



INSTALLATION • OPERATION • MAINTENANCE INSTRUCTIONS

Oil-Immersed INSTRUMENT TRANSFORMERS AND METERING OUTFITS

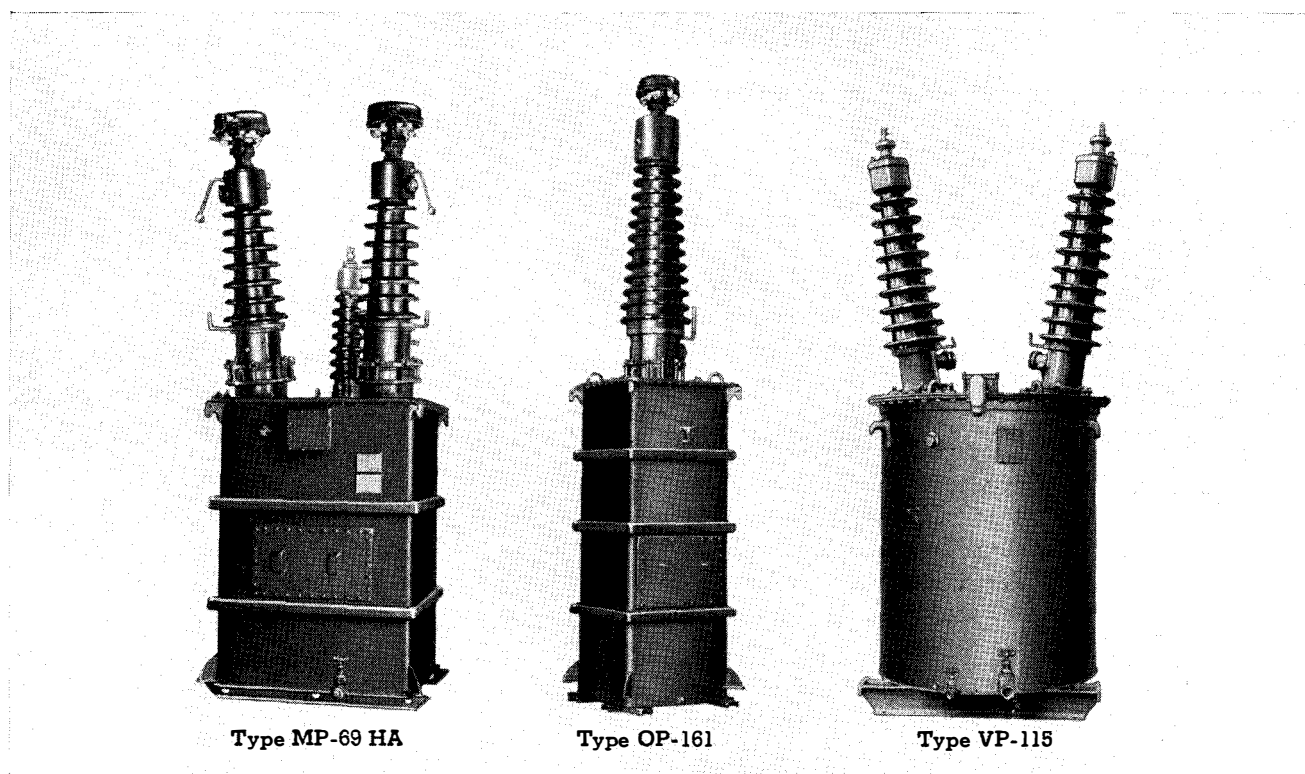


FIG. 1. Various Types of Oil-Immersed Instrument Transformers.

Instrument transformers in general, although they are precision devices and should be carefully handled, are actually of rugged construction and generally simple and foolproof. Usually no special instruction besides what is given on the nameplate is necessary for their operation. A review of the Catalog Section and the Nameplate, as well as the data given in this leaflet, is suggested. Also, see Application Data 45-000.

RECEIVING

Instrument transformers when shipped have been thoroughly tested for defects and are perfectly dry. When received by the customer, they should be carefully examined before they are accepted from the carrier. If any damage is evident, a claim should be filed with the transportation company and the manufacturer should be notified at once.

HANDLING

Instrument transformers are usually of very rugged construction, but they may be damaged by rough handling.

When oil-immersed instrument transformers cannot be moved by a crane, they may be skidded or moved on rollers, but care should be taken not to damage the tank base nor to tip them over. Oil-immersed instrument transformers should not be lifted or moved by means of a jack or pry under the drain valve, and no mechanical force should be applied to the leads or bushings.

INSTALLATION

Before instrument transformers are installed, they should be carefully inspected for breakage, injury or misplacement of parts during shipment.

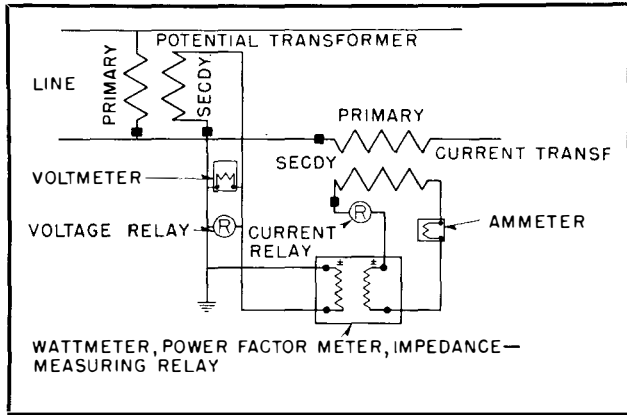


FIG. 2. Connection of Current and Potential Transformers in a Simple Single-Phase Circuit.

or storage, and carefully examined for moisture. All accessible bolts, nuts and studs should be tight. Instrument transformers should be installed on solid supports, and all connections should be made so that no mechanical stress is put on the leads or terminals of the transformers.

OPERATION

The Insulating Function of High Voltage Instrument Transformers. The primary reason for use of high voltage instrument transformers is the necessity of insulating instruments and relays from the line voltage. The conventional connection is shown in Fig. 2.

More complicated arrangements are used in three-phase or differential circuits. The secondary circuit must always be grounded because while the secondary circuit and the transformer tank are insulated from the high voltage, they are coupled to it electrostatically as shown in Fig. 3.

The windings of the transformer may be thought of as plates of a capacitor. The electrostatic voltage from the secondary winding to ground will depend on the relative capacitances and may easily reach a dangerous and destructive value unless the secondary winding is connected to ground. **Therefore, the secondary circuit should always be grounded.** (See AIEE Application Guide for Grounding of Instrument Transformer Cores and Secondary Circuits).

Short-Circuit of Potential Transformers: Short-circuit of a potential transformer secondary is like short-circuit of any other transformer; it burns out in a very short time. Accidental short-circuits do occur, and the windings are designed to withstand the large mechanical forces which result, but they cannot be practically designed to

carry the short-circuit current for much more than one second. **The secondary winding of a potential transformer should never be short circuited.**

Current Transformers with Open-Circuited Secondary. Normally the secondary winding delivers a secondary current in correct ratio to the primary current into a burden never in excess of a few ohms, requiring only a low voltage at the secondary terminals. But, if the secondary circuit is opened, the impedance of the burden in effect becomes infinite, and the current transformer does its best to supply the corresponding infinite voltage. In other words, the entire primary current becomes exciting current for the iron core. Oil-immersed transformers generally can develop more than 5000 volts (crest value) which is both dangerous and destructive. **The secondary winding of a current transformer should never be open circuited.**

Insulation Structures, Processing, and Dielectric Losses. Modern transformers usually have an insulation structure composed of paper, pressboard, and oil, so arranged that the mechanical and dielectrical strengths of each are used to best advantage. (See Application Data 45-000).

These insulation structures are thoroughly dried under heat and vacuum to remove moisture, and impregnated with oil. The whole transformer is filled with oil under a vacuum to make sure that no air pockets or bubbles remain inside the insulation structure at any point.

The power factor of the majority of all Westinghouse oil-immersed instrument transformers above 25 kv class is now measured as a part of the routine test to detect excess moisture and other impurities in the insulation or oil. Certain impurities in the oil or in certain insulation parts may cause higher

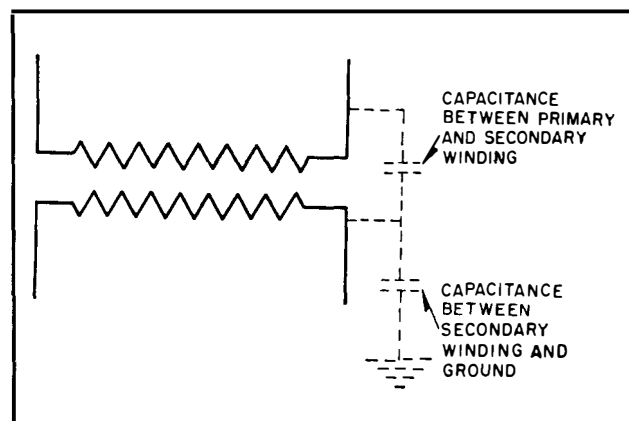


FIG. 3. Equivalent Circuit Showing Capacitance Effect.

power factor but without reducing the insulation strength, and are not cause for rejection. However, no units exceeding 4% P.F. at 20°C. are at present considered to be acceptable in oil-immersed transformers above 25 kv class.

Insulation Classes, Tests, and Service Voltage. Instrument transformers, as well as other kinds of transformers, are given "Insulation Class" ratings, as the ASA Standard C-57.11, Paragraph 11.030 states: "to indicate the dielectric tests which the apparatus is capable of withstanding."

In addition, the ASA Standards include tables indicating application of standard transformer ratings. Tables 13.016 and 13.051 are reproduced below (in part, 25 kv and up).

The voltage ratings 24000/24000 Y etc., may need some explanation. This means that the line-to-line system voltage should not exceed 24000 volts whether the transformers are connected in delta, or if they are connected in wye. The 24000 volt transformer is not good for continuous operation with 24000 volts *line to ground*, because this is equivalent to a 24000 $\sqrt{3}$ or 41600 volt system. This same principle applies to all transformers in Group 2.

14400 for 25000 Grd.Y indicated in Group 3 means that the transformer is suitable for connection to a 25000 volt system, connected from *line to ground* only, but it may be used in this way on grounded or ungrounded systems. According to Paragraph 13.008, these transformers "shall be suitable for operation at 1.73 times rated line to ground voltage under emergency conditions without appreciable injury". The 200/120 to 1 ratio means that both ratios are available, for separate or simultaneous use, by means of a double secondary winding or by a tap in the secondary.

Voltage transformers connected *line to ground* on an ungrounded system may be subjected to destructive voltage caused by the phenomenon called "ferro-resonance" or "neutral inversion". Neutral inversion and means for its control are discussed in Westinghouse Technical Data Section 45-910 and references in its Bibliography.

If one terminal of a transformer is connected to a line, but the other terminal left unconnected, the capacity current into the winding may induce a rather high voltage. The secondary winding should be loaded with resistance to prevent the high induced voltage.

Operation With Rated Voltage to Ground During Line-to-Ground Faults. Transformers are designed with the expectation that the system to which they are connected will be sufficiently well grounded to maintain the neutral at ground potential, with each line above ground at $1/\sqrt{3}$ of rated line-to-line voltage. No system is really ever totally isolated from ground. The so-called "ungrounded" system is actually connected to ground by the capacitance and leakage resistance of its lines to ground.

If a line becomes grounded, line-to-line voltage is applied from line to ground on the other two lines, and to the terminals of transformers connected to them. This will overstress the line bushings as well as the winding insulation; corona, with resulting radio interference and deterioration of insulation, may result. Continuous operation with one line grounded or partially grounded should not be contemplated.

Yet it is obvious that lines sometimes do become grounded, and transformers must be designed for emergency operation at line-to-line voltage applied from one terminal to ground. Operation under this condition should be contemplated for emergencies only with the knowledge that transformer insulation deterioration is being accelerated.

METERING OUTFITS

Metering outfits are complicated only in that they consist of two or more transformers in one tank. The individual transformers and their principles of connection and operation are not different from any other instrument transformers.

A diagram nameplate is mounted on all metering outfits to show the schematic connections between the primary windings of potential and current transformers and the connections to the terminals. This should be studied carefully. All secondary leads are brought out to the secondary terminal block so that they are available for any connection arrangement which may be desired. *Particular attention should be given to correct identification of secondary leads* as confusion of current and potential transformer leads can cause severe damage (see short circuit of Potential Transformers and Open Circuit of Current Transformers). The marking of the leads of the transformers are in accordance with the EEI Metermen's Handbook.

OIL-IMMERSED INSTRUMENT TRANSFORMERS

MAINTENANCE

Modern transformers are sealed to prevent entrance of moisture and oxidation of the oil. This eliminates the deterioration of the oil, and oil maintenance is usually unnecessary. A periodic check of the oil level is all that is usually necessary. In case of doubt as to whether a leak has occurred and moisture has entered, a measurement of oil strength and insulation power factor is desirable. (See I.B. 44-820-1, Insulating Oil for Electrical Apparatus).

Insulation power factor should be measured only after the transformer has been disconnected for several hours to permit it to attain a uniform temperature. The power factor corrected to 20°C. should not exceed 4%.

If measurements indicate that moisture is entering the transformer, the first step is to find the leak and eliminate it; the second, to dry out the transformer. The means to be used depends on the type of transformer and the available equipment. Drying in a vacuum oven after draining the oil is the ideal method, and 24 hours at 90°—100°C. in

vacuum will usually dry the transformer. If a vacuum oven is not available, application of vacuum to the tank for 48 hours after draining the oil, without any heat, will remove moisture which has entered recently. Other means can be suggested by the factory depending on circumstances. Heating at a temperature of 100°C. or more in air can cause sufficient chemical change in oil-impregnated insulation that the power factor may increase instead of decrease. After drying, the transformer should be refilled by applying a vacuum to one filling plug for at least 2 hours, then admitting oil through the drain valve or any other fitting. The oil should be admitted slowly to reduce foaming and the vacuum should be maintained for at least an hour after the transformer is full.

TAKING AN OIL SAMPLE

To take an oil sample from a sealed oil insulated instrument transformer, it is generally necessary to break the seal above the oil by removing the filling plug. The filling plug must be replaced, and the transformer seal re-established after taking the oil sample.



WESTINGHOUSE ELECTRIC CORPORATION
SHARON PLANT • TRANSFORMER DIVISION • SHARON, PA.

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TABLE 13.016 (in Part)

NAMEPLATE MARKING					STANDARD DIELECTRIC TESTS			
Standard Insulation Class Kv	Standard Marked Ratio	Standard Primary Voltage Ratings Volts	Usual Circuit Voltage Volts	Permissible Transformer Connections	Standard Low Frequency Test Kv RMS	Standard Impulse Tests		
						Chopped Wave		Full Wave
						Crest Voltage Kv	Min. Time to FO Sec.	Kv Crest
GROUP 2—25 TO 345 KV, FULL INSULATION, WYE VOLTAGE LIMIT EQUALS DELTA VOLTAGE LIMIT								
25	200:1	24000/24000Y	24000	Delta or Wye	50	175	3.0	150
34.5	300:1	34500/34500Y	34500	Delta or Wye	70	230	3.0	200
46	400:1	46000/46000Y	46000	Delta or Wye	95	290	3.0	250
69	600:1	69000/69000Y	69000	Delta or Wye	140	400	3.0	350
92	800:1	92000/92000Y	92000	Delta or Wye	185	520	3.0	450
115	1000:1	115000/115000Y	115000	Delta or Wye	230	630	3.0	550
138	1200:1	138000/138000Y	138000	Delta or Wye	275	750	3.0	650
161	1400:1	161000/161000Y	161000	Delta or Wye	325	865	3.0	750
196	1700:1	196000/196000Y	196000	Delta or Wye	395	1035	3.0	900
230	2000:1	230000/230000Y	230000	Delta or Wye	460	1210	3.0	1050
287	2500:1	287000/287000Y	287000	Delta or Wye	575	1500	3.0	1300
345	3000:1	345000/345000Y	345000	Delta or Wye	690	1785	3.0	1550
GROUP 3—25 KV TO 345 KV, REDUCED INSULATION AT NEUTRAL END, GRD.Y APPLICATION ONLY								
25	200/120:1	14400 For 25000 Grd.Y	24000	Grd.Y only	50	175	3.0	150
34.5	300/175:1	20125 For 34500 Grd.Y	34500	Grd.Y only	70	230	3.0	200
46	400/240:1	27600 For 46000 Grd.Y	46000	Grd.Y only	95	290	3.0	250
69	600/350:1	40250 For 69000 Grd.Y	69000	Grd.Y only	140	400	3.0	350
92	800/480:1	55200 For 92000 Grd.Y	92000	Grd.Y only	185	520	3.0	450
115	1000/600:1	69000 For 115000 Grd.Y	115000	Grd.Y only	230	630	3.0	550
138	1200/700:1	80500 For 138000 Grd.Y	138000	Grd.Y only	275	750	3.0	650
161	1400/800:1	92000 For 161000 Grd.Y	161000	Grd.Y only	325	865	3.0	750
196	1700/1000:1	115000 For 196000 Grd.Y	196000	Grd.Y only	395	1035	3.0	900
230	2000/1200:1	138000 For 230000 Grd.Y	230000	Grd.Y only	460	1210	3.0	1050
287	2500/1500:1	172500 For 287000 Grd.Y	287000	Grd.Y only	575	1500	3.0	1300
345	3000/1800:1	207000 For 345000 Grd.Y	345000	Grd.Y only	690	1785	3.0	1550

INSTALLATION OR CHANGING OF CONDENSER BUSHINGS

Caution: When working around oil-immersed instrument transformers, special care should be taken in handling tools and other loose articles, since anything metallic dropped into the windings and left there may cause a breakdown. It is sometimes convenient to have a long string tied to the tools so that if they are accidentally dropped they may be easily recovered.

General Information for New Equipment.

All transformers 92 kv class and above, and some of lower voltages, are shipped with the bushings

removed, and the bushings must be installed by the user. The applicable instruction leaflets (I.L. 33-155-1 for Type O Bushings; I.L. 46-719-3 for Type S Bushings) give the general information and precautions for this part of the work.

Potential Transformer Bushings. The bushing cable lead for potential transformers will be found coiled and suspended from the underside of the shipping flange on the bushing boss. The cable lead must be fished through the bushing, making sure that there is no kink in the cable. The lead must be kept taut while the bushing is being lowered into position through the cover.

