HANDLING • INSPECTION • MAINTENANCE

INSTRUCTIONS

WEMCO C

INSULATING OIL

P. D. S. 2772

for

Electrical Apparatus

WESTINGHOUSE ELECTRIC CORPORATION

SHARON WORKS
SHARON, PA.

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SUPERSEDES I. B. 65-000

EFFECTIVE JUNE, 1946

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WEMCO C INSULATING OIL

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Wemco C insulating oil is a development of the Westinghouse Electric Corporation in cooperation with oil refiners. It has proven its suitability for use in all Westinghouse oil-insulated apparatus. In order to insure the proper performance of the apparatus, only Wemco C oil 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 oil is shipped in tank cars, drums or cans. The modern tank cars are usually lagged to prevent rapid fluctuations in temperature during transit and thus reduce the amount of expansion and contraction of oil. Changes in the volume of the oil due to temperature changes tend to cause breathing in of moist air resulting in condensation of moisture inside the tank, and lowering of the dielectric strength of the oil.

The oil and the drums are both heated above room temperature while the drums are being filled, and the bungs are tightened immediately after filling. After cooling to normal temperature, the bungs are again tightened. The drums are provided with screw bungs having gaskets to prevent admission of water.

The cans are of metal. The cans as well as the oil are heated above room temperature while being filled and are hermetically sealed immediately after filling.

STORING

Drums. As soon as a drum of oil has been unloaded the bung should be examined and tightened if it is loose. It is possible for bungs to become loosened by change in temperature or rough handling in transit.

It is very desirable that oil in drums be stored in a closed room. Outdoor storage of oil is always hazardous and should be avoided if at all possible. If it is necessary to store oil outside, protection against direct precipitation of rain and snow should be provided. Drums stored outdoors should be placed on timbers so as to be clear of the ground. They should always be placed on their sides, with bungs approximately 45 degrees from the bottom. *Drums should never be turned up on end.* It is desirable to cover them with a tarpaulin.

Cans. Cans containing 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 hermetic seal has been broken. By replacing the screw caps, contamination by moisture and dirt will be retarded.

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.

It is desirable to maintain the temperature of the oil and tank a little above the temperature of the surrounding air as this prevents condensation of moisture in the tank which would affect the dielectric strength of the oil.

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 the Wemco C oil furnished with circuit breakers and transformers will not take fire unless brought to a very high temperature, it should be remembered that under abnormal conditions such a temperature can be reached, so that proper precaution against fire should be taken. Suitable means should always be provided for drawing off oil from storage tanks and extinguishing fire. 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

Note: The oil should be sampled and tested, except when received in cans, before being transferred from the container to the apparatus, particularly in cases where the wire lock-seal has been broken. In cases where the apparatus is received with the oil installed, the oil should be sampled and tested before the apparatus is put into service, as described later in this book.

When putting a new circuit breaker or transformer into service, see that the tank is free from moisture and foreign material.

When carbonized oil is removed from a circuit breaker or transformer in service, thoroughly clean the interior of the apparatus so that the new oil will not be contaminated. This may be done by flushing with clean insulating oil and wiping with clean, dry, lint-free cotton cloths. Cotton waste is undesirable because of the lint which may be introduced into the oil.

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, oil which has not been filtered should be strained through two or more thicknesses of muslin, or other closely woven cotton cloth which has been thoroughly washed and dried to remove the sizing. The straining cloths may be stretched across a funnel of large size and should be renewed at frequent intervals.

Important: Extreme precautions must be taken to insure the absolute dryness and cleanliness of the apparatus before filling it with oil, and to prevent the entrance of water and dirt during the transfer of the oil to the apparatus.

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.

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

When it is necessary to transfer oil from warm surroundings to apparatus exposed to extremely cold weather, even when the dielectric strength at room temperature is high, it is desirable to circulate the oil through a blotter press or centrifuge at room temperature. A similar procedure is also advisable in the case of apparatus erected inside and later exposed to cold weather; the reason being that oil will dissolve more water at higher temperatures which will be thrown out of solution at lower temperatures. The excess will appear in suspension in the oil and will lower the dielectric strength.

A drum of cold oil when taken into a warm room will "sweat", and the resulting moisture on the surface may mix with the oil as it flows from the drum. Before breaking the seal the drum should therefore be allowed to stand long enough to reach room temperature, which may require eight hours, or even longer under extreme temperature conditions.

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 bunghole down, in a venti) lated 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. The practice of refilling 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 refill them for storage, drums which have been used only for oil in good condition should be reserved for this purpose. They should be closed immediately after being emptied, to exclude dirt and water. After refilling, they should be examined to see that they do not leak.

Whenever a drum is to be filled with oil, the temperature of the drum and of the oil should be at least 5.5°C (10°F) higher than the air, but the temperature of the drum need not be the same as that of the oil.

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.

Drums to be refilled with oil for storage should be plainly marked with paint for identification.

SAMPLING AND INSPECTION

REQUIREMENTS FOR INSULATING OIL

The requirements for good insulating oil used in transformers are not inconsistent with the requirements for oil used in circuit breakers. Wemco C oil is particularly well suited for both applications and for either indoor or outdoor service. In transformers the oil provides an electrical insulating medium which also will carry the heat away from the windings. In circuit breakers, the oil serves primarily as an electrical insulating medium which interrupts the arc when the circuit breaker operates. Wemco C oil meets these requirements:

1. High dielectric strength.

2. Freedom from inorganic acid, alkali and corrosive sulphur (to prevent injury to insulation and conductors).

3. Low viscosity (to provide good heat transfer in transformers; in circuit-breakers, to aid in dissipating the products formed by the arc when the circuit is interrupted).

4. Good resistance to emulsification (so that any moisture entering the apparatus, or carbon formed by arcing in the circuit-breaker, will settle to the bottom of the tank; water in suspension is a menace to safe operation).

5. Freedom from sludging under normal conditions.

6. Low pour point.

7. Low specific gravity.

CAUSES OF DETERIORATION OF OIL

Transformers. The principal causes of deterioration of insulating oil in transformers are:

1. Presence of water.

2. Oxidation.

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. By careful refining, the components of oil which are most readily oxidized to form sludge can be removed, so as to provide an insulating oil which will not sludge under normal operating conditions.

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 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. Proven and accepted methods are not yet available in the field that will completely remove the oxidation products which are encountered in transformer service and bring sludged oil back to its original condition. (It is not economical to send used oil to the refinery for re-refining as they will allow only fuel oil price, which would probably be less than the cost of transportation.)

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 are:

1. Presence of water.

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

Insulating oils may receive water through condensation on the surface of the oil or on the inside of the tank due to the entrance of moist air, and, of course, by direct leakage.

All oil in circuit breakers is subject to carbonization due to arcing between the contacts. Part of the carbon formed is deposited on the mechanism 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.

