Westinghouse

Portable Three-Element Oscillograph

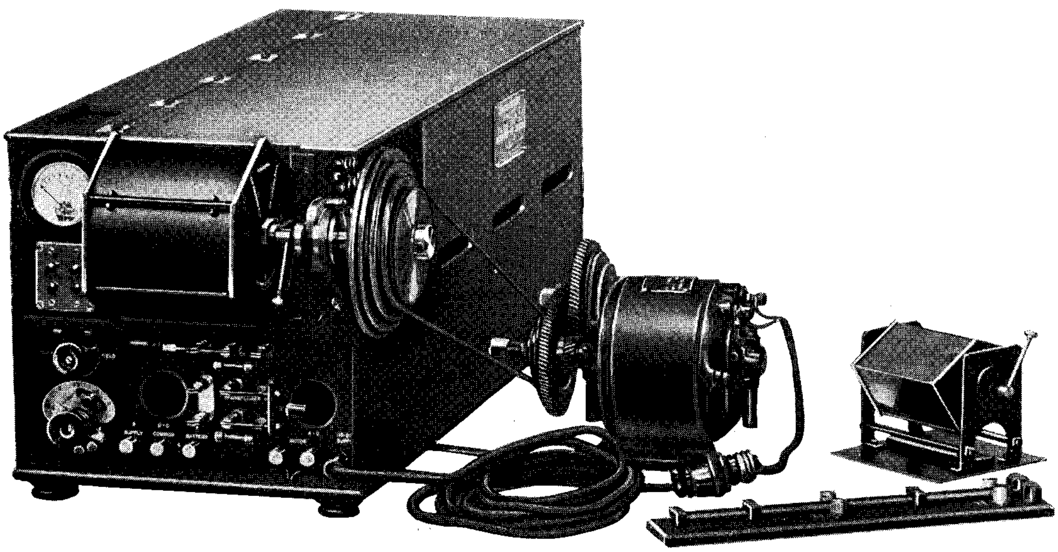

Fig. 1—General Assembly View With Motor and Film Holder Attached

Instruction Book 5242

Westinghouse Electric & Manufacturing Company

East Pittsburgh Works East Pittsburgh, Pa.

CONTENTS

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Style No....................... **Serial No.......................**

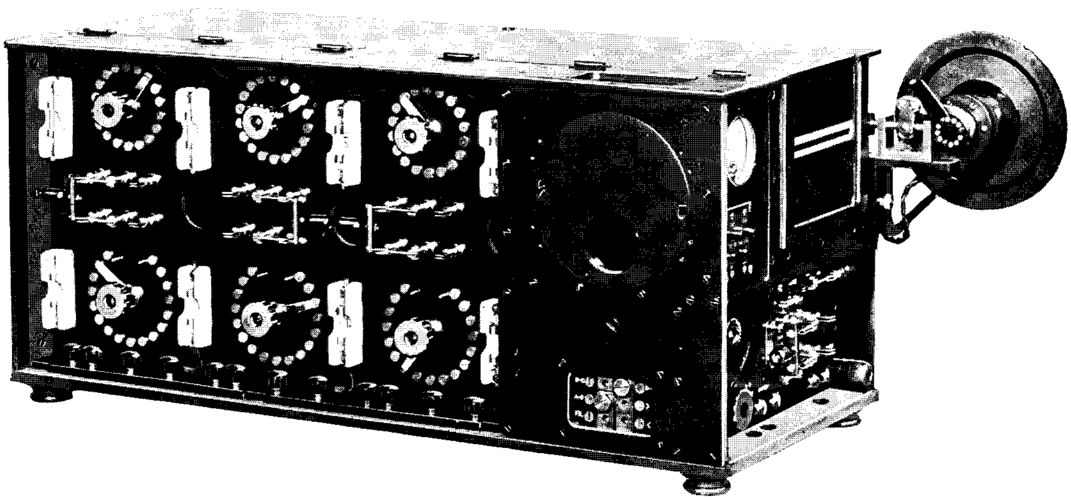

Fig. 2—Element Control Side of Oscillograph

I—APPARATUS INCLUDED

Standard Equipment

The Complete Device Comprises the Items Checked (√) Below

(a) Main Oscillograph Case (11″ x 11½″ x 25″) inc.:
- Three element galvanometer with vibrators
- Supply panels with switches and fuses.
- Optical system.
- Incandescent lamp with control switch and automatic extinguisher.
- Photographic shutter and control
- Remote control mechanism.
- Driving head for films and mirrors.
- Galvanometer field ammeter and control.
- Element resistances (30,300 ohms) and dial switches.
- Rectigon for battery charging.
- Transformer for supplying:
  - Lamp, rectigon bulb, motor and trip magnet.
- Diagram of connections, with key, moulded into panel.

(b) Back Geared induction motor with step pulleys for driving photographic film and viewing mirrors.

(c) Daylight loading film attachment for taking 5 inch or 10 inch oscillograms.

(d) Rotating viewing mirrors with ground glass calibration window.

(e) Three non-inductive shunts for currents from 2 to 20 amperes.

Special Equipment

(f) Small six-volt motor for battery operation.
(g) Slow-Speed long-film attachment.
(h) Variable, non-inductive shunt—
20 to 1000 amperes continuous capacity.
(i) Rheostat for operating galvanometer field from 110 volts D-C. supply. S# 313960
(j) Small six-volt storage-battery to supply galvanometer field.
(k) Polar (circular) film attachment with synchronous motor.
(l) Harmonic analizer for polar films.
(m) Oscillograph table for laboratory use.
(n) Special super-sensitive vibrator element.
(o) Special case for carrying oscillograph on pullman
(p) Additional external resistance unit for use when making records on high voltage d-c. lines.
(q) Contactor to act as relay for large remote control apparatus. S# 300947
(r) Spare or repair parts for standard equipment.
One complete vibrator element.
One dozen vibrator strips
One dozen vibrator mirrors
One small bottle mirror cement
One bottle damping fluid
Six element cell windows
One "rectigon" bulb S# 277681-A
Five special oscillograph lamps.
Four 3 amp. Transformer fuses
Two 6 amp. battery fuses
Six special element fuses
One dozen standard # 3 A Roll films—(non-autographic).
One endless round belt.

Approximate Sensitivity of Vibrator

Standard: End Units = 0.10 ampere d-c., per inch deflection (0.040 Amp./cm)
Standard: Central Unit = 0.15 ampere, d-c., per Inch deflection
Super-sensitive: End units = 0.02 ampere, d-c., per Inch deflection. (0.008 amp./cm.)

Approximate Natural Period of Vibration (Undamped)

Standard: 5000 complete **cycles** per second.
Super-sensitive: 2,500 complete cycles per second.
Normal field current: 3 amperes.
Safe voltage of power supply applied to resistance panel binding posts: 660 volts.
Actual test voltage that has been applied (momentarily) to binding posts: 10,000 volts.
Actual test voltage applied between vibrator elements, (with leads removed): 10,000 volts.
Actual test voltage applied to insulating gaps in galvanometer: 22,000 volts.

Required Supply—
To operate lamp and motor on a-c.
110 or 220 volts at 25, 50 or 60 cycles. 250 watts.
To operate lamp and special motor on battery:
One large 6 volt or 12 volt storage battery.
To operate Galvanometer field
Small 6 volt storage battery or other d-c.

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II—PREFACE

A—Rapid strides in electrical advancement have been made possible by the help of the oscillograph. With the expanding field of electric railways, great interconnected power systems, electrically driven submarines and electrically equipped airplanes, there is increased need for an oscillograph outfit which is readily portable and which will work equally well in an air-plane or in a perfectly equipped laboratory. Such an instrument was thought impossible a few years ago when literally a ton of apparatus was required to carry on an oscillograph test where no suitable direct-current supply was available.

The instrument described in this book is extremely compact and portable and in addition it will cover a broader field of work and is more easily operated than its predecessors.

B—Principle of the Oscillograph

The **oscillograph** consists essentially of an instantly responding moving-coil galvanometer (first worked out by M. A. Blondel) and an optical system to cast a beam of light on the tiny vibrating mirror of the galvanometer from which it is reflected to a photographic film passing at right angles to the vibrating beam. This makes a **current-time** record, on the film, in which distance along the film is proportional to **time**; and deflection (of the beam of light) is proportional to the **instantaneous** value of current passing thru the galvanometer vibrator.

The **moving coil oscillograph galvanometer** actually consists of a single turn of a very fine conductor, supported by two ivory bridges so that the effective part of the coil is essentially two parallel wires with the current passing down one wire and up the other. This coil is located in a strong magnetic field. The motor action of the conductors, carrying a current at right angles to the lines of force of the magnetic field, tends to force one wire forward and the other backward, in proportion to the current passing thru them. These parallel conductors are kept very taut by a tension spring which transmits its force to the loop thru a lever and a tiny ivory pulley. A very small mirror bridges the parallel conductors at the center of the magnetic gap. This reflects the beam of light to the photographic film, the deflection being proportional to the instantaneous current in the conductors. Any vibrator element may be connected across a shunt (as a milli-voltmeter) to record instantaneous values of line current; or it may be connected thru a series resistance to act as an instantaneous voltmeter.

C—Special Advantages of this Oscillograph

This oscillograph is complete in one unit except for the motor and film holder.