TABLE 13.051 (in Part)

STANDARD INSULATION CLASSES AND STANDARD DIELECTRIC TESTS FOR CURRENT TRANSFORMERS					
Standard Insulation Class (Nameplate Rating)	Maximum Line-to-Line Voltage	STANDARD DIELECTRIC TESTS			
		Standard Low Frequency Tests	Standard Impulse Tests		
			Chopped Wave		Full Wave
			Crest Voltage	Minimum Time to Flashover	
Kv	Kv	Kv Rms	Kv Crest	Seconds	Kv Crest
25	25	50	175	3.0	150
34.5	34.5	70	230	3.0	200
46	46	95	290	3.0	250
69	69	140	400	3.0	350
92	92	185	520	3.0	450
115	115	230	630	3.0	550
138	138	275	750	3.0	650
161	161	325	865	3.0	750
196	196	395	1035	3.0	900
230	230	460	1210	3.0	1050
287	287	575	1500	3.0	1300
345	345	690	1785	3.0	1550

Current Transformer Bushings. The current transformer bushing is shipped complete with its outlet cable leads. Drain the oil out of the case precisely enough to bring the oil level to just below the bottom of the service hole on the side of the case. *The transformer coils and insulation should be under the lower oil level at all times.* Remove the service hole cover and install the bushing on the tank cover. Connect the leads through the bushing to the H.V. coil leads of the same number. Smooth around bolts and terminals with treated cambric tape and cover each connection separately with treated cambric tape to approximately $\frac{1}{8}$ inch thick. Group the four leads together and cover with two layers of treated cambric tape from the H.V. coil to the bushing.

Replace the service hole cover and slowly re-fill with oil through the filling plug on the cover. If a vacuum facility is available, it is highly recommended that a vacuum be applied during the re-filling operation and at least an hour after refilling.

Changing Bushings. Follow above procedure in general after removing old bushing.

High voltage current transformers and metering outfits manufactured prior to 1950 were not supplied with the service hole in the tank wall. For units of this design it will be necessary to

remove the core and coil assembly, which is cover suspended, install the high voltage bushings, and tape the connections as outlined above.

Carefully replace the complete core and coil, cover and bushing assembly into the tank. It is highly recommended that a vacuum be applied for at least an hour after assembly. The core and coil assembly should not be out of oil more than eight hours, if possible, especially in humid weather.

Changing Weather Casings on Types OPT-OCT. This is an involved operation requiring special procedure. For information contact nearest Westinghouse Office.

INSPECTION FOR DAMAGE

If there is reason to believe the transformer has been internally damaged by shipment or handling, it may be necessary to remove it from the tank for inspection. Care should be taken to put it back under oil within 8 hours if possible, especially in humid weather.

The transformer should be refilled under vacuum if the oil is drained for any reason, or if the core and coils are removed from the tank. (See following section on Maintenance.)

HANDLING • INSPECTION • MAINTENANCE



I N S T R U C T I O N S

WEMCO[®] C

and

WEMCO CI

INSULATING OILS

P.D.S. 2772 and P.D.S. 9855

for

Electrical Apparatus

WESTINGHOUSE ELECTRIC CORPORATION

SHARON PLANT

SHARON, PA.

TRAFFORD PLANT

TRAFFORD, PA.

SUPERSEDES I.B. 44-820-1B

OCTOBER, 1961

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WEMCO® C INSULATING OIL P.D.S. 2772

WEMCO CI--INHIBITED INSULATING OIL--P.D.S. 9855

Wemco C insulating oil and Wemco-CI oil are developments of the Westinghouse Electric Corporation in cooperation with oil refiners. They have been proven suitable for use in all Westinghouse oil-insulated apparatus. In order to insure the proper performance of the apparatus, only Westinghouse approved oils should be used.

This publication gives the instructions for handling, inspection and maintenance which experience has shown are important in obtaining the best service from the insulating oil.

PART ONE

RECEIVING, STORING AND HANDLING

SHIPMENT

Wemco C and Wemco CI oils are shipped in tank cars, drums or cans. Modern tank cars are usually equipped with breathers which bar the admission of moisture and are otherwise well gasketed to protect the oil from moisture. These precautions are necessary because the volume of the oil changes with temperature variations.

When shipped in drums, the drums are provided with screw bungs having gaskets to prevent admission of water.

When shipped in cans, the cans are hermetically sealed immediately after filling and should not be opened until the oil is needed.

STORING

Drums. As soon as a drum of oil has been unloaded, the bung should be examined for damage or leaks.

It is very desirable that oil in drums be stored in a closed room. Outdoor storage of oil is always hazardous to the oil and should be avoided if at all possible. Regardless of storage location all drummed oil should be stored with the bungs down so that the bungs are under positive oil pressure. Do not open the drums until the oil is actually needed. Partially emptied drums must be tightly resealed and stored the same as new drums.

Cans. One and five-gallon cans of oil must not be exposed to the weather. Seals should be kept intact until the oil is actually needed. It is not necessary to make dielectric tests on oil in sealed cans.

Screw caps are provided on the cans to use when the oil is only partially removed after the hermetic seal has been broken. By replacing the screw caps, contamination by moisture and dirt will be retarded but the oil must be tested before using.

Storage Tank. The storage tank should be mounted on piers so that it will not touch the ground, and will be accessible to all points for inspection for leakage.

In larger storage systems, it is desirable to provide equipment to supply **dry air** for breathing purposes. This is often accomplished by the use of

a breather making use of silica gel or aluminum oxide as the drying medium.

The tank should preferably have a convex bottom, allowing the installation of a drain cock at the lowest point for removing any free water or dirt which might settle out. When a cylindrical tank is installed with its axis horizontal, one end should be a little lower than the other, with a drain cock at the lowest point, and the oil supply pipe should enter at the opposite end of the tank. The oil may enter and leave the tank by the same pipe, but this should be at some distance from the bottom to prevent stirring up any settlings when the tank is being filled. It is desirable that the pipe be provided with a swing joint and float, so that it will automatically move with the change in oil level and remain near the surface of the oil.

FIRE PROTECTION

IMPORTANT: While Wemco C or Wemco CI oil will not take fire unless brought to a high temperature (320° F), it should be remembered that under abnormal conditions such a temperature can be reached, so that proper precaution against fire should be taken. The best way to extinguish burning oil is to smother the flames so that the supply of fresh air is cut off. Chemical fire extinguishers are effective, but water should not be used unless it is applied by a special atomizing spray nozzle.

HANDLING

SAMPLE AND DIELECTRIC TEST ALL OIL BEFORE PLACING IT IN APPARATUS.

Before putting the oil into equipment see that the tank is free from moisture and foreign material. The presence of impurities, particularly moisture, in the oil or apparatus may lower its dielectric strength to an unusable value. If the oil is supplied in more than one container, each container must be sampled and tested.

Although the drums and tank cars are thoroughly washed and dried at the refinery before filling, a certain amount of scale is sometimes loosened from the inside in transit. Therefore, it is recommended that all the oil be passed through a filter press to remove any moisture or solid contaminants which may be present.

The preparation and filling of outdoor apparatus should preferably be done on a clear, dry day; if this is not practicable, protection against moisture must be provided.

All vessels used for transferring the oil should be carefully inspected to see that they are absolutely dry and free from dirt.

Whenever possible it is recommended that all equipment should be allowed to stand for at least eight hours between filling and energizing the apparatus to allow gas bubbles to escape from the oil. This is especially important when filling under vacuum is impossible.

IMPORTANT: Always use a metal or oil proof hose when handling the oil. A hose made of natural rubber must not be used. Oil may easily become contaminated from the sulfur in the natural rubber, and should not be allowed to come in contact with it.

When it is necessary to fill equipment with oil, it is essential that the oil be allowed to come to the same temperature as the apparatus. This may require eight hours, or even longer, under extreme temperature conditions. Otherwise, condensation of moisture may lower the dielectric strength of the oil to an unusable value. Cold oil in drums should never be brought into a warmer area and transferred to equipment until it has reached the same temperature as the apparatus.

FILLING DRUMS

The practice of filling drums with oil is undesirable and should be avoided whenever possible, for unless the utmost precautions are taken, the oil is likely to become contaminated.

If it is necessary to fill drums for storage, use only those drums which are in good condition and which have been used previously for transformer oil. A good practice is to reserve drums for this purpose by sealing them immediately after being emptied to exclude dirt and water. Before reusing each drum should be carefully examined to be sure it is clean and free of water.

A new washer should be used with the bung each time the drum is refilled, to insure a tight seal. These washers may be obtained from the oil refineries and it is recommended that a supply be kept on hand. Natural rubber composition washers should never be used as they would be attacked by the oil.

Cleaning Contaminated Drums. The cleaning of drums which have contained used insulating oil requires great care in order to insure a thoroughly clean drum. It is preferable to return such drums to the refinery where adequate cleaning facilities are available, rather than to attempt to clean them. If it is necessary to clean such drums, the following procedure is recommended:

Rinse the drum thoroughly with gasoline or benzine, using about one gallon each time, until the solvent shows no discoloration after using. Allow it to drain, then pump out the last traces of solvent with a vacuum pump, using a brass pipe flattened at the lower end to explore the corners of the drum.

CAUTION: Do not use a steel pipe because of the danger of a spark igniting the vapor.

Heat the drum with bung hole down, in a ventilated oven at a temperature of at least 88°C (190°F) for sixteen hours. Screw the bung on tightly before removing drum from the oven. Use a new washer with the bung to insure a tight seal. A simple oven for this purpose may be made from sheet metal and heated with steam or an electric heater.

CAUTION: An open flame must always be kept away from the oven to prevent igniting inflammable gases.

REFILLING DRUMS

CAUTION: STATIC ELECTRICITY—Pumping and filtering of oil under certain circumstances may cause electrical charges to be built up in the oil to such an extent that electrical breakdown of the gas above the oil is possible. When a filter press is used to filter the oil in the equipment, precautionary measures should be taken to prevent an explosion caused by the possible static discharge of the electrical charge which could be built up in the equipment. If this electrical discharge takes place in an explosive gas mixture, the result could be a damaging explosion.

This static charge is variable and depends upon a number of variable factors. Since some of these factors are beyond the range of control, it may be best to surmise that they will always be present. Thus there will always be the possibility of this static discharge.

A thorough purging with the use of nitrogen, of the accumulated gases formed in any electrical equipment should be made before filtering the oil. This will offset any possible reaction between the static discharge and the accumulated gases.

PART TWO

OIL CHARACTERISTICS, SAMPLING AND INSPECTION

CHARACTERISTICS OF INSULATING OIL

Wemco "C" insulating oil is a refined mineral oil obtained from the fractional distillation of crude petroleum. It contains no moisture, inorganic acid, alkali, free sulfur, asphalt, tar, vegetable, or animal oils. It is used as an insulating and heat transfer medium and is intended principally for use in tanks of oil insulated circuit breakers, switches and transformers. In circuit breakers and other apparatus subject to arcing, the cooling and deionizing characteristics of the oil become important in extinguishing the arc.

Wemco "CI" inhibited insulating oil has a minimum of 0.2 percent by weight of Di-Tertiary-Butyl-Paracresol, (D.B.P.C.) added to Wemco "C" insulating oil to provide additional oxidation resistance for use in distribution transformers that may be subject to breathing of air and where it is difficult to maintain tight seals.

ADVANTAGES OF WEMCO "C" OIL

1. High dielectric strength.
2. Low viscosity—provides for good heat transfer.
3. Freedom from inorganic acids, alkalis, and corrosive sulfur—prevents injury to insulation and materials of construction.
4. Good resistance to emulsification. In case of moisture contamination it quickly settles to the bottom of the tank.
5. Freedom from sludging under normal operating conditions over long periods of time—accomplished by proper selection of crudes and refining methods.
6. Because of its low viscosity it is more able to dissipate the arcing products in circuit breakers, tap changers, and other arcing contact apparatus.
7. Low pour point allows use under low temperature conditions.
8. The higher than average flash point allows higher operating temperatures with freedom from fire hazard.

PHYSICAL PROPERTIES AND TEST PROCEDURE

1. Color—nearly water white—1.0 max.—ASTM D155

2. Reaction—Neutral
3. Neutralization Number—Mg. KOH per g. oil—0.03 max. ASTM D914
4. Precipitation Number—zero
5. Free or Corrosive Sulfur—No. 2 Strip Max.—ASTM D1275
6. Steam Emulsion—35 sec. max.—ASTM D157
7. Flash Point—293°F (145°C) Min.—ASTM D92
8. Pour Point—Minus 50°F (minus 45.0°C) Max.—ASTM D97
9. Viscosity—Saybolt Universal—100°F (37.8°C) Max.—62 sec.—ASTM D88
10. Moisture Content—35 ppm. Max. ASTM D1533
11. Specific Gravity—60°F (15.5°C)—.898 Max. ASTM D1298
12. Specific Heat—0.488 Approx.
13. Inorganic Chlorides or Sulfates—None—ASTM D878
14. Coefficient of Expansion 32°F (0°C)—.000725
15. Coefficient of Expansion 212°F (100°C)—.000755
16. Interfacial Tension dynes/cm.—40 Min. ASTM D971
17. Dielectric Constant—2.2
18. Dielectric Strength at point of shipment—26,000 Volts—ASTM D877
19. Dielectric Strength at destination—22,000 Volts—ASTM D877
20. Weight per gallon—7.5 lbs.
21. Power Factor—60 cycle 25°C—Max. 0.1%—ASTM D924
22. Inhibitor (D.B.P.C.) (PDS 9855) (Wemco CI only) Min. 0.2% ASTM D1473

CAUSES OF DETERIORATION OF OIL

Transformers. Deterioration of oil is a problem to which much thought and research has been devoted. Westinghouse Sealedaire, Inertiaire, Thermosiphon, and expansion tank transformers are

the results of this research in methods of preventing deterioration.

Generally speaking, however, the principal causes of deterioration of insulating oils are:

1. Presence of moisture.
2. Oxidation.
3. Excessive temperature.

Condensation from moist air due to breathing of the transformer, especially when the transformer is not continuously in service, may injure oil. (The moist air drawn into the transformer condenses moisture on the surface of the oil and inside of the tank.) The oil may also be contaminated with water through leakage such as from leaky cooling coils or covers.

Sludge is an oxidation product, the amount formed in a given oil being dependent upon the temperature and the time of exposure of the oil to the air. In the refining process for our transformer oil, the components of the oil which are most readily oxidized to form sludge are removed so as to provide an insulating oil which will not sludge under normal operating temperatures.

Note: Excessive temperatures may cause sludging of any transformer oil regardless of how well it is refined.

Transformer oil which has begun to sludge will continue to do so even after it has been reconditioned by means of the centrifuge or filter press, as these methods of reconditioning do not remove the deterioration products which are in process of formation but have not yet been precipitated as sludge.

Reconditioning by means of fuller's earth and vacuum dehydration will remove many of the deterioration products, and if stabilized by the addition of an oil inhibitor, further sludging can be prevented for long periods of time.

Another effect of oxygen is to gradually produce organic or "fatty" acids in oil in service. These should not be confused with the mineral acids such as sulphuric acid used in refining, as in small amounts the former do not have a deteriorating effect upon insulation.

Circuit Breakers. The principal causes of deterioration of insulating oil in circuit breakers or other arc producing apparatus, are:

1. Presence of water.
2. Carbonization of the oil (caused by operation of the circuit breaker).

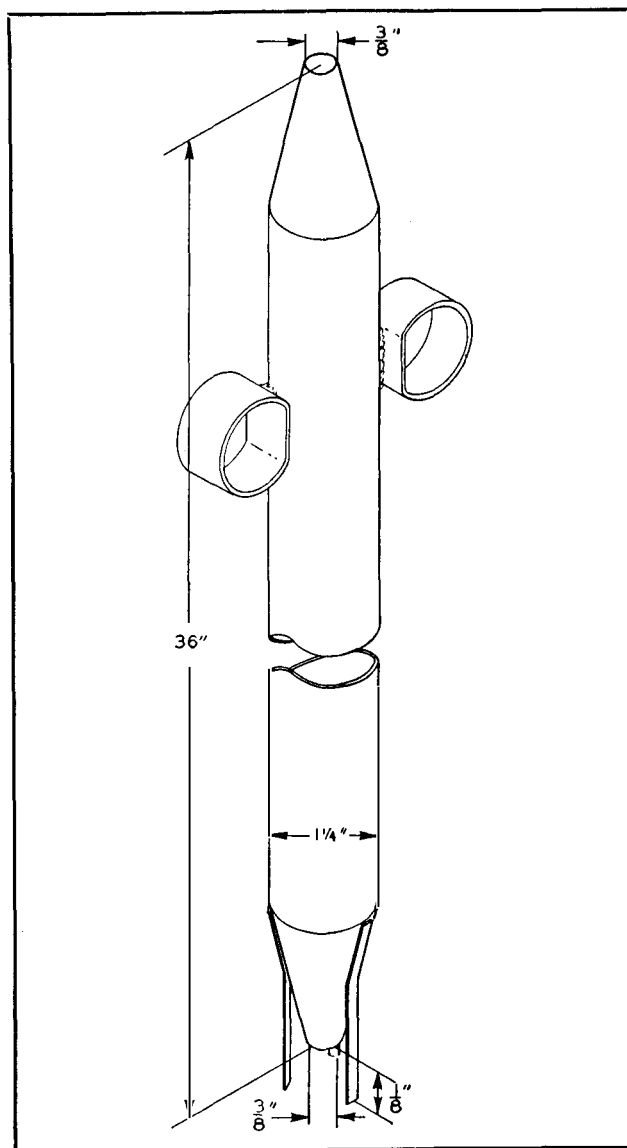


FIG. 1. Drum Thief.

The arcing of the oil in circuit breakers produces small amounts of water, acids, and carbon due to oil decomposition. These acids may in extreme cases form metal soap on plated hardware but this in no way harms the apparatus. Water may also result from the entrance of moist air into the tank. Some of the carbon is deposited on the contact components and at the bottom of the tank while the remainder continues in suspension in the oil.

Carbonization takes place not only when the circuit breaker opens heavy short circuits, but also whenever an arc is formed, even during such light service as the opening of the charging current of the line, and this latter service, repeated, may eventually produce enough carbon to be a source of trouble.

