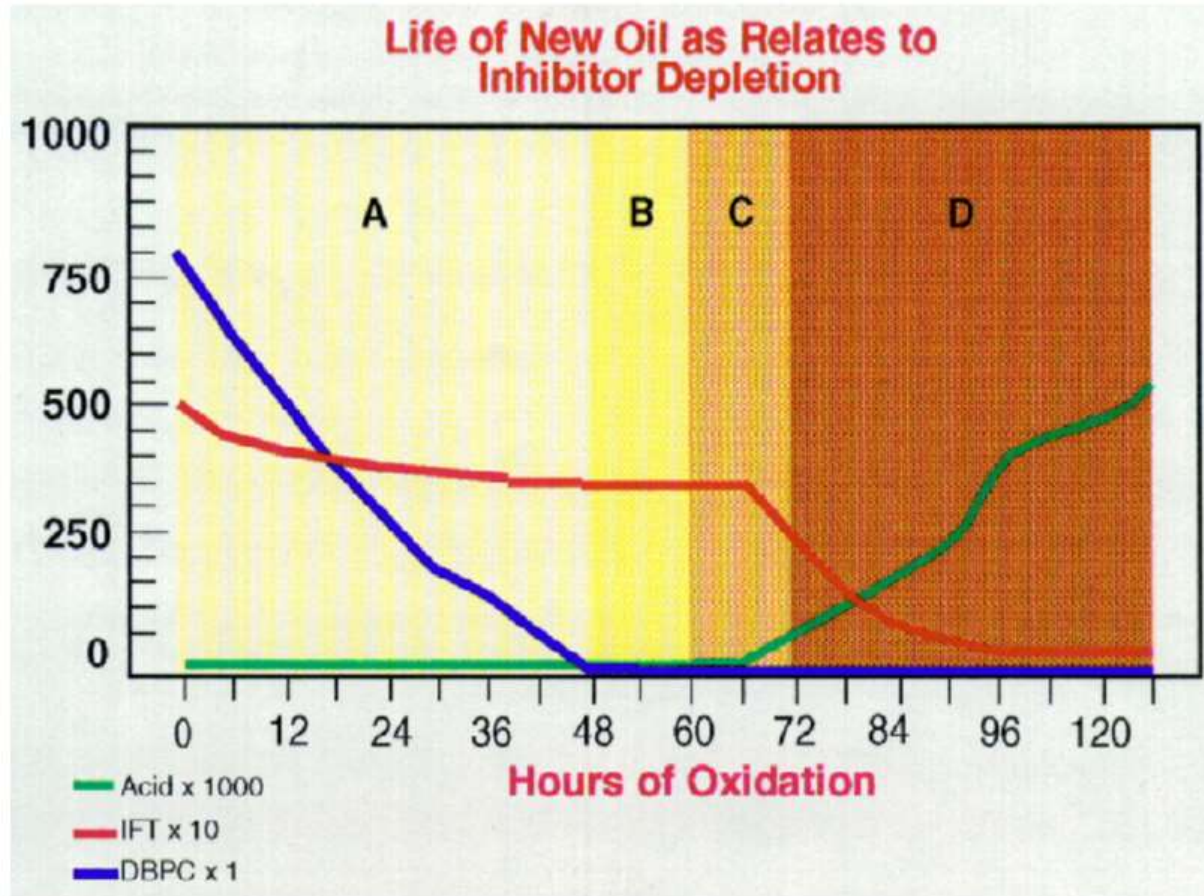


Inhibitor content.

- The amount of inhibitor is recommended as a percentage of the total amount of the insulation fluid.

Acceptable	Problematic	Unacceptable
Over 0.2%	Between 0.1% and 0.2%	Less than 0.1%

Problems caused by lack of inhibitor.



Parameters of regenerated oil

- Oil regeneration influences three parameters:
- Physical.
 - Viscosity.
 - Color.
 - Interfacial tension.
- Electrical.
 - Dielectric strength.
 - Power factor.
- Chemical.
 - Neutralization number.
 - Resistance to oxidation.