This **main unit** is 11 inches wide, 11½ inches high and 25 inches long; and includes: the entire optical system; special incandescent-lamp illuminant; highly sensitive 3 element galvanometer; complete control equipment for vibrator-elements (including 30,300 ohms of non-inductive resistors); transformer (for operating lamp and motor) for 110 or 220 volts supply, at any frequency from 25 to 70 cycles; ammeter and control for galvanometer field; a "Rectigon", for charging galvanometer-field storage battery; and a complete set of bus-bars, fuses and switches, for controlling the apparatus.

The special lamp-control switch and automatic lamp-extinguishing switch enables the operator to apply a greatly abnormal voltage to the incandescent lamp so as to obtain results equal to that formerly obtained only with the intense light of the electric arc. With the automatic features of this instrument, the same lamp may be used for hundreds and even thousands of oscillograms as the lamp is at great abnormal voltage only for a small fraction of a second, during the exposure.

The special back-geared induction-motor has step pulleys which give a great speed range for the photographic film.

The outfit also includes a special film-holder which may be loaded and unloaded without resort to a dark room. This takes standard "Kodak" films which also may be developed without a dark room by using a tank developing outfit.

Even for laboratory use, this outfit has many advantages. Its ease of manipulation and reliability of results is in itself an advantage but its perfect control of the commercial apparatus to be tested makes it practically as easy to take transient phenomena as to take ordinary recurrent a-c phenomena.

The main unit weighs but eighty pounds (80 lbs.) complete, and the whole outfit together weighs scarcely more than one hundred pounds.

III—UNPACKING OF APPARATUS

Unpack according to directions given on the paster attached to the packing box, and preserve the packing case for use whenever it may become necessary either to store or reship the instrument.

IV—SET-UP OF APPARATUS

A—Thoroughly **familarize** yourself with all the information given in this Instruction Book.

B—Place the **main oscillograph case** on some convenient table, preferably, at least the galvanometer compartment (Fig. 3) and mount this, to the edge of the optical box, with the same three thumb screws which secured it in the compartment. Place the attached plug in the receptable to right of optical box (Fig. 14-C), thus connecting the two driving-head brushes in the trip-magnet circuit.

D—There are four general choices for mounting the film driving motor (Fig. 5). Locate motor on table, at right side of oscillograph box, with end of shaft about one inch from oscillograph case. Before bolting motor to table, be sure that it is at the proper distance from the driving head so that the belt may be shifted from one position to another. The slack in the belt may be taken up by moving the oscillograph case forward, the weight of the outfit being sufficient to prevent it from being pulled back by the belt. The smallest pulley diameter of the motor should work with the largest of the driving head, and the largest of the motor with the smallest of the driving head.

The motor may be placed on a base large enough to include the storage battery, to be used for galvanometer field excitation. The combined weight of battery and motor should

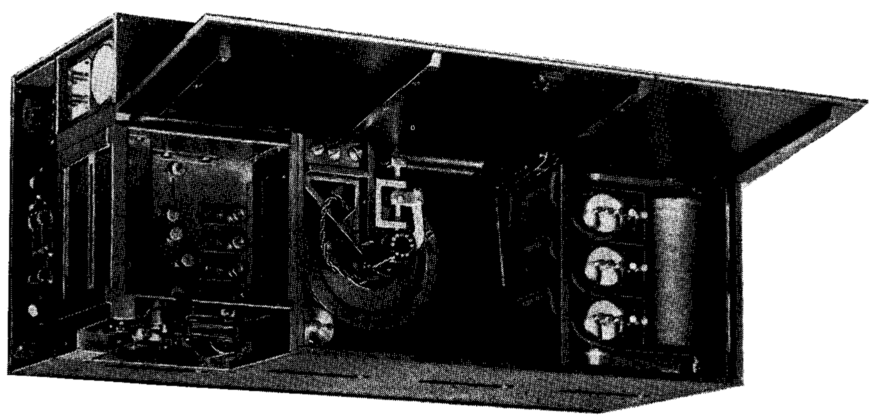


Fig. 3—Top View Showing Galvanometer, Optical Box, Etc.

thirty inches long, and at least twelve or twenty-two inches wide, depending upon whether the motor is to be slung beneath or placed at one side of the oscillograph. See Fig. 1. Unlock the side panel (Fig. 2) and the cover (Fig. 3) with keys found tied to the switch blades on the supply panel.

C—Remove the driving head (Fig. 4) from

be enough to hold the base to the table with the belt sufficiently tight for driving purposes. If the base is covered with a felt, or other frictional surface, the belt will be still less liable to become slack. This method permits the operator to place the outfit on any table without permanently disfiguring the table with bolt or screw holes.

The motor may be mounted on a shelf, beneath the main table top. In this case, the motor shaft would extend to the right and it would be necessary to remove the driving head pulley from its bushing and force it on again (in a machine shop, with an arbor press) so that the largest step will be furthest from the oscillograph. Three tapped holes, for the No. 8-.164-32 machine screws, must be made to secure the clutch ring of the remote control adjusting contact. With this mounting the belt should be crossed, as the motor shaft gear is designed to rotate clockwise only (when viewing unit from shaft end). Some shift of oscillograph case, relative to motor shaft must be allowed to keep belt tight.

The motor may be inverted and bolted to the under side of the oscillograph table. The same changes would be necessary in this case as when mounting on shelf. In addition, however, the grease cups should be reversed with the dummies. See Fig. 5.

E—The galvanometer element wells must be filled with a damping fluid before the instrument will properly record rapid changes in current. The most satisfactory fluid for the widest field of work is found to be a transparent crude oil product, sold under the name "Nujol". This does not discolor with age and does not attack the element finish nor the window shellac unduly. For certain particular work a more viscuous oil may be required to prevent the slightest over-shooting when a current is instantaneously interrupted or instantaneously set up in the element circuit. Such an increased viscosity is too great to give the most reliable records of a-c waves with high harmonics. Hence, "Nujol" is recommended for for general use. Do not use anything else without heeding warnings in Section XV, on "Notes on Damping Fluids".

To introduce damping fluid, first remove element leads from binding posts Fig. 3. and pinion knob from rear of well. Then carefully unscrew and withdraw centering post (Fig. 22) with spring washer, being careful not to raise element frame from well top-plate. Gently press the element (Fig. 23) backward about three-sixteenths of an inch ($\frac{3}{16}$ inch) until the inside frame touches the rear of the well plate opening. A flange on the forward half of the well plate helps to guide the element so that the fibers and tiny mirror will not touch the pole pieces, which are only a few thousandths of an inch from either side. Then carefully raise the element, keeping it back so that the fine fibers and ivory bridges will not be damaged by the front edge of the well plate opening. See (Fig. 22). Fill the open well to within three-eights of an inch ($\frac{3}{8}$ inch) of the top plate so that when the element is replaced the fibers (metallic ribbon conductors) will be totally immersed in the damping fluid. When inserting the element, keep it back in the well so that the ivory bridges, mirror, etc., will not touch the well plate or pole faces. After the element flange sits on the well plate, carefully draw the whole element forward, allowing the flange on the well plate to guide the element so that the mirror will not touch the near-by pole faces. When inserting (or withdrawing) the element, do not force it hard against the back of the well plate for this may strike the spring lever and break the element fibers. Replace the centering post and spring washer and screw this tight, with the knurled head, so that the post does not move when the element is slightly rotated (by means of the small pinion meshing with the fine gear-segment on the element flange).

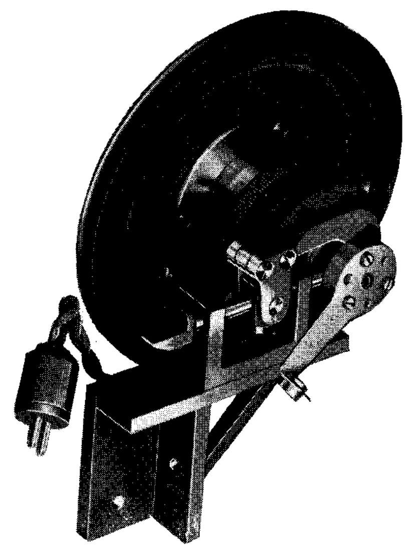


Fig. 4—Driving Head With Adjustable Contact and Shutter Release Arm

F—Attach the ground glass calibration window (with the polygon of viewing mirrors) to the faces of the optical box, by inserting its face-plate in the guides on optical box. The slot behind the ground glass must line up with the slot in the optical box. This will be the case when the gear end of the polygon is to the right, so that the dog may connect the unit to the driving head. Should the polygon frame be removed from the face plate and ground glass, be sure to insert the face plate right side up, on the optical box, with the ground glass slightly above the center of the face plate.

Induction Motor With Step-Pulleys and Gears for Driving Photographic Film and Viewing Mirrors.

When the pulley on the main shaft is pushed in, a clutch engages with the motor shaft pin and gives direct drive to this four-step pulley.

The motor operates on 110 volts at 50 or 60 cycles, and on 55 volts at 25 cycles.

The drum speed remains nearly the same, within a fraction of one per cent, for any one belt position. Each motor and belt should be calibrated together in order to obtain reliable results.

The pulley belt-positions give reductions of 1, 1⅔, 3 and 7, while the back-gearing gives an additional reduction of 16 to 1.

