Westinghouse

Insulating Oil

for

Electrical Apparatus

INSTRUCTION BOOK

Westinghouse Electric & Manufacturing Company
East Pittsburgh, Pa.

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Importance of Maintenance and Inspection

CENTRAL STATIONS and other large users of transformers, oil circuit-breakers, and feeder regulators have become more and more convinced of the necessity for making periodical inspection and tests of insulating oil and of dehydrating and purifying oil that has absorbed moisture or sediment. Where this practice has been systematically followed, it has been found that failure of apparatus from burnouts, with consequent interruption of service, has been reduced to a minimum and a resulting economy in the use of oil has been effected. Notwithstanding the fact that many central stations carefully inspect the oil in their apparatus, it is believed that the importance of this subject justifies the recommendation that all companies, in the interest of good service, adopt some system of oil inspection and test.

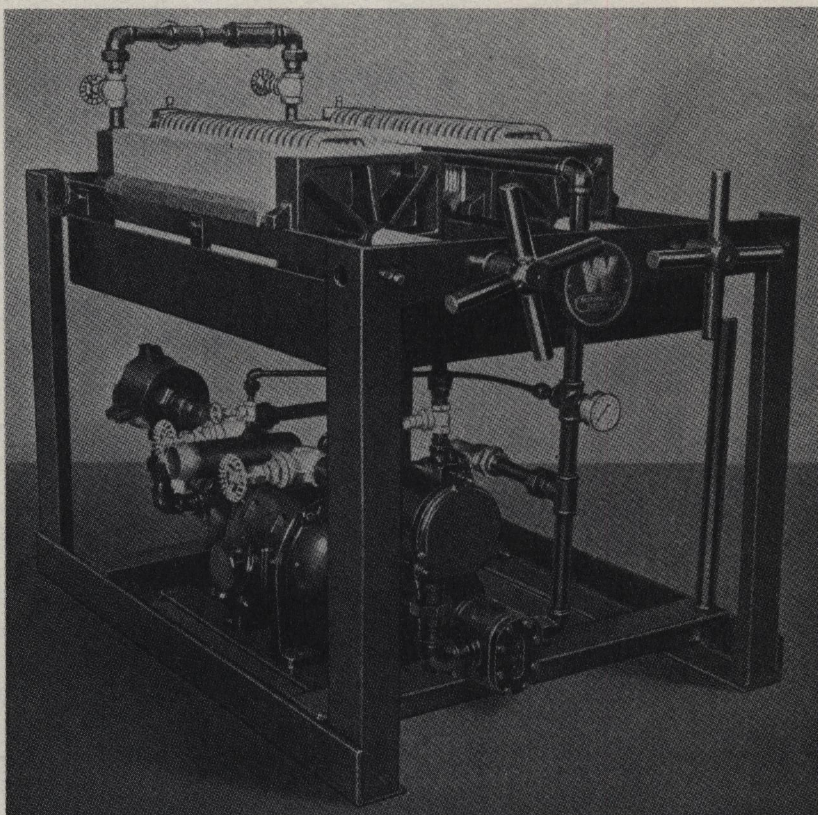

FIG. 1—A-60 FILTER PRESS

Westinghouse

Insulating Oil for Electrical Apparatus

General Information

The insulating oil furnished by the Westinghouse Electric & Manufacturing Company has been developed after many years of research work in cooperation with the oil refiners. In response to requests from customers for a reduction in the number of grades of insulating oil used in electrical apparatus, we have developed the Universal Wemco Coil which is particularly well adapted for all Westinghouse oil insulated apparatus, and may be used in transformers after arcing in circuit-breakers when purified to meet values, given on page 12. (Interchangeability after Purification.)

The insulating oil is just as much a part of the apparatus in which it is used as any of the other materials which are built into the apparatus. In order to insure the performance guaranteed for the apparatus, only the insulating oil furnished by the Westinghouse Electric & Manufacturing Company should be used. This is manufactured under our supervision so that we can assure our customers that every shipment is up to the proper standard of quality on which the design of the apparatus has been based.

As all oil is subject to deterioration in service even under the most favorable conditions, it is essential to provide for periodic inspection and test, and to purify the oil whenever it is necessary in order to maintain it in good condition.

The more handling which an insulating oil receives, the greater the opportunity for contamination unless adequate precautions are taken.

This publication gives instructions for storing, handling, inspecting, testing and purifying of insulating oil which experience has shown are important in order to maintain the quality of the oil.

Functions of Insulating Oil—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.

Primary Requirements for Insulating Oil

For Transformers and Induction Regulators—High dielectric strength.

Freedom from inorganic acid, alkali and corrosive sulphur to prevent injury to insulation or conductors.

Low viscosity to provide good heat transfers.

Good resistance to emulsion, so that the oil will throw down any moisture entering the apparatus instead of holding it in suspension. (Water in suspension is a menace to safe operation).