The carbon reduces the dielectric strength of the oil, lowers the surface resistance of the insulation if water is present, and also lowers 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. Many of the low dielectric test results reported from the field have been caused by carelessness in sampling. 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 clear glass, of at least 8 oz. capacity, and shall be cleaned and dried. The glass bottle is preferable to the 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 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. Use only good quality cork and use new cork for each sample.

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 cork to a temperature of 100°C (212°F) for one hour after thoroughly draining. The bottle shall then be tightly corked and cork and neck of the bottle dipped in melted paraffin.

Important: Glass jars having rubber gaskets or stoppers should not be used. Oil can easily become contaminated from the sulphur in natural rubber.

Thiefs for Sampling. A convenient and simple thief (see Figure 1) for use with 50 gal. drums may be made of tin as follows:

Length 36 in., diameter 1¼ in. with cone shaped caps over the ends and openings at the ends ⅜ in. in diameter. Three legs equally spaced around the thief at the bottom, and long enough to hold the opening ⅛ 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 Figure 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 ⅛ in. from the bottom.

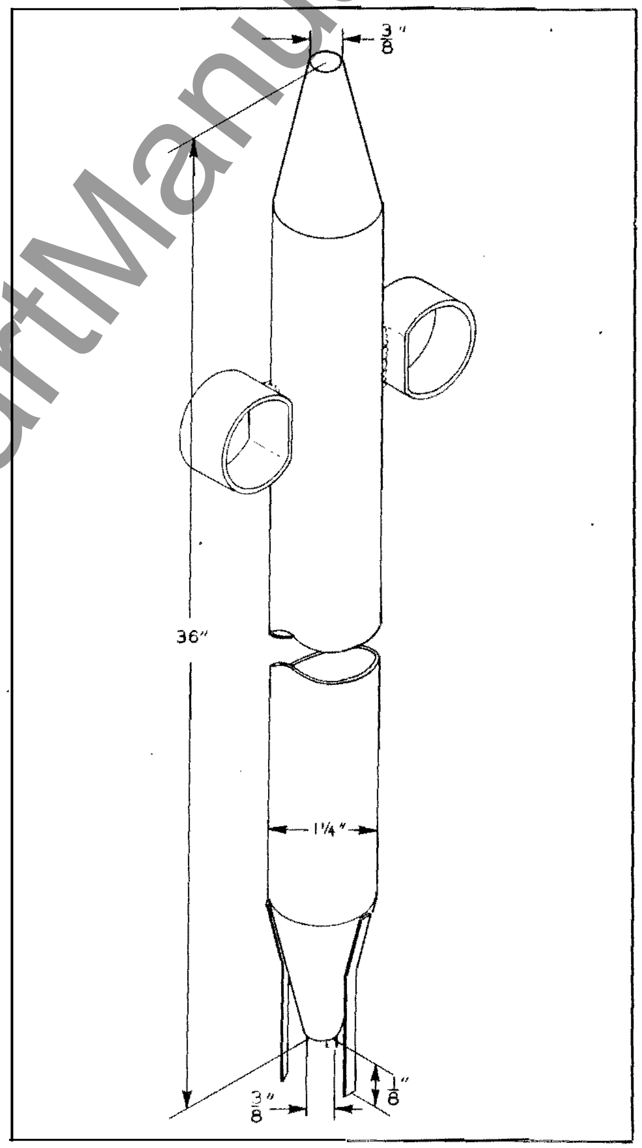


FIG. 1. Drum Thief

Procedure. Thiefs 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

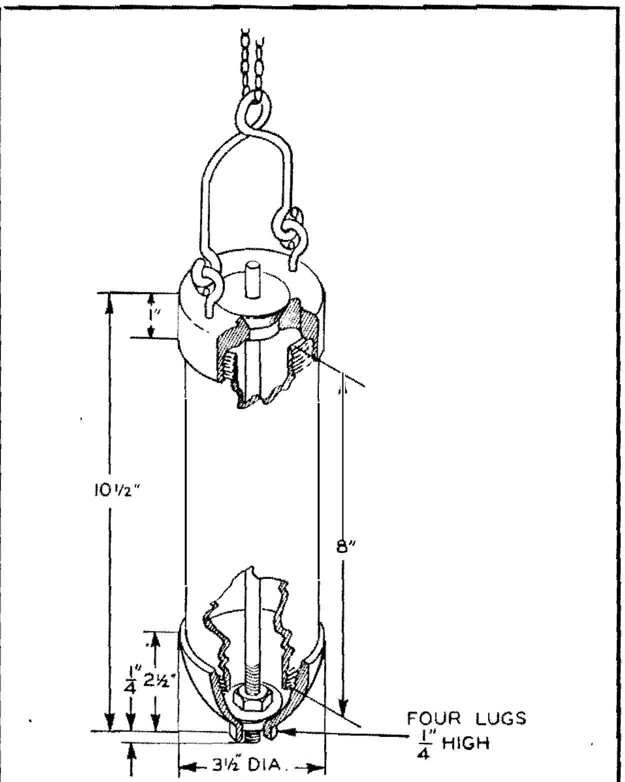


FIG. 2. Tank Car Thief

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.)

The drums shall be lined up preferably on their sides, 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 be used to guide the stream of oil by touching the thief 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 thiefs 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 thiefs 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 thiefs are sufficient, but for obtaining a large number of samples (for example, sampling a carload of drummed oil) six or more thiefs 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 8 oz. bottle of oil be taken as a sample for dielectric tests, and 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 sample and bottle should be discarded, as sample would not be suitable for dielectric test. If the sample is being taken from a tank car, sufficient liquid should be drawn from the bottom of the tank to remove all free water before obtaining another sample of oil for the dielectric test.

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 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 prime importance that the sample of insulating oils be kept free from water and other impurities.

Moisture may find its way into insulating oil in several ways. The oil is frequently shipped in metal drums, and if these are exposed to rain, moisture may enter around the threads of the bung, or through imperfections in the seams. In water-cooled transformers, the portions of the water pipes which extend above the oil level are always heavily lagged with a heat-insulating material. If this lagging is damaged, moisture in the air inside of the transformer may condense on the cold water pipe and may run down into the oil. Another source to which the presence of moisture in large transformers is sometimes attributed, is the "breathing" of the transformer. When the transformer carries a load and becomes warm, both the oil and the air in the tank expand, and if there is a vent, part of the air will be forced out of the tank. When the load is cut off and the transformer cools, this action is reversed, and a corresponding volume of air is drawn into the tank from the atmosphere. This air carries a certain amount of moisture, which is condensed as the air becomes cooler, and collects on the cover and tank wall.

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. Sufficient liquid should be drawn from the bottom of the tank to remove all free water before obtaining another sample of oil for the dielectric test.

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: Therefore, 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.

