Reclosers, Sectionalizers, Switches and Fault Interrupters

Oil is employed in reclosers, sectionalizers, and switches as a coolant, electrical insulator, and arc quencher. Reclosers and sectionalizers use oil in operation-counting mechanisms. Oil, in most reclosers, also serves as a hydraulic fluid for establishing timing of opening and reclosing. Because these versatile devices are important tools for reducing system operating cost and improving public relations, care in selection, handling, testing, and renewing of oil is important.

What constitutes a good oil for switchgear use? What characteristics should be known and how can they be determined? These and other questions are discussed in *TD280022EN*.

Specifications for oil used in Eaton's Cooper Power series distribution switchgear are shown in Table 1. Values shown are for new bulk oil before it is introduced into the switchgear tank. Samples taken from new equipment before it is put into service will show a slight degradation due to condensation during transit and storage.

The recommended minimum dielectric strength for oil sampled from new equipment is 26 kV rms as specified in ANSI C37.61, *Guide for the Application, Operation, and Maintenance of Automatic Circuit Reclosers*.

Significance of Characteristics

Viscosity

Viscosity is a measure of an oil's resistance to uniform, continuous flow. In simpler terms it is the length of time required to empty a container of oil. If oil is too heavy or too thin, timing will be affected in reclosers that establish time delay by forcing oil through an orifice. Moreover, oil that is too thick cannot circulate freely to remove heat from current-carrying parts. Viscosity is also an important factor in an oil's ability to cool the hot core of an arc.

Table 1. Specifications for Oil Used in Eaton's Cooper Power series Distribution Switchgear

Characteristic	Acceptable Value	ASTM Test Standard*
Color	0.5 max (ASTM colorimeter)	D1500
Reaction	Neutral	
Neutralization no.	0.03 mg KOH/g max	D974
Corrosive sulfur	Noncorrosive	D1275
Steam emulsion no.	25 seconds max	D1935
Flash point	145 C min	D92
Fire point	160 C min	D92
Pour point	-40° C max	D97
Viscosity, max		D445, D88
cST (SUS) at		
100 C	3.0 (36)	
40 C	12.0 (66)	
0 C	76.0 (350)	
Specific gravity at 15 C	0.91 g/cc max	D1298
Coefficient of expansion (from 25 to 100 C)	0.0007 to 0.0008	D1903
Interfacial tension	40 dynes per cm min	D971
Dielectric constant	2.2-2.3	D924
Dielectric strength	30 kV min	D877, D1816
Water content (by Karl Fischer test)	30 ppm	D1533
PCB content	No detectable amount	D4059
Weight	0.9 kg/liter	
	7.5 lb/gal	

* Tests are described in latest revision of ASTM standards.

Viscosity can be specified in centistokes (cSt) or saybolt universal seconds (SUS) depending on the test method.

Viscosity Index

Viscosity index is the rate of change of viscosity with a change in temperature. An oil with a high viscosity index will have a small change in viscosity with a change in temperature. A high index is desirable for oil used in reclosers because timing will be more nearly constant. In any switchgear the oil should be free flowing at all times to provide efficient cooling of hot arc cores. As the viscosity of an oil increases, the amount of carbon formed during arc interruption also increases.

Dielectric Strength

Dielectric strength is the average voltage at which electrical failure or breakdown occurs under prescribed conditions. The dielectric strength test, as now applied, is not entirely satisfactory and is somewhat controversial. This is because the test indicates the condition of the sample being tested but does not give a complete picture of the oil's behavior under varying conditions. A dielectric test will indicate the presence of free water held in suspension in the oil but will not indicate the presence of dissolved water because water in solution has little, if any, effect upon the dielectric strength.

Oil usually contains water in both the dissolved and the free state. The amount of water held in solution is determined by the temperature and the condition of the oil. As oil deteriorates or as the temperature is raised, water solubility increases. Figure 1 shows the water solubility of new oil at various temperatures.

A water-and-salt analogy can be drawn to help illustrate the difference between dissolved and free water. A small amount of salt added to water at room temperature will be completely dissolved. If more salt is added, a point will be reached at which it will not be dissolved by the water. If the water is warmed, some of the free salt will go into solution but, when the water is cooled, this salt reverts to the free state. Left undisturbed, the salt will eventually settle to the bottom of the container. However, a product can be added to the water which will cause the free salt to tend to remain in suspension even though it is not dissolved. In a similar manner, deteriorated oil contains products that cause free water to remain dispersed throughout the oil and this water causes a marked reduction in dielectric strength.