FREEDOM FROM SLUDGING UNDER NORMAL OPERATING CONDITIONS.

For Circuit-Breakers—High dielectric strength.

Freedom from inorganic acid, alkali and corrosive sulphur, to prevent injury to insulation or conductors.

Low viscosity to aid in dissipating the arc when the circuit is interrupted.

Low freezing point to insure proper fluidity at all operating temperatures.

Good resistance to emulsion so that any moisture entering the apparatus or carbon formed by arcing will settle to the bottom of the tank.

It will be noted that the requirements for insulating oil for transfromers are not inconsistent with those for oil for service in circuit-breakers. A single grade of oil, Universal Wemco C oil, has been developed which is particularly well suited for both applications and for either indoor or outdoor service.

Shipment

Universal Wemco C oil is shipped in tank cars, drums and 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.

Storage

Cans and 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. If it is necessary to store it out doors, protection against direct precipitation of rain or snow should be provided. Out door storage of oil is always hazardous and should be avoided if at all possible. Drums stored out doors should be placed on timbers so as to be clear of the ground. They should always be placed on their sides and never turned up on end. The bungs should be turned at an angle of about 45 degrees from the top. It is desirable to cover them with a tarpaulin.

Cans containing oil must not be exposed to the weather. They should not be unsealed before the oil is actually needed. It is not necessary to make dielectric tests on oil in sealed cans.

Screw caps are being provided on the cans, for use where the contents are only partially used after the hermetic seal is broken, to prevent contamination with moisture or dirt.

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.

The same precaution should be taken in filling storage tanks as mentioned below under "Placing Oil in Service, Temperature of Oil."

Refilling of Drums—The practice of refilling drums with oil is very 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 drums for storage, drums should be reserved for this purpose which have been used only for oil in good condition. 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.

Drums which have been used for good oil only, but which have perhaps received some water should be drained, placed in an oven with the bung hole down, and heated to a temperature of at least 88°C. (190°F.) for sixteen hours. The bung should be screwed on tightly before removing from the oven. 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. It is recommended that a supply of the washers be kept on hand. 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 for identification by painting.

Cleaning of 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 after using shows no discoloration. 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. (Steel must not be used, on, account of the danger of a spark igniting the vapor.) Heat the drum with bung hole down, in an 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. An open flame must be kept away from the oven to prevent igniting inflammable gases.

Protection from Fire

Fire Risk—While the Universal 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.

Placing Oil in Service

The most careful precaution must be taken to insure the absolute dryness and cleanness 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.

Cleaning of Apparatus—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 on account of the lint which may be introduced into the oil.

Temperature of Oil—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.

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

Straining—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 should be renewed as often as necessary. The cloth may be stretched across a funnel of large size.

Hose—RUBBER HOSE MUST NOT BE USED in handling oil. Always use metal hose. Oil can easily become contaminated from the sulphur in rubber and should not be allowed to come in contact with it.

Testing—The oil should be sampled and tested before being transferred to the apparatus. The oil in all apparatus should be sampled and tested before the apparatus is put into service.

Maintenance

Cause of Deterioration of Oil in Transformers—The principal causes of deterioration of insulating oil in service are water and oxidation. The oil may be exposed to moisture through condensation from moist air due to breathing of the transformer especially when the transformer is not continuously in service. 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. 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 purified by means of the centrifuge or filter press, as these methods of purification do not remove the deterioration products which are in process of formation but have not yet been thrown down as sludge. No method is yet available in the field which will remove these products and bring sludged oil back to its original condition when new. Such oil can be refined so as to be equivalent to new oil, but this would require equipment which is only available in an oil refinery. It is not economical to send used oil to the refinery as they will allow 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 acid such as sulphuric acid used in refining, as in small amounts they do not have a deteriorating effect upon insulation. There is no method available in the field for purifying oil of high organic acidity.

In an effort to produce oil which has less tendency to sludge, it is possible to "over-refine" it. Such an oil developes organic acidity, which when once started, increases rapidly to a point where it becomes a menace to insulation. This high acid development is characteristic of some of the so called "water-white" oils. (Examination of one of these oils in our research laboratory showed the extremely high organic acidity of 18 mg. of KOH per gram of oil in six months at 80°C. (176°F.)

There is at present no adequate method for determining the sludging tendency of oil which is correlated with actual performance of the oil in service. The American Society of Testing Material is studying the various methods advocated, but none of them duplicate conditions in transformer service. Obviously any such method to be of value, must be correlated with data on the oil in actual transformer service.

Causes of Deterioration of Oil in Circuit-Breakers—The principal causes of deterioration of insulating oil in circuit-breakers in service are:

1. Water.
2. Carbonization of the oil caused by operation of the circuit-breaker.

Insulating oils do not absorb water, but they 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.