Note: A periodic inspection and reconditioning schedule is not essential for oil in transformers equipped with the Inertaire device; such oil should last indefinitely without need for reconditioning, provided the Inertaire equipment is properly maintained.

Regular inspection and tests of insulating oils by central stations and other large users of these oils have convinced them of the necessity of this practice. Where these inspections and tests have been systematically followed it has been found that failure of the apparatus from burnouts, 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 apparatus is subjected, and the construction of and the materials used in the apparatus.

Circuit breakers which are called upon to open the circuit frequently under heavy loads require more frequent inspection and reconditioning of the oil than those subjected to lighter duty.

Transformers subjected to heavy duty should be more frequently inspected than those 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 never be longer than six months or until experience indicates that the time between tests can be extended. When the dielectric strength of the oil drops to 20 kv in the standard dielectric test (see page 14) the oil should be looked upon with suspicion. In no case should the dielectric strength be allowed to drop below 16.5 kv.

Inspection of oil should include:

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 failure of circuit breaker to open heavy overloads properly.

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 to check the dielectric strength after exposure to severe overload operation in a circuit breaker.

Checking for Carbonization. The presence of carbon in circuit breaker oil introduces 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 essential that such oil be reconditioned immediately and when put in service again should be carefully watched to see that the proper dielectric strength is maintained and that the oil is reconditioned again before sludge has formed to such an extent as to interfere with the operation of the transformer. *Oil which has once sludged, will, after being reconditioned, sludge more quickly than the first time.*

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.

A special 8 oz. oil sample bottle and mailing container,* (W) style # 310368, as well as necessary packing and printed matter, may be obtained by contacting the nearest Westinghouse District Office.

After drawing the sample of oil, the customer should seal the bottle and mail it to the Westinghouse Engineering Laboratory at East Pittsburgh, Pa. To simplify these details, an instruction and order sheet and a printed return label have been included in the carton container. The instructions cover the taking of the sample and its proper preparation for mailing. The label carries an envelope in which the customer should enclose his order covering the work of testing.

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 on page 14.

As soon as the test has been made, a report giving five breakdown test readings and the average of these 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 approximately one quart.

Power factor test of oil at 60 cycles can be made. Unless otherwise requested, the test will be made at a stress of 30 volts per mill.

(For details refer to the nearest Westinghouse District Office.)

* The bottle and the container will not be returned to the customer.

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 sulphur 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 though only the 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 hydro-carbons, 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 three types of equipment in general use for simple reconditioning of oil in transformers and circuit breakers are: the centrifuge, the blotter filter press, and the combination centrifuge and filter press. (See Part Five.) The combination of centrifuge with chemical treatment is particularly well adapted to the reconditioning or carbonized circuit-breaker oil.

INTERCHANGEABILITY

Wemco C oil may be used in transformers after arcing in circuit breakers, provided all carbon is removed and the purified oil meets the following values:

1. Specific Gravity: 15.5 C, .898 max.
2. Viscosity: Saybolt at 37.8 C (100 F), 60 secs. max.
3. Flash Point: 135 C (275 F) min.
4. Pour Test: –45.6 C (–50 F) max.
5. S. E. Number: 35 secs. max.
6. Neutralization Number: Mg KOH per gram of oil, 0.08 max.
7. Corrosive Sulphur: None
8. Dielectric Strength: 22 kv min. in a standard test cup.

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 sulphuric 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 District 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 ½ 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.

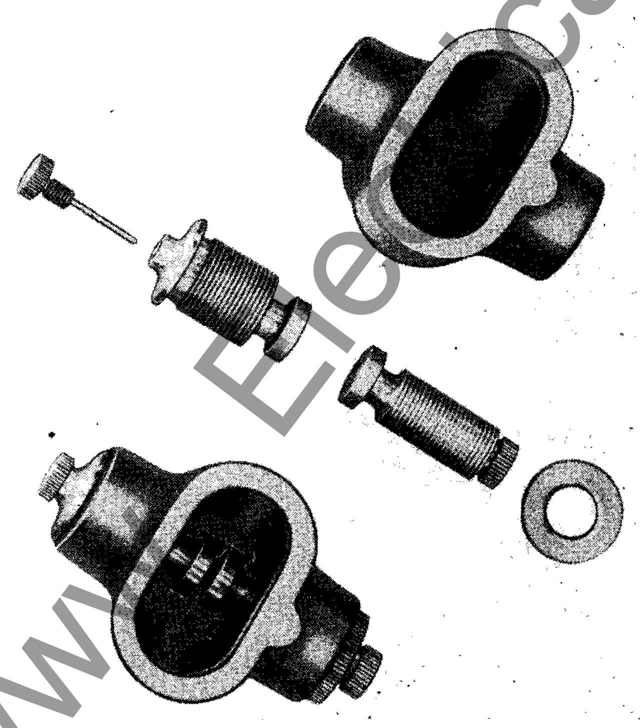


FIG. 3. Oil or Fluid Test Cup for Dielectric Test

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 1¼ in. below the top of the cup. (A suitable test cup is shown in Figure 3, and portable testing outfits in Figures 4, 5 and 6.)

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 used.

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 86 F). 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 the bottom and the test may be misleading.

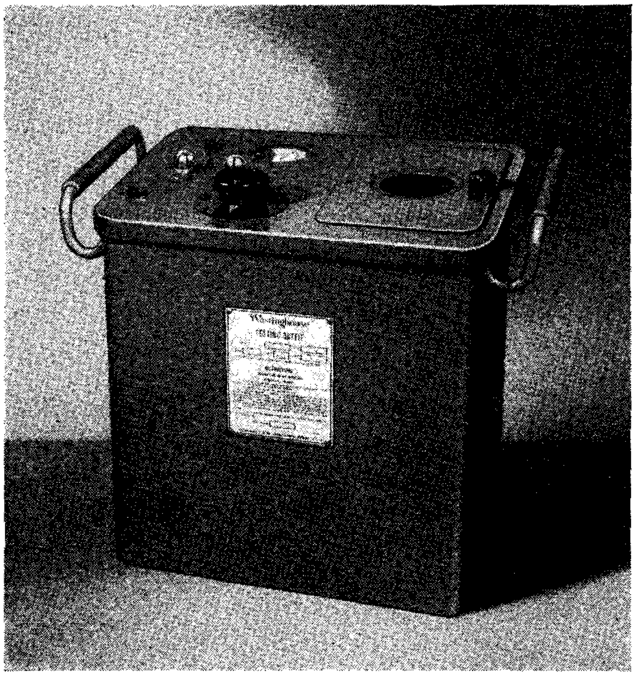


FIG. 4. Portable Oil Testing Set ½ kva, 35,000 volts

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 the first and one minute before each succeeding puncture. 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. After each puncture, the testing vessel shall be jarred to loosen particles of carbon adhering to the electrodes and the oil gently agitated but not with sufficient violence to introduce air bubbles.