Table 2—Suggested property requirements of reclaimed oil for transformers^{a, b}

ASTM test property	Limit	ASTM test method
Physical		
Flash point, minimum, °C	140 ^c	D92
Pour point, minimum, °C	-40 ^d	D97
Specific gravity, 15/15 °C, maximum	0.91	D1298
Viscosity, maximum, cSt at 40 °C (mm ² /s)	12.0	D88 or D445
Color, maximum	1.5	D1500
Visual examination	Clear	D1524
Interfacial tension, minimum, mN/m	35	D971
Electrical		
Dielectric breakdown voltage, 60 Hz, kV, minimum	30	D877
Power factor at 60 Hz, 100 °C, maximum, %	1	D924
Chemical		
Acid number, maximum, mg KOH/g	0.05	D974
Oxidation inhibitor, maximum %, by weight	0.3	D2668
Oxidation stability, minimum, minutes	150	D2112
Oxidation Stability 164h		D2440
% sludge, maximum	0.25	
Total acid no, maximum, mg KOH/g	0.50	
Water, maximum, ppm	35	D1533

Fuller's earth

- Fuller's earth is an active medium which contains internal and external polar centers, which allow the non-polar oil components to pass, but capture polar contaminants and decomposition products solved in the oil.

IEC 60422-2013



Fuller's earth types

LVM Clay

- Activates at high temperature.
- High water absorption.
- High acid absorption.
- Low efficiency of bleaching

RVM Clay

- Activates at lower temperature.
- Lower absorption capability.
- Higher bleaching ability.
- Higher acid absorption