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, and lowers the surface resistance of the insulation if water is present and also lowers the resistance to emulsification. The carbon 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 on account of the increased viscosity of the oil at low temperatures. Also the carbon is not as readily dispersed through the oil.

Westinghouse Oil Testing Service

It is of prime importance that insulating oils be kept free from water and other impurities. Tests have shown that as little as .005 per cent of moisture held in suspension will reduce the dielectric strength of oil to half of its strength when dry.

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 be condensed 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 a 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 forms on the cover and tank wall.

Foreign matter may get into the oil through handling, although oil is usually handled with sufficient care to keep it clean. There is another source of dirt however that cannot be avoided with certain insulating oils used in the past which throw down a heavy precipitate or sludge when overheated. Modern oils are so prepared that this effect is practically eliminated.

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 at regular intervals. The E. E. I. recommends that oil samples from all power stations and substation apparatus be tested at least once every three months, and that samples from distrbution transformers be tested at least once a year. Inertaire transformers will not require such frequent tests.

Many users of transformers and large oil circuit-breakers do not have the necessary equipment for testing insulating oil. In order that these users may be able to make the periodic tests recommended, the Westinghouse Electric & Manufacturing Company has established an Oil Testing Service.

The oil sample container shown in Fig. 3 has been developed as a part of the Westinghouse Oil Testing Service. This Service furnishes a means by which customers can mail samples of insulating oil to the East Pittsburgh Works for test, and provides:

A thoroughly dry bottle
A safe mailing container

A careful test by experienced engineers

A prompt report of test results.

The bottles are dried and sealed at our East Pittsburgh Works, and assembled in the parcel post mailing container together with the necessary packing and printed matter.

This service has been developed to make it simple for the customer to handle, and to give him a prompt report as to the condition of the oil.

After drawing the oil the customer should reseal and repack the bottle and mail it to the Engineering Laboratory at East Pittsburgh. To simplify these details, an instruction and order sheet and a printed return label have been provided, and are inserted 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 oil testing service as outlined above they are sent to the electrical testing laboratory and tested for dielectric strength in a standard test cup, using 1″ diameter flat discs spaced 0.1″ apart. Extreme care is taken to see that the test cup is clean and dry before the sample is poured in and that the sample is not contaminated.

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. It is our aim to mail reports within 24 hours from the time that are samples received.

In addition to dielectric tests we are also prepared to make a physical and chemical examination.

This service consists in the 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, if this is found to be desirable. 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 in size.

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 sales office.

Note—The containers will not be returned to the customer. In submitting samples, the type of service desired should be plainly indicated.

Fig. 2—Style No. 310 368, Sample Container for Oil Testing Service.
Style No. 688 493, Covers Six of These Containers Packed in a Carton.

Inspection and Testing

It is essential, therefore, that periodic inspection and tests be made so that the oil can be renewed when necessary.

The frequency of inspection and testing depends upon the service to which the apparatus is subjected.

Circuit-breakers which are called upon to open the circuit frequently under heavy loads require much more frequent inspection and purification 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. When the dielectric strength of the oil drops to 20 kv., in the standard dielectric test (see page 8) the oil should be looked upon with suspicion and in no case should it be allowed to drop below 18 kv.

Inertaire Transformers

A periodic purification schedule is not essential for transformers equipped with the Inertaire device since such transformers should run indefinitely without need for purification provided the inertaire equipment is properly maintained.

Inspection of oil in service should include:

Check on the 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 properly open heavy overloads.

Check on the 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.

Check on 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 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 purified even though the dielectric test is good.

Check on 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 purified 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 purified again before sludge has formed again to such an extent as to interfere with the operation of the transformer. Oil which has once sludged, will, after being purified, sludge more quickly than the first time.

Check on Steam Emulsification—The S.E. test (see pages 11 and 12) 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

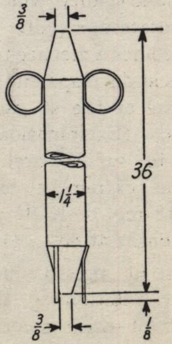

Fig. 3—Drum Thief

impaired when the oil has been exposed to the operation of a circuit-breaker.

The dielectric strength of oil is very greatly affected by the most minute traces of certain impurities, particularly water. It is exceedingly important that the greatest care be taken in obtaining the samples and in handling them to avoid contamination. A great 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 strictly followed to assure accurate results:

Sampling Oil

Sampling Oil from Shipping Containers

Sample Bottle—The sample container shall be made of clear glass, of at least 8 ounce 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 kilovolts in a test cup having electrodes 1″ in dia. and spaced 0.100″ apart and shall be allowed to drain. The bottle shall then be tightly corked and cork and neck of the bottle dipped in melted paraffin. DO NOT USE RUBBER STOPPERS. Oil can easily become contaminated from the sulphur in rubber.