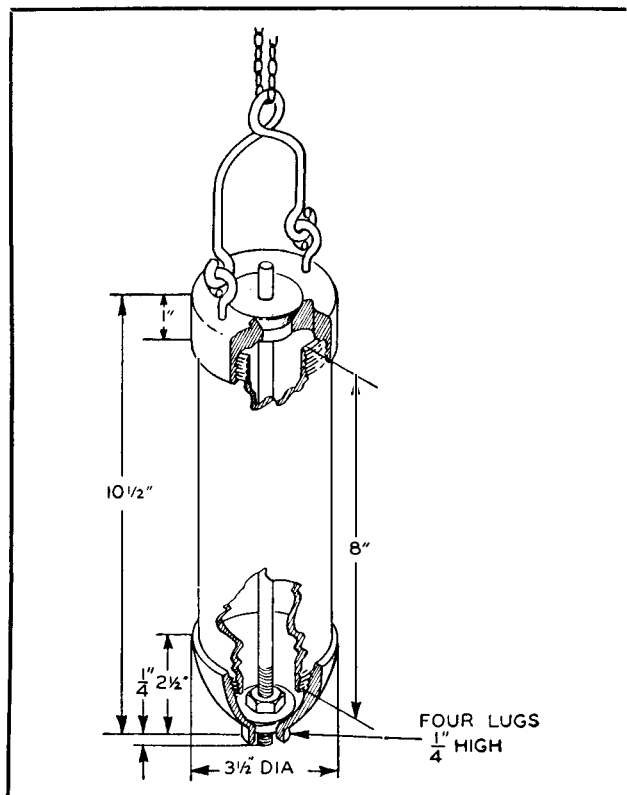


FIG. 2. Tank Car Thief.

The carbon may reduce the dielectric strength of the oil, lower the surface resistance of the insulation if water is present, and also may lower the resistance to emulsification. The carbon alone may not be detected by the dielectric test, particularly if the oil is free from moisture.

In cold weather, a larger amount of carbon is formed than in warm weather because of the increased viscosity of the oil at low temperatures. Also the carbon is not as readily dispersed through the oil.

SAMPLING OIL FROM SHIPPING CONTAINERS

The dielectric strength of oil is affected by the most minute traces of certain impurities, particularly water. It is important that the greatest care be taken in obtaining the samples and in handling them to avoid contamination. There have been low dielectric test results reported from the field which, upon investigation, have been found to have been largely a matter of carelessness in handling. The following instructions, based on the specifications of the American Society for Testing Materials, must be followed to assure accurate results:

Sample Bottle. The sample container shall be made of amber glass, of at least 16 oz. capacity,

and shall be cleaned and dried. The glass bottle is preferable to a metal container as it may be examined to see if it is clean. It also allows visual inspection of the oil before testing, particularly as regards free water and solid impurities. However, any samples to be tested for color power factor or sludge-forming characteristics must be kept in the dark, as light produces changes in these properties. This is not necessary for any other tests.

The clean, dry bottle shall be thoroughly rinsed with benzine or dry lead-free gasoline which has previously withstood a dielectric test of at least 25 kv in a standard test cup, and shall be allowed to drain. It is preferable to heat the bottle and cap to a temperature of 100°C (212°F) for one hour after thoroughly draining. The bottle shall then be tightly capped and the neck of the bottle dipped in melted paraffin.

IMPORTANT: Glass jars having rubber gaskets or stoppers must not be used. Oil may easily become contaminated from the sulfur in natural rubber.

Thieves for Sampling. A convenient and simple thief (See Fig. 1) for use with 55 gal. drums may be made of metal as follows:

Length 36 in., diameter 1 1/4 in. with cone shaped caps over the ends and openings at the ends 3/8 in. in diameter. Three legs equally spaced around the thief at the bottom, and long enough to hold the opening 1/8 in. from the bottom of the container being sampled, aid in securing a good representative sample. Two rings soldered to the opposite sides of the tube at the outer end will be found convenient for holding the thief by slipping two fingers through them and leaving the thumb free to close the opening. In an emergency a piece of glass tubing 36 in. long may be used. For the tank cars, a thief employing a trap at the bottom may be used. (See Fig 2.)

The thief shall be suitable for reaching the bottom of the container and the sample shall be taken with the thief not more than about 1/8 in. from the bottom.

Thieves should be cleaned *before and after* use by rinsing with dry lead-free gasoline; be sure that no lint or other fibrous material remains on them. When not in use they should be kept in a hot, dry cabinet or compartment at a temperature not less than 37.8°C (100°F), and shall be stored in a vertical position in a rack having a suitable drainage receptacle at the base.

Samples shall not be drawn from containers indoors until the oil is at least as warm as the

surrounding air. Cold oil may condense enough moisture on the surface from a humid atmosphere to seriously affect its insulating properties. Sampling oil from containers out of doors is undesirable, due to the possibility of condensation of moisture, and should be avoided whenever possible. (Samples should never be taken in the rain.)

Procedure. The drums to be sampled shall be assembled in line, with bungs up, and numbered. The bungs shall be unsealed and removed and laid with the oily side up beside the bungholes. The unstoppered sampling receptacle can be placed on the opposite side of the bungholes. The top hole of the thief shall be closed with the thumb, the thief quickly thrust to the bottom of the container and the thumb removed. When the thief is filled, the thumb shall be replaced, the thief quickly withdrawn and the contents allowed to flow into the sampling receptacle. The lower holes shall not be closed with the fingers of the other hand. The free hand shall not be used to guide the stream of oil except by touching the thief, and this only when necessary. The oil shall not be allowed to flow over the hand or fingers before it flows into the sampling receptacle.

When the sampling receptacle is filled, it shall be closed quickly and the bung replaced in the container and tightened. The sampling receptacle shall be taken under cover to the testing laboratory as quickly as feasible.

After using, thoroughly clean all thieves and sampling receptacles as outlined above.

The tank cars of oil shall be sampled by introducing the thief through the manhole on top of the car, the cover of which shall be removed carefully so as not to contaminate the oil with dirt. The sample shall be taken as near as possible to the bottom of the tank car. This shall not be done while rain or snow is falling.

When separate samples are being taken from a consignment or part of a consignment, care should be exercised to prevent contaminating the samples. A separate thief shall be used for each sample or the thief previously used shall be well drained and then thoroughly washed with oil from the next container to be sampled; the oil thus used for washing should be thrown away before the next sample is taken. (Enough thieves shall be provided to insure thorough drainage of each thief after rinsing with oil to be sampled before using it to withdraw the actual sample.) For obtaining only a few samples, two thieves are sufficient, but for obtaining a large number of samples (for example, sam-

pling a carload of drummed oil) six or more thieves are desirable.

When one average sample of a consignment or batch is being taken, the same thief may be used throughout the sampling operation, and it is not necessary to rinse the thief with oil before taking any of the portions that go to make up the total average sample.

Quantity of Sample. It is recommended that one 16 oz. bottle of oil be taken as a sample for dielectric tests, and a one quart sample be taken when complete physical and chemical tests are to be made. At least one sample should be taken from a tank car of oil. One sample may be taken from each drum, or if desired, a composite sample may be made from oil from five drums, provided all of the drums are airtight. When the bung is first loosened, a hissing sound should be heard, which indicates that the drum has been airtight. If the test of the composite sample is not satisfactory, a sample from each of the drums represented should be tested.

When drums have been stored exposed to the weather, a sample from each drum shall be tested. The sample of oil should be examined for free water, and if any is noted, the drum of oil should be put through a blotter filter press and resampled for dielectric strength.

If the sample is being taken from a tank car, and water appears, follow the same procedure.

SAMPLING OIL FROM APPARATUS

When taking samples of oil from apparatus in which a thief cannot be used, use the sampling valve and follow the procedure outlined above as far as practicable.

Care should be taken to procure a sample which fairly represents the oil at the bottom of the tank. A sufficient amount of oil should therefore be drawn off before the sample is taken, to insure that the sample will not be that which was stored in the sampling pipe. For this reason, the valve and the drain pipe should be sufficiently small to be emptied with convenience and yet sufficiently large to give an even flow of oil and avoid clogging by sediment. A $\frac{1}{4}$ in. pipe and valve is recommended. This, of course, may be separate from the drainage pipe and valve or it may be connected to the drainage valve by means of a suitable reducer.

It is of utmost importance that the sample of insulating oil represents the actual condition of the oil in the apparatus. Every precaution should be

taken to keep the sample and container free from foreign impurities or moisture.

If the apparatus is installed outdoors, care should be taken to prevent contamination of the sample by rain, snow, etc.

A glass bottle is recommended as a sampling receptacle, so that any water present may readily be seen.

If the sample contains free water it is not suitable for dielectric test and the sample and bottle should be discarded. A second sample should be taken after at least two quarts of oil have been withdrawn. If free water still exists in the sample, the oil in the apparatus should be put through a blotter filter press and resampled for dielectric strength.

In order to make sure that the dielectric strength is up to its proper value, the insulating oil in any piece of apparatus should be tested before its initial operation, and at regular intervals thereafter.

PERIODIC INSPECTION

Oil may deteriorate in service even under what seems to be the most favorable conditions. The more handling an insulating oil receives, the greater the opportunity for contamination unless adequate precautions are taken.

IMPORTANT: It is essential to provide for periodic inspection and test, and to purify the oil whenever necessary in order to maintain it in good condition.

Regular inspection and tests of insulating oils by electric utilities and other large users have proven the necessity of this practice. Where these inspections and tests have been systematically followed it has been found that failure of the apparatus due to the fact the oil had become contaminated with moisture and sediment, has been reduced to a minimum and has resulted in greater economy of operation. In view of the importance of the subject, it is, therefore, recommended that all companies, in the interest of good service, adopt some system of oil inspection and test.

The frequency of inspecting and testing depends upon the service to which the oil is subjected, and the construction of and the materials used in the apparatus.

Even though field experience has shown that it is not necessary to frequently examine the oil in Inertiaire or Sealedaire transformers, such oils should be inspected to insure that the Inertiaire

equipment is being maintained and the tanks are tight.

The oil in circuit breakers and transformers which are operated under extremely heavy loads requires more frequent inspection than that in normal or light service.

It is recommended that operators prepare a schedule for inspection based on the operating conditions. Reference to the station log, together with the record of dielectric tests of the oil, should determine the frequency of inspection and test. The period between successive inspections should not be longer than six months or until experience indicates that the time between tests can be extended. If the dielectric strength of the oil drops below 22 KV in the standard dielectric test the oil should be blotter pressed. In the event that the dielectric strength is not readily restored to 26 KV or above, other tests should be made to determine if the oil should be reconditioned or replaced.

Checking Oil Level. It is essential that the proper oil level be maintained. Low oil level may cause breakdown of insulation or flashover of bushing in any apparatus, or malfunctioning of circuit breakers mechanically or electrically.

Checking Dielectric Strength. The oil should be tested regularly for dielectric strength and purified when the tests show need of it. The testing should be systematized and complete records kept. It is particularly important in a circuit breaker to check the dielectric strength after exposure to near rating short-circuit operations.

Checking for Carbonization. The presence of carbon in circuit breaker oil may introduce a hazard, due to the tendency of the carbon to lower the dielectric strength of the oil, and also to deposit on insulating surfaces, thereby reducing the insulation resistance.

Visual inspection of the oil samples should be made and, if any appreciable amount of carbon is present, the oil should be reconditioned even though the dielectric test is good.

IMPORTANT: Certain washing compounds have been used by some operating companies to assist in separating the carbon from the oil. Investigation in the Westinghouse laboratories has shown that these compounds leave the oil in poor condition. Customers are warned against using any form of chemical treatment that has not been investigated and recommended by Westinghouse Electric Corporation.

Checking for Sludge. Transformers should be regularly examined for evidence of sludge. A visual inspection will indicate its presence. Appreciable amounts of sludge may clog the oil ducts and interfere with heat transfer. It is desirable that such oil be reconditioned or replaced immediately. If the oil is to be returned to service, oil inhibitor should be added to extend the life of the oil. Oil which has once sludged, will, after being reconditioned, sludge more quickly than the first time unless the inhibitor is added.

WESTINGHOUSE OIL TESTING SERVICE

Many users of transformers and large oil circuit breakers do not have the necessary facilities for testing insulating oil. In order that these users may be able to make the periodic tests recommended, Westinghouse Electric Corporation has established an oil testing service to provide a careful test by experienced engineers, and a prompt report of test results.

Two special 16 oz. sample bottles per mailing container (Westinghouse Sampling Set Style #1608 629) as well as necessary packing and printed matter, may be obtained by contacting the nearest Westinghouse office.

After drawing the sample of oil, the customer should seal the bottle with care, and mail it to the Westinghouse Electric Corp., Plant Laboratory, Sharon, Pa. The details of this transaction have been simplified by the inclusion in the Sampling Set of an instruction sheet and a printed return label. The instructions cover the taking of the sample and its proper preparation for mailing, and the label carries an envelope for enclosing customer's order covering the testing work. (Also see details given in Price List 45-825).

If customer desires to use his own bottles, he should be sure to obtain Form 24670 from the Westinghouse Office. Lack of this form will cause much delay in various accounting procedures involved, and thereby delay the test. Samples should

be taken in accordance with ASTM D-117. Note that the bottles and containers involved will not be returned to the customer.

When samples of oil are received for testing they are sent to the engineering testing laboratory and tested for dielectric strength in accordance with methods described in ASTM D-117.

As soon as the test has been made, a report giving the average is sent by mail directly to the person in the customer's organization who has been designated on the order to receive it.

In addition to dielectric tests, Westinghouse is also prepared to make a physical and chemical examination. (The customer should plainly indicate the type of service desired.)

This service consists of an examination of the oil by a competent oil chemist. Recommendations will be made as to the suitability of the oil for continued use, whether it would be desirable and economical to clean it, and in a general way, the preferred method of cleaning. In submitting samples for this service, the history of the oil represented should be given as completely as possible. Samples should be not less than one pint.

Other tests available include a complete Physical and Chemical Examination; a power factor test; and the establishment of a Power Factor Curve from 25°C to 100°C.

The Physical and Chemical Examination encompasses tests of acid and base numbers, color, interfacial tension test, pour point, specific gravity, and viscosity.

A combination is offered of the dielectric test, the acid and base number test, the interfacial tension test, and the power factor test. This combination covers those tests most often requested for general purposes.

(For further details on available tests, refer to the nearest Westinghouse Office.)

PART THREE

PURIFICATION AND RECONDITIONING

PURITY OF OIL

Wemco C oil is clear and nearly water-white in color. It is free from water, acid, alkali, and deleterious sulfur compounds.

The oil is carefully refined so as to have a high resistance to emulsion; that is, the water is not held in suspension but quickly separates out. This is particularly essential in circuit-breaker service since this apparatus cannot be tightly closed like a transformer and some moisture may be introduced into the oil. Wemco C oil has been designed with this particular property in mind and precipitates water and carbon promptly. However, certain impurities develop while the oil is in service and these impurities must be removed to insure safe operation of the apparatus. The source and kind of impurities developed in the oil depend upon the type of apparatus in which it is used.

In circuit-breaker service, each time the circuit is opened some carbon is formed in the oil, even when only a small charging current is being interrupted. The resistance to emulsion of the oil is also lessened, both by a change in the oil and by the presence of carbon in the oil. Oil which has been subjected to arc action in the circuit breaker tends to slowly form organic acids, which further tend to lower its resistance to emulsion. The major portion of the carbon slowly precipitates to the bottom of the tank, but the more finely divided carbon has a tendency to remain suspended in the oil, and lower the dielectric strength. Both carbon and moisture are attracted to the insulating surfaces of the bushings by the electrostatic field, and when so deposited, lower the insulation resistance of the terminals from line to ground.

Oil in transformers is generally subjected to heat, oxidation and sometimes to moisture. Heat in the presence of oxygen produces a gradual physical and chemical change in oil and the extent of this change will depend upon the amount of heat,

time and the catalytic action of exposed metals in the apparatus to which it is subjected. High temperature over a short period of time or somewhat lower temperature over a long period of time affect the characteristics of the oil, particularly in the development of organic acidity and sludge.

Heat in the presence of oxygen affects the unsaturated hydrocarbons, at first through formation of organic acids and later by precipitation in the form ordinarily called sludge.

RECONDITIONING

The reconditioning of oil used in circuit breakers and transformers consists principally of the removal of water, carbon and sludge and the restoration of resistance to emulsification, thereby putting the oil in the best condition to separate out any water which may later be introduced.

The four types of equipment in general use for simple reconditioning of oil in transformers and circuit breakers are: the centrifuge, the blotter filter press, the combination centrifuge and filter press and the combination fullers earth and vacuum dehydration process. (See Part Five.)

IMPORTANT: In general, when small quantities of oil have been contaminated with fire extinguishing agents, it is preferable to replace the oil rather than to attempt to reclaim it.

Insulating oil which has been contaminated with carbon tetrachloride or soda sulfuric acid cannot be reclaimed. (It would have to be refined.)

When large quantities of oil have been contaminated with other fire extinguishing agents, the reclaiming of the oil will depend upon the kind and degree of contamination. There may be factors other than the fire extinguishing agent (for instance, high temperatures cracking the oil, carbonized insulation, etc.) which should be considered. Any question should be referred to the nearest Westinghouse Office.

TESTING METHODS

Instructions for all tests listed correspond in general to the recommendations of the American Society for Testing Materials.

DIELECTRIC STRENGTH TEST

Apparatus. The transformer and the source of supply of energy shall not be less than $\frac{1}{2}$ kva, and the frequency shall not exceed 100 cycles per second. Regulation shall be so controlled that the high tension testing voltage taken from the secondary of the testing transformer can be raised gradually without opening either primary or secondary circuit. The rate of rise shall approximate 3000 volts per second. The voltage may be measured by any approved method which gives root-mean-square values.

Some protection is desirable to prevent excessive flow of current when breakdown of the oil takes place. This protection preferably should be in the primary or low voltage side of the testing transformer. It is not especially important for transformers of 5 kva or less, as the current is limited by the regulation of the transformer.

The test cup for holding the sample of oil shall be made of a material having a suitable dielectric

strength. It must be insoluble in and unattacked by mineral oil and gasoline, and nonabsorbent as far as moisture, mineral oil and gasoline are concerned.

The electrodes in the test cup between which the sample is tested shall be circular discs of polished brass or copper, 1 in. in diameter, with square edges. The electrodes shall be mounted in the test cup with their axes horizontal and coincident, with a gap of 0.100 in. between their adjacent faces, and with tops of electrodes about $1\frac{1}{4}$ in. below the top of the cup. (A suitable test cup shown in Fig. 3, and portable testing outfits in Figs. 4 and 5.)