Five breakdowns shall be made on each filling, after which the vessel shall be emptied and refilled with fresh oil from the original sample. The test shall be continued until the averaged values of at least three fillings do not differ from their mean by more than 10 per cent.

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

POUR TEST

The pour point of a petroleum oil is the lowest temperature at which this oil will pour or flow when it is chilled without disturbance under certain definite specified conditions.

Apparatus. The test jar (see Figure 6) shall be clear glass, of cylindrical shape, approximately 1¼ in. inside diameter and 4½ to 5 in. high, with a flat bottom. An ordinary 4 oz. oil sample bottle may be used if the test jar is not available.

The cork shall fit the test jar, and shall be bored centrally to accommodate the test thermometer.

The thermometer shall conform to A.S.T.M. specifications for pour test. It may be ordered as: A.S.T.M. thermometer low cloud and pour, 56.7 C (–70 F) to +21.1 C (70 F).

The jacket shall be of glass or metal and shall be watertight, of cylindrical form, flat bottomed, about 4½ in. deep, with inside diameter ½ in. greater than outside diameter of the test jar.

A disc of cork or felt ¼ in. thick and of the same diameter as the inside of the jacket shall be placed in the bottom of the jacket.

The ring gasket shall be about $\frac{3}{16}$ in. thick, made to fit snugly around the outside of the test jar and

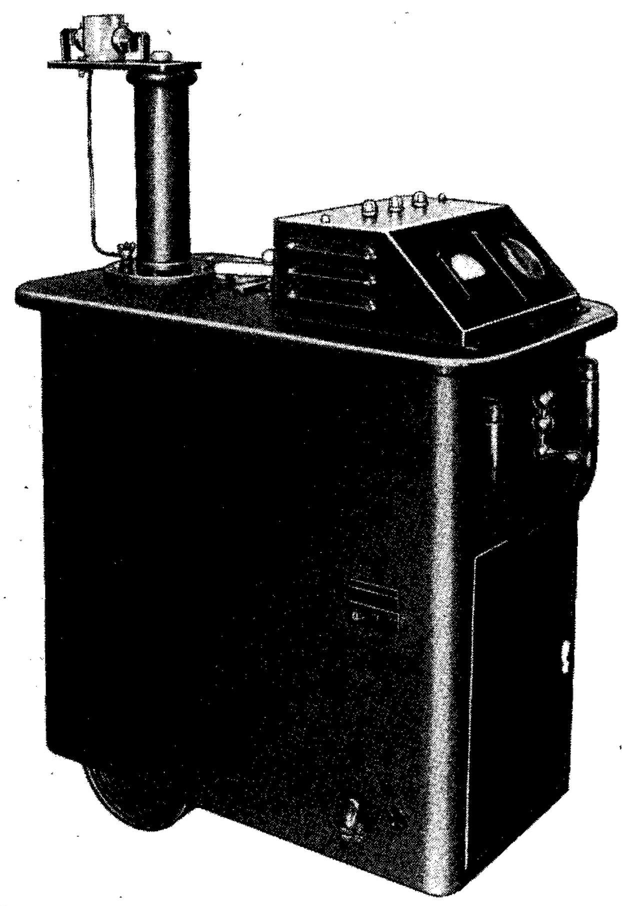


FIG. 5. Portable Truck Type Oil and Insulation Testing Set, 5 kva, 30,000/60,000 volts

loosely inside the jacket. This gasket may be made of cork, felt or other suitable material, elastic enough to cling to the test jar and hard enough to hold its shape. The purpose of the ring gasket is to prevent the test jar from touching the jacket.

The cooling bath shall be of a type suitable for obtaining the required temperature. The size and shape of the bath are optional but a support suitable for holding the jacket firmly in a vertical position is essential. For determination of very low pour points, a smaller insulated cooling bath may be used and the test jar placed directly in it. The required bath temperature may be maintained by refrigeration if available, otherwise by suitable freezing mixtures.

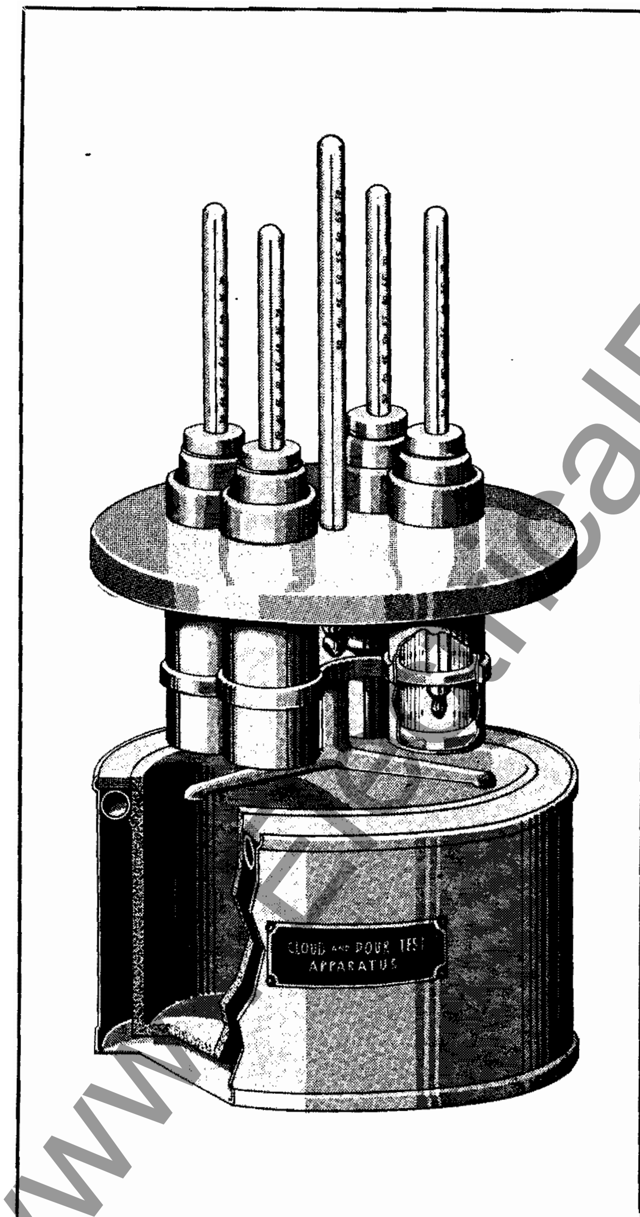


FIG. 6. Apparatus for Pour Test

Procedure. The oil to be tested shall be brought to a temperature at least 14 C (25 F) above the approximate cloud point. Moisture, if present, shall be removed by any suitable method, as by filtration through dry filter paper until the oil is perfectly clear. (Such filtration shall be made at a temperature at least 14 C (25 F), above the approximate cloud point.) The oil shall be poured into the test jar, to a height of not less than 2, or more than 2¼ in. When necessary, the oil shall be heated in a water bath just enough so it will pour into the test jar.