Note: Glass jars having rubber gaskets should not be used.

It is preferable to heat the bottle and cork to a temperature of 100°C. (212°F.) for one hour after thoroughly draining, and cork the bottle while hot.

Thiefs for Sampling—Thiefs should be cleaned by rinsing with dry lead free gasoline taking special care 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.

Note: A convenient and simple thief (see Fig. 3) for use with 50 gal. drums may be made of tin as follows:

Length 36″, diameter 1¼″ with cone shaped caps over the ends and having openings at the ends ⅜″ in diameter. Three legs equally spaced around the thief at the bottom, long enough to hold the opening ⅛″ 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 leaving the thumb free to close the opening. In an emergency a piece of glass tubing 36″ long may be used. For the tank cars, a thief employing a trap at the bottom may be used. (See Fig. 4).

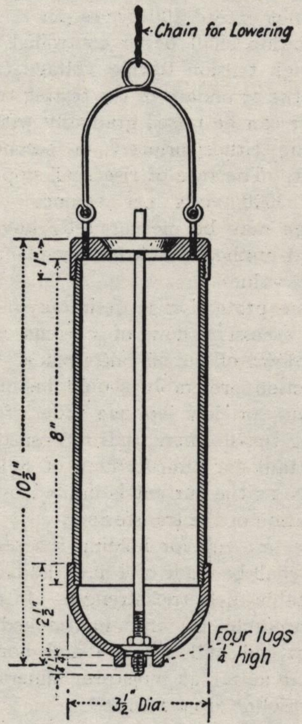

Fig. 4—Thief for Sampling Tank Cars

Procedure—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 and numbered, bungs up. The bungs shall be unsealed and removed and laid with the oily side up beside the bung holes. The unstoppered sampling receptacle can be placed on the opposite side of the bung holes. 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 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″ from the bottom.

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, throwing away the oil thus used for washing, before taking the portion reserved for the sample. 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 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 are desirable.

When one average sample of a consignment or batch is being taken, the same thief may be used throughout the sampling operation, omitting the precaution of rinsing the thief with oil before taking any of the portions that go to make up the total average sample.

Sample—It is recommended that one pint 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 air tight. When first loosening the bung, a hissing sound should be heard indicating that the drum has been air tight. If the test of the composite sample is not satisfactory, a sample from each of the drums represented should be tested.

When drums are 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 dielectric test is not necessary. 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 where a thief cannot be used, the procedure outlined above should be followed as far as practicable. In addition, care should be taken to procure a sample which fairly represents the oil at the bottom of the tank. Sufficient 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 ¼″ pipe and valve is recommended. This, of course, may be separate from the drainage pipe and valve or may be connected to the drainage valve by means of a suitable reducer.

A glass sample bottle is recommended for this purpose 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.

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

Test Method*

Dielectric Strength

Apparatus—The transformer and the source of supply of energy shall not be less than ½ kv-a., 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 kv-a. 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 non-absorbent 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, one inch in diameter and having square edges. The electrodes shall be mounted in the test cup having their axes horizontal and coincident, with a gap of 0.100″ between their adjacent faces, and with top of electrodes about 1¼″ below the top of the cup. A suitable test cup is shown in Fig. 5 and portable testing outfits in Figs. 6, 7 and 8.

Procedure—(a) 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.

(b) The spacing of electrodes shall be checked with a standard round gauge having a diameter of 0.100″ and the electrodes then locked in position. Care shall be taken not to touch the electrodes with the gauge or in any other manner after cleaning the electrodes and cup, so as to avoid any possible contamination.

(c) 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 proceeded with at once, or the electrodes should be thoroughly dried.

(d) 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.

(e) The sample in the container shall be agitated with a swirling motion to avoid introducing air, so as to thoroughly

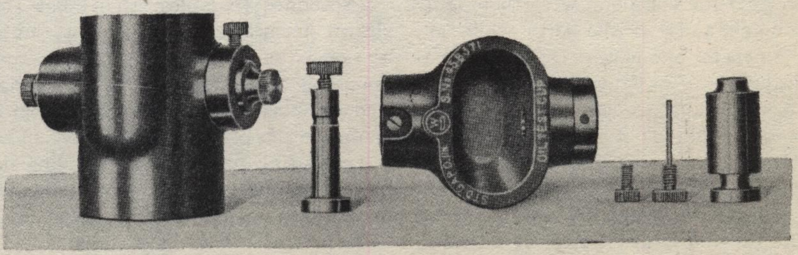

Fig. 5—Oil Test Cup for Dielectric Test

* Instructions for testing correspond in general to the recommendations of the American Society for Testing Materials.