Procedure. The spacing of electrodes shall be checked with a standard round gauge having a diameter of 0.100 in., and the electrodes then locked in position.

The electrodes and the test cup shall be wiped clean with dry, calendered tissue paper or with a clean, dry chamois skin and thoroughly rinsed with oil-free dry gasoline or benzine until they are entirely free from fibres.

The test cup shall be filled with dry, lead-free gasoline or benzine, and voltage applied with uniform increase at the rate of approximately 3000 volts (rms) per second until breakdown occurs. If the dielectric strength is not less than 25 kv, the cup shall be considered in suitable condition for testing the oil. If a lower test value is obtained the cup shall be cleaned with gasoline and the test repeated.

Note: Evaporation of gasoline from the electrodes may chill them sufficiently to cause moisture to condense on their surface. For this reason, after the final rinsing with gasoline, the test cup should be immediately filled with the oil which is being tested, and the test made at once, or the electrodes should be thoroughly dried before using.

The temperature of the test cup and of the oil when tested shall be the same as that of the room, which should be between 20 and 30 C (68 and 86F). Testing at lower temperatures is likely to give variable results which may be misleading.

The sample in the container shall be agitated with a swirling motion to avoid introducing air, so as to mix the oil thoroughly before filling the test cup. This is even more important with used oil than with new oil as the impurities may settle to

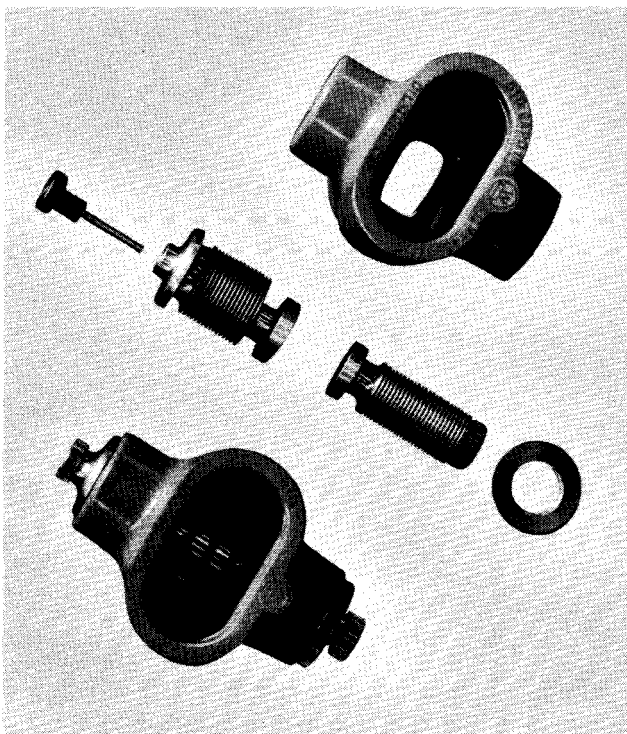


FIG. 3. Oil or Fluid Test Cup for Dielectric Test.

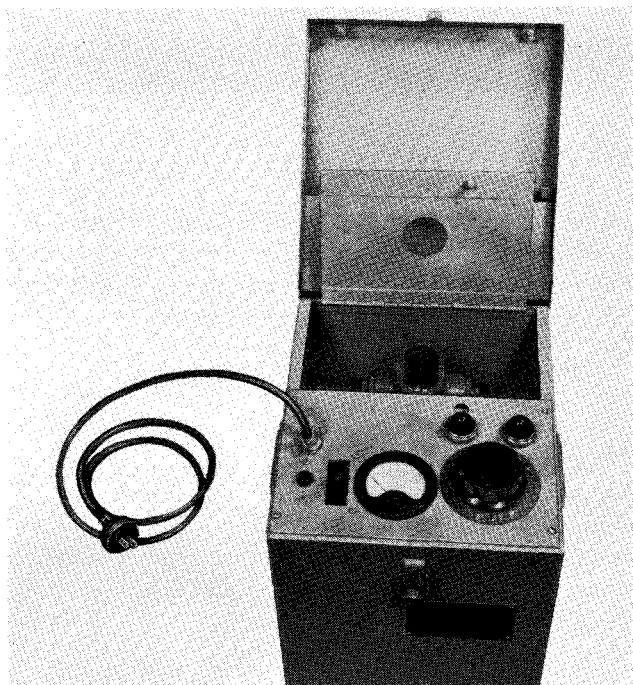


FIG. 4. Portable Oil Testing Set $\frac{1}{2}$ Kva, 35,000 Volts.

the bottom and the test may be misleading.

The cup shall be filled with oil to a height of no less than 0.79 in. (20 mm) above the top of the electrodes.

The oil shall be gently agitated by rocking the cup and allowing it to stand in the cup for three minutes before testing. This will allow air bubbles to escape.

Voltages shall be applied and increased uniformly at a rate of approximately 3000 volts (rms) per second until breakdown occurs as indicated by a continuous discharge across the gap. (Occasional momentary discharges which do not result in a permanent arc may occur; these should be disregarded.)

Provision shall be made for opening the circuit as promptly as possible after breakdown has occurred in order to prevent unnecessary carbonization of the oil.

TESTS

a. Except as specified in (b) one breakdown test shall be made on each of five fillings of the test cup. If the average deviation from the mean exceeds 10 percent or if any individual test deviates more than 25 percent from the average, additional tests shall be made. The dielectric strength shall be determined by averaging the first five tests that conform to the allowable variations.

b. When oil is tested in considerable quantity, so that the time required for testing is excessive and when it is merely desired to determine whether the breakdown safely exceeds the limit specified, or in those cases where the amount of oil available for test may be very limited, one breakdown test shall be made on each of two fillings of the test cup. If neither breakdown is below the specified value, the oil may be considered satisfactory and no further tests shall be required. If either of the breakdowns is less than the specified value, a breakdown shall be made on each of three additional fillings and test results analyzed in accordance with (a).

Report. The report shall include the volts (rms value) at each puncture, the average voltage for each of the two or five fillings, grand average voltage, and the approximate temperature of the oil at the time of the test.

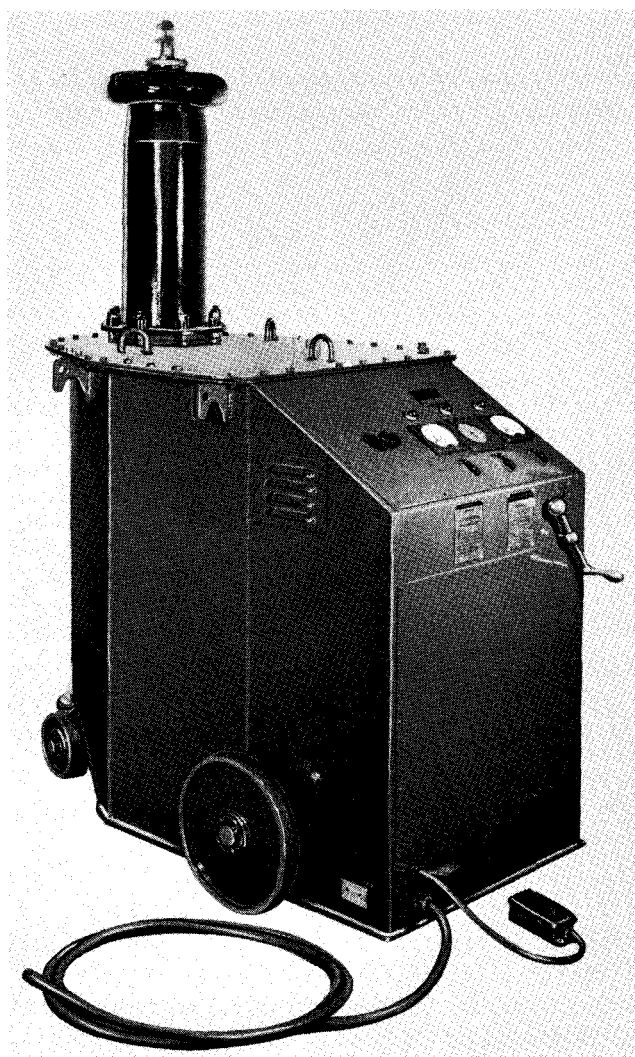


FIG. 5. Portable Truck Type Oil and Insulation Testing Set, 5 Kva, 30,000/60,000 Volts.

STEAM EMULSION TEST

The S. E. test gives a good indication of the resistance to emulsification of the oil, or its ability to throw down moisture and carbon developed through arcing in a circuit breaker. (This property of an oil is impaired when the oil has been exposed to the operation of circuit breaker.)

Apparatus. The steam generator (see Fig. 6) shall be made of either metal or glass of at least one-quart capacity, capable of withstanding the heat necessary for continued use in the production of steam. It shall be fitted with three outlets with suitable connections for rubber tubing. In the case of a metal generator, a large opening for filling and a suitable water gauge shall be a necessary part of the apparatus.

The baths shall be glass with a capacity of 3 to 3½ quarts and a depth of 7½ to 9 in. A good-quality battery jar or beaker is entirely satisfactory.

Heat for the steam generator shall be supplied by a suitable gas burner or electric hot plate. The separating bath may be heated by any convenient means, including an auxiliary steam line.

The oil container shall be a 25 by 200 mm test tube, graduated from zero or from 10 to 50 cc in

cubic centimeters, each even 5 cc line to encircle the tube.

The steam piping or the steam delivery tube shall consist of a piece of thin-wall glass tubing, not less than 2.3 nor more than 2.7 mm inside diameter, and 12 in. in length. The steam pipe shall be cut off diagonally at an angle of 30 degrees with the axis of the tube at the discharge orifice, and shall be bent at right angles 10 in. from the discharge orifice.

Accessories shall consist of suitable wooden or metal frames or holders for holding all containers in a vertical position in the baths; thermometers for the separating and emulsifying baths (floating type thermometers of suitable range); thermometers for the oil container tube (engraved-stem type, of suitable range, graduated in 1°F, 5 to 7 mm in diameter); corks, rubber tubing and screw pinchcocks.

Procedure. The apparatus shall be assembled as shown in Fig. 6. The steam generator shall be filled one-half full of water and heat applied. The baths shall be filled with 3 quarts plus or minus 60 cc of water. The temperature in the separating bath shall be raised to and maintained at 200 to 230°F (93.3 to 95°C).

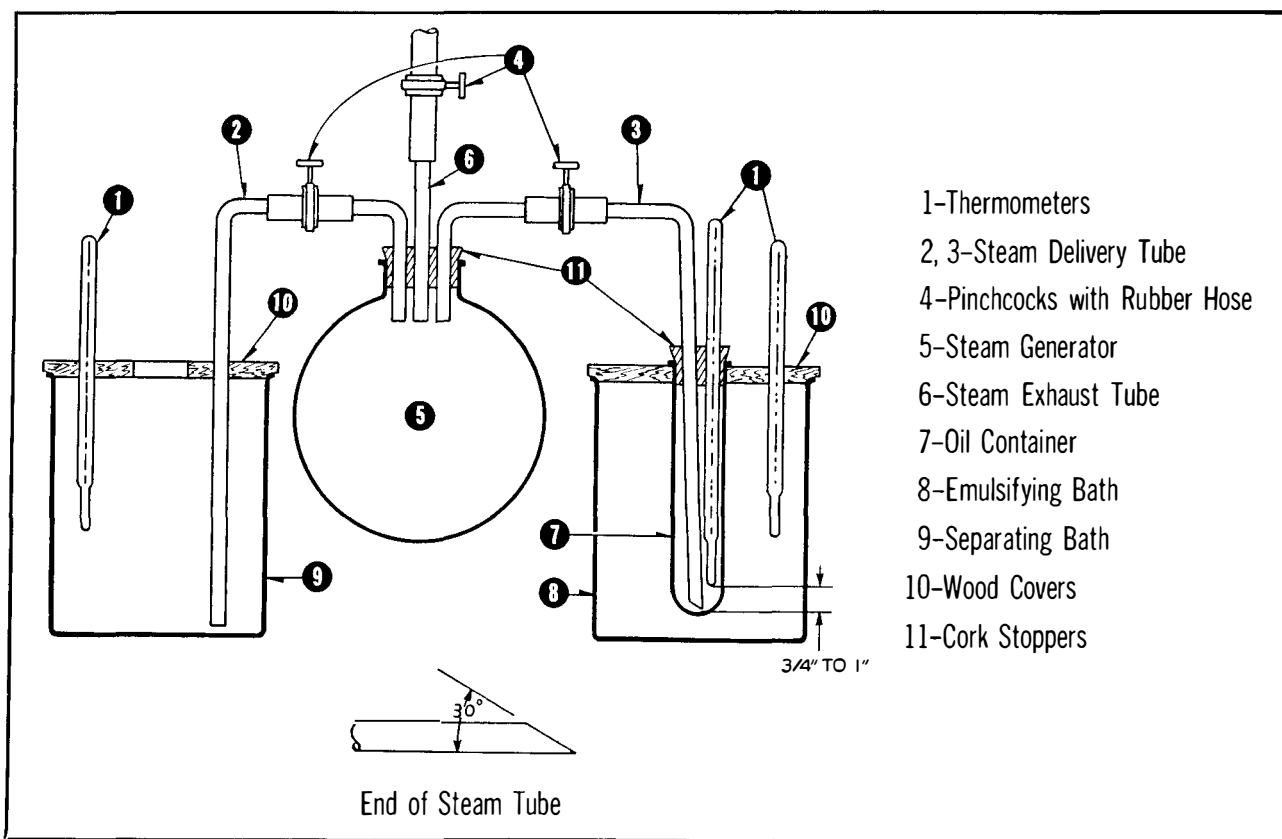


FIG. 6. Apparatus for Steam Emulsion Test.

TESTING METHODS

CAUTION: Care must be taken if glass battery jars are used, as direct heating by flame or electric hot point may cause breakage. Use of steam in this case insures against breakage.

The temperature of the emulsifying bath shall be brought to not less than 67°F (19.4°C) nor more than 78°F (25.6°C) at the start of the test, and is not controlled thereafter. Twenty cubic centimeters of the oil to be tested shall be measured in the oil container at room temperature and the latter placed in the holder of the emulsifying bath. The steam pipe, or delivery tube, shall be connected to the steam generator with suitable rubber tubing, and screw pinchcocks placed as shown in Fig. 6.

Care shall be taken to see that the apparatus, particularly the oil container, oil container thermometer and steam delivery tube, are chemically clean before using. Care shall also be taken to prevent any foreign materials from entering the steam generator as any contamination of the steam renders the test valueless.

Emulsification. The steam delivery tube line shall be steamed out until all condensation disappears. A cork having two openings with the thermometer in one, shall be placed in the mouth of the oil container. The thermometer shall be adjusted so that the bottom of the bulb is $\frac{3}{4}$ to 1 in. from the bottom of the oil container. The steam delivery tube shall be inserted through the second opening in the cork. This fitting shall be loose so that the end of the steam delivery tube shall touch the center of the bottom of the oil container. Steam shall be admitted at a rate that will maintain the temperature of the oil, as shown on the thermometer in the oil container, between 190°F (87.8°C) and 195°F (90.6°C). (The usual time necessary for the temperature of the oil to come to this point is 45 to 75 seconds, depending on its character.)

This control shall be effected by manipulation of the pinchcocks on the steam delivery line and steam exhaust line from the steam generator. The steam supply shall be sufficient at all times to cause a generous discharge from the exhaust line. Steaming shall be continued until the volume of condensed steam and oil in the oil container tube is 40 cc plus or minus 3 cc. The time required for this operation shall be 4 to 6.5 minutes, depending on the quality of the oil, altitude, etc. If condensation water alone amounts to 20 cc in less than 4 minutes, it shall be taken as an indication of wet steam or incomplete steam out of the line, and the test shall be repeated.

The apparent volume in the tube near the end of

the steaming operation is approximately 12 to 15 cc greater than the actual volume due to displacement caused by steam, thermometer and steam delivery tube.

Separation. The steam delivery tube shall be withdrawn as soon as the required volume is obtained. The oil container shall be transferred immediately to the separating bath which shall be maintained at 200 to 203°F (93.3 to 95°C). It is extremely important that the temperature of the separating bath be maintained within the given limits. As soon as the oil container has been transferred to the separating bath, immediately start the stop watch and observe the contents of the oil container continuously through the walls of the bath and note the volume of the separated oil layer, reading from the bottom of the oil meniscus. The cork containing the thermometer should be removed after placing the oil container and contents in the separating bath. No difference shall be made between clear and turbid oil. The reading in seconds shall be taken when the volume of the separated oil reaches 20 cc and this time in seconds shall be the S. E. Number.

In cases where the interface between more or less clear oil and the emulsion is not a clear, straight, horizontal line, the position of such a line is carefully estimated to the nearest 0.5 cc.

On oils which separate into three layers having top (clear or turbid) oil; middle (lacy or creamy) emulsion; bottom (clear or milky) water; the S. E. Number is derived from the top layer. The Steam Emulsion Number of new Wemco C oil is 35 sec. maximum.

NEUTRALIZATION TEST

The Neutralization Number is the weight in milligrams of potassium hydroxide required to neutralize the acid in one gram of oil. The Neutralization Number of new Wemco C oil is 0.03 maximum.

Solutions Required.

a. Standard Potassium Hydroxide Solution (alcoholic, 0.1 N)—add 6 g. of c.p. solid KOH to 1 liter of c.p. anhydrous isopropyl alcohol. Boil, add 2 g. of c.p. Ba (OH)₂ and boil again. Cool, filter and store in a chemically resistant bottle protected by a guard tube containing soda lime and soda asbestos (Ascarite). Standardize against pure potassium acid phthalate using phenolphthalein as an indicator.

b. Titration Solvent—Add 500 ml. of c.p. benzene and 5 ml. of water to 495 ml. of c.p. anhydrous isopropyl alcohol.

c. Alpha-Naphtholbenzein Indicator Solution — Prepare a solution containing 10 g. of alpha-naphtholbenzein per liter of c.p. anhydrous isopropyl alcohol.

Procedure. Into a 250 ml. Erlenmeyer flask introduce 40 g. of Wemco C oil weighed to nearest 0.1 gram. Add 100 ml. of the titration solvent and 3 ml. of the indicator solution. Titrate immediately at a temperature below 30°C. Consider the end point definite if the color change to green persists

for 15 seconds. A blank shall be determined on the solvent.