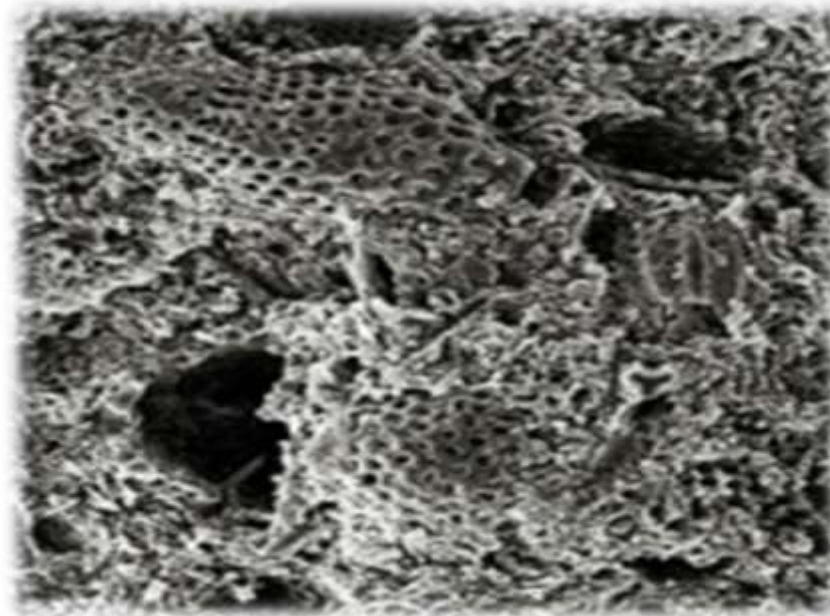
Fuller's earth types

AARVM

- Maximum bleaching in a system without moisture

AALVM

- For optimum acid removal from oil with high water content



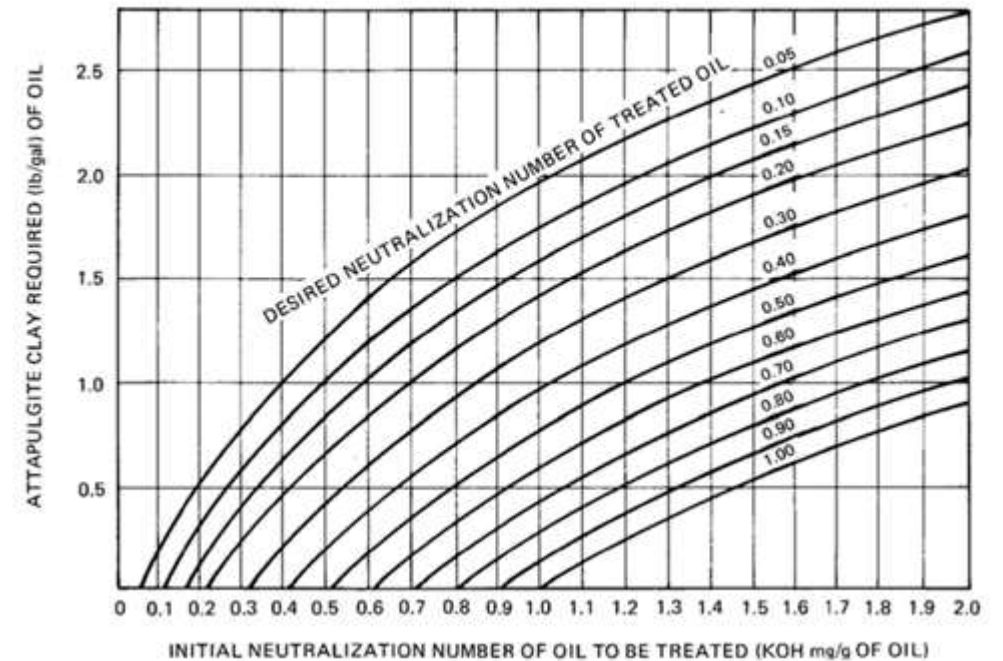
<http://www.jaxonfiltration.com/>

How to quickly lower acidity?

The amount of acid removed depends on many factors, since adsorption is a process of dynamic equilibrium.

- Temperature.
- Flow rate
- Oil viscosity.
- Retention time.
- Initial acidity.

IEEE Std C57.637-2015
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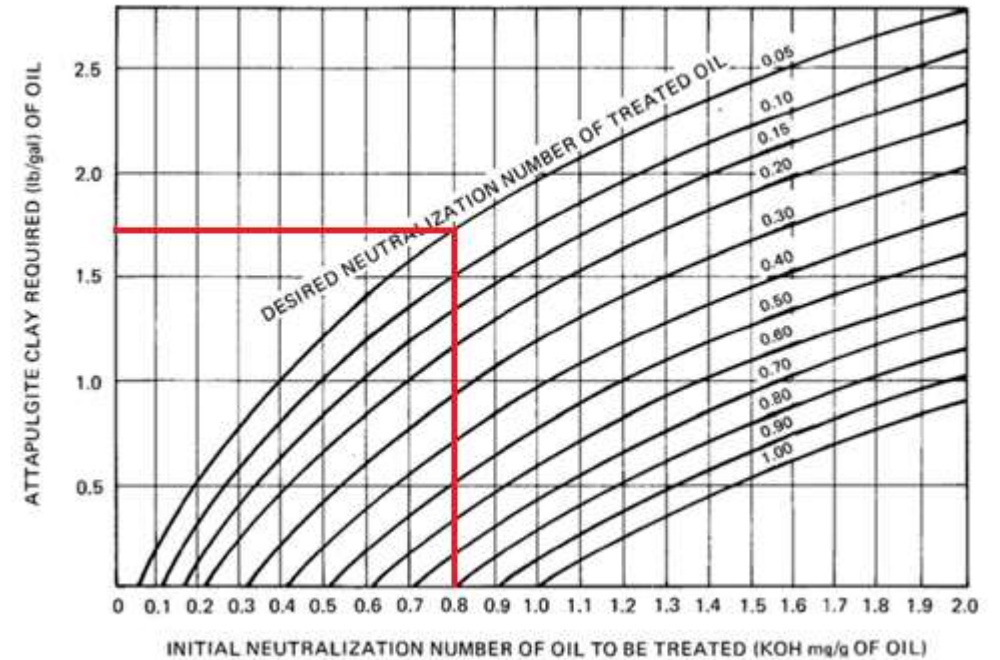


How much oil can be regenerated with fuller's earth?