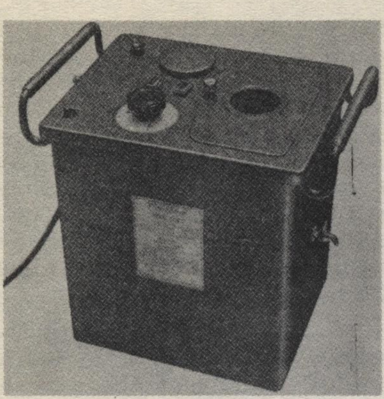

Fig. 6—Portable Oil Testing Set
½K-va. 35,000 Volts

mix the oil 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.

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

(g) 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.

(h) 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.)

(i) 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.

(j) 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. The diameter of disc electrodes and the gap should also be given.

Note: A precision of about 3 per cent may reasonably be expected in 15 tests distributed among three consistent fill ings taken in succession. But if the length of the gap is readjusted and possibilities of contamination exist, the precision may be only 6 or 7 per cent. Difference as great as 10 or 12 per cent may occur between different laboratories even where the work is carefully done.

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—(See **Fig. 8**)—The test jar shall be of clear glass, of cylindrical form, flat bottom, approximately 1¼″ inside diameter and 4½ to 5″ high. An ordinary 4 oz. oil sample bottle may be used if the test jar is not available.

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, minus 56.7°C. (minus 70°F.) to plus 21.1°C. (70° F.).

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

The jacket shall be of glass or metal, shall be water tight, of cylindrical form, flat bottom, about 4½″ deep, with inside diameter ½″ greater than outside diameter of the test jar.

A disc of cork or felt ¼″ 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 $\frac{3}{16}$″ thick, and made to fit snugly around the outside of the test jar and 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.

Note: The freezing mixtures commonly used are as follows:

For temperature down to 10°C. (50°F.) ice and water.

For temperature down to minus 12°C. (10°F.), crushed ice and sodium chloride.

For temperature down to minus 26.1°C. (minus 15°F.), crushed ice and calcium chloride.

For temperature down to minus 56.7°C. (minus 70°F.), solid carbon dioxide and acetone or gasoline.

The last named mixture may be made as follows: In a covered metal breaker chill a suitable amount of acetone to minus 12°C. (10°F.) or lower, by means of an ice-salt mixture. Invert a cylinder of liquid carbon dioxide and draw off carefully into a chamois skin bag the desired amount of carbon dioxide, which through rapid evaporation will quickly become solid. Then add to the chilled acetone enough of the solid carbon dioxide to give the desired temperature.

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, but 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 nor more than 2¼″. When necessary the oil shall be heated in a water bath just sufficiently for pouring 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 with the thermometer bulb immersed so that the beginning of the capillary shall be ⅛″ 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.

* The instructions for pour test correspond in general to the recommendations of The American Society for Testing Materials.

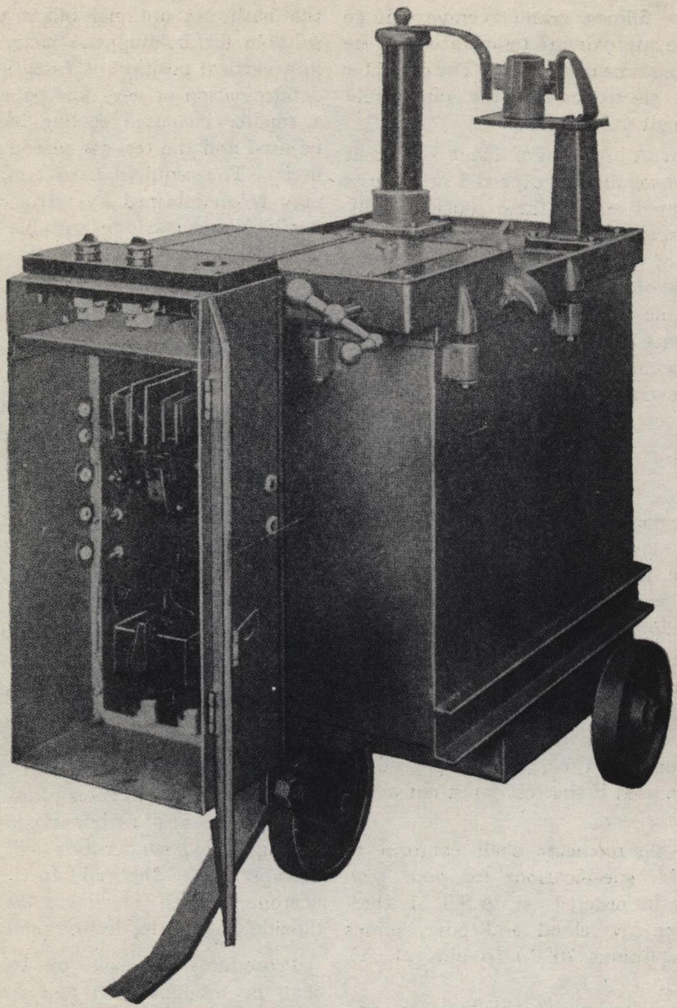

FIG. 7—PORTABLE TRUCK TYPE OIL AND INSULATION TESTING SET, 10 KV-A., 50,000 VOLTS

(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 disc shall be placed in the bottom of the jacket and the test jar, with the ring gasket, 1″ 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″ 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.) lower.