The third position direct-drive is to be used with rotating-polygon of viewing-mirrors for 25 cycle phenomena. This is designed to make the re-current a-c. wave float along in the field of vision. To check this floating condition, apply a slight pressure on the driving

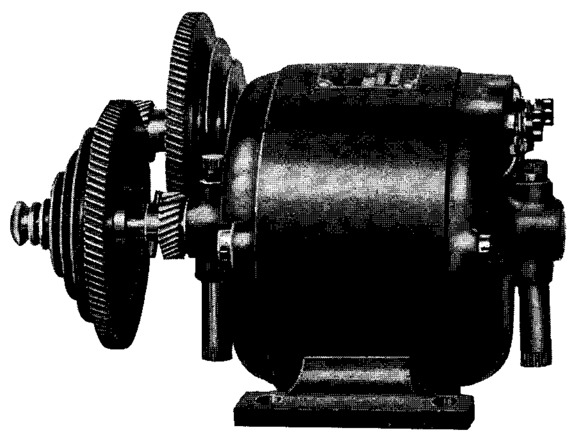


Fig. 5—Induction Motor With Step Pulleys and Gearing

An endless, flexible, round belt is used to connect this pulley with the driving head pulley, so as to give four different film speeds without changing the center distance between shafts.

When the main pulley is carefully pulled out, its helical gear meshes with the pinion of the countershaft gear so that the main pulley is driven at one-sixteenth motor speed.

head pulley, thus retarding the motion until it becomes an exact fraction of synchronous speed For 60 cycle observation place belt on smallest motor pulley and on next to the smallest driving head pulley.

By changing the center distances (each time) it is possible to obtain a very large number of belt positions and corresponding film speeds.

TABLE OF APPROXIMATE FILM SPEEDS

For 4¾ Inch Drum

Driving Pulley	Belt Position	25 Cycle Operation		60 Cycle Operation		Tot. Cy. / 10″
		Rpm.	Sec. / Inch	Rpm.	Sec. / Inch	
Direct	1st	685	0.006	Too Fast	Danger	1.5
Direct	2nd	410	0.010	1010	0.004	2.5
Direct	3rd	230	0.018	570	0.007	4.4
Direct	4th	98	0.042	243	0.017	10.2
Geared	1st	43	0.095	107	0.038	23.
Geared	2nd	25.5	0.160	63.2	0.065	39.
Geared	3rd	14.3	0.286	35.5	0.115	70.
Geared	4th	6.1	0.675	15.1	0.272	160.

V—CONNECTIONS FOR VARIOUS SOURCES OF SUPPLY

A—To operate the incandescent lamp, trip-magnet and induction motor from alternating current supply, throw the d.p., d.t. transformer switch (Fig. 1) to the right for 110 volts supply and to the left for 220 volts supply, thus connecting the primary coils in parallel or in series. See diagram moulded in element panel cover or (Fig. 6-7-8). For 25 cycle supply, throw the s.p., d.t. motor switch to the left, thus supplying the motor with 55 volts, when circuit is completed. For either 50 cycles or 60 cycles supply, throw the motor switch to the right, thus supplying the motor with 110 volts. To operate the lamp from the secondary of the transformer (enclosed in the oscillograph case) screw the two thumb screws tightly into the bus-bars (Fig. 2) with left hand one in position marked "A-C" and right hand one in idle position marked "D-C".

The a-c. supply should be plugged in at lower right hand side of supply panel, after bus-bars are properly set, and after motor is properly connected to binding posts marked "Motor" on a-c side of supply panel. The motor and transformer switches may be used to make and break the circuit.

In case no suitable a-c is available (as would be the case when making tests on a moving car, sub-marine, or air-plane), the incandescent lamp and trip-magnet may be supplied by a large six-volt storage battery (such as is used for automobile starting and lighting). By adding a small six-volt shunt-motor, belted to a small pulley, placed on the end of the induction motor shaft, the whole outfit may be operated with six volt batteries. In this case the bus-bar thumb screws should be securely fastened in the two upper positions marked D-C and D-C. This adds additional resistance to the circuit so that the lamp will operate properly from a six-volt battery connected to the terminals marked "SUPPLY" and "COMMON".

B—The galvanometer field may be supplied by a small six volt storage battery connected to terminals marked "BATTERY" and "COMMON" or from any d-c circuit, provided a suitable external rheostat and switch is added. In case a six-volt storage battery is used, it may be charged from a "Rectigon" bulb, supplied by the transformer, within the case. This makes the outfit entirely independent of any d-c supply. To connect in the "Rectigon", place the thumb-screws in the lower positions of the bus-bars and press the ammeter push-button switches to "SUP"—"BAT". See key and diagrams moulded into element panel cover. On distant tests, the operator may hire a (motorcycle lighting) battery from the nearest service station. For laboratory use, where lightness is not so essential, a low-gravity electrolyte battery is preferable to the strong-acid type, used in motorcycles, as the former will not deteriorate so readily.

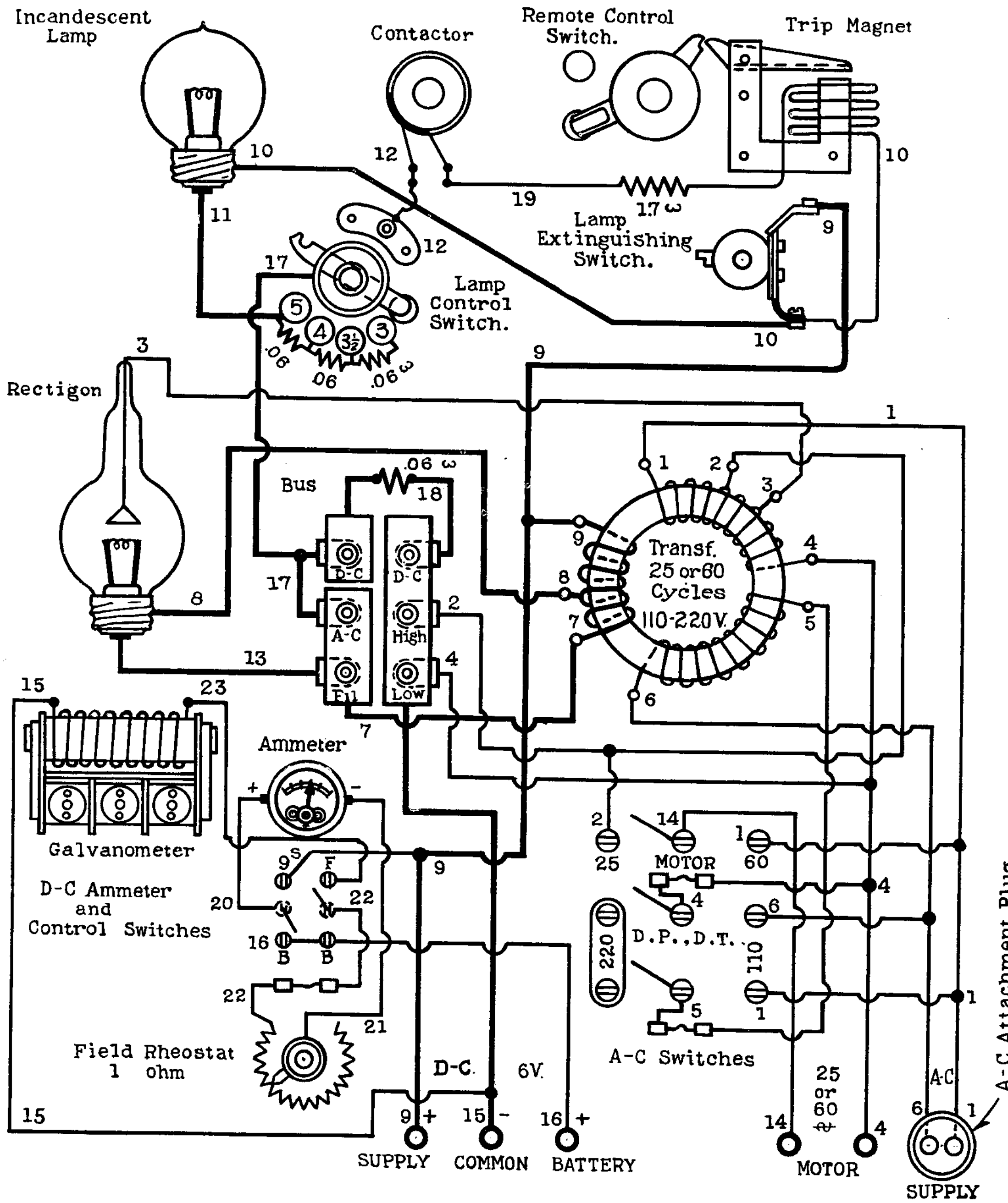
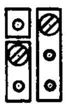


Fig. 6—Supply Circuit for Lamp, Motor, Galvanometer Field, Etc.

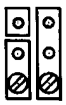
WESTINGHOUSE PORTABLE OSCILLOGRAPH

Note: Do not handle any bus or terminal when plug (1 & 6) is connected to the A-C supply.

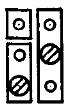
BUS-BAR THUMB-SCREW ARRANGEMENT



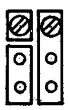
For A-C operation of lamp from 5 volt secondary of transformer. A-C supply at detachable plug (1 & 6). Secondary, only, of transformer interconnected with the D-C circuits.