Calculations. The neutralization number or mg KOH per g. of Wemco C oil = $\frac{(A-B) (N) \times 56.1}{W}$

A = ml. KOH solution required for sample.

B = ml. KOH solution required for blank.

N = normality of KOH solution.

W = grams of sample used.

PART FIVE

RECONDITIONING

APPARATUS FOR RECONDITIONING

RECONDITIONING

In order that oil in circuit breakers and transformers performs its function, certain essential properties must be maintained. Various types of equipment are available to assist the operator in the maintenance of insulating oil.

The first step is to classify oils in service based upon an evaluation of their properties.

GROUP I—This group contains oils which are in satisfactory condition for continued service.

GROUP II—This group contains oils which are low in dielectric strength or contain insoluble contaminants and requires only minor reconditioning by blotter press and/or centrifuge to restore them to condition for continued service.

GROUP III—This group contains oils in poor condition which should be reclaimed or scrapped depending upon economic considerations.

GROUP IV—This group contains oils in such poor condition that it is advisable to dispose of them.

Many tests are available which can be applied to transformer oils in order to classify them into the four groups described. It is recommended that the latest revisions of standards as described by the American Society for Testing Materials (ASTM) be used.

APPARATUS FOR RECONDITIONING

There are several types of reconditioning apparatus available, the relative advantages of each of which are as follows:

1. The centrifuge, connected as a separator, may be used where there are large quantities of water present in the oil, without waiting for it to settle out, and connected as a clarifier, for removing small quantities of water. It will remove sludge and coarse carbon particles but not all finely divided carbon.

2. The filter press is suitable for reconditioning oil containing small quantities of water and will remove finely divided carbon and sludge. It will not materially reduce organic acidity or improve

the resistance to emulsification except as this is caused by the presence of carbon.

3. The combination centrifuge and filter press, passing the oil first through the centrifuge, may be used advantageously in the removal of large quantities of carbon and water. It unites the exceptional qualities of the centrifuge with the excellent characteristics of the blotter press. This flexibility of operation makes it very desirable as standard equipment in the reconditioning of insulating oil for the removal of large quantities of carbon from the oil. However, the clogging of the pores of the filter reduces the output of this combination.

CAUTION: STATIC ELECTRICITY—In the operation of a filter press it is necessary that the problem of static electricity be recognized and areas and tanks vented as much as possible. (See caution note on Static Electricity—Part I page 5.)

4. A fuller's earth filter is the method most frequently used for oils in Group III. In general, reclaiming is done by one of two methods, percolation through the fuller's earth, or by contact at an elevated temperature with finely divided material. The excellent absorbent properties of the fuller's earth will remove acids and other contaminants.

5. A vacuum dehydrator is an efficient means of reducing the water content of insulating oils and is frequently used in conjunction with a fuller's earth filter. Here the oil is exposed to a high vacuum and heat for a short interval of time.

The final criterion of the effectiveness of any method of reconditioning is the quality of the reconditioned oil. The dielectric strength of the reconditioned oil should be at least 26 KV to provide some margin over the lowest limit of 22 KV.

Oils which have been reconditioned by a fuller's earth process should have properties closely approaching those of new oil. It is recommended that to extend the life of reconditioned oils that at least 0.2 percent by weight of inhibitor, Di-Tertiary-Butyl-Paracresol, (D.B.P.C.), be added to the oil.

BLOTTER FILTER PRESS

The blotter filter press (see Fig. 8) is probably most widely used for the reconditioning of insulating oils which have become unfit for use due to the presence of carbon or other foreign matter. It is essentially a number of sets of filter papers in parallel, each set containing several thicknesses. The oil is pumped through the filter paper which absorbs the water and strains out the sediment.

Note: Cleaning devices intended for reconditioning of insulating oil should never be used for other types of work, due to the danger of contaminating the oil.

Capacity. The capacity of these machines, with oil pressure and filtering area fixed, depends on the viscosity of the oil and its freedom from dirt. With fairly clean oil at ordinary room temperature, the capacity of the machines will vary from normal to about 15 per cent above normal, depending on the viscosity (which varies with the temperature). It has been found that the best results are obtained when the oil temperature is about 50°C. The average working pressure of these machines is less than 40 lbs. per square inch and the pressure relief valve is set at the factory to by-pass the full flow at 60 to 70 lbs. per square inch.

Apparatus. There are two standard sizes of Westinghouse filter presses: B-10 and A-30. The letter designates the size of filter paper; the number indicates the relative capacity in gallons per minute.

The complete outfit consists of filter press, motor, strainer, pump, gas trap, pressure gauge, drip pan, casters and piping. The piping is arranged so the suction line can be tested for leaks under pressure.

The strainer can be cleaned by unscrewing a plug. The pumps are of the positive pressure type and are directly connected to the motor through flexible couplings.

The filter press proper is made up of a series of cast iron plates and frames assembled alternately, with the filter papers between them. By means of a screw and cast-iron end block, the plates, frames and papers are forced tightly together. Except for a machined rim which serves as a joint to prevent the escape of oil, the plates are cast with small pyramids on both surfaces.

The plates and frames have holes in two corners and supporting lugs at the sides. The plates have handles cast on the top edge. When the plates and

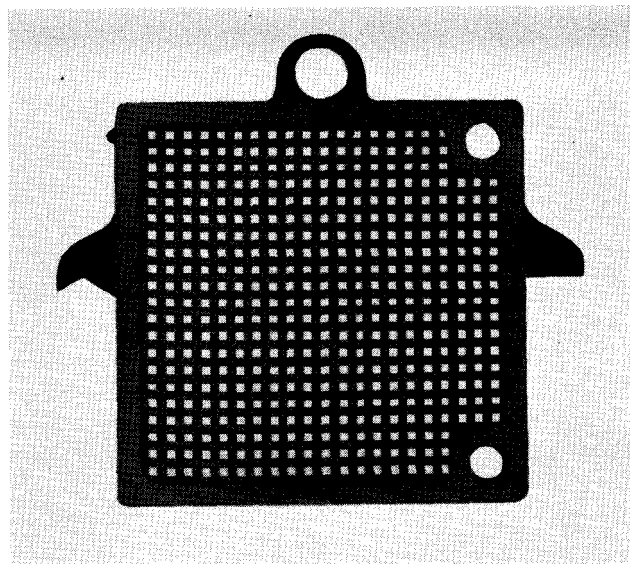


FIG. 7. Filter Press Frame with Blotters in Place.

frames are assembled with the filter papers between, the holes form the inlet and outlet. The frames have the holes in the upper corner connected by small ducts to the middle of the frame. The plates have ducts leading from the surface of the plate to the hole in the lower corner. (See Fig. 7.)

The oil enters under pressure at the top corner through the inlet formed by the holes in the frames, plates, and filter papers, flows into the frames through the same ducts, and completely fills the chamber formed by the frame and two sets of filter paper. As there are no outlet ducts in the frame, the oil is forced through the paper and flows along the grooves between the rows of pyramids and out through the ducts provided at the lower corner of the plates. The dry filter paper takes up the moisture and removes the sediment from the oil.

Operation. The filter press is made ready for operation by placing a set of five sheets of filter paper, that have been thoroughly dried in an electric oven, between each filter plate and frame. The holes in the filter paper must line up with the holes in the plates and frames. The sediment is strained out by the first layer of paper and the moisture is taken up by the capillary action of the paper.

Oil which has only a very small quantity of moisture may be satisfactorily reclaimed by the filter press, but when a large quantity of water is to be removed, the centrifuge or combination centrifuge and filter press is preferred, and is also more economical.

APPARATUS FOR RECONDITIONING

If any moisture remains, it indicates that the filter papers are saturated with moisture and should be renewed. No rule can be given as to how often the papers must be changed, as this depends entirely on the condition of the oil. The usual procedure is to run the machine for about half an hour (if the oil is not in very bad condition) and then shut down; remove one sheet from the inlet side of each set and put in a new sheet on the outlet side of each set. (The frame is the inlet side and the plate is the outlet side.) Frequent dielectric tests should be made during this procedure as wet oil may necessitate recharging the filter press with a full set of papers before the five sheets have been removed in succession.

The quickest method of filtering a quantity of oil is to pump all the oil through the filter and into another tank which is clean and dry. If care is taken to change the filter papers before they become saturated, the oil will be clean and dry. If a second tank for holding the oil is not available, or if it is desired to filter the oil of a transformer while it is in service, the oil may be pumped from the bottom of the tank through the filter and returned to the top of the same tank under the surface of the oil to prevent aeration. This operation should be continued until the oil in the tank shows a sufficiently high dielectric strength.

When a large quantity of oil is to be filtered, time may be saved by using two filter presses, one of which may be operated while the other is being recharged.

The filter press is not intended to remove large amounts of free water from the oil. Obviously the changing of filter papers necessary for obtaining dry oil would so reduce the capacity as to make this method of reconditioning impractical. In such cases, the water may be removed by a centrifuge, or should be allowed to settle out and be drawn off from the bottom of the container before passing the oil through a filter press.

With badly fouled oil, it may be necessary to pass the oil through the filter press several times to take out the more finely divided carbon which is not caught on the filter papers, especially when they are new. The efficiency of the filter press for removing carbon increases as the pores of the filter papers become partly clogged. This produces a material slowing-down in the rate of flow through the filter papers.

Filtering through filter papers does not materially reduce organic acidity or improve resistance

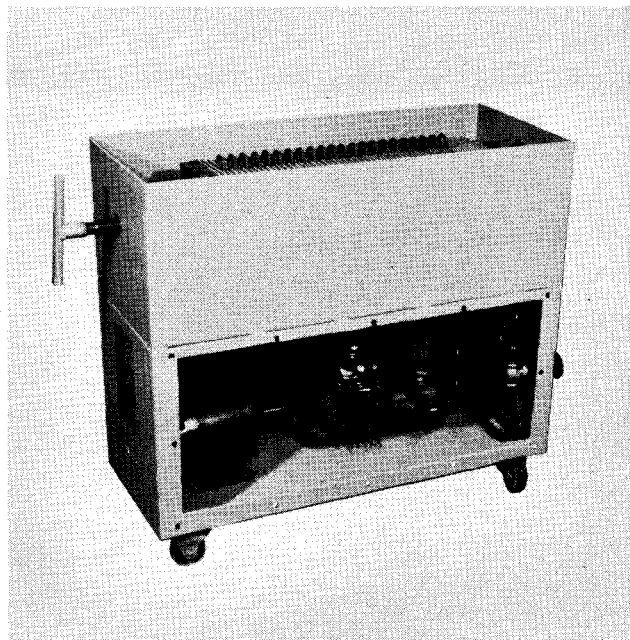


FIG. 8. B-10 Filter Press with Top and Side Panel Removed. (Explosion-Proof Model).

to emulsification except as the latter is affected by the presence of carbon, although the dielectric strength may be restored to a satisfactory value.

The capacity of the filter press is much reduced when operating at low temperatures.

When the oil has to be filtered at low temperatures an additional pump in the pipe line is desirable.

Oil in transformers contaminated by only a small amount of moisture may be reconditioned by drawing the oil from the bottom of the tank, passing it through the filter press or centrifuge and pumping it back into the top of the transformer, preferably at a point below the surface of the oil. The oil should be put through the system until a sample drawn from the bottom of the transformer gives satisfactory dielectric values.

Pumping the oil from a circuit-breaker tank to the purifying outfit and directly back to the tank is not desirable, as the clean oil is again contaminated by the carbonized oil remaining in the tank. Also, it is then impossible to clean the carbon deposit from the surfaces inside the tank. Do not filter oil from a circuit-breaker while the breaker is in service on an energized line.

Filter Paper. The filter paper used is a special grade of blotting paper about .025 in. thick; it contains no coloring matter or chemicals which might injure the oil. Five sheets cut to the proper size,

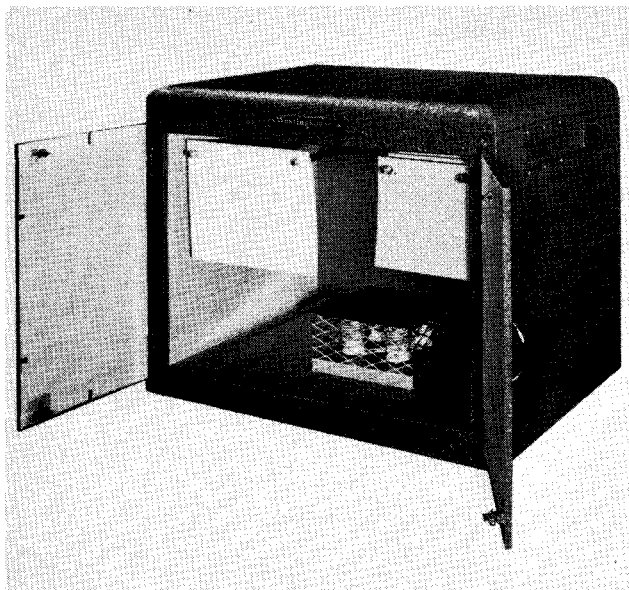


FIG. 9. Electric Drying Oven.

12 $\frac{7}{8}$ in. square for the A sizes and 7 $\frac{3}{4}$ in. square for the B sizes, and with holes punched to correspond with the holes in the plates and frames, are between each plate and the adjacent frames.

To obtain the best results in reconditioning oil, the paper must be perfectly dry when first placed in the press. Filter paper always takes up moisture if exposed to the air for any length of time and for this reason care must be used in handling. The standard paper is carried in packages containing one ream carefully wrapped in waxed paper and covered with heavy wrapping paper.

ELECTRIC DRYING OVEN

The importance of the drying oven cannot be over-emphasized since the effectiveness of the whole filtering process is dependent on the dryness of the paper. For satisfactory results, the dried filter paper should either be inserted in the filter press and used immediately, or kept in dry transformer oil until it is transferred to the filter press. No filter paper can be effectively dried after it has once become saturated with oil. Therefore, care should be taken to insure that the paper is thor-

oughly dried when placed in the filter.

The oven can be used on 110/220/440 DC or single phase AC, 1000 watts. The normal capacity of 7 inch or 12-inch paper is 180 sheets.

The paper is suspended from two rods with the sheets separated from each other, thus permitting thorough circulation of heated air. The rods can be rearranged for hanging either 12 inch or 7 inch filter paper.

Normally, the filter paper should be dried 6 to 12 hours, depending upon condition of the paper and spacing of the sheets in the oven.

The cabinet is constructed of fabricated sheet steel and insulated with $\frac{1}{4}$ inch asbestos board. (See Figure 9)

The air vents are designed to provide cross ventilation so that dry heated air replaces moisture laden air.

Oil can be dried rapidly and thoroughly if the filter paper is carefully prepared, transferred to the press without reabsorbing moisture, and replaced when its effectiveness is exhausted. If good results are not obtained, it is probably because the paper was not sufficiently dry when placed in the press, due either to improper drying or careless handling.

CENTRIFUGE

The centrifuge is the most convenient equipment known for removing water from oil. It also removes solid material other than finely divided carbon. The temperature of the oil should be maintained at 48.9 to 51.7 C (120 to 125 F) in order to insure removal of all the water at full capacity of the machine. A higher temperature gives no advantage, and if excessive, will permit the oil to carry more moisture through in solution. (A 6 kw heater will raise the oil about 15.6 C (60 F) per 100 gallons per hour.) The centrifuge equipment may be arranged to act as a separator, discharging the oil and water by different outlets, or as a clarifier, discharging the oil but retaining the water and other impurities in the bowl*.

*For further details, see manufacturer's information.



**Instructions for
WEMCO[®] C and WEMCO C1
Insulating Oils**



Westinghouse Electric Corporation

Power Transformer Division, Sharon, Pa.

I.B. 45-063-100A Effective May, 1964, Supersedes I.B. 45-063-100, October, 1961

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WEMCO® C INSULATING OIL P. D. S. 2772
WEMCO CI--INHIBITED INSULATING OIL--P.D.S. 9855

Wemco C insulating oil and Wemco-CI oil are developments of the Westinghouse Electric Corporation in cooperation with oil refiners. They have been proven suitable for use in all Westinghouse oil-insulated apparatus. In order to insure the proper performance of the apparatus, only Westinghouse approved oils should be used.

This publication gives the instructions for handling, inspection and maintenance which experience has shown are important in obtaining the best service from the insulating oil.

PART ONE

RECEIVING, STORING AND HANDLING

SHIPMENT

Wemco C and Wemco CI oils are shipped in tank cars, drums or cans. Modern tank cars are usually equipped with breathers which bar the admission of moisture and are otherwise well gasketed to protect the oil from moisture. These precautions are necessary because the volume of the oil changes with temperature variations.

When shipped in drums, the drums are provided with screw bungs having gaskets to prevent admission of water.

When shipped in cans, the cans are hermetically sealed immediately after filling and should not be opened until the oil is needed.

STORING

Drums. As soon as a drum of oil has been unloaded, the bung should be examined for damage or leaks.

It is very desirable that oil in drums be stored in a closed room. Outdoor storage of oil is always hazardous to the oil and should be avoided if at all possible. Regardless of storage location all drummed oil should be stored with the bungs down so that the bungs are under positive oil pressure. Do not open the drums until the oil is actually needed. Partially emptied drums must be tightly resealed and stored the same as new drums.

Cans. One and five-gallon cans of oil must not be exposed to the weather. Seals should be kept intact until the oil is actually needed. It is not necessary to make dielectric tests on oil in sealed cans.

Screw caps are provided on the cans to use when the oil is only partially removed after the hermetic seal has been broken. By replacing the screw caps, contamination by moisture and dirt will be retarded but the oil must be tested before using.

Storage Tank. The storage tank should be mounted on piers so that it will not touch the ground, and will be accessible to all points for inspection for leakage.

In larger storage systems, it is desirable to provide equipment to supply dry air for breathing purposes. This is often accomplished by the use of

a breather making use of silica gel or aluminum oxide as the drying medium.

The tank should preferably have a convex bottom, allowing the installation of a drain cock at the lowest point for removing any free water or dirt which might settle out. When a cylindrical tank is installed with its axis horizontal, one end should be a little lower than the other, with a drain cock at the lowest point, and the oil supply pipe should enter at the opposite end of the tank. The oil may enter and leave the tank by the same pipe, but this should be at some distance from the bottom to prevent stirring up any settleings when the tank is being filled. It is desirable that the pipe be provided with a swing joint and float, so that it will automatically move with the change in oil level and remain near the surface of the oil.