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 as the temperature 2.8°C. (5°F.) above this solid point.

Steam Emulsion Number (S. E. Number)

Apparatus—(a) The steam generator 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 case of a metal generator, a large opening for filling and a suitable water gauge shall be a necessary part of the apparatus.

(b) The baths shall be glass, with a capacity of 3 to 3½ liters and a depth of 7½ to 9″. A good quality of battery jar or beaker is entirely satisfactory.

(c) 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.

(d) 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.

(e) 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 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″ from the discharge orifice.

(f) 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 .55°C. (1°F.), 5 to 7 mm. in diameter); corks, rubber tubing and screw pinch cocks.

Procedure—(a) Preparation—The apparatus shall be assembled as shown in Fig. 9. 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.). (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 connection 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 pinch-cocks placed as shown in Fig. 9.

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.

(b) 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″ from the bottom of the oil container. The steam delivery tube shall be inserted through the second opening in the cork (Note—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).

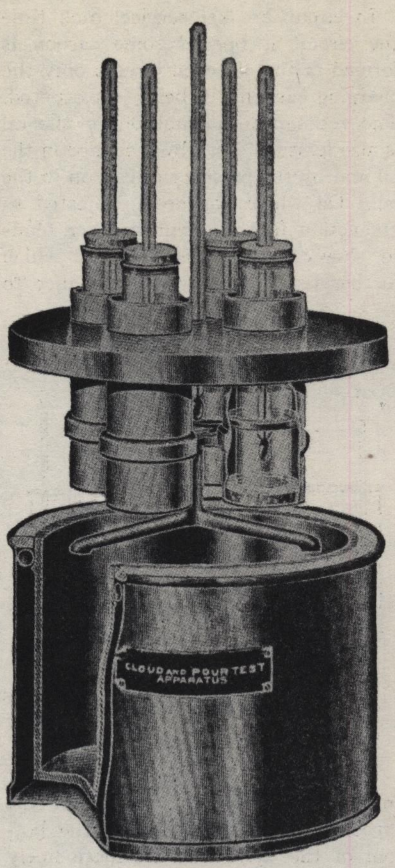

Fig. 8—Apparatus for Pour Test

This control shall be effected by manipulation of the pinch-cocks 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 rerun.

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.

(c) 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 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. The cork containing the thermometer shall be removed after the oil container and contents have been placed 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 Number

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., on 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:

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

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.

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.

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.

Neutralized 95 per cent alcohol. Add a few drops of phenolphtalein 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 found necessary.

The color change is noted in the alcohol water layer.

Calculation:

$$\frac{\text{(Cubic centimeters of KOH)} \times 5}{\text{Weight of oil taken}}$$

= mg. KOH per 1 g. of oil.

Purification

Impurities—New Universal 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 is likely to be introduced into the oil. Universal Wemco C oil has been designed with this particular property in mind and precipitates water and carbon promptly.

However, there are developed in service certain impurities which 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.

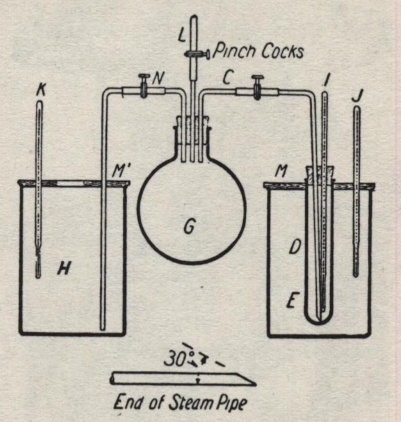

Fig. 9—Apparatus for S. E. Tests

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 or somewhat lower temperature over a long time will 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.

Purification—The purification of oil used in circuit-breakers and transformers consist principally in the removal of water, carbon and sludge and the restoration of its resistance to emulsification, putting the oil in the best condition to separate out any water which may later be introduced.

Three types of equipment for simple purification of oil in circuit-breakers and transformer service are in general use, the centrifuge, the blotter filter press and the combination centrifuge and filter press. The combination of centrifuge with chemical treatment is particularly well adapted for the purification of carbonized circuit-breaker oil. The application of chemical treatment for purifying sludged oil or oil having high acidity for transformer service is still in the experimental stage.

Interchangeability after Purification—Universal 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:

Specific Gravity at 15.5°C., .898 Max.

Viscosity, Saybolt at 37.8°C. (100°F.), 60 Secs. Max.

Flash Point, 132°C. (270°F.) Min.
Pour Test, -45.6°C. (-50°F.) Max.
S.E. Number, 35 Secs. Max.