- Example

Calculation of the quantity of Fullers Earth as per Oil Quantity		
	Quantity	Unit
Initial Neutralisation number	0.8	mg/KoH
Final Neutralisation number	0.05	mg/KoH
Quantity of Fullers Earth per Gallon Aprox.	1,7	Pounds

IEEE Std C57.637-2015
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Example #1

Regeneration Capacity

Filterung Capacity of the machines GlobeCore FEES				
		Quantity	Unit	
	Initial Neutralisation number	0.8	mg/KoH	
	Final Neutralisation number	0.05	mg/KoH	
Number of Columns	FEES	By Column	Total	Unit
2	Quantity of Fullers Earth	130,00	260,00	Kilagrams
	Quantity of Fullers Earth	286,60	573,20	Pounds
	Quantity of Oil that can be treated	168,59	337,18	Gallons
	Quantity of Oil that can be treated	638,18	1.276,36	Litres

Example

If the machine can reactivate fuller's earth

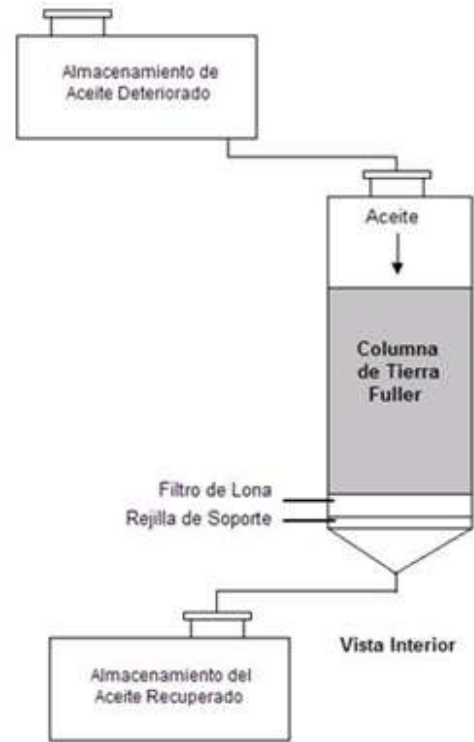
Regeneration process Equipment				
	Inicial Neutralisation number		0.8	
	Final Neutralisation number		0.05	
Number of Columns	CMMPEs	By Column	Total	Unit
2	Quantity of Fullers Earth	130,00	260,00	Kilograms
	Quantity of Fullers Earth	286,60	573,20	Pounds
	Number of regenerations	300,00		Unit
	Quantity of Oil that can be treated	50.576,64	101.153,27	Gallons
	Quantity of Oil that can be treated	191.453,40	382.906,79	Litres