For charging 6 volt battery, with the Rectigon, with A-C supply at attachment plug. This setting when A-C line is normal at 110 or 220 volts. Primary of transformer interconnected with the battery circuit.

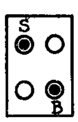


For charging battery when A-C line voltage is low (100 or 200). This connection gives higher charging current. Rectigon capacity from 1.5 to 2.5 amperes.

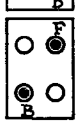


For operating lamp from a large 6 volt battery, connected to D-C supply terminals (9 & 15). May also operate a 6 volt motor from this battery for driving the photographic drum.
If a 12 volt battery is used: connect positive to #16, middle tap to #15 and negative to #9 (but do not press ammeter switches to "SUP.-BAT"!).

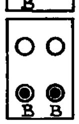
D-C AMMETER SWITCHES



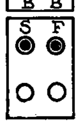
"SUP.-BAT" Ammeter indicates charging current of battery from RECTIGON or external D-C supply thru ext. rheo.



"BAT.-FLD." Ammeter indicates galvanometer field current supplied by the 6 volt storage battery. Field strength adjusted by rheostat knob. 3.0 amperes normal excitation.

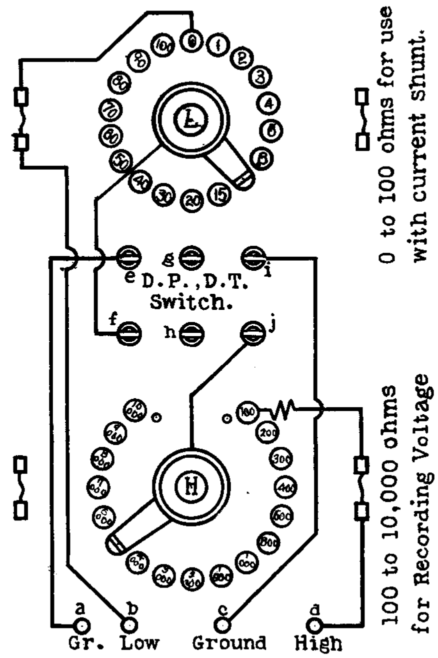


"BAT.-BAT." This is the "OFF" position. Use it and save the battery! It should not be used to break 3 amps at 110 volts.



"SUP.-FLD." This can be used when it is desired to supply the field from an external D-C source thru ext. rheo.

Fig. 7—Supply Circuit for Lamp, Motor, Galvonameter, Field, Etc.



ELEMENT RESISTANCE CIRCUIT DIAGRAM

For potential differences below ten volts use left hand binding posts, "a"&"b", with the D.P., D.T. switch thrown to left so as to connect in the low resistance dial (upper). This is suitable for current measurements by taking the drop across a low resistance current shunt (constructed to be practically non-inductive).
For higher potentials use right hand binding posts, with switch to right, thus connecting the high resistance dial in series with the element. For higher voltages better place lead nearest ground potential on "c" and high side of line on "d". For fine adjustment connect supply to "a" and "d", then connect "b" to "c" and "e" to "f"
Note: Always set for at least ten ohms per volt when making initial observation.

Fig. 8—Element Resistance and Dial Control

VI—OPERATION OF INCANDESCENT LAMP

A—The lamp control switch is located at the left of the supply panel (Fig. 1). This switch has an "Off" button and buttons marked "3", "3½", "4", and "5" which indicate, approximately, the voltages applied to the incandescent lamp. The lamp has a normal life at 3 volts. At 3½ volts, the life is several hours. At 4 volts the life is but a few minutes for continuous operation. At 5 volts, the life is very short, possibly only a second, continuous burning. For visual work, the lamp gives sufficient light on the "3" position. For long, slow-speed films the switch is thrown to the "3½" position. The automatic extinguisher cuts the current off at end of exposure and gives a long life for oscillograph work.

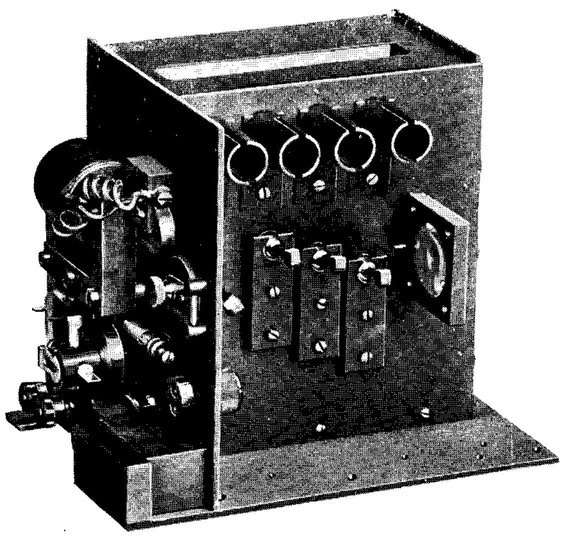


Fig. 9—Bottom View of Optical Box

For high speed films the switch may be thrown to the last notch, thus cutting out all series resistors. At this position, marked "5", the automatic extinguisher is absolutely essential. The same lamp has been operated over a thousand successive times, at 5 volts, each time long enough to reach maximum intrinsic brilliancy and take a fast oscillogram.

The adjustible stop and contact may be set for any one of the abnormal voltage positions, according to the speed of film to be used for recording. This prevents the operator from accidently applying a greater voltage than intended. The chief function of this stop is to connect the trip-magnet circuit, to the supply as soon as abnormal voltage is applied to the lamp. An adjustible contact on the driving head (Fig. 4) shorts two brushes in the trip-magnet circuit, thus causing the trip-magnet (Fig. 14-B) to release the remote control switch (this function described later) and the shutter finger.

B—The lamp-extinguishing switch is located between the trip-magnet and the optical box (Fig. 14-D). This is opened by the closing of the shutter, thus extinguishing the light immediately after the exposure is completed, and thus preventing the destruction of the lamp filament on abnormal voltage.

VII—ADJUSTMENT OF OPTICAL SYSTEM

A—The **incandescent-filament lamp** (especially designed for this oscillograph) requires adjustment but once during its life. If properly adjusted, before leaving the factory, its adjustment will probably be correct when received.

To replace lamp unscrew old lamp and insert new (spare) lamp in socket, within the lamp house. (The lamp-house door can be removed after unscrewing the two flat-head screws, about ¼", and twisting the round door until the screws permit its removal). With the bulb securely screwed into the socket, slightly loosen the screw located just above the bus-bar opening. The lamp socket may then be turned so that the lamp filament will present a very nearly solid central mass of light towards the condensing lens, in the optical box (Fig 9).

The socket may be raised, or lowered, and shifted to one side, or the other, until the three first reflecting prisms are well covered with light. (When 110 volts a-c. is used for supply it is very convenient to throw the transformer switch to the left, marked 220, so as to apply only half voltage to the lamp. Then adjustments can be made with no fear of a brilliant filament.)

B—The **main condensing lens** is slung beneath the optical box but may be adjusted from above by the knurled thumb-nut. The lens is located relatively near the filament (impossible with an arc-lamp) so that it gathers a relatively large proportion of the light rays and casts a relatively large image on the galvanometer. To adjust this lens,—first open the small round door on the side of the optical box, then open the main cover of the oscillograph case and slightly loosen the thumb-nut and slide it (with lens) to and from the lamp until the filament image comes to a focus (on a piece of paper held in the hand), at a distance of 12″ from the right hand side of the oscillograph case.

C—The **reflecting prisms** are also located beneath the floor of the optical box and are also adjusted from above. The four knurled disks are used to control the twisting and the longitudinal angular-adjustment of the prisms (seen thru the small round doorway). When these are properly adjusted the reflected beams strike the corresponding vibrator mirrors, provided the slots are properly adjusted. The most intense part of the filament image should be focused on the vibrator mirrors. When once properly directed and focused, these adjustments remain fixed for months of operation until the lamp burns out.

D—The **width of beam** may be adjusted by slightly rotating the knurled thumb nut over the respective "slot". Each double slot also has a sidewise adjustment, which when once properly made, requires no further attention. A small screw, reached thru a hole in the flat slot-spring, holds the slot from shifting sidewise. The flat spring holds the slot, at any desired setting of light-beam width. Rotating the thumb nut, slightly, decreases (or increases) the beam width. The narrower beam is used whenever the oscillogram is slow enough to permit sufficient exposure with a fine pencil of light, or when recurrent phenomena are recorded on a synchronously driven film. For faster film speeds, recording transient phenomena, the slot must be set for a wider beam.

E—With the filament image focused on the vibrator mirror, thru element well window and dampening fluid, slowly twist the knurled headed brass adjusting screw (located at rear of element well) to the right for raising, or to the left for lowering, the tiny beam of light. This should be adjusted until the reflected beam passes into the shutter opening. The final adjustment must be made later while viewing the light spot on the ground glass.

F—The horizontal adjustment (or "Zero" adjustment) of the reflected beam, is made by slowly turning the insulated, knurled-head, on the fine pinion, located just behind the element cap on the well plate. This pinion meshes with the gear segment of the element support and makes it possible to shift the reflected beam to any spot on the ground glass.