The test jar shall be tightly closed by the cork carrying the test thermometer in a vertical position in the center of the jar; the thermometer bulb should be immersed so that the beginning of the capillary shall be ⅛ in. below the surface of the oil.

Heat without stirring to a temperature of 46.1 C (115 F) in a bath maintained at not higher than 47.8 C (118 F). The oil shall then be cooled to 32.2 C (90 F) in air or in a water bath approximately 25 C (77 F) in temperature. Oils with which the low-cloud and pour-test thermometer can be used from the beginning of the test shall be cooled to 15.6 C (60 F) in any convenient manner before placing that thermometer in position.

The cork or felt disc shall be placed in the bottom of the jacket and the test jar, with the ring gasket, 1 in. above the bottom, shall be inserted into the jacket. The disc, gasket and inside of jacket shall be clean and dry.

After the oil has cooled enough to allow the formation of paraffin wax crystals, great care shall be taken not to disturb the mass of the oil nor to permit the thermometer to shift in the oil. Any disturbance of the spongy network of wax crystals will lead to low and fictitious results.

The temperature of the cooling bath shall be adjusted so that it is below the pour point of the oil by not less than 8.3 C (15 F) nor more than 16.7 C (30 F), and this temperature shall be maintained throughout the test. The jacket containing the test jar shall be supported firmly in a vertical position in the cooling bath so that not more than 1 in. of the jacket projects out of the cooling medium.

Beginning at a temperature 11.1 C (20 F) above the expected pour point, at each test-thermometer reading which is a multiple of 2.8 C (5 F), the test jar shall be removed from the jacket carefully and shall be tilted just sufficiently to ascertain whether there is a movement of the oil in the test jar. The complete operation of removal and replacement shall require not more than three seconds. As soon as the oil in the test jar does not flow when the jar is tilted, the test jar shall be held in a horizontal position for exactly five seconds, as noted by a stop watch or other accurate timing device, and observed carefully. If the oil shows any movement under these conditions, the test jar shall be immediately replaced in the jacket and the same procedure repeated at the next temperature reading 2.8 C (5 F) below the previous reading.

The test shall be continued in this manner until a point is reached at which the oil in the test jar shows no movement when the test jar is held in a horizontal position for exactly five seconds. The reading of the test thermometer at this temperature, corrected for error if necessary, shall be recorded. The pour point shall be taken at the temperature 2.8 C (5 F) above this solid point.

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 a circuit breaker.)

Apparatus. The steam generator (see Figure 7) shall be made of either metal or glass of at least one-liter 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 liters 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

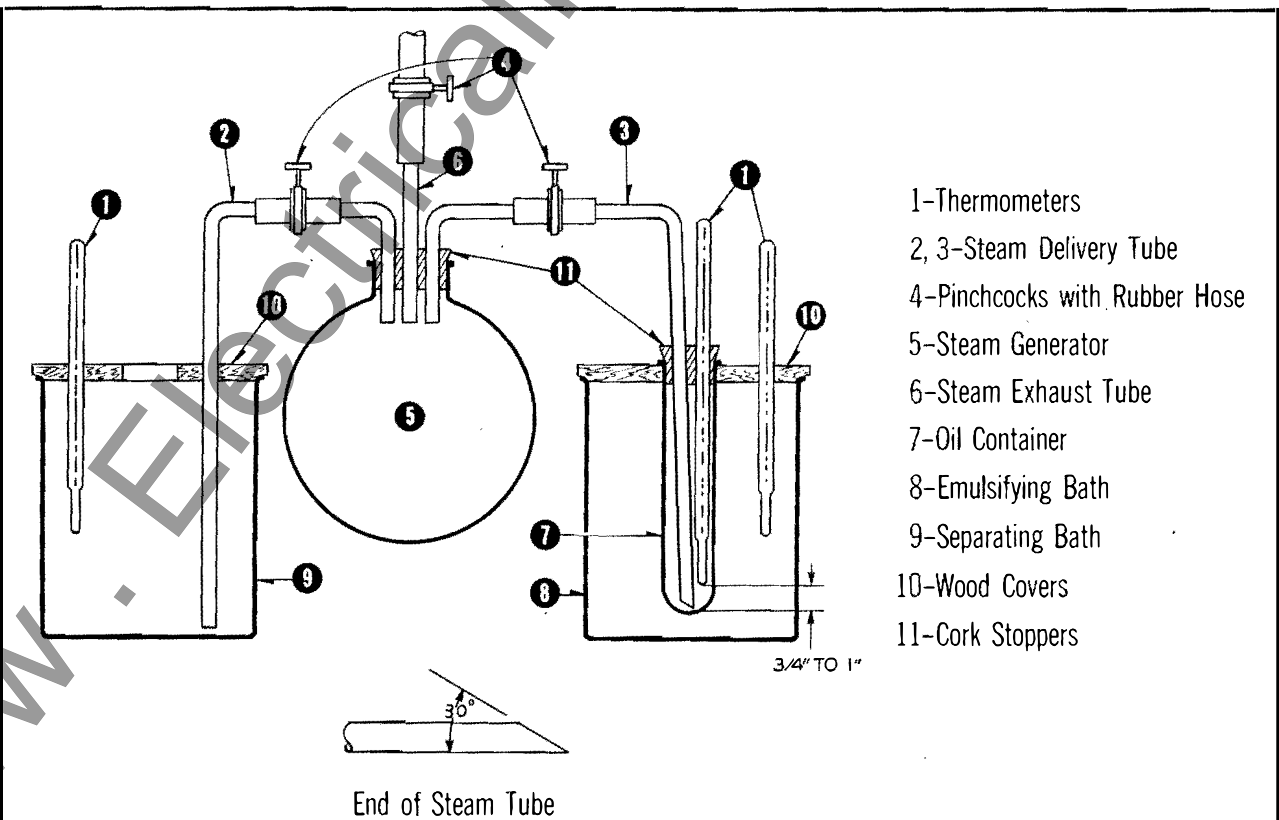


FIG. 7. Apparatus for S. E. Test

suitable range, graduated in .55 C (1 F), 5 to 7 mm in diameter); corks, rubber tubing and screw pinchcocks.

Procedure. The apparatus shall be assembled as shown in Figure 7. The steam generator shall be filled one-half full of water and heat applied. The baths shall be filled with 3 liters plus or minus 60 cc of water. The temperature in the separating bath shall be raised to and maintained at 93.3 to 95 C (200 to 203 F).

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 19.4 C (67 F) nor more than 25.6 C (78 F) 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 Figure 7.

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 ¾ 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 87.8 C (190 F) and 90.6 C (195 F). (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 condensed water 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 93.3 to 95 C (200 to 203 F). 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.