Types of regeneration

Contact method



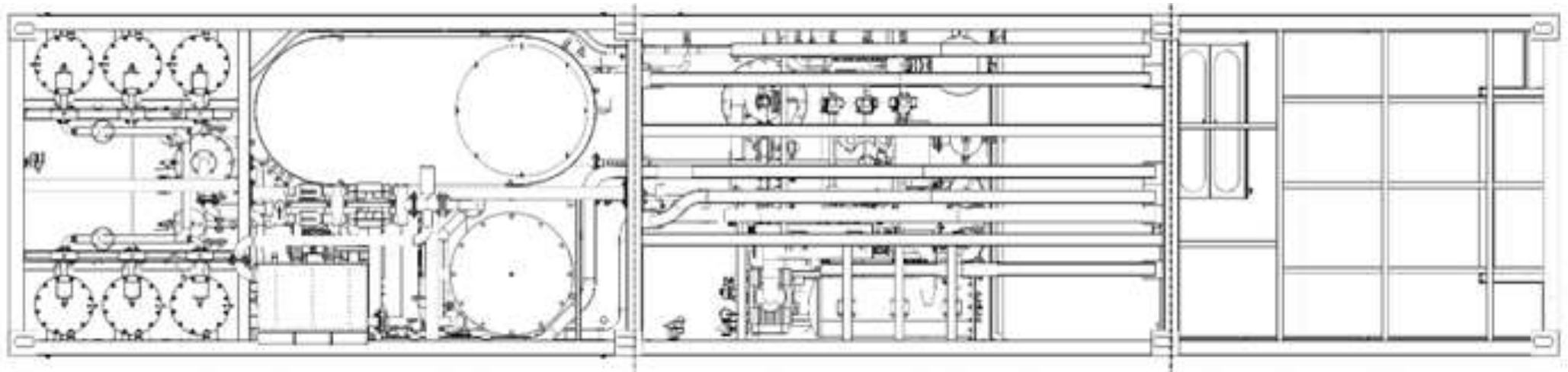
Percolation



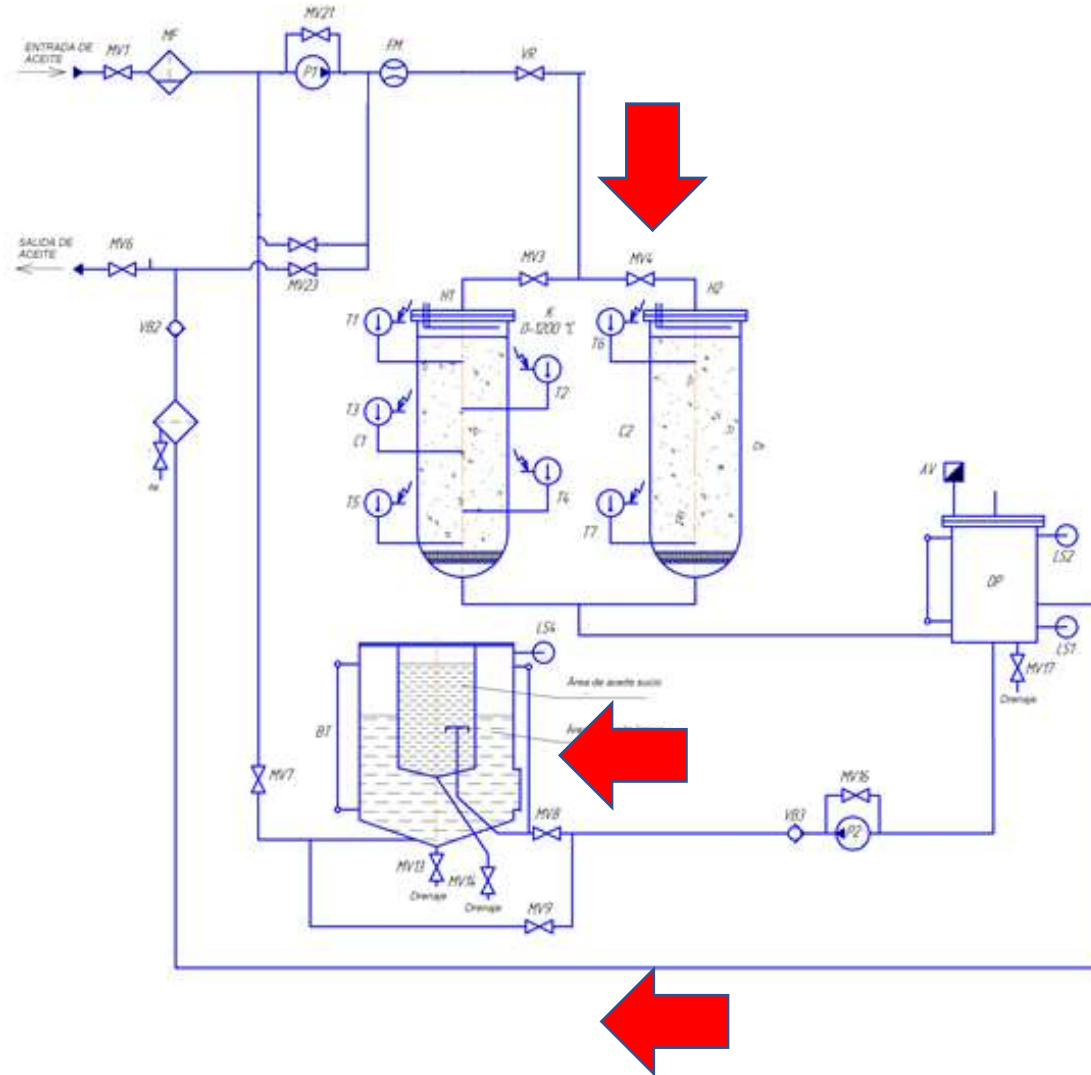
Regeneration of dielectric oil