FIRE PROTECTION

IMPORTANT: While Wemco C or Wemco CI oil will not take fire unless brought to a high temperature (320° F), it should be remembered that under abnormal conditions such a temperature can be reached, so that proper precaution against fire should be taken. The best way to extinguish burning oil is to smother the flames so that the supply of fresh air is cut off. Chemical fire extinguishers are effective, but water should not be used unless it is applied by a special atomizing spray nozzle.

HANDLING

SAMPLE AND DIELECTRIC TEST ALL OIL BEFORE PLACING IT IN APPARATUS.

Before putting the oil into equipment see that the tank is free from moisture and foreign material. The presence of impurities, particularly moisture, in the oil or apparatus may lower its dielectric strength to an unusable value. If the oil is supplied in more than one container, each container must be sampled and tested.

Although the drums and tank cars are thoroughly washed and dried at the refinery before filling, a certain amount of scale is sometimes loosened from the inside in transit. Therefore, it is recommended that all the oil be passed through a filter press to remove any moisture or solid contaminants which may be present.

RECEIVING, STORING AND HANDLING

The preparation and filling of outdoor apparatus should preferably be done on a clear, dry day; if this is not practicable, protection against moisture must be provided.

All vessels used for transferring the oil should be carefully inspected to see that they are absolutely dry and free from dirt.

Whenever possible it is recommended that all equipment should be allowed to stand for at least eight hours between filling and energizing the apparatus to allow gas bubbles to escape from the oil. This is especially important when filling under vacuum is impossible.

IMPORTANT: Always use a metal or oil proof hose when handling the oil. A hose made of natural rubber must not be used. Oil may easily become contaminated from the sulfur in the natural rubber, and should not be allowed to come in contact with it.

When it is necessary to fill equipment with oil, it is essential that the oil be allowed to come to the same temperature as the apparatus. This may require eight hours, or even longer, under extreme temperature conditions. Otherwise, condensation of moisture may lower the dielectric strength of the oil to an unusable value. Cold oil in drums should never be brought into a warmer area and transferred to equipment until it has reached the same temperature as the apparatus.

FILLING DRUMS

The practice of filling drums with oil is undesirable and should be avoided whenever possible, for unless the utmost precautions are taken, the oil is likely to become contaminated.

If it is necessary to fill drums for storage, use only those drums which are in good condition and which have been used previously for transformer oil. A good practice is to reserve drums for this purpose by sealing them immediately after being emptied to exclude dirt and water. Before reusing each drum should be carefully examined to be sure it is clean and free of water.

A new washer should be used with the bung each time the drum is refilled, to insure a tight seal. These washers may be obtained from the oil refineries and it is recommended that a supply be kept on hand. Natural rubber composition washers should never be used as they would be attacked by the oil.

Cleaning Contaminated Drums. The cleaning of drums which have contained used insulating oil requires great care in order to insure a thoroughly clean drum. It is preferable to return such drums to the refinery where adequate cleaning facilities are available, rather than to attempt to clean them. If it is necessary to clean such drums, the following procedure is recommended:

Rinse the drum thoroughly with gasoline or benzine, using about one gallon each time, until the solvent shows no discoloration after using. Allow it to drain, then pump out the last traces of solvent with a vacuum pump, using a brass pipe flattened at the lower end to explore the corners of the drum.

CAUTION: Do not use a steel pipe because of the danger of a spark igniting the vapor.

Heat the drum with bung hole down, in a ventilated oven at a temperature of at least 88°C (190°F) for sixteen hours. Screw the bung on tightly before removing drum from the oven. Use a new washer with the bung to insure a tight seal. A simple oven for this purpose may be made from sheet metal and heated with steam or an electric heater.

CAUTION: An open flame must always be kept away from the oven to prevent igniting inflammable gases.

REFILLING DRUMS

CAUTION: STATIC ELECTRICITY—Pumping and filtering of oil under certain circumstances may cause electrical charges to be built up in the oil to such an extent that electrical breakdown of the gas above the oil is possible. When a filter press is used to filter the oil in the equipment, precautionary measures should be taken to prevent an explosion caused by the possible static discharge of the electrical charge which could be built up in the equipment. If this electrical discharge takes place in an explosive gas mixture, the result could be a damaging explosion.

This static charge is variable and depends upon a number of variable factors. Since some of these factors are beyond the range of control, it may be best to surmise that they will always be present. Thus there will always be the possibility of this static discharge.

A thorough purging with the use of nitrogen, of the accumulated gases formed in any electrical equipment should be made before filtering the oil. This will offset any possible reaction between the static discharge and the accumulated gases.

PART TWO

OIL CHARACTERISTICS, SAMPLING AND INSPECTION

CHARACTERISTICS OF INSULATING OIL

Wemco "C" insulating oil is a refined mineral oil obtained from the fractional distillation of crude petroleum. It contains no moisture, inorganic acid, alkali, free sulfur, asphalt, tar, vegetable, or animal oils. It is used as an insulating and heat transfer medium and is intended principally for use in tanks of oil insulated circuit breakers, switches and transformers. In circuit breakers and other apparatus subject to arcing, the cooling and deionizing characteristics of the oil become important in extinguishing the arc.

Wemco "CI" inhibited insulating oil has a minimum of 0.15 percent by weight of Di-Tertiary-Butyl-Paracresol, (D.B.P.C.) added to Wemco "C" insulating oil to provide additional oxidation resistance for use in distribution transformers that may be subject to breathing of air and where it is difficult to maintain tight seals.

ADVANTAGES OF WEMCO "C" OIL

1. High dielectric strength.
2. Low viscosity—provides for good heat transfer.
3. Freedom from inorganic acids, alkalis, and corrosive sulfur—prevents injury to insulation and materials of construction.
4. Good resistance to emulsification. In case of moisture contamination it quickly settles to the bottom of the tank.
5. Freedom from sludging under normal operating conditions over long periods of time—accomplished by proper selection of crudes and refining methods.
6. Because of its low viscosity it is more able to dissipate the arcing products in circuit breakers, tap changers, and other arcing contact apparatus.
7. Low pour point allows use under low temperature conditions.
8. The higher than average flash point allows higher operating temperatures with freedom from fire hazard.

PHYSICAL PROPERTIES AND TEST PROCEDURE

1. Color—nearly water white—0.5 max.—ASTM D1500

2. Reaction—Neutral
3. Neutralization Number—Mg. KOH per g. oil—0.03 max. ASTM D974
4. Precipitation Number—zero
5. Free or Corrosive Sulfur—non-corrosive —ASTM D1275
6. Steam Emulsion—35 sec. max.—ASTM 1935
7. Flash Point—293°F (145°C) Min.—ASTM D92
8. Pour Point—Minus 50°F (minus 45.0°C) Max.—ASTM D97
9. Viscosity—Saybolt Universal—100°F (37.8°C) Max.—62 sec.—ASTM D88
10. Moisture Content—35 ppm. Max. ASTM D1533
11. Specific Gravity — 60°F (15.5°C) — .898 Max. ASTM D1298
12. Specific Heat—0.488 Approx.
13. Inorganic Chlorides or Sulfates — None —ASTM D878
14. Coefficient of Expansion 32°F (0°C)—.000725
15. Coefficient of Expansion 212°F (100°C) —.000755
16. Interfacial Tension dynes/cm.— 40 Min. ASTM D971
17. Dielectric Constant—2.2
18. Dielectric Strength—30 KV—ASTM D877
19. Weight per gallon—7.5 lbs.
20. Power Factor—60 cycle 25°C—Max. .05 %—ASTM D924
21. Inhibitor (D.B.P.C.) (PDS 9855) (Wemco CI only) Min. 0.15% ASTM D1473

CAUSES OF DETERIORATION OF OIL

Transformers. Deterioration of oil is a problem to which much thought and research has been devoted. Westinghouse Sealedaire, Inertiaire, Thermosiphon, and expansion tank transformers are

the results of this research in methods of preventing deterioration.

Generally speaking, however, the principal causes of deterioration of insulating oils are:

1. Presence of moisture.
2. Oxidation.
3. Excessive temperature.

Condensation from moist air due to breathing of the transformer, especially when the transformer is not continuously in service, may injure oil. (The moist air drawn into the transformer condenses moisture on the surface of the oil and inside of the tank.) The oil may also be contaminated with water through leakage such as from leaky cooling coils or covers.

Sludge is an oxidation product, the amount formed in a given oil being dependent upon the temperature and the time of exposure of the oil to the air. In the refining process for our transformer oil, the components of the oil which are most readily oxidized to form sludge are removed so as to provide an insulating oil which will not sludge under normal operating temperatures.

Note: Excessive temperatures may cause sludging of any transformer oil regardless of how well it is refined.

Transformer oil which has begun to sludge will continue to do so even after it has been reconditioned by means of the centrifuge or filter press, as these methods of reconditioning do not remove the deterioration products which are in process of formation but have not yet been precipitated as sludge.

Reconditioning by means of fuller's earth and vacuum dehydration will remove many of the deterioration products, and if stabilized by the addition of an oil inhibitor, further sludging can be prevented for long periods of time.

Another effect of oxygen is to gradually produce organic or "fatty" acids in oil in service. These should not be confused with the mineral acids such as sulphuric acid used in refining, as in small amounts the former do not have a deteriorating effect upon insulation.

Circuit Breakers. The principal causes of deterioration of insulating oil in circuit breakers or other arc producing apparatus, are:

1. Presence of water.
2. Carbonization of the oil (caused by operation of the circuit breaker).

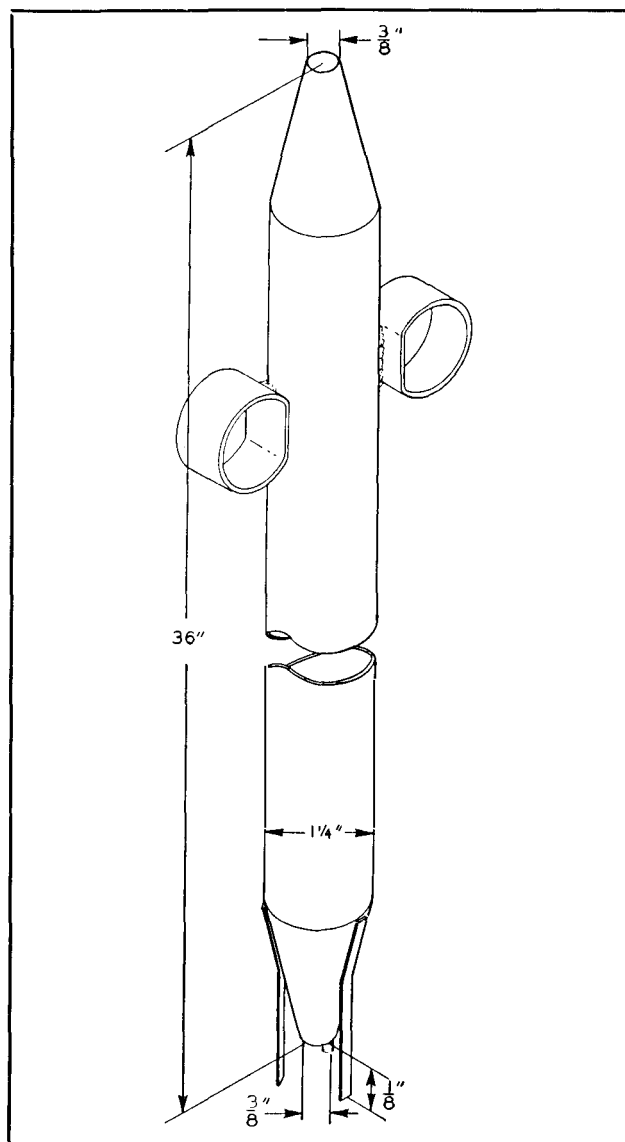


FIG. 1. Drum Thief.

The arcing of the oil in circuit breakers produces small amounts of water, acids, and carbon due to oil decomposition. These acids may in extreme cases form metal soap on plated hardware but this in no way harms the apparatus. Water may also result from the entrance of moist air into the tank. Some of the carbon is deposited on the contact components and at the bottom of the tank while the remainder continues in suspension in the oil.

Carbonization takes place not only when the circuit breaker opens heavy short circuits, but also whenever an arc is formed, even during such light service as the opening of the charging current of the line, and this latter service, repeated, may eventually produce enough carbon to be a source of trouble.

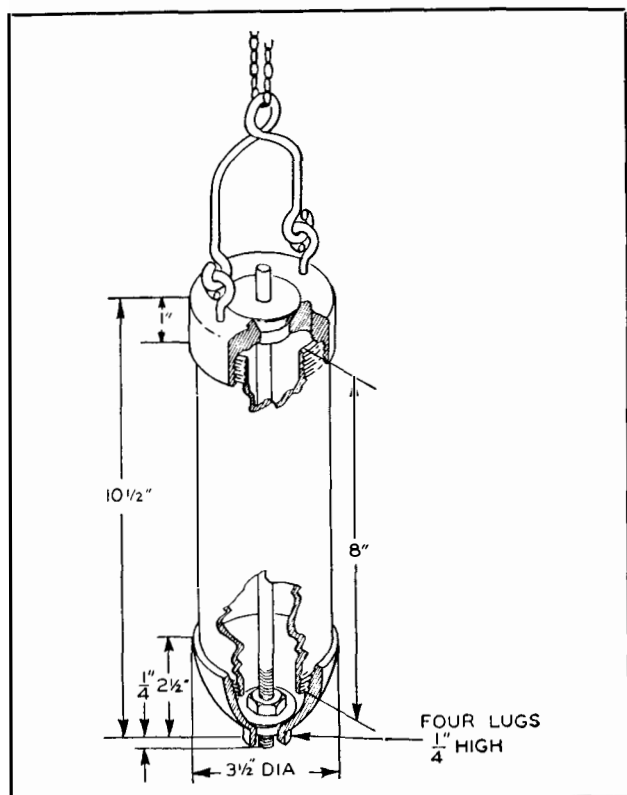


FIG. 2. Tank Car Thief.

The carbon may reduce the dielectric strength of the oil, lower the surface resistance of the insulation if water is present, and also may lower the resistance to emulsification. The carbon alone may not be detected by the dielectric test, particularly if the oil is free from moisture.

In cold weather, a larger amount of carbon is formed than in warm weather because of the increased viscosity of the oil at low temperatures. Also the carbon is not as readily dispersed through the oil.

SAMPLING OIL FROM SHIPPING CONTAINERS

The dielectric strength of oil is affected by the most minute traces of certain impurities, particularly water. It is important that the greatest care be taken in obtaining the samples and in handling them to avoid contamination. There have been low dielectric test results reported from the field which, upon investigation, have been found to have been largely a matter of carelessness in handling. The following instructions, based on the specifications of the American Society for Testing Materials, must be followed to assure accurate results:

Sample Bottle. The sample container shall be made of amber glass, of at least 16 oz. capacity,

and shall be cleaned and dried. The glass bottle is preferable to a metal container as it may be examined to see if it is clean. It also allows visual inspection of the oil before testing, particularly as regards free water and solid impurities. However, any samples to be tested for color power factor or sludge-forming characteristics must be kept in the dark, as light produces changes in these properties. This is not necessary for any other tests.

The clean, dry bottle shall be thoroughly rinsed with benzine or dry lead-free gasoline which has previously withstood a dielectric test of at least 25 kv in a standard test cup, and shall be allowed to drain. It is preferable to heat the bottle and cap to a temperature of 100°C (212°F) for one hour after thoroughly draining. The bottle shall then be tightly capped and the neck of the bottle dipped in melted paraffin.

IMPORTANT: Glass jars having rubber gaskets or stoppers must not be used. Oil may easily become contaminated from the sulfur in natural rubber.

Thieves for Sampling. A convenient and simple thief (See Fig. 1) for use with 55 gal. drums may be made of metal as follows:

Length 36 in., diameter 1 1/4 in. with cone shaped caps over the ends and openings at the ends 3/8 in. in diameter. Three legs equally spaced around the thief at the bottom, and long enough to hold the opening 1/8 in. from the bottom of the container being sampled, aid in securing a good representative sample. Two rings soldered to the opposite sides of the tube at the outer end will be found convenient for holding the thief by slipping two fingers through them and leaving the thumb free to close the opening. In an emergency a piece of glass tubing 36 in. long may be used. For the tank cars, a thief employing a trap at the bottom may be used. (See Fig 2.)

The thief shall be suitable for reaching the bottom of the container and the sample shall be taken with the thief not more than about 1/8 in. from the bottom.

Thieves should be cleaned *before and after* use by rinsing with dry lead-free gasoline; be sure that no lint or other fibrous material remains on them. When not in use they should be kept in a hot, dry cabinet or compartment at a temperature not less than 37.8°C (100°F), and shall be stored in a vertical position in a rack having a suitable drainage receptacle at the base.

Samples shall not be drawn from containers indoors until the oil is at least as warm as the

surrounding air. Cold oil may condense enough moisture on the surface from a humid atmosphere to seriously affect its insulating properties. Sampling oil from containers out of doors is undesirable, due to the possibility of condensation of moisture, and should be avoided whenever possible. (Samples should never be taken in the rain.)

Procedure. The drums to be sampled shall be assembled in line, with bungs up, and numbered. The bungs shall be unsealed and removed and laid with the oily side up beside the bungholes. The unstoppered sampling receptacle can be placed on the opposite side of the bungholes. The top hole of the thief shall be closed with the thumb, the thief quickly thrust to the bottom of the container and the thumb removed. When the thief is filled, the thumb shall be replaced, the thief quickly withdrawn and the contents allowed to flow into the sampling receptacle. The lower holes shall not be closed with the fingers of the other hand. The free hand shall not be used to guide the stream of oil except by touching the thief, and this only when necessary. The oil shall not be allowed to flow over the hand or fingers before it flows into the sampling receptacle.

When the sampling receptacle is filled, it shall be closed quickly and the bung replaced in the container and tightened. The sampling receptacle shall be taken under cover to the testing laboratory as quickly as feasible.

After using, thoroughly clean all thieves and sampling receptacles as outlined above.

The tank cars of oil shall be sampled by introducing the thief through the manhole on top of the car, the cover of which shall be removed carefully so as not to contaminate the oil with dirt. The sample shall be taken as near as possible to the bottom of the tank car. This shall not be done while rain or snow is falling.