NEUTRALIZATION TEST

The Neutralization Number is the weight in milligrams of potassium hydroxide required to neutralize the acid in one gram of oil.

Solutions Required. Aqueous Potassium Hydroxide (1 cc 5 mg. KOH). Dissolve 5.1 g of potassium hydroxide, c.p., in one liter of freshly boiled and cooled distilled water. Add a very small amount of barium hydroxide, sufficient to precipitate any potassium carbonate present. Standardize this solution against Bureau of Standards certified benzoic acid, using phenolphthalein as an indicator according to the relation:

$$\frac{5 \text{ mg. KOH}}{x \text{ mg benzoic acid}} = \frac{56.104 \text{ g KOH}}{122.048 \text{ g benzoic acid}}$$

1 cc of KOH = 10.88 mg. benzoic acid

This weight of benzoic acid is required for standardization; make necessary adjustments so that the value of potassium hydroxide equals 5 mg. KOH per cc.

The weight of benzoic acid should be dissolved in 50 cc of 95 per cent alcohol and titrated cold. For blank, use same amount of alcohol and correct the titration.

Note: Fit the solution bottle with a guard tube of soda lime to prevent access of carbon dioxide. The solution should be standardized at necessary intervals.

Neutralized 95 Per Cent Alcohol. Add a few drops of phenolphthalein and neutralize carefully the alcohol to a very faint pink end point with some of the above prepared alkali solution.

Phenolphthalein Indicator. Dissolve 10 g of the indicator in 1 liter of 95 per cent alcohol, preferably ethyl alcohol. Use 1 cc of this strength for titration.

Weight of Oil. Approximately 20 g weighed accurately.

Volume of Solvent. 100 cc of a mixture of 1.1 neutralized alcohol and distilled water.

Procedure. Agitate oil and solvent thoroughly and heat to boiling. Add 1 cc of phenolphthalein indicator and titrate rapidly, with vigorous agitation, to a sharp pink end point. The titration must be completed in a hot solution, reheating same if necessary.

The color change is noted in the alcohol water layer.

Calculation. $\frac{\text{(Cubic centimeters of KOH) x 5}}{\text{Weight of oil taken}} =$ mg KOH per 1 g of oil

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.

The final criterion of the effectiveness of any method of reconditioning insulating oil is the quality of the reconditioned oil.

Oil which has been reconditioned by means of the filter press, centrifuge or a combination of the two should always be tested for dielectric strength before being passed into the apparatus tank. It is recommended that the tests for resistance to emulsion and neutralization value be made from time to time on oil repeatedly reconditioned by either of these methods. There is a progressive decrease in the demulsibility and increase in organic acidity not corrected by these methods. These effects should be detected and corrected before they reach a harmful value either by chemical treatment or by replacing the oil.

The dielectric strength of reconditioned oil should be at least 22 kv when tested as described in Testing Methods.

The S. E. Number of reconditioned oil should not be over 35 seconds for Wemco C oil when tested by the method described in Testing Methods, and not over 75 seconds for Wemco C oil received prior to July 11, 1924.

The neutralization value of reconditioned oil should not be over 0.08 mg. of KOH per gram of oil with no trace of alkali when tested as described in Testing Methods.

BLOTTER FILTER PRESS

The blotter filter press (see Figure 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.

Other Classes of Service. While the principal class of service for which these cleaning devices were developed is the treatment of insulating oils, they may be used for numerous other applications, such as cleaning of low-viscosity insulating compounds, benzine, petroleum, machine oil, etc. However, it is recommended that a cleaning device intended for insulating oil reconditioning should not be used for other classes of work, due to danger of subsequent contamination of the insulating 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 from 60 to 80 lbs.

Apparatus. These are four standard sizes of Westinghouse filter presses: B-5, B-10, A-30 and A-60. 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, wheels, and piping. The piping is arranged so the line can be tested for leaks under pressure. All machines are mounted on a fabricated structural frame. The drip pan can be removed by disconnecting one pipe coupling and four bolts. The strainer can be cleaned by disconnecting three bolts. The pumps are of the helical-gear type to insure quietness and smooth flow of oil. The A-30 and A-60 pumps are directly connected to the motor through flexible couplings. The B-5 and B-10 pumps are mounted directly on the rear motor bracket and driven through a helical reduction gear.

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.

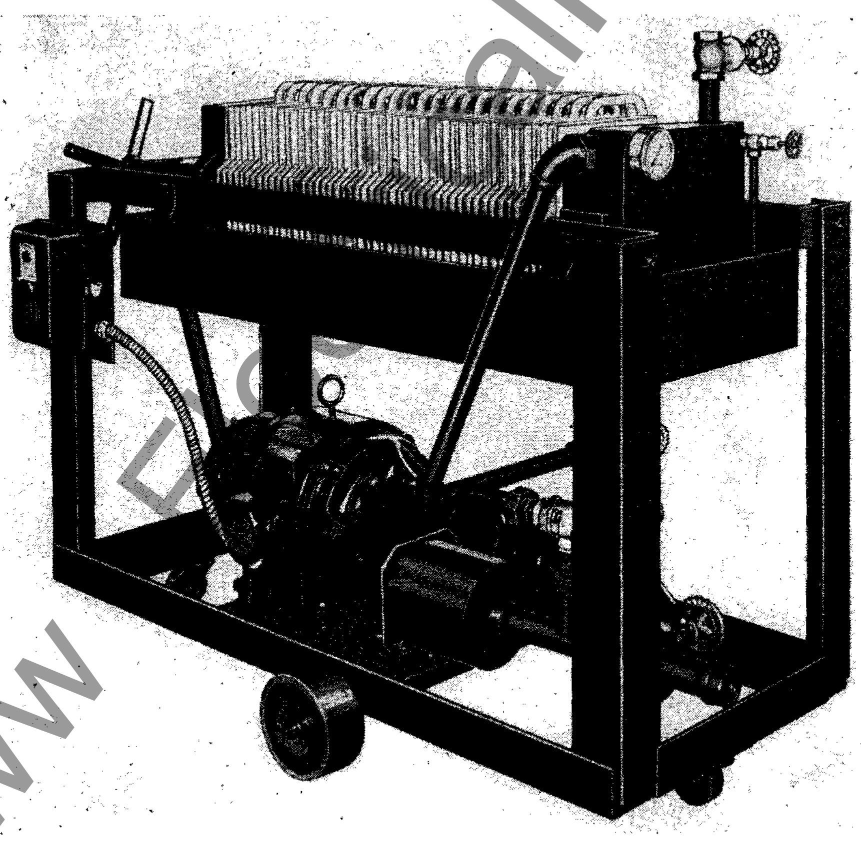
The plates and frames have holes in two corners and supporting lugs at the sides. The plates have handles cast on the top edge. When the plates and frames are assembled with the filter papers between, the holes form the inlet and outlet. The frames have the holes in the upper corner connected by small 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 inset Figure 8.)