G—The **shutter** is of the focal plane type, mechanically operated. It consists, essentially, of two tubes with diametrical longitudinal openings. The central tube rotates. When the openings line up, the reflected light from the vibrator mirrors is free to pass on through the cylindrical lens to the ground glass or film. For observation, on the ground glass, or viewing mirrors, the shutter may be held open by an arm from the lower part of the trip-magnet to the shorter of the two shutter fingers. (Fig. 13). This setting also holds the movable shutter-finger slightly above the driving-head cross-arm, so that the driving head is free to rotate the polygon of viewing mirrors.

H—With the shutter open and the ground glass calibration (or observation) window in place, readjust the incline of the element wells until the three reflected beams pass thru the **cylindrical condensing** lens and all line-up in the horizontal plane of the ground glass. Shift the elements by means of their respective pinions, until the central element spot is near the center of the ground glass, with the others about 1″ to each side (with respect to the elements). If the long cylindrical lens has been

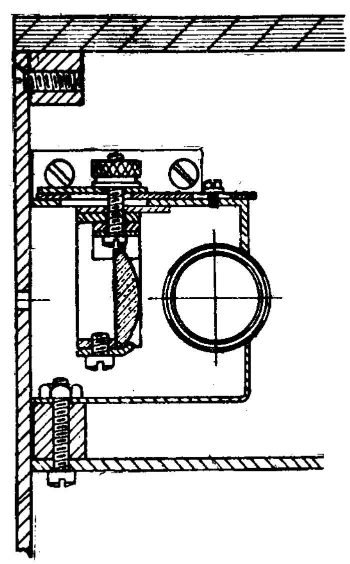


Fig. 10—Cylindrical Lens Adjustment for Either the Daylight Loading or Polar Film Attachment

properly adjusted the light spots will be fairly sharp, horizontal lines, with lengths approximately proportional to the openings on the corresponding slots. There are two means of adjusting the cylindrical lens. The thumb nuts (Fig. 10) permit a quick shift from proper position for the day-light loading film-holders and the polygon of viewing-mirrors, to the proper position for the Westinghouse Polar film attachment or the old single-strip film-holders. (Dark room loading). The focal plane, for the daylight-loading film-holders, is ⅜″ nearer the oscillograph, so as to accommodate a larger film drum and to take advantage of the greater optical efficiency, of the wider angle of convergence from the cylindrical lens. The other adjustment is made once for all (unless the cylindrical lens has to be replaced). If the image on the ground glass is not sharp (horizontally) when the thumb nuts are set in the extreme position nearest the galvanometer, then slightly loosen the two small screws (located behind the thumb nuts) and carefully shift the whole plate to and fro until the reflected beams are sharply focused (as short lines) on the ground glass. Set the screws tightly in this position. For polar films: reset the thumb-nuts, on the extreme forward position, so as to allow for the ⅜″ extension in the proper focal plane.

I—The ground glass window may be used to get an idea of the d-c. deflection but some other movement is required to give oscillations a time-component. A quick movement of the observer's head up or down before the ground glass will give a momentary vision on any a-c. wave that may be thrown on the glass from the vibrator. The **rotating viewing mirrors** (Fig. 15) give a very satisfactory time-component to oscillations, especially to re-current phenomena when the polygon is revolved at the proper fraction of synchronous speed. The induction motor must be fed from a generator which is at least in step with that in the circuit under observation.

Have the viewing mirrow attachment properly in place and the dog set to connect it (through carefully chosen gears) to the driving head mechanism; then place the induction-motor belt in the third position (3 to 1 reduction). This set-up is designed to drive the polygon at slightly over ⅛ the fundamental two pole synchronous speed.

VIII—VIBRATOR CONTROL FOR TESTS

A—A most complete set of vibrator element resistances is enclosed in the lower half of the oscillograph case. The **control panel** (Fig. 2) permits quick adjustment to proper values of series resistance for tests on practically any commercial circuit. The exception is high voltage d-c. railway circuits which (for safety) would require an external resistor located at a safe distance from the operator.

A diagram of the element control panel is moulded (to the right) in the side cover. This shows one of the three similar units (one for each element). The upper resistance dial ranges form 0 to 100 ohms i.e. 0, 1, 2, 3, 4, 6, 8, 10, 15, 20, 30, 40, 50, 60, 70, 80, 90 and 100 ohms. The lower dial has values one hundred times as great, except that the zero is omitted. The resistance wire is wound on thin micarta cards so as to make each unit practically non-inductive (Fig. 11). Fuses are provided to protect the element, one to the left of each low-resistance dial and one to the right of each high-resistance dial. These fuses are each specially provided with a short length of the element-ribbon. As the fuse ribbon is in the air, while the ribbon in the vibrator element is totally immersed in oil, the fuse will melt before the element-ribbon is injured. The upper right hand and the lower left hand fuse-blocks hold spare fuses only.

B—The leads used from the circuits to be tested to the oscillograph binding posts should be, preferably, of the twisted double conductor type. A good grade of lamp cord may be used for circuits up to 220 volts. If the lamp cord is exceptionally good grade and is in good condition, it is sometimes used in circuits as high as 660 volts (similar cord should have stood tests of 2,200 volts without breakdown). Twisted leads are used to make them approximately non-inductive. A good factor of safety is necessary especially when transients in the circuit may momentarily kick the voltage to several times normal peak value.

C—For use as an **instantaneous voltmeter** set the lower dial at a resistance value equal, numerically, to approximately ten times the voltage to be measured. Connect the voltage leads to the right hand pair of binding posts (spaced much further apart than the left hand pair) pertaining to the element to be used.

If the circuit, being studied, is grounded on one side, it is good practice to place the higher voltage lead to the right hand binding post (leading direct to the fuse) so that if the fuse blows, the element and resistances will be at ground potential. The safe voltage which can be directly applied to the oscillograph terminals depends on several factors: first, the skill and reliability of the operator, second, the amount of power available in the circuit; and third, the condition of insulation surfaces of the oscillograph. Faulty handling of the apparatus might result in the death of the operator from a 250 volt d-c. circuit. On the other hand, a good operator often uses 660 volts, d-c. connected directly to the oscillograph. When making tests on a small (250 watt) d-c. generator, it might be considered safe to apply as high as 3000 volts, directly to the oscillograph. Where greater power is available, a greater factor of safety should be used.

The d.p., d.t. switch, between dials, should be thrown to the right to complete the circuit for voltage tests. This should not be opened on potentials above 660 volts, and an inexperienced operator should observe great care on anything over 220 volts. For higher voltages, cut off the supply with standard power switches.

D—For taking records of **current** it is necessary to use some form of non-inductive shunt. This shunt carries the main current while but a fraction of the current passes thru the vibrator element. Potential leads from across the shunt should be connected to the left hand pair of binding posts, on the element control panel, pertaining to the element to be used as an instantaneous ammeter. The resistance of the shunt should be known (at least approximately). The resistance of the element circuit can be varied, with the upper dial switch until the resistance of the element circuit is to that of the shunt as the current in the shunt (nearly equal to the total current) is to the proper element current (from 0.05 amp. to 0.3 amp. depending on the deflection desired). For example; if a current shunt is available with a resistance of 0.1 ohm (=Rs) and if a standard element is used with an approximate resistance of 1.1 ohm (=Re) and a sensitivity of approximately 0.10 amperes per inch deflection; then a line current of 5 amperes (=I) would give nearly a half-volt drop in the shunt. For a d-c. deflection of $2\frac{1}{2}''$ the element current would be approximately 0.25 amperes (=Ie). Then the total resistance in the element circuit (=R) would be R=Is x Rs / Ie or R = 5 x 0.1 / 0.25 = 2 ohms.

But R= Re + Rr ∴ Rr = R-Re or resistance inserted by dial = Rr = 2-1.1 = 0.9 ohms.

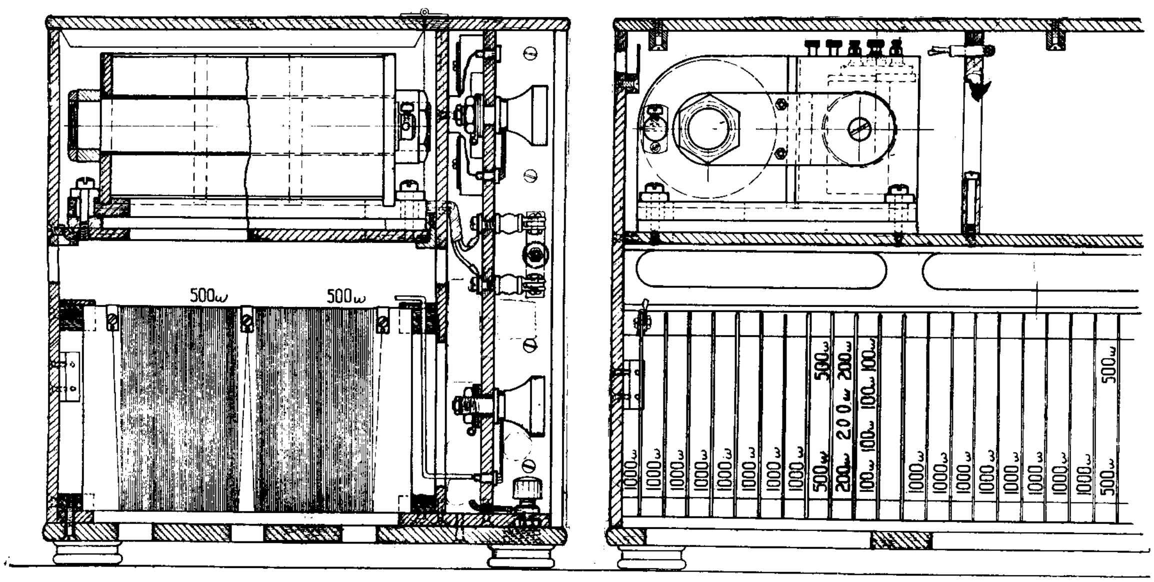


Fig. 11—Rear Transverse and Longitudinal Sections of Oscillograph

The nearest value (without paralleling units) is 1 ohm. Hence with 1 ohm on dial

Ie = Rs x Is / R = 0.1 x 5 / 2.1 = 0.24 amps. This would make approximately 0.24 /0.1 = 2.4 inches deflection on film, or ground glass.