Neutralization Number—Mg. KOH per gram of oil, 0.08 Max.

Corrosive Sulphur, None.

Dielectric Strength (1″ dia. discs, space 1/10″ apart) 22 K.V. Min.

Blotter Filter Press—The filter press 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. (See Fig. 10).

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 purification 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.

A description of the Westinghouse Blotter Filter Press is given on pages 14 to 16 inclusive. An Instruction Book is furnished with the equipment. There are three standard sizes divided into two classes, according to the size of the filter paper.

If the oil contains only a small amount of water, carbon or sludge, all sediment and water should be removed by passing the oil once through the outfit. If any water remains, it indicates that the filter papers are saturated with water and must be renewed. No rule can be given as to how often the filter paper should be changed, as this depends entirely upon the amount of water and carbon in the oil.

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

Filtering through blotters 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 best and quickest method for filtering or centrifuging a quantity of oil is to pump all the oil from the tank through the filter or centrifuge and into another tank that is dry and clean.

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 only by a small amount of moisture may be purified 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. This may be done if necessary with transformers while in service with voltage on.

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 not possible to clean the carbon deposit from the surfaces inside the tank.

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, is harmful to the oil. (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 in the bowl, the water and other impurities. When there is considerable water in the oil it should be operated as a separator. The necessity of this will be apparent by the quantity of water coming from the outlet. If only a small amount of water appears through the water outlet, a larger output may be obtained by operating as a clarifier, in which case the moisture is retained in the bowl. Generally only small quantities of water are present and the clarifier is the equipment used. When operating as a clarifier the bowl should be drained at intervals, in order to insure dry oil and avoid contamination through wet oil passing into the purified oil container.

The centrifuge will remove the coarser particles of carbon from the oil. For removal of fine particles of carbon, the blotter filter press or centrifuge with suitable chemical treatment should be used.

Insoluble impurities such as sludge. carbon and free water may be removed by the centrifuge or filter press as indicated under the description of these equipments.

Soluble impurities developed by constant use of the oil in circuit-breakers or transformers **can only be removed by chemical treatment.**

Through combination of the centrifuge with a proper chemical treatment, carbon and water can be removed. Organic acidity produced in the oil in service, may be reduced to a satisfactory value, and the demulsibility of the oil can be restored. Choice of a chemical is essential in order that it may accomplish this purpose without producing harmful compounds in the oil.

The Combination Centrifuge and Filter Press—The combination centrifuge and filter press meets the need for a compact unit which may be used advantageously in the purification of insulating oil. It consists briefly of a motor driven centrifuge, electric heaters, regulating float valve, pumps and filter press or presses, mounted upon a truck.

The popularity of this combination unit is due to its ability to rapidly remove either large quantities of water, sediment, or both. When oil is contaminated with water it may be satisfactorily dehydrated by operating the centrifuge as a separate unit. If finely divided carbon or dirt is present in large amounts, the water and nearly all of the sediment may be removed by the centrifuge and the remaining finely divided material will be easily removed by the blotter press. The operation is continuous and delivers oil at full rated capacity. A drying oven is not needed for the blotter papers due to removal of the moisture by the centrifuge.

Oil Contaminated with Fire Extinguishing Agents—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 as it would have to be refined.

When large quantities of oil are involved which 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 other factors involved than the fire extinguishing agent; as for instance, high temperatures cracking the oil, carbonized insulation, etc., which should be considered. Any questions should be referred to the nearest Sales Office of the Westinghouse Electric & Manufacturing Company.

The Relative Advantages of Insulating Oil Purification Processes follow:

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.

The filter press is suitable for use for the purification of 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.

The combination centrifuge and filter press 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. The clogging of the pores of the filter reduces the output of this combination.

Check on the Degree of Purification of Oil—The final criterion of the effectiveness of any method of purification of insulating oil is the quality of the purified oil.

Oil which has been purified 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 purified 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 purified oil should be at least 22 kv. when tested as described on pages 8 and 9.

The S.E. Number should not be over 35 seconds for Universal Wemco C oil or Wemco A oil when tested by the method described on pages 10 and 11, and not over 75 seconds for Wemco C oil received prior to July 11, 1924.

The Neutralization Value should not be over 0.08 milligram of KOH per gram of oil as determined by the method described on pages 11 and 12, and with no trace of alkali by the same method.