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



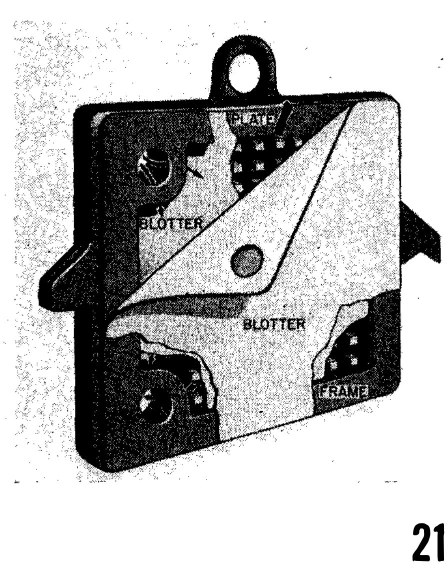


Fig. 8. A-30 Oil Filter Press. Inset: Blotter Filter Press Frames Showing Blotters in Place

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 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 lifted 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 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, 12⅞ in. square for the A sizes and 7¾ in. square for the B sizes, and with holes punched to correspond with the holes in the plates and frames, are used 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.

Drying Ovens. An electric oven is used for drying the filter paper. The oven is substantially built of sheet iron with double walls. Adjustable slides are provided near the top of the oven for regulating the temperature and the circulation of air through the oven.

These ovens are furnished in three sizes, designated by types A-30, A-10 and B, to correspond to the sizes of filter paper. Type A Ovens are used for large size paper that is used in the A size filter presses; Type B Oven is used with the B filter presses.

The filter papers are held in a vertical position in a rack and supported by rods through the holes in the corners of the papers. When the door in the front of the oven is opened, the rack may be withdrawn and the filter paper conveniently inserted or withdrawn. (The paper should be dried for about 24 hours before being used, but this time can be decreased, depending upon the condition of the paper and degree of heat.)

Ovens are listed for four different voltage ranges and may be used equally well on either alternating- or direct-current circuits. Three heats are obtainable by means of a rotary snap switch mounted on the front of the oven. It will usually be found desirable, however, to use the high heat.

The input of the ovens will vary from low heat to high heat as follows: Type A-30: from 400 to 1600 watts; Type A-10: from 200 to 800 watts; Type B: from 100 to 400 watts.

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.

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CEDAR RAPIDS, IOWA, 361 21st St., S.E., P.O. Box 1828
CHARLESTON, S. C., 89 G. Smith St., P.O. Box 303
CHARLESTON 23, W. VA., 610 Union Bldg., P.O. Box 911
CHARLOTTE 1, N. C., 210 East Sixth St.
CHATTANOOGA 2, TENN., Volunteer State Life Bldg., Georgia Ave & East Ninth St.
CHICAGO 6, ILL., 20 N. Wacker Drive, P.O. Box B, Zone 90
CINCINNATI 2, OHIO, 207 West Third St.
CLEVELAND 13, OHIO, The Standard Bldg., 1370 Ontario St.
COLUMBUS 15, OHIO, 85 E. Gay St.
CORPUS CHRISTI, TEXAS, P. O. Box 1756
DALLAS 1, TEXAS, 209 Browder St.
DAVENPORT, IOWA, 206 E. Second St., P.O. Box 29
DAYTON 2, OHIO, 30 North Main St.
DENVER 2, COLORADO, 910 Fifteenth St.
DES MOINES 8, IOWA, 1400 Walnut St.
DETROIT 31, MICH., 5757 Trumbull Ave., P.O. Box 828
DULUTH 2, MINN., 10 East Superior St.
EL PASO, TEXAS, Oregon and Mills St.
EMERYVILLE 8, CALIF., 5915 Hollis St.
ERIE, PA., 1003 State St.
EVANSVILLE 8, IND., 106 Vine St.
FAIRMONT, W. VA., 10th and Beltline, P.O. Box 1147
FORT WAYNE 6, IND., 1010 Packard Ave.
FT. WORTH, TEXAS, 1004 Houston St.
GARY, IND., 846 Broadway
GRAND RAPIDS 2, MICH., 148 Monroe Ave., N.W.
GREENVILLE, S. C., 106 W. Tallulah Drive, P.O. Box 1591
HAMMOND, IND., 235 Locust St.
HARTFORD 3, CONN., 36 Pearl St.
HONOLULU, T. H., Hawaiian Elec. Co., Agt.
HOUSTON 2, TEXAS, 1314 Texas Ave.
HUNTINGTON 1, W. VA., 1029 Seventh Ave., P.O. Box 1150
INDIANAPOLIS 9, IND., 137 S. Penna. St.
JACKSON, MICH., 212 West Michigan Ave.
JACKSONVILLE 3, FLA., 37 South Hogan St., P.O. Drawer K
JOHNSTOWN, PA., 107 Station St.
KANSAS CITY 6, MO., 101 W. Eleventh St.
KNOXVILLE 8, TENN., Gay & Clinch St.
LITTLE ROCK, ARKANSAS, 103 W. Capitol St.
LOS ANGELES 13, CALIF., 420 S. San Pedro St.
LOUISVILLE 2, KY., 332 West Broadway
MADISON 3, WISC., 1022 E. Washington Ave.
MANSFIELD, OHIO, 246 E. Fourth St.
MEMPHIS 3, TENN., 130 Madison Ave.
MIAMI 4, FLA., 11 N. E. Sixth St., P.O. Box 590
MIDDLESBORO, KENTUCKY, 123 Birnamwood Rd., P. O. Box 517
MILWAUKEE 2, WISC., 538 N. Broadway
MINNEAPOLIS 13, MINN., 2303 Kennedy St., N.E.
MONROE, LA., 1107 N. 2nd St., P.O. Box 1851
NASHVILLE 3, TENN., 219 Second Ave., N.
NEWARK 2, N. J., 1180 Raymond Blvd.
NEW HAVEN 8, CONN., 42 Church St., P.O. Box 1817
NEW ORLEANS 13, LA., 238 South Saratoga St.
NEW YORK 5, N. Y., 40 Wall St.
NIAGARA FALLS, N. Y., 253 Second St.
NORFOLK 1, VA., 2600 Hampton Boulevard, P.O. Box 2120
OKLAHOMA CITY 2, OKLA., 120 N. Robinson St.
OMAHA 2, NEB., 409 South Seventeenth St.
PEORIA 2, ILL., 418 S. Washington St.
PHILADELPHIA 4, PA., 3001 Walnut St.
PHOENIX, ARIZONA, 11 West Jefferson St.
PITTSBURGH 30, PA., 306 4th Ave., Box 1017
PORTLAND 4, OREGON, 309 S. W. Sixth Ave.
PROVIDENCE 3, R. I., 16 Elbow St.
RALEIGH 1, N. C., 1, 803 North Person St., P.O. Box 2146
RICHMOND 19, VA., 301 S. Fifth St.
ROCHESTER 7, N. Y., 1048 University Ave.
ROCKFORD, ILL., 130 South Second St.
SACRAMENTO 14, CALIF., Rooms 411 & 412 Ochsner Bldg., 719 K St.
ST. LOUIS 1, MO., 411 North Seventh St.
SALT LAKE CITY 1, UTAH, 10 West First S. St.
SAN ANTONIO 5, TEXAS, 115 W. Travis St.
SAN DIEGO 1, CALIF., 861 Sixth Ave.
SAN FRANCISCO 4, CALIF., 1 Montgomery St.
SEATT 4, WASH., 3451 East Marginal Way
SIOUX CITY 17, IOWA, 2307 Kennedy Drive
SOUTH BEND 4, IND., 216 East Wayne St.
SPOKANE 8, WASH., 1023 W. Riverside Ave.
SPRINGFIELD, ILL., 601 E. Adams St., Box 37
SPRINGFIELD 1, MASS., 395 Liberty St.
SYRACUSE 4, N. Y., 700 W. Genesee St.
TACOMA 2, WASH., 1930 Pacific Ave.
TAMPA 1, FLA., 417 Ellamae Ave., Box 230
TOLEDO 4, OHIO, 245 Summit St.
TULSA 3, OKLA., 303 East Brady St.
WASHINGTON 6, D. C., 1625 K St., N.W.
WICHITA 2, KANSAS, 301 South Market St.
WILKES-BARRE, PA., 267 N. Pennsylvania Ave.
WILLIAMSPORT 1, PA., 348 W. Fourth St.
WORCESTER 8, MASS., 507 Main St.
YORK 2, PA., 11 W. Market St., P. O. Box 1466
YOUNGSTOWN 3, OHIO, 25 E. Boardman St.