To be more accurate, however, Is = I-Ie = 5.00 -0.24 = 4.76 amperes. Then Ie = 0.1 x 4.76 / 2.1 = 0.226 amperes, making approximately 2¼" deflection.

In practice these values are seldom figured accurately for it is generally necessary to calibrate each shunt with its element circuit (including leads) unchanged. This is taken up later.

In practice the operator simply makes certain that the shunt e. m. f. drop is reasonable and then connects in the element with a large value of resistance and then slowly cuts out resistance until the deflection is satisfactory. A safe rule to follow is to "**insert one ohm for each ampere**" for one inch d-c. deflection **when using a 0.1 ohm shunt.** This would give nearly three times this deflection (extreme) for a-c. waves. NOTE: Be sure the galvanometer field is excited, with normal field current before materially reducing the element circuit resistance. A current of 0.2 amperes, continuous, should not harm the element. Any alternating deflection **which is confined to the scale, may be used.**

E—The operator will find that several combinations of resistances may be used to obtain a finer adjustment of deflection. When one element is to be used, to record voltage phenomena, it is possible to place the two dial units in series. Short circuit the two idle prongs of the d.p., d.t. switch, also short circuit the two central binding posts and then connect the potential leads to the extreme binding posts (all pertaining to the same element). Use the lower (high resistance) dial for coarse adjustment and the upper dial for fine adjustment.

F—Great **precautions** must be used in testing **high voltage** circuits. Usually high voltage a-c. is tested from the secondaries of potential transformers. Even a larger factor of safety must be used when considerable power backs the high voltage. Protective fuses should be inserted between the circuit to be tested and the leads passing to the oscillograph. In d-c. testing the higher potential lead should be connected to the right hand (fused) binding post. It should be remembered that inductive kicks sometimes momentarily increase the voltage of the circuit a thousand percent or more. An oscillograph operator, dealing with transient phenomena, soon acquires a sufficient knowledge of these inductive kicks to be able to judge the proper element circuit resistance to keep the deflection on the film; and also to more properly judge the safe voltage that may be applied to the oscillograph.

As an example of serious inductive kicks, it might be stated that an older form of oscillograph apparatus was nearly completely wrecked when taking oscillograms in a test on a huge mecury arc rectifier. The voltage kick across an inductance, in the a-c. supply, was one-thousand-five-hundred percent higher than the fundamental sine-wave peak. This was due to the sudden shifting of current from one anode to the other when the rectifier was supplying uni-directional current to an inductive load. The duration of this kick was less than one thousandth of a second, but this was enough to bridge a gap and establish a power arc within the oscillograph case. The portable oscillograph has stood a test voltage many times as high as that of older instruments, but the operating voltage should not be increased in a direct ratio.

An external, non-inductive resistance and fuse should be used when making tests on 3000 volts d-c. railway circuits and their like. The ground (or low side) of the circuit should be connected directly to the unfused (left hand) binding post "c" on the element panel. The high voltage side of the supply should be connected thru a low-current, high voltage fuse to the external rheostat (of at least 10,000 ohms resistance for a 3000 volt circuit) and from this rheostat to the right hand binding post of the set on the element panel. It would be safer to remove the special element fuse (and short circuit the clips), on the oscillograph panel, and insert an equally low current fuse in the circuit near the external rheostat.

In case very high voltages are to be measured using high external resistances, a shunt may be placed across the potential leads, (one of them being near ground potential) before they reach the oscillograph. All internal oscillograph resistance should be cut out, so that 100 ohm external shunt would take but a small fraction of the total current. The capacity of this shunt should be such that, if the vibrator element broke or burned out, this shunt would carry the current without materially increasing the voltage reaching the oscillograph. A water resistance thru a long rubber hose, may be used for very high voltages. Distributed capacity, as well as reactance, should be avoided in oscillograph resistances used with high voltages.

IX—OPERATION FOR OBSERVATION WITH ROTATING MIRRORS

With the rotating polygon of viewing mirrors in place, on the face of the optical box, and the driving dog properly secured, place the motor belt in the "3rd" position (with a 3 to 1 reduction). Also be sure that the shutter is held open by the special arm (Fig. 13). The waves, to be observed, must come from a source in synchronism with that supplying the oscillograph motor, etc. Otherwise, it will be difficult to adjust the speed of the mirrors to give a slowly shifting wave (or waves).

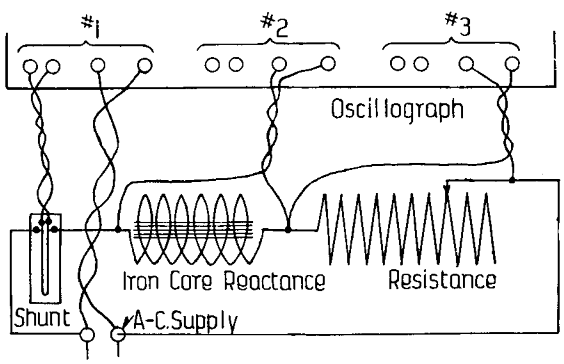


Fig. 12—Diagram of Simple Layout for Recurrent Phenomena

As an example of operation for a simple demonstration, take an iron core reactance, such as the low potential (110 volts) coil of a 5 Kw. transformer (preferably a modern type using a high flux density in the steel), and insert this in series with an adjustable resistance and an oscillograph shunt (0.1 ohm). See diagram (Fig. 12) for connections to oscillograph, in which #1 element (left) is used to show current in series circuit, when d.p., d.t. switch is thrown to left, and also to show e.m.f. wave of supply when switch is thrown to the right. The #2 element (center) is used to show the e.m.f. wave across the iron core reactance (be sure to insulate the ends of any high voltage windings on the transformer being studied). The #3 element (right) is connected to show the e.m.f. across the variable resistance.

To adjust the element resistances, assume the magnetizing current may be 5% of the rated load current. For example, with a 5

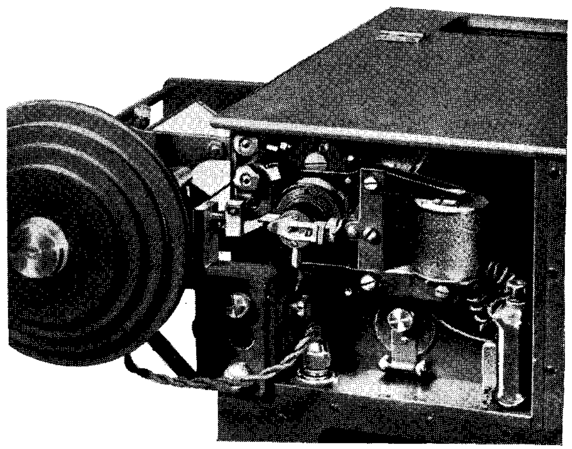


Fig. 13—Rotating Viewing Mirrors in Place on Oscillograph Showing Shutter Prop.

kw. transformer and a 110 volt winding, the magnetizing current may be in the order of 2½ amperes. Hence, if the upper left hand dial unit is set at 2 ohms, the extreme deflection may be about 2¼″ from peak to peak (for sine wave). Unless the wave is very peaked this will be a satisfactory deflection.

(For this 0.1 ohm shunt and 0.1 amp. per inch element:

D = deflection = approximately $(0.1 \text{ x } I \text{ x } \sqrt{2}) / (R \text{ x } 0.1)$

= 2.83 x Current in Shunt divided by Element Circuit Resistance.

= 2.8 x 2½ divided by 3.1 = 2.26 inches (approx.)

The e.m.f. across the reactance may approach line voltage, hence insert 1,500 ohms in #2 element circuit, for an extreme a-c. deflection of about 2″. (After observation this may be reduced to 1,000 ohms or possibly lower). The #3 element circuit may be set for 1,500 ohms, later this may be greatly reduced to give proper deflection. The lower left hand dial should be set at 1,500 ohms for recording the 110 volt a-c. supply.

Set the rheostat for at least 40 ohms resistance and close in the a-c. supply switch. Close the #1 d.p., d.t. knife switch in right-hand position. Then if the oscillograph is properly adjusted, the lamp switch held on the 3 volt position and the galvanometer properly excited, the sine-wave of the supply should appear in the rotating mirrors. Close the other two element switches to show the distorted waves of e.m.f. across the resistance and across the reactance. As the resistance is cut out with the rheostat, the e.m.f. across the reactance should increase. Also, the distortion of this wave should increase as the iron becomes more saturated. When the rheostat is nearly cut out, the e.m.f. across the coil becomes nearly that of the supply. The e.m.f. across the rheostat (if the latter is non-inductive) is similar in shape and in phase with that across the shunt, as can be seen when the left hand (#1 element) d.p., d.t. switch is thrown to the left to show current. This wave becomes more and more distorted as the iron core approaches normal saturation. The current wave should lag behind the applied e.m.f. It may be necessary to reverse the leads passing to the shunt, unless their polarity has been observed when making the initial connections. It is often convenient to have the extremities of one lead, in each pair, marked so that the operator can connect them properly the first time, after duly referring to his diagram.