To further illustrate the effect water solubility has on the dielectric strength of an oil, consider a unit operating with an oil temperature of 100° F. The oil can then contain about 110 parts per million (ppm) of dissolved water. If the temperature increases to 130° F due to increased load, the dissolved water content can be increased to about 280 ppm. This increase can only come from free water already in the oil.

Under these conditions, the dielectric strength is raised because the amount of free water is lowered. When load and, consequently temperature, decreases, the 170 ppm of water absorbed are released as free water. If the oil is appreciably deteriorated, it will not isolate this free water but will tend to hold it in suspension. Thus, a marked decrease in dielectric strength will occur. If a dielectric test had been performed at the higher temperature, an unrealistically high reading could have been obtained.

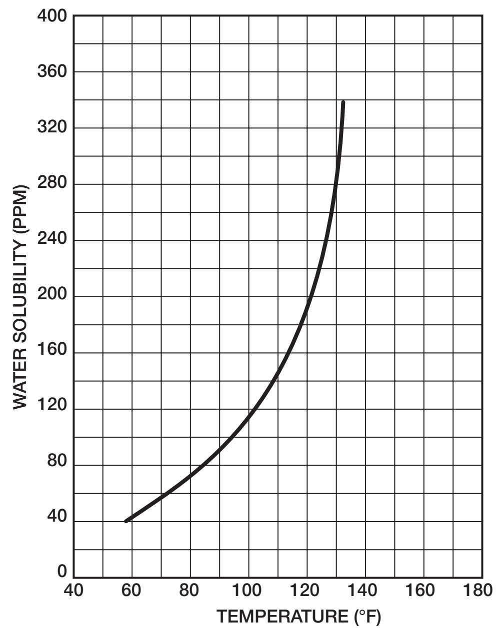

Figure 1. Water solubility of new oil at various temperatures

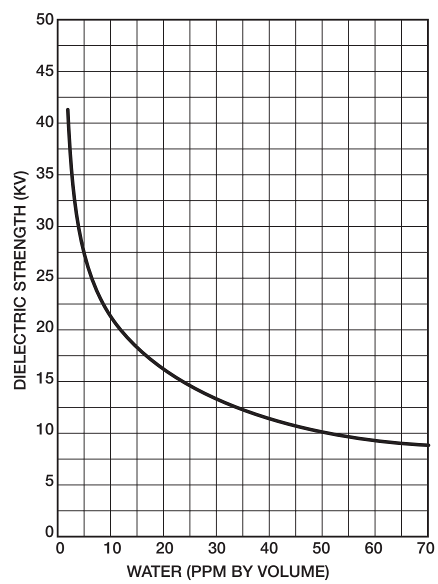

Figure 2. Effect of free water on dielectric strength

Figure 2 shows the effect free water has on dielectric strength. Although the graph is approximately correct for absolutely clean oil, the dielectric strength will be sharply reduced if foreign particles and free water are present at the same time. All foreign particles tend to affect dielectric strength to some extent but cellulosic fibers seem to be the worst offenders. These fibers tend to absorb water and orient themselves across points of electrical stress and lead to arcing. Sources of cellulosic fiber contamination include insulation and blotter-press papers.

The dielectric strength of oil, as presently measured, is not appreciably affected by the presence of contaminants as long as the oil is dry. Water in solution (not suspension), acids, and polar materials do not affect the dielectric strength until concentrations are quite large. Carbon in the presence of free water will cause a 30 to 40% drop in dielectric strength. This contrasts to a drop of only 15% if the oil is dry. Fibers in dry oil cause a drop of only about 20% whereas, in the presence of free water, the oil can experience a drop of 90% in dielectric strength. The combination of ordinary atmospheric dust and free water in oil can cause up to a 50% reduction. These figures emphasize that oil must be handled carefully at all times to obtain optimum results.

Steam Emulsion Number

The steam emulsion number indicates the time required for oil and condensed steam to completely separate under carefully controlled conditions. This number is important because, as previously noted, the dielectric strength of an oil is adversely affected by free water held in suspension.

Pour Point

Pour point is the temperature at which oil just flows. An oil's pour point should be at least -40° C to ensure correct cold-weather operation of switchgear. Pour-point depressants can be added to oil that does not meet this specification, but the resulting compound will not be satisfactory for arc interruption.