MANUFACTURING AND REPAIR SHOPS

ATLANTA 2, GA., 1299 Northside Drive, N.W., P.O. Box 4898
BALTIMORE 24, MD., 4015 Foster Ave.
BATON ROUGE, LA., 555 Choctaw Drive
BOSTON 27, MASS., 235 Old Colony Ave., So. Boston
BRIDGEPORT 8, CONN., 540 Grant St.
BUFFALO 10, N. Y., 1132 Seneca St.
CHARLOTTE 1, N. C., 210 East Sixth St.
CHICAGO 9, ILL., 2211 W. Pershing Road, P.O. Box 1103, Zone 90
CINCINNATI 2, OHIO, 207 West Third St.
C VELAND 2, OHIO, 5901 Breakwater Ave., Station A
DENVER 4, COLORADO, 988 Cherokee St.
DETROIT 31, MICH., 5757 Trumbull Ave., P.O. Box 828
EMERYVILLE 8, CALIF., 5915 Green St.
FAIRMONT, W. VA., 10th and Beltline, P.O. Box 1147
HOUSTON 2, TEXAS, 2315 Commerce Ave.
HUNTINGTON 1, W. VA., 1029 Seventh Ave., P.O. Box 1150
INDIANAPOLIS 2, IND., 551 West Merrill St.
JOHNSTOWN, PA., 107 Station St.
LOS ANGLES 13, CALIF., 420 S. San Pedro St.
MILWAUKEE 3, WISC., 424 North Fourth St.
MINNEAPOLIS 13, MINN., 2303 Kennedy St., N.E.
NEWARK 1, N. J., Haynes Ave. & Lincoln Hwy.
PHILADELPHIA 4, PA., 3001 Walnut St.
PITTSBURGH 8, PA., 543 N. Lang Ave.
PORTLAND 12, ORE., 626 North Tillamook St.
PROVIDENCE 3, R. I., 16 Elbow St.
ST. LOUIS 2, MO., 717 South Twelfth St.
SALT LAKE CITY 7, UTAH, 346A Pierpont Ave.
SEATTLE 4, WASH., 3451 East Marginal Way
SPRINGFIELD 1, MASS., 395 Liberty St.
SYRACUSE 4, N. Y., 700 W. Genesee St.
UTICA 1, N. Y., 113 N. Genesee St.
WILKES-BARRE, PA., 267 N. Pennsylvania Ave.

DISTRICT ENGINEERING AND SERVICE DEPARTMENTS

ATLANTA 2, GA., 1299 Northside Drive, N.W., P.O. Box 4898
AUGUSTA, MAINE, 9 Bowman St.
BALTIMORE 2, MD., 118 E. Lombard St.
BLUEFIELD, W. VA., Appalachian Elec. Power Co. Bldg., Room 620, 704 Bland St., P.O. Box 848
BOSTON 10, MASS., 10 High St.
BBIDGEPORT 8, CONN., 540 Grant St.
BUFFALO 3, N. Y., 814 Ellicott Square Bldg.
CHARLOTTE 1, N. C., 210 East Sixth St.
CHICAGO 6, ILL., 20 N. Wacker Drive, P.O. Box B, Zone 90
CINCINNATI 2, OHIO, 207 West Third St.
CLEVELAND 13, OHIO, The Standard Bldg., 1370 Ontario St.
DENVER 2, COLORADO, 910 Fifteenth St.
DETROIT 31, MICH., 5757 Trumbull Ave., P.O. Box 828
DULUTH 2, MINN., 10 East Superior St.
HOUSTON 2, TEXAS, 1314 Texas Ave.
HUNTINGTON 1, W. VA., 1029 Seventh Ave., P.O. Box 1150
INDIANAPOLIS 9, IND., 137 S. Penna. St.
KANSAS CITY 6, MO., 101 W. Eleventh St.
LOS ANGELES 13, CALIF., 420 S. San Pedro St.
MILWAUKEE 2, WISC. 538 N. Broadway
MINNEAPOLIS 13, MINN., 2303 Kennedy St., N.E.
NEW ORLEANS 13, LA., 238 South Saratoga St.
NEW YORK 5, N. Y., 40 Wall St.
PHILADELPHIA 4, PA., 3001 Walnut St.
PITTSBURGH 30, PA., 306 4th Ave., Box 1017
PORTLAND 4, OREGON, 309 S.W. Sixth Ave.
PROVIDENCE 3, R. I., 16 Elbow St.
ST. LOUIS 1, MO., 411 North Seventh St.
SAN FRANCISCO 4, CALIF., 1 Montgomery St.
SEATTLE 4, WASH., 3451 East Marginal Way
SPRINGFIELD 1, MASS., 395 Liberty St.
UTICA 1, N. Y., 113 N. Genesee St.
WASHINGTON 6, D. C., 1625 K Street, N.W.
WILKES-BARRE, PA., 267 N. Pennsylvania Ave.