If the observed wave (from viewing mirrors) is not great enough in amplitude, then carefully reduce the resistance in the element circuit until proper deflection ensues. The zero positions of the light beams may be shifted to coincide, or take any other position on the ground glass by carefully turning the insulated heads of the element pinions. The operator may prefer to insert a small coin between the "off" button and the 3 volt button of the lamp control switch. This will hold the switch in the normal voltage position, but the lamp should not be left burning when not in use. Take care not to turn the switch to the abnormal voltage positions except when photographs are to be taken (followed by the immediate automatic interruption of the lamp current).

Many other simple or more complicated layouts will suggest themselves to the new operator. Small, direct connected, a-c. generators, having two, six, ten, fourteen, etc. poles each, may be connected in series to give the effect of fundamental and harmonic waves, both combined and individually. It is desirable to be able to control separately the field of each alternator and also to shift the shaft coupling so as to give a shift to the harmonics.

The rotating viewing mirrors often make it possible for the operator to direct the adjust ment of apparatus under test before taking photographs.

X—PHOTOGRAPHIC RECORDING

A—The special shutter mechanism (and remote-control mechanism) makes it possible to use a daylight loading film holder, in which the active part of the film cannot cover the complete circumference of the rotating drum. (Fig. 15). Fig. 14-A shows how to set the shutter. The arrow-headed flat spring (on head of shutter shaft) is slightly drawn out (with the tip of one's finger) until the pin, on the movable shutter finger, is released (by the flat spring). This finger is forced out by an internal helical spring until it is about 1/8" longer than the stationary finger (at right angles to it). The photo shows the operator's right thumb and fore-finger in the act of pulling out the shutter-head (about 1/4") and twisting it (clock-wise) until the elongated finger may be inserted under the catch of the trip-magnet armature. Fig. 14-B shows the shutter all set, ready for operation. In this position the shorter (fixed) finger clears the shutter-release arm (of the driving head mechanism) so that the latter is free to move to and fro, whenever the motor is running.

When the armature of the trip-magnet is depressed, the extended finger of the shutter head is released but the shorter finger immediately strikes the release arm, thus preventing the shutter from opening until this arm reaches its extreme outward position (corresponding to the beginning of the film). In this position, as shown in Fig. 14-C the short (fixed) finger is released and the spiral spring (about the shutter shaft) causes the shutter to snap open. The elongated finger strikes the shock absorbing head of the release arm and holds the shutter in the open position. This arm returns in its stroke and forces the movable finger in, so that the flat spring closes over the pin and prevents the arm from returning to its extended position. As the release arm passes

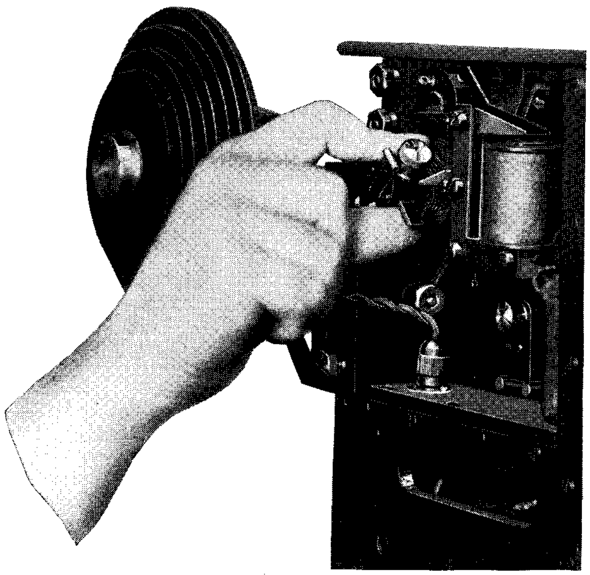


Fig. 14-A—Setting Shutter

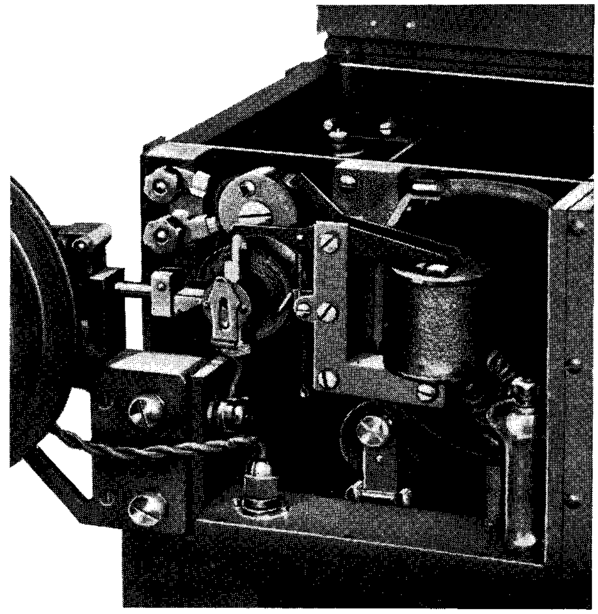


Fig. 14-B—Shutter and Remote-Control-Switch Set

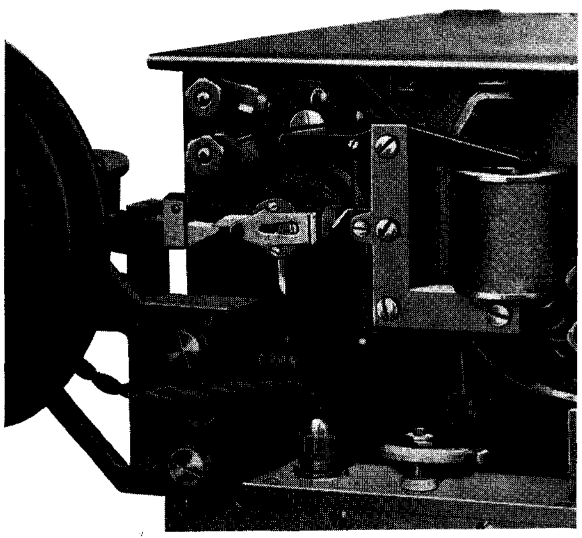


Fig. 14-C—Shutter Open and Switch Closed

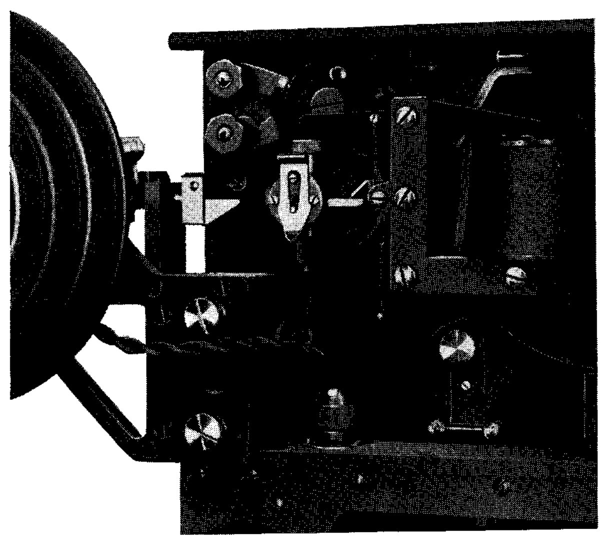


Fig. 14-D—Shutter Closed and Lamp Switch Open

Fig. 14—Shutter Mechanism, Remote Control Switch and Lamp Extinguishing Switch

away, it at last releases the second (movable) finger just one revolution after releasing the first. The spiral spring then snaps the shutter closed, as shown in Fig. 14-D. At the end of the stroke the closing shutter knocks open the lamp extinguishing switch (located between the trip-magnet and the optical box).

In actual operation the trip-magnet armature should remain down even after the current is cut off. The spring is set so that it will **not** return the armature against any residual magnetism tending to hold it down. If the spring tension is increased, so as to instantly return the armature, the armature will snap down again (during the active exposure) and the vibration resulting may be transmitted to the galvanometer elements and thus cause a very slight vibration on a fast oscillogram.

When the remote control switch is to be used, it should be set before setting the shutter. First, press down lightly on the trip magnet arm; then set the remote-control switch (with the finger knob) so as to catch on the slanting arm of the armature; then release the movable finger of the shutter head (by slightly extending the flat spring); then withdraw, twist, and set the shutter head in place (ready for another automatic operation).

B—The daylight-loading rotating-film holder is shown in Fig. 15. This is designed to use standard, non-autographic roll films. A ten exposure, # 3 A "Kodak" film will give five oscillograms, about 11.3 inches long, having an effective exposure of 10 x 3⅝″. In some cases half this length may be sufficient. In this case, ten oscillograms (5 x 3⅝″) may be taken on one standard ten exposure film.