Flash Point

Flash point is the temperature at which oil gives off enough vapor to form a flammable mixture with air. An unusually low flash point indicates the presence of volatile combustible contaminants. Oil employed in Eaton's Cooper Power series switchgear should have a minimum flash point of 145° C.

Interfacial Tension

Interfacial tension is the attractive force between water and oil molecules at the plane boundary between the two liquids when they are in contact with each other. This characteristic is measured by determining the force required to pull a platinum ring through an oil-water interface. Interfacial tension is significant because it gives an early indication that deterioration is taking place. The reason for this is that polar contaminants and products of oxidation tend to concentrate at an oil-water interface. The resultant drop in interfacial tension can be detected before other test methods indicate that deterioration has started. Plastics, rubber, sponge, and metals can all contribute to a lowering of interfacial tension values.

Oils with low interfacial tension values tend to hold free moisture in suspension and, consequently, have a lower dielectric strength. The dielectric strength can be improved by filtering the oil to remove free water and solid contaminants. If however, the filtering process does not remove the contaminants that caused a lowering of the interfacial tension value, the oil will pick up moisture rapidly and the dielectric strength will again fall. One method of improving the interfacial tension value of a used oil is to treat it with Fuller's earth and then filter it.

Neutralization Number

Neutralization number is defined as the number of milligrams of potassium hydroxide required to neutralize one gram of oil. Impurities such as uncured plastics, resins, and varnishes or oxidation of oil can cause high acidity. Arc interruption also causes formation of some acids. Acids will attack organic insulation and this, in turn, causes a further deterioration of the oil. New oil should have a neutralization number no greater than 0.03.

Treatment of Oil

New Oil

New oil should always be filtered before using even though it was obtained from an approved source. Passing the oil through a blotter press removes free water and solid contaminants such as rust, dirt, and lint. No further treatment of new oil should be necessary. When filtering the oil, aeration should be minimized because moisture in the air might condense in the oil and lower the dielectric strength.

Used Oil

Used oil generally must be treated before using in switchgear. The amount of treatment depends upon the oil's condition and the service it must perform. A convenient classification of possible actions is given in the ANSI/IEEE Standard C57. 106, *Guide for Acceptance and Maintenance of Insulating Oil in Equipment*.

Methods in the Guide are classified as reconditioning and reclaiming. Reconditioning means the removal of moisture and solid contaminants by mechanical methods. Reclaiming means removal—by chemical and absorbent methods—of products of oxidation, collodial and acidic contamination, and products of combustion. Common methods of reconditioning include passing oil through a filter press or centrifuge. Free and suspended water and insoluble contaminants can be removed by this process but soluble sludge, acids, air, and dissolved water cannot. Oil can be treated as a vacuum dehydrator to remove water, air, and volatile products of deterioration but soluble sludges and acids remain.

Reclaiming is necessary to salvage oil that is badly deteriorated. One chemical method involves washing the deteriorated oil with a solution of trisodium phosphate in water. The oil-and-phosphate mixture is agitated thoroughly and allowed to settle for a period of time. Sludge, trisodium phosphate, and water are then drained off, leaving clean oil. This oil is then passed through Fuller's earth until the neutralization number and interfacial tension are within acceptable limits. Another chemical method involves the use of carbon and sodium silicate.

Reclaiming can also be performed by the use of activated clay or activated alumina filters. In any specific instance, the choice between reclaiming and discarding the oil will depend upon economic factors. If reclaiming or reconditioning is decided upon, care should be taken to ensure that the oil is returned to a like-new condition.

Testing

Most users perform some of the tests listed in Table 1 but few are prepared to completely analyze oil samples. The extent of testing must be based on the amount of oil used, value of equipment, personnel safety, test equipment available, and skill of operators. If a complete oil analysis is desired for any reason, Eaton will perform all the tests necessary to determine the oil's condition at a nominal charge. Shipping containers are provided as part of the service. Sampling techniques outlined in ASTM D923, *Standards on Electrical Insulating Materials*, should be observed to ensure a representative sample is obtained.

Eaton
1000 Eaton Boulevard
Cleveland, OH 44122
United States
Eaton.com

Eaton's Power Systems Division
2300 Badger Drive
Waukesha, WI 53188
United States
Eaton.com/cooperpowerseries

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