When separate samples are being taken from a consignment or part of a consignment, care should be exercised to prevent contaminating the samples. A separate thief shall be used for each sample or the thief previously used shall be well drained and then thoroughly washed with oil from the next container to be sampled; the oil thus used for washing should be thrown away before the next sample is taken. (Enough thieves shall be provided to insure thorough drainage of each thief after rinsing with oil to be sampled before using it to withdraw the actual sample.) For obtaining only a few samples, two thieves are sufficient, but for obtaining a large number of samples (for example, sam-

pling a carload of drummed oil) six or more thieves are desirable.

When one average sample of a consignment or batch is being taken, the same thief may be used throughout the sampling operation, and it is not necessary to rinse the thief with oil before taking any of the portions that go to make up the total average sample.

Quantity of Sample. It is recommended that one 16 oz. bottle of oil be taken as a sample for dielectric tests, and a one quart sample be taken when complete physical and chemical tests are to be made. At least one sample should be taken from a tank car of oil. One sample may be taken from each drum, or if desired, a composite sample may be made from oil from five drums, provided all of the drums are airtight. When the bung is first loosened, a hissing sound should be heard, which indicates that the drum has been airtight. If the test of the composite sample is not satisfactory, a sample from each of the drums represented should be tested.

When drums have been stored exposed to the weather, a sample from each drum shall be tested. The sample of oil should be examined for free water, and if any is noted, the drum of oil should be put through a blotter filter press and resampled for dielectric strength.

If the sample is being taken from a tank car, and water appears, follow the same procedure.

SAMPLING OIL FROM APPARATUS

When taking samples of oil from apparatus in which a thief cannot be used, use the sampling valve and follow the procedure outlined above as far as practicable.

Care should be taken to procure a sample which fairly represents the oil at the bottom of the tank. A sufficient amount of oil should therefore be drawn off before the sample is taken, to insure that the sample will not be that which was stored in the sampling pipe. For this reason, the valve and the drain pipe should be sufficiently small to be emptied with convenience and yet sufficiently large to give an even flow of oil and avoid clogging by sediment. A $\frac{1}{4}$ in. pipe and valve is recommended. This, of course, may be separate from the drainage pipe and valve or it may be connected to the drainage valve by means of a suitable reducer.

It is of utmost importance that the sample of insulating oil represents the actual condition of the oil in the apparatus. Every precaution should be

taken to keep the sample and container free from foreign impurities or moisture.

If the apparatus is installed outdoors, care should be taken to prevent contamination of the sample by rain, snow, etc.

A glass bottle is recommended as a sampling receptacle, so that any water present may readily be seen.

If the sample contains free water it is not suitable for dielectric test and the sample and bottle should be discarded. A second sample should be taken after at least two quarts of oil have been withdrawn. If free water still exists in the sample, the oil in the apparatus should be put through a blotter filter press and resampled for dielectric strength.

In order to make sure that the dielectric strength is up to its proper value, the insulating oil in any piece of apparatus should be tested before its initial operation, and at regular intervals thereafter.

PERIODIC INSPECTION

Oil may deteriorate in service even under what seems to be the most favorable conditions. The more handling an insulating oil receives, the greater the opportunity for contamination unless adequate precautions are taken.

IMPORTANT: It is essential to provide for periodic inspection and test, and to purify the oil whenever necessary in order to maintain it in good condition.

Regular inspection and tests of insulating oils by electric utilities and other large users have proven the necessity of this practice. Where these inspections and tests have been systematically followed it has been found that failure of the apparatus due to the fact the oil had become contaminated with moisture and sediment, has been reduced to a minimum and has resulted in greater economy of operation. In view of the importance of the subject, it is, therefore, recommended that all companies, in the interest of good service, adopt some system of oil inspection and test.

The frequency of inspecting and testing depends upon the service to which the oil is subjected, and the construction of and the materials used in the apparatus.

Even though field experience has shown that it is not necessary to frequently examine the oil in Inertiaire or Sealedaire transformers, such oils should be inspected to insure that the Inertiaire

equipment is being maintained and the tanks are tight.

The oil in circuit breakers and transformers which are operated under extremely heavy loads requires more frequent inspection than that in normal or light service.

It is recommended that operators prepare a schedule for inspection based on the operating conditions. Reference to the station log, together with the record of dielectric tests of the oil, should determine the frequency of inspection and test. The period between successive inspections should not be longer than six months or until experience indicates that the time between tests can be extended. If the dielectric strength of the oil drops below 22 KV in the standard dielectric test the oil should be blotter pressed. In the event that the dielectric strength is not readily restored to 26 KV or above, other tests should be made to determine if the oil should be reconditioned or replaced.

Checking Oil Level. It is essential that the proper oil level be maintained. Low oil level may cause breakdown of insulation or flashover of bushing in any apparatus, or malfunctioning of circuit breakers mechanically or electrically.

Checking Dielectric Strength. The oil should be tested regularly for dielectric strength and purified when the tests show need of it. The testing should be systematized and complete records kept. It is particularly important in a circuit breaker to check the dielectric strength after exposure to near rating short-circuit operations.

Checking for Carbonization. The presence of carbon in circuit breaker oil may introduce a hazard, due to the tendency of the carbon to lower the dielectric strength of the oil, and also to deposit on insulating surfaces, thereby reducing the insulation resistance.

Visual inspection of the oil samples should be made and, if any appreciable amount of carbon is present, the oil should be reconditioned even though the dielectric test is good.

IMPORTANT: Certain washing compounds have been used by some operating companies to assist in separating the carbon from the oil. Investigation in the Westinghouse laboratories has shown that these compounds leave the oil in poor condition. Customers are warned against using any form of chemical treatment that has not been investigated and recommended by Westinghouse Electric Corporation.

Checking for Sludge. Transformers should be regularly examined for evidence of sludge. A visual inspection will indicate its presence. Appreciable amounts of sludge may clog the oil ducts and interfere with heat transfer. It is desirable that such oil be reconditioned or replaced immediately. If the oil is to be returned to service, oil inhibitor should be added to extend the life of the oil. Oil which has once sludged, will, after being reconditioned, sludge more quickly than the first time unless the inhibitor is added.

WESTINGHOUSE OIL TESTING SERVICE

Many users of transformers and large oil circuit breakers do not have the necessary facilities for testing insulating oil. In order that these users may be able to make the periodic tests recommended, Westinghouse Electric Corporation has established an oil testing service to provide a careful test by experienced engineers, and a prompt report of test results.

Two special 16 oz. sample bottles per mailing container (Westinghouse Sampling Set Style #1608 629) as well as necessary packing and printed matter, may be obtained by contacting the nearest Westinghouse office.

After drawing the sample of oil, the customer should seal the bottle with care, and mail it to the Westinghouse Electric Corp., Plant Laboratory, Sharon, Pa. The details of this transaction have been simplified by the inclusion in the Sampling Set of an instruction sheet and a printed return label. The instructions cover the taking of the sample and its proper preparation for mailing, and the label carries an envelope for enclosing customer's order covering the testing work. (Also see details given in Price List 45-825).

If customer desires to use his own bottles, he should be sure to obtain Form 24670 from the Westinghouse Office. Lack of this form will cause much delay in various accounting procedures involved, and thereby delay the test. Samples should

be taken in accordance with ASTM D-117. Note that the bottles and containers involved will not be returned to the customer.

When samples of oil are received for testing they are sent to the engineering testing laboratory and tested for dielectric strength in accordance with methods described in ASTM D-117.

As soon as the test has been made, a report giving the average is sent by mail directly to the person in the customer's organization who has been designated on the order to receive it.

In addition to dielectric tests, Westinghouse is also prepared to make a physical and chemical examination. (The customer should plainly indicate the type of service desired.)

This service consists of an examination of the oil by a competent oil chemist. Recommendations will be made as to the suitability of the oil for continued use, whether it would be desirable and economical to clean it, and in a general way, the preferred method of cleaning. In submitting samples for this service, the history of the oil represented should be given as completely as possible. Samples should be not less than one pint.

Other tests available include a complete Physical and Chemical Examination; a power factor test; and the establishment of a Power Factor Curve from 25°C to 100°C.

The Physical and Chemical Examination encompasses tests of acid and base numbers, color, interfacial tension test, pour point, specific gravity, and viscosity.

A combination is offered of the dielectric test, the acid and base number test, the interfacial tension test, and the power factor test. This combination covers those tests most often requested for general purposes.

(For further details on available tests, refer to the nearest Westinghouse Office.)

PURIFICATION AND RECONDITIONING

PURITY OF OIL

Wemco C oil is clear and nearly water-white in color. It is free from water, acid, alkali, and deleterious sulfur compounds.

The oil is carefully refined so as to have a high resistance to emulsion; that is, the water is not held in suspension but quickly separates out. This is particularly essential in circuit-breaker service since this apparatus cannot be tightly closed like a transformer and some moisture may be introduced into the oil. Wemco C oil has been designed with this particular property in mind and precipitates water and carbon promptly. However, certain impurities develop while the oil is in service and these impurities must be removed to insure safe operation of the apparatus. The source and kind of impurities developed in the oil depend upon the type of apparatus in which it is used.

In circuit-breaker service, each time the circuit is opened some carbon is formed in the oil, even when only a small charging current is being interrupted. The resistance to emulsion of the oil is also lessened, both by a change in the oil and by the presence of carbon in the oil. Oil which has been subjected to arc action in the circuit breaker tends to slowly form organic acids, which further tend to lower its resistance to emulsion. The major portion of the carbon slowly precipitates to the bottom of the tank, but the more finely divided carbon has a tendency to remain suspended in the oil, and lower the dielectric strength. Both carbon and moisture are attracted to the insulating surfaces of the bushings by the electrostatic field, and when so deposited, lower the insulation resistance of the terminals from line to ground.

Oil in transformers is generally subjected to heat, oxidation and sometimes to moisture. Heat in the presence of oxygen produces a gradual physical and chemical change in oil and the extent of this change will depend upon the amount of heat,

time and the catalytic action of exposed metals in the apparatus to which it is subjected. High temperature over a short period of time or somewhat lower temperature over a long period of time affect the characteristics of the oil, particularly in the development of organic acidity and sludge.

Heat in the presence of oxygen affects the unsaturated hydrocarbons, at first through formation of organic acids and later by precipitation in the form ordinarily called sludge.

RECONDITIONING

The reconditioning of oil used in circuit breakers and transformers consists principally of the removal of water, carbon and sludge and the restoration of resistance to emulsification, thereby putting the oil in the best condition to separate out any water which may later be introduced.

The four types of equipment in general use for simple reconditioning of oil in transformers and circuit breakers are: the centrifuge, the blotter filter press, the combination centrifuge and filter press and the combination fullers earth and vacuum dehydration process. (See Part Five.)

IMPORTANT: In general, when small quantities of oil have been contaminated with fire extinguishing agents, it is preferable to replace the oil rather than to attempt to reclaim it.

Insulating oil which has been contaminated with carbon tetrachloride or soda sulfuric acid cannot be reclaimed. (It would have to be refined.)

When large quantities of oil have been contaminated with other fire extinguishing agents, the reclaiming of the oil will depend upon the kind and degree of contamination. There may be factors other than the fire extinguishing agent (for instance, high temperatures cracking the oil, carbonized insulation, etc.) which should be considered. Any question should be referred to the nearest Westinghouse Office.

PART FOUR

TESTING METHODS

Instructions for all tests listed correspond in general to the recommendations of the American Society for Testing Materials.

DIELECTRIC STRENGTH TEST

Apparatus. The transformer and the source of supply of energy shall not be less than $\frac{1}{2}$ kva, and the frequency shall not exceed 100 cycles per second. Regulation shall be so controlled that the high tension testing voltage taken from the secondary of the testing transformer can be raised gradually without opening either primary or secondary circuit. The rate of rise shall approximate 3000 volts per second. The voltage may be measured by any approved method which gives root-mean-square values.

Some protection is desirable to prevent excessive flow of current when breakdown of the oil takes place. This protection preferably should be in the primary or low voltage side of the testing transformer. It is not especially important for transformers of 5 kva or less, as the current is limited by the regulation of the transformer.

The test cup for holding the sample of oil shall be made of a material having a suitable dielectric

strength. It must be insoluble in and unattacked by mineral oil and gasoline, and nonabsorbent as far as moisture, mineral oil and gasoline are concerned.

The electrodes in the test cup between which the sample is tested shall be circular discs of polished brass or copper, 1 in. in diameter, with square edges. The electrodes shall be mounted in the test cup with their axes horizontal and coincident, with a gap of 0.100 in. between their adjacent faces, and with tops of electrodes about $1\frac{1}{4}$ in. below the top of the cup. (A suitable test cup shown in Fig. 3, and portable testing outfits in Figs. 4 and 5.)

Procedure. The spacing of electrodes shall be checked with a standard round gauge having a diameter of 0.100 in., and the electrodes then locked in position.

The electrodes and the test cup shall be wiped clean with dry, calendered tissue paper or with a clean, dry chamois skin and thoroughly rinsed with oil-free dry gasoline or benzine until they are entirely free from fibres.

The test cup shall be filled with dry, lead-free gasoline or benzine, and voltage applied with uniform increase at the rate of approximately 3000 volts (rms) per second until breakdown occurs. If the dielectric strength is not less than 25 kv, the cup shall be considered in suitable condition for testing the oil. If a lower test value is obtained the cup shall be cleaned with gasoline and the test repeated.

Note: Evaporation of gasoline from the electrodes may chill them sufficiently to cause moisture to condense on their surface. For this reason, after the final rinsing with gasoline, the test cup should be immediately filled with the oil which is being tested, and the test made at once, or the electrodes should be thoroughly dried before using.

The temperature of the test cup and of the oil when tested shall be the same as that of the room, which should be between 20 and 30 C (68 and 86F). Testing at lower temperatures is likely to give variable results which may be misleading.

The sample in the container shall be agitated with a swirling motion to avoid introducing air, so as to mix the oil thoroughly before filling the test cup. This is even more important with used oil than with new oil as the impurities may settle to

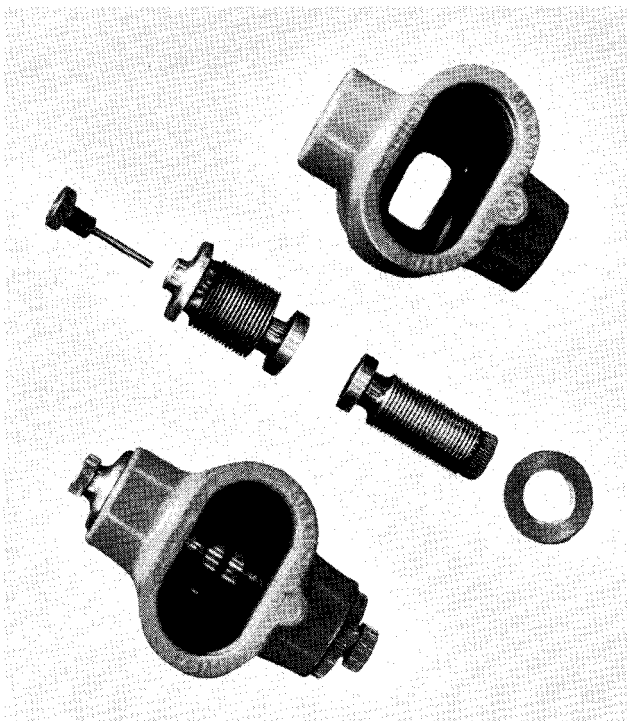


FIG. 3. Oil or Fluid Test Cup for Dielectric Test.

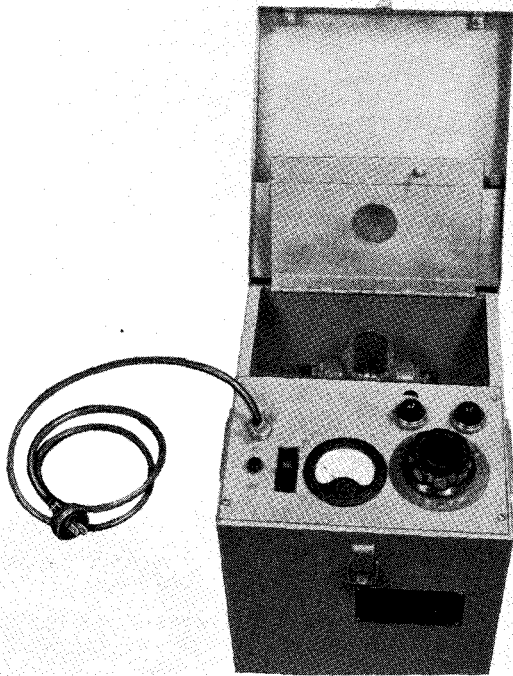


FIG. 4. Portable Oil Testing Set 1/2 Kva, 35,000 Volts.

the bottom and the test may be misleading.

The cup shall be filled with oil to a height of no less than 0.79 in. (20 mm) above the top of the electrodes.

The oil shall be gently agitated by rocking the cup and allowing it to stand in the cup for three minutes before testing. This will allow air bubbles to escape.

Voltages shall be applied and increased uniformly at a rate of approximately 3000 volts (rms) per second until breakdown occurs as indicated by a continuous discharge across the gap. (Occasional momentary discharges which do not result in a permanent arc may occur; these should be disregarded.)

Provision shall be made for opening the circuit as promptly as possible after breakdown has occurred in order to prevent unnecessary carbonization of the oil.

TESTS

a. Except as specified in (b) one breakdown test shall be made on each of five fillings of the test cup. If the average deviation from the mean exceeds 10 percent or if any individual test deviates more than 25 percent from the average, additional tests shall be made. The dielectric strength shall be determined by averaging the first five tests that conform to the allowable variations.

b. When oil is tested in considerable quantity, so that the time required for testing is excessive and when it is merely desired to determine whether the breakdown safely exceeds the limit specified, or in those cases where the amount of oil available for test may be very limited, one breakdown test shall be made on each of two fillings of the test cup. If neither breakdown is below the specified value, the oil may be considered satisfactory and no further tests shall be required. If either of the breakdowns is less than the specified value, a breakdown shall be made on each of three additional fillings and test results analyzed in accordance with (a).

Report. The report shall include the volts (rms value) at each puncture, the average voltage for each of the two or five fillings, grand average voltage, and the approximate temperature of the oil at the time of the test.