The Filter Press

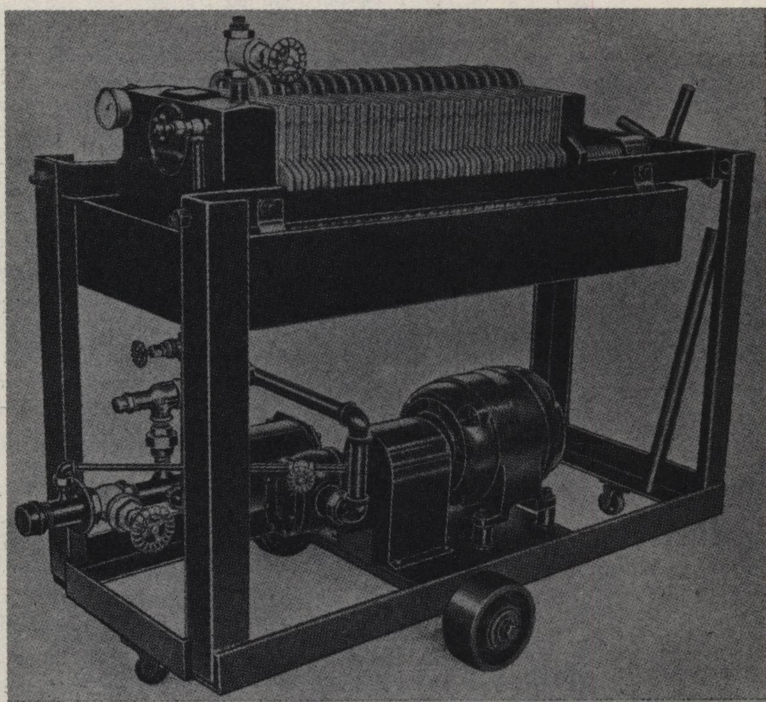

Fig. 10—A-30 Oil Filter Press

General

The filter press is probably the most widely used machine for the purification of insulating oils which have become unfit for use due to the presence of carbon or other foreign matter.

Other Classes of Service

While the principal class of service for which these outfits were developed is the treatment in 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 an outfit intended for insulating oil purification should not be used for other classes of work, due to danger of subsequent contamination of the insulating oil.

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. Like 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. This water in suspension in the oil will be reflected in the dielectric strength.

Capacity

The capacity of these outfits, 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 outfits will vary from normal to about 15% above normal, depending on the viscosity of the oil 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# per square inch and the pressure relief valve is set at the factory to by-pass the full flow at from 60 to 80#.

Apparatus

There are four standard sizes of filter presses B-5, B-10, A-30 and A-60. The letter designates the size of filter paper; the number the gallons per minute on 60 cycles. Refer to price list 44-020 for motor data. Figs. 1-12-14

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 outfits 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 60 pumps are directly connected to the motor through flexible couplings. The B-5 and 10 pumps are mounted directly on the rear motor bracket and driven through a helical reduction gear.

Fig. 11—Assembly of One Filter-press Plate and One Filter-press Frame, Showing Formation of Oil Chambers Between Filter Papers.

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 of the 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 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. (Fig. 11)

The oil enters under pressure at the top corner through the inlet formed by the holes in the frames, plates, and papers, flows into the frames through the same ducts provided 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 strains out all sediment from the oil.

Filter Paper—The filter used is a special grade of blotting paper about .025 inch thick and contains no coloring matter or chemicals which might injure the oil. Five sheets cut to the proper size, 12⅞ inches square for the A size and 7¾ inches square for the B size, 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 treating 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 paper. The standard paper is carried in packages containing one ream carefully wrapped in waxed paper and covered with heavy wrapping paper.

Drying Ovens—The 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. The type A ovens are used for large size paper that is used in the A size filter presses. The type 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 and type B from 100 to 400 watts.

Operation

The oil to be purified is forced through several layers of specially prepared filter paper. The sediment is strained out by the first layer of paper and the moisture is taken up by the capillary action of the paper.

The filter press is made ready for operation by placing a set of five sheets of filter paper that has 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.

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

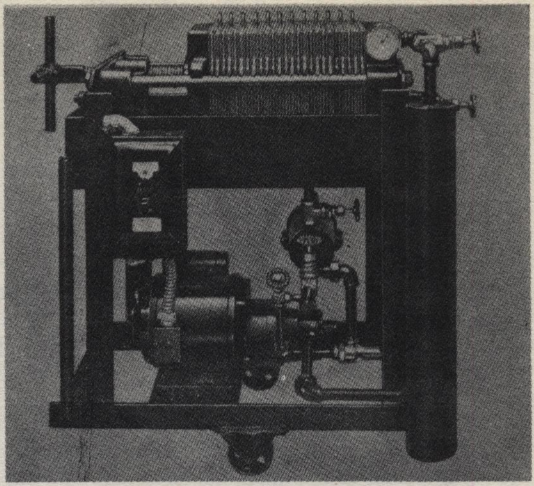

Fig. 12—B-10 Filter Press

of the oil. The usual procedure is to run the machine for a period of one-half hour or so (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 it may be necessary with wet oil to re-charge 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. When a large percentage of water is present it is more economical to use the combination filter press and centrifuge. 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, the time may be shortened by using two filter presses, one being operated while the other is being re-charged.