GlobeCore

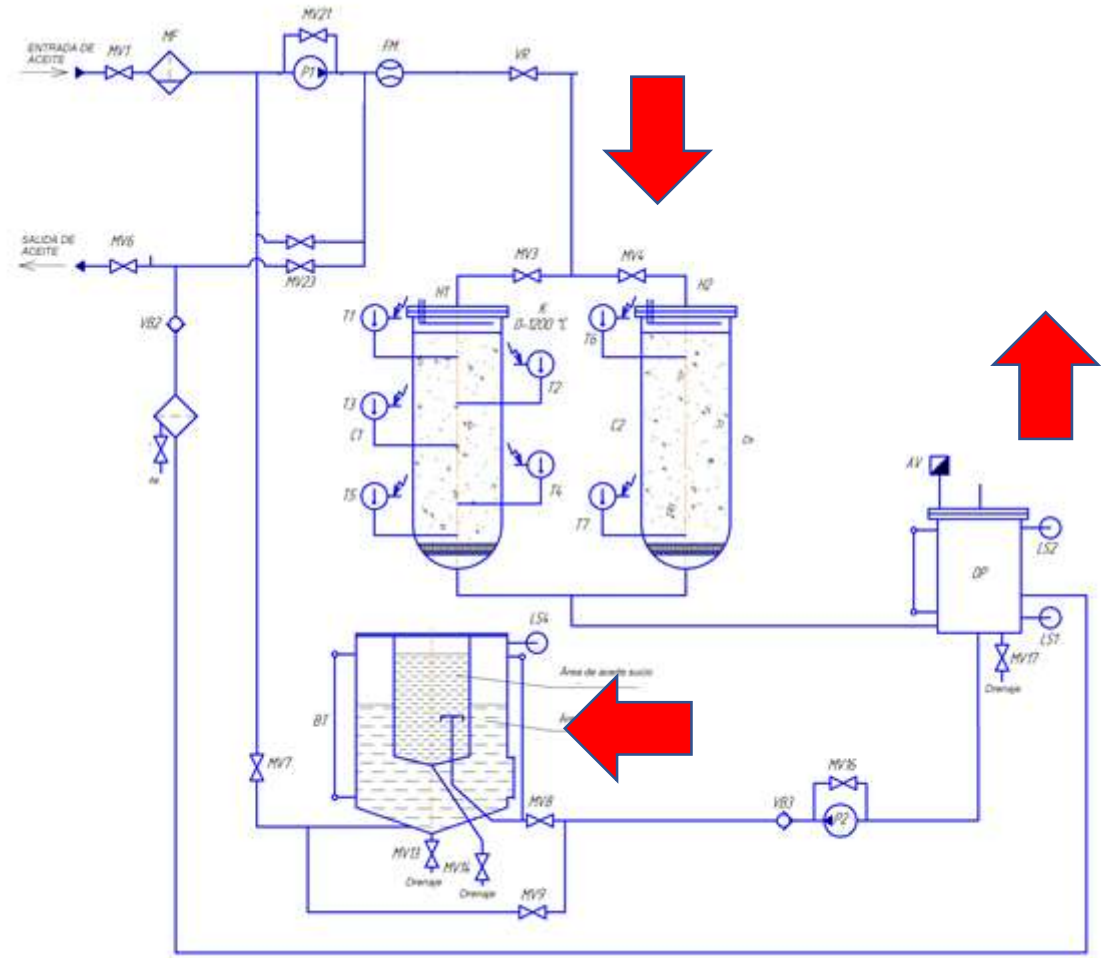
CMM-R class transformer oil
regeneration plants



Oil regeneration process



Fullers earth reactivation process



Thank you.