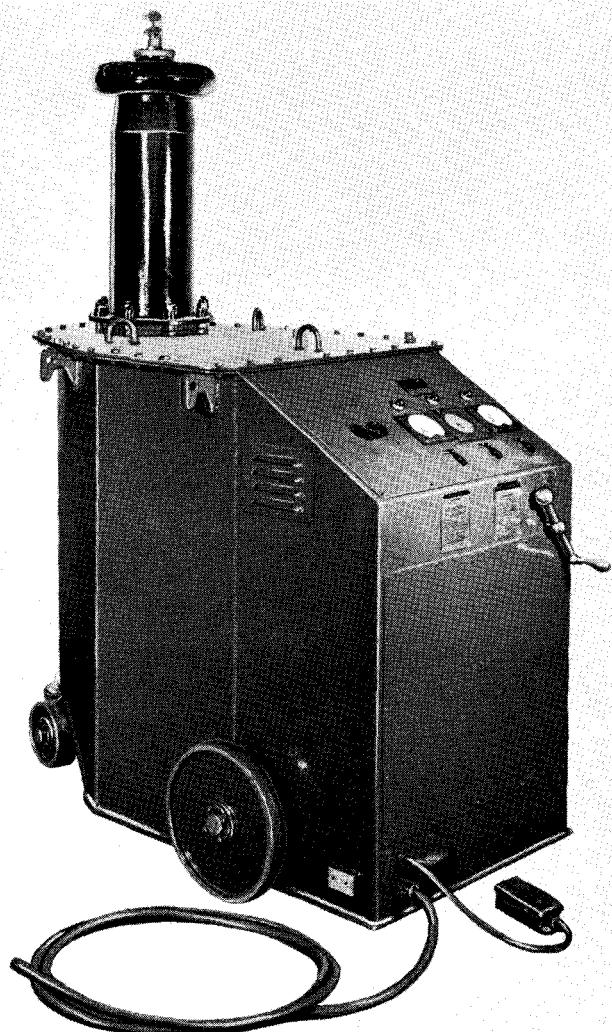


FIG. 5. Portable Truck Type Oil and Insulation Testing Set, 5 Kva, 30,000/60,000 Volts.

NEUTRALIZATION TEST

The Neutralization Number is the weight in milligrams of potassium hydroxide required to neutralize the acid in one gram of oil. The Neutralization Number of new Wemco C oil is 0.03 maximum.

Solutions Required.

a. Standard Potassium Hydroxide Solution (alcoholic, 0.1 N)—add 6 g. of c.p. solid KOH to 1 liter of c.p. anhydrous isopropyl alcohol. Boil, add 2 g. of c.p. Ba (OH)₂ and boil again. Cool, filter and store in a chemically resistant bottle protected by a guard tube containing soda lime and soda asbestos (Ascarite). Standardize against pure potassium acid phthalate using phenolphthalien as an indicator.

b. Titration Solvent—Add 500 ml. of c.p. benzene and 5 ml. of water to 495 ml. of c.p. anhydrous isopropyl alcohol.

c. Alpha-Naphtholbenzein Indicator Solution — Prepare a solution containing 10 g. of alpha-naphtholbenzein per liter of c.p. anhydrous isopropyl alcohol.

Procedure. Into a 250 ml. Erlenmeyer flask introduce 40 g. of Wemco C oil weighed to nearest 0.1 gram. Add 100 ml. of the titration solvent and 3 ml. of the indicator solution. Titrate immediately at a temperature below 30°C. Consider the end point definite if the color change to green persists for 15 seconds. A blank shall be determined on the solvent.

Calculations. The neutralization number or mg KOH per g. of Wemco C oil = $\frac{(A-B) (N) \times 56.1}{W}$

A = ml. KOH solution required for sample.

B = ml. KOH solution required for blank.

N = normality of KOH solution.

W = grams of sample used.

PART FIVE

RECONDITIONING

APPARATUS FOR RECONDITIONING

RECONDITIONING

In order that oil in circuit breakers and transformers performs its function, certain essential properties must be maintained. Various types of equipment are available to assist the operator in the maintenance of insulating oil.

The first step is to classify oils in service based upon an evaluation of their properties.

GROUP I—This group contains oils which are in satisfactory condition for continued service.

GROUP II—This group contains oils which are low in dielectric strength or contain insoluble contaminants and requires only minor reconditioning by blotter press and/or centrifuge to restore them to condition for continued service.

GROUP III—This group contains oils in poor condition which should be reclaimed or scrapped depending upon economic considerations.

GROUP IV—This group contains oils in such poor condition that it is advisable to dispose of them.

Many tests are available which can be applied to transformer oils in order to classify them into the four groups described. It is recommended that the latest revisions of standards as described by the American Society for Testing Materials (ASTM) be used.

APPARATUS FOR RECONDITIONING

There are several types of reconditioning apparatus available, the relative advantages of each of which are as follows:

1. The centrifuge, connected as a separator, may be used where there are large quantities of water present in the oil, without waiting for it to settle out, and connected as a clarifier, for removing small quantities of water. It will remove sludge and coarse carbon particles but not all finely divided carbon.

2. The filter press is suitable for reconditioning oil containing small quantities of water and will remove finely divided carbon and sludge. It will not materially reduce organic acidity or improve

the resistance to emulsification except as this is caused by the presence of carbon.

3. The combination centrifuge and filter press, passing the oil first through the centrifuge, may be used advantageously in the removal of large quantities of carbon and water. It unites the exceptional qualities of the centrifuge with the excellent characteristics of the blotter press. This flexibility of operation makes it very desirable as standard equipment in the reconditioning of insulating oil for the removal of large quantities of carbon from the oil. However, the clogging of the pores of the filter reduces the output of this combination.

CAUTION: STATIC ELECTRICITY—In the operation of a filter press it is necessary that the problem of static electricity be recognized and areas and tanks vented as much as possible. (See caution note on Static Electricity—Part I page 5.)

4. A fuller's earth filter is the method most frequently used for oils in Group III. In general, reclaiming is done by one of two methods, percolation through the fuller's earth, or by contact at an elevated temperature with finely divided material. The excellent absorbent properties of the fuller's earth will remove acids and other contaminants.

5. A vacuum dehydrator is an efficient means of reducing the water content of insulating oils and is frequently used in conjunction with a fuller's earth filter. Here the oil is exposed to a high vacuum and heat for a short interval of time.

The final criterion of the effectiveness of any method of reconditioning is the quality of the reconditioned oil. The dielectric strength of the reconditioned oil should be at least 26 KV to provide some margin over the lowest limit of 22 KV.

Oils which have been reconditioned by a fuller's earth process should have properties closely approaching those of new oil. It is recommended that to extend the life of reconditioned oils that at least 0.2 percent by weight of inhibitor, Di-Tertiary-Butyl-Paracresol, (D.B.P.C.), be added to the oil.

BLOTTER FILTER PRESS

The blotter filter press (see Fig. 8) is probably most widely used for the reconditioning of insulating oils which have become unfit for use due to the presence of carbon or other foreign matter. It is essentially a number of sets of filter papers in parallel, each set containing several thicknesses. The oil is pumped through the filter paper which absorbs the water and strains out the sediment.

Note: Cleaning devices intended for reconditioning of insulating oil should never be used for other types of work, due to the danger of contaminating the oil.

Capacity. The capacity of these machines, with oil pressure and filtering area fixed, depends on the viscosity of the oil and its freedom from dirt. With fairly clean oil at ordinary room temperature, the capacity of the machines will vary from normal to about 15 per cent above normal, depending on the viscosity (which varies with the temperature). It has been found that the best results are obtained when the oil temperature is about 50°C. The average working pressure of these machines is less than 40 lbs. per square inch and the pressure relief valve is set at the factory to by-pass the full flow at 60 to 70 lbs. per square inch.

Apparatus. There are two standard sizes of Westinghouse filter presses: B-10 and A-30. The letter designates the size of filter paper; the number indicates the relative capacity in gallons per minute.

The complete outfit consists of filter press, motor, strainer, pump, gas trap, pressure gauge, drip pan, casters and piping. The piping is arranged so the suction line can be tested for leaks under pressure.

The strainer can be cleaned by unscrewing a plug. The pumps are of the positive pressure type and are directly connected to the motor through flexible couplings.

The filter press proper is made up of a series of cast iron plates and frames assembled alternately, with the filter papers between them. By means of a screw and cast-iron end block, the plates, frames and papers are forced tightly together. Except for a machined rim which serves as a joint to prevent the escape of oil, the plates are cast with small pyramids on both surfaces.

The plates and frames have holes in two corners and supporting lugs at the sides. The plates have handles cast on the top edge. When the plates and

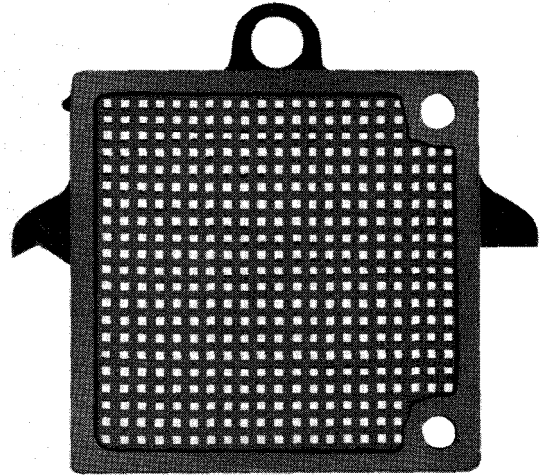


FIG. 7. Filter Press Frame with Blotters in Place.

frames are assembled with the filter papers between, the holes form the inlet and outlet. The frames have the holes in the upper corner connected by small ducts to the middle of the frame. The plates have ducts leading from the surface of the plate to the hole in the lower corner. (See Fig. 7.)

The oil enters under pressure at the top corner through the inlet formed by the holes in the frames, plates, and filter papers, flows into the frames through the same ducts, and completely fills the chamber formed by the frame and two sets of filter paper. As there are no outlet ducts in the frame, the oil is forced through the paper and flows along the grooves between the rows of pyramids and out through the ducts provided at the lower corner of the plates. The dry filter paper takes up the moisture and removes the sediment from the oil.

Operation. The filter press is made ready for operation by placing a set of five sheets of filter paper, that have been thoroughly dried in an electric oven, between each filter plate and frame. The holes in the filter paper must line up with the holes in the plates and frames. The sediment is strained out by the first layer of paper and the moisture is taken up by the capillary action of the paper.

Oil which has only a very small quantity of moisture may be satisfactorily reclaimed by the filter press, but when a large quantity of water is to be removed, the centrifuge or combination centrifuge and filter press is preferred, and is also more economical.

If any moisture remains, it indicates that the filter papers are saturated with moisture and should be renewed. No rule can be given as to how often the papers must be changed, as this depends entirely on the condition of the oil. The usual procedure is to run the machine for about half an hour (if the oil is not in very bad condition) and then shut down; remove one sheet from the inlet side of each set and put in a new sheet on the outlet side of each set. (The frame is the inlet side and the plate is the outlet side.) Frequent dielectric tests should be made during this procedure as wet oil may necessitate recharging the filter press with a full set of papers before the five sheets have been removed in succession.

The quickest method of filtering a quantity of oil is to pump all the oil through the filter and into another tank which is clean and dry. If care is taken to change the filter papers before they become saturated, the oil will be clean and dry. If a second tank for holding the oil is not available, or if it is desired to filter the oil of a transformer while it is in service, the oil may be pumped from the bottom of the tank through the filter and returned to the top of the same tank under the surface of the oil to prevent aeration. This operation should be continued until the oil in the tank shows a sufficiently high dielectric strength.

When a large quantity of oil is to be filtered, time may be saved by using two filter presses, one of which may be operated while the other is being recharged.

The filter press is not intended to remove large amounts of free water from the oil. Obviously the changing of filter papers necessary for obtaining dry oil would so reduce the capacity as to make this method of reconditioning impractical. In such cases, the water may be removed by a centrifuge, or should be allowed to settle out and be drawn off from the bottom of the container before passing the oil through a filter press.

With badly fouled oil, it may be necessary to pass the oil through the filter press several times to take out the more finely divided carbon which is not caught on the filter papers, especially when they are new. The efficiency of the filter press for removing carbon increases as the pores of the filter papers become partly clogged. This produces a material slowing-down in the rate of flow through the filter papers.

Filtering through filter papers does not materially reduce organic acidity or improve resistance

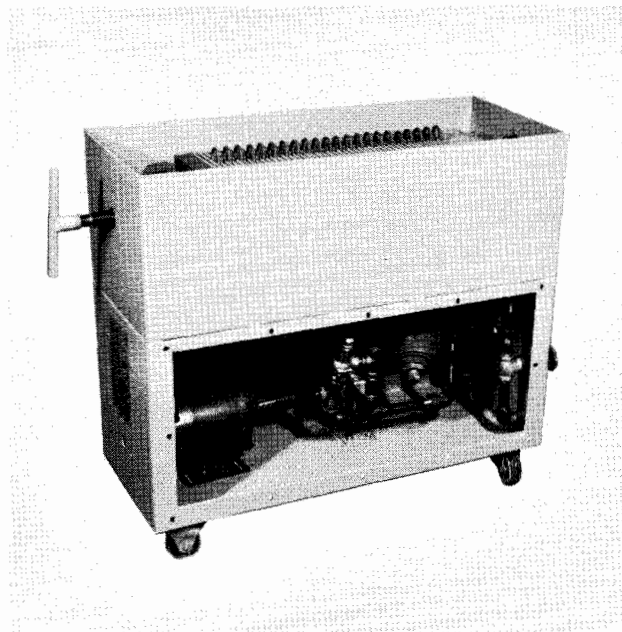


FIG. 8. B-10 Filter Press with Top and Side Panel Removed. (Explosion-Proof Model).

to emulsification except as the latter is affected by the presence of carbon, although the dielectric strength may be restored to a satisfactory value.

The capacity of the filter press is much reduced when operating at low temperatures.

When the oil has to be filtered at low temperatures an additional pump in the pipe line is desirable.

Oil in transformers contaminated by only a small amount of moisture may be reconditioned by drawing the oil from the bottom of the tank, passing it through the filter press or centrifuge and pumping it back into the top of the transformer, preferably at a point below the surface of the oil. The oil should be put through the system until a sample drawn from the bottom of the transformer gives satisfactory dielectric values.

Pumping the oil from a circuit-breaker tank to the purifying outfit and directly back to the tank is not desirable, as the clean oil is again contaminated by the carbonized oil remaining in the tank. Also, it is then impossible to clean the carbon deposit from the surfaces inside the tank. Do not filter oil from a circuit-breaker while the breaker is in service on an energized line.

Filter Paper. The filter paper used is a special grade of blotting paper about .025 in. thick; it contains no coloring matter or chemicals which might injure the oil. Five sheets cut to the proper size,

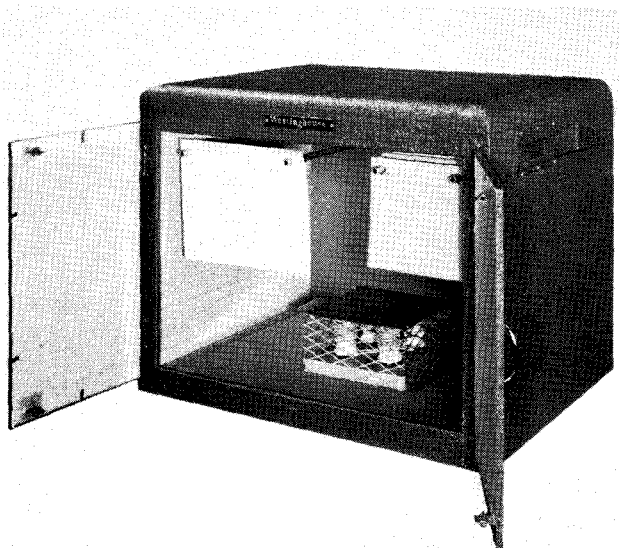


FIG. 9. Electric Drying Oven.

12 $\frac{7}{8}$ in. square for the A sizes and 7 $\frac{3}{4}$ in. square for the B sizes, and with holes punched to correspond with the holes in the plates and frames, are between each plate and the adjacent frames.

To obtain the best results in reconditioning oil, the paper must be perfectly dry when first placed in the press. Filter paper always takes up moisture if exposed to the air for any length of time and for this reason care must be used in handling. The standard paper is carried in packages containing one ream carefully wrapped in waxed paper and covered with heavy wrapping paper.

ELECTRIC DRYING OVEN

The importance of the drying oven cannot be over-emphasized since the effectiveness of the whole filtering process is dependent on the dryness of the paper. For satisfactory results, the dried filter paper should either be inserted in the filter press and used immediately, or kept in dry transformer oil until it is transferred to the filter press. No filter paper can be effectively dried after it has once become saturated with oil. Therefore, care should be taken to insure that the paper is thor-

oughly dried when placed in the filter.

The oven can be used on 110/220/440 DC or single phase AC, 1000 watts. The normal capacity of 7 inch or 12 inch paper is 180 sheets.

The paper is suspended from two rods with the sheets separated from each other, thus permitting thorough circulation of heated air. The rods can be rearranged for hanging either 12 inch or 7 inch filter paper.

Normally, the filter paper should be dried 6 to 12 hours, depending upon condition of the paper and spacing of the sheets in the oven.

The cabinet is constructed of fabricated sheet steel and insulated with $\frac{1}{4}$ inch asbestos board. (See Figure 9)

The air vents are designed to provide cross ventilation so that dry heated air replaces moisture laden air.

Oil can be dried rapidly and thoroughly if the filter paper is carefully prepared, transferred to the press without reabsorbing moisture, and replaced when its effectiveness is exhausted. If good results are not obtained, it is probably because the paper was not sufficiently dry when placed in the press, due either to improper drying or careless handling.

CENTRIFUGE

The centrifuge is the most convenient equipment known for removing water from oil. It also removes solid material other than finely divided carbon. The temperature of the oil should be maintained at 48.9 to 51.7 C (120 to 125 F) in order to insure removal of all the water at full capacity of the machine. A higher temperature gives no advantage, and if excessive, will permit the oil to carry more moisture through in solution. (A 6 kw heater will raise the oil about 15.6 C (60 F) per 100 gallons per hour.) The centrifuge equipment may be arranged to act as a separator, discharging the oil and water by different outlets, or as a clarifier, discharging the oil but retaining the water and other impurities in the bowl*.

*For further details, see manufacturer's information.