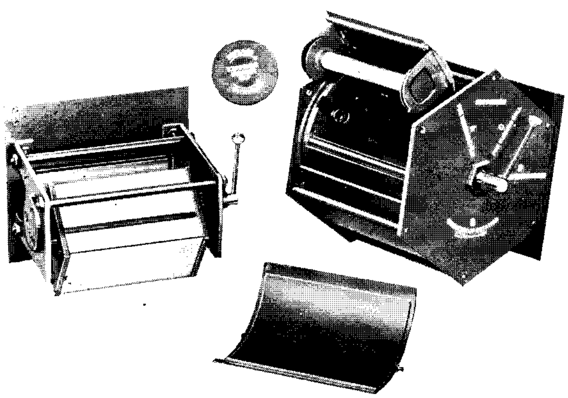


Fig. 15—Rotating Viewing Mirrors and Daylight-Loading, Rotating Film-Holder

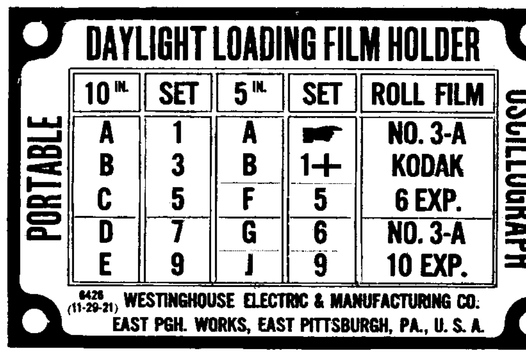
To load this film holder, first slip it in place on the oscillograph, with the shaft to the right, next to the driving head, then remove the case cover (by drawing in the bolts from each side), then insert the driving dog in the film shaft and turn this to position "A" (for inserting film). Open the inner cover (on the rotating drum) by forcing in the bolts (by means of the two pins) and swinging the unit out so that the film clips are free from the case. Place the roll-film between the clips with the slotted side of the spool to the left, away from the driving-head. Then spring the clips against the spool and insert them part way into the rotor. Then break the seal, withdraw a few inches of the opaque paper and snap the unit in place within the rotor. Then slowly rotate the dog through the "B" position to the "C" position, constantly holding on to the paper, permitting it to unroll from the spool. Keeping this paper tight, open the other inner unit and insert the tapered end of the paper in the longitudinal slot of the empty spool. Before fully inserting this whole unit in its place in the rotor, take up any slack in the paper by turning the spool dog protruding from one clip. Be sure that these two units are each securely bolted in place in the rotor before replacing the cover on the main case. Exert a little pressure on the cover in order to have the bolts snap in place.

With the light tight cover in place and with the shutter lever forced down (in the closed position), it is permissible to open the exposure number window. With the shaft dog in the "C" position, put pressure on the exposure cap and twist it (counter-clockwise), as indicated by the arrow over the word "WITHDRAW". This slips (through the medium of two pins) an inner sleeve into a cavity in the rotor, so that it is safe to remove the cap, for observation of the exposure number on the inside of the rotatable drum. To turn the film, first press in on the winding key and turn it (clockwise) until it engages with the spool dog and then continue to turn until the figure "1" appears in the round hole in the rotor. Never turn the key backward. Before rotating the drum, replace the exposure number cap and turn it clockwise until it locks the inner sleeve, in the casing, well away from the rotor.

Just before taking an oscillogram (after dog secures film shaft to the driving head and film is rotating at proper speed), open the film holder shutter by sliding the shutter lever up and over the case (about ⅜″). A flat spring, on the lever, will hold the shutter open. After the exposure, close the film holder shutter, set the dog in the "C" position, adjust the exposure number cap for observation, turn the film to figure "3" and replace the cap. This procedure should be followed whether or not the film is to be used immediately for another oscillogram. The film should never be set at the last figure on the roll, for this would not even give a correct exposure and would surely cause a jamming of the film when the drum is rotated. After the last oscillogram has been taken, turn the winding key until after the last end of the opaque paper has passed the observation window; then remove the case cover and slightly hold back on the paper (while turning the key) so that the paper will remain tightly wound on the spool; then (still holding the paper tight) open the spool compartment, remove the spool, completely roll up the paper and secure it with the gummed paper.

Notes—The film may be developed in a "Kodak" tank developer or in a dark room. Contrastive developer should be used (see notes on "Developing Films"). As a safety precaution, to prevent a possible catching of the strip of paper (securing the film to the opaque paper) on the edge of the inner door, carefully unroll the opaque paper from the unexposed film, until the forward edge of the gummed paper appears; then make certain that this is evenly stuck to the opaque paper so that it cannot catch on the edge of the second inner door (of the rotor). Generally this is in perfect condition, but occasionally one requires to be more completely stuck to the opaque paper. Re-roll the opaque paper (before inserting film in holder) taking care not to loosen it at any time, for such action would permit light to fog the film. A small flash light or a 6 volt lamp operated from the storage battery, would be a help in observing exposure numbers.

To load short oscillograms, follow the same procedure, except stop the dog at "B" and insert the opaque paper (about 3″) into the slot above the middle roller, than rotate the dog further on to the "C" position. The exposure number sleeve may be inserted at this time so as to lock the rotor conveniently in this position (for either the long oscillograms or the short oscillograms). Open the second spool compartment and catch hold of the end of the opaque paper and insert it in the longitudinal slot in the empty spool. Give this spool a few turns as it is forced into place in the rotor, close the cover and proceed as usual, except stop turning winding key when hand appears in observation window. The marking on the standard film is not strictly ideal for short oscillograms. It would be better to stop shortly before the hand appears, but as this is impracticable, the operator may turn film to "hand" position, for first oscillogram, and then turn film beyond figure "1" for the second oscillogram. The name plate on the film holder gives a table of settings for short and for long oscillograms, for use with either six exposure or ten exposure roll films. Remember that the film should **never** be set at the last figure of the roll, for the standard marking is always ahead of the actual oscillogram number (or letter). As seen from examination of the apparatus, extra frictional devices are provided to prevent the film from coming loose on the roll (provided the operator does not turn the winding key back, in the least).



10 IN.	SET	5 IN.	SET	ROLL FILM
A	1	A	☛	NO. 3-A
B	3	B	1+	KODAK
C	5	F	5	6 EXP.
D	7	G	6	NO. 3-A
E	9	J	9	10 EXP.

Fig. 16—Daylight-Loading, Rotating, Film-Holder Name Plate

C—The actual operation of the oscillograph is very simple. With personal instructions a man could learn to operate the oscillograph in less time than it takes to read the preceding instructions. The operation will prove very simple after a little practice.

To photograph recurrent phenomena, connect up lamp, motor, and galvanometer-field supply, as per preceding directions (according to supply available), connect leads from apparatus to be tested to element control panel, as per preceding directions; with optical system in proper adjustment, shutter open, and lamp control switch on 3 volt position, arrange light beams on ground glass as desired; close element switches (after inserting safe resistance) and adjust deflection so as to be wholly on the ground glass (experience will show how great a deflection and how fine a line may be used for a given film speed, and still give a good record).

A new operator, inexperienced in developing, cannot expect to take an oscillogram at such a high film speed that shows (successfully) only two or three complete cycles of a 60 cycle wave. Good results should be obtained on a 10″ oscillogram, showing ten cycles of a 60 cycle wave (or five cycles of a 25 cycle wave) at a film speed of approximately 240 rpm. Film speeds up to about six hundred rpm. should give good exposures when care is used in developing. Film speeds of 1000 rpm. may be used by a good operator when excellent developing and printing is to be done.

Note—For ideal oscillograms of a-c. recurrent phenomena, see notes on sychronously driven films (X-I and J).

For oscillograms of recurrent phenomena, it matters little as to when the trip-magnet releases the mechanical shutter. The adjustable contact, on driving head, may be set so as to cause the trip magnet to release the shutter (and remote-control switch) any desired fraction of a revolution ahead of the opening of the shutter. When no transients are to be controlled, set the contact (by knurled adjuster) so that it will short-circuit the brushes (in trip-magnet circuit) at anywhere from one-third to two-thirds of a revolution ahead of the opening of the shutter. This will give the lamp time to come up to abnormal brilliancy (after receiving abnormal voltage) before the exposure starts.

When ready to take an oscillogram, be sure that: the element switches are closed, the mechanical shutter set, the film holder in place (with dog connecting it to driving head), the motor driving the film at proper speed, and the film shutter open. Then: snap on the galvanometer field, turn lamp-control switch to the 3-volt position, and then **quickly** to the proper abnormal voltage position (as predetermined by setting the adjustable stop). Within a fraction of a revolution after the lamp-control switch strikes the conducting portion of the stop, the adjustable contact shorts the brushes, thus closing the circuit of the trip-magnet. The trip-magnet releases the shutter-finger and later the shutter opens, just before the forward edge of the film reaches the focal line, in front of the optical box. The shutter does not close until after the effective part of the film has passed by the focal line. The closing of the shutter extinguishes the lamp, thus preventing its destruction by the abnormal voltage. Snap open the galvanometer field switch ("Bat."—"Bat." position), open the motor switch, reset the shutter, and open the vibrator switches in preparation for a "zero line" record. Then repeat exposure,as before, only keep vibrator switches open.

D—The greatest value of the special features of this oscillograph is the ease and reliability of its operation for **transient phenomena. The remote control switch is used to start the mechanical action of remote controlled apparatus, a sufficient time before the opening of the shutter so that the actual start of the electrical phenomena will occur shortly after the exposure begins on the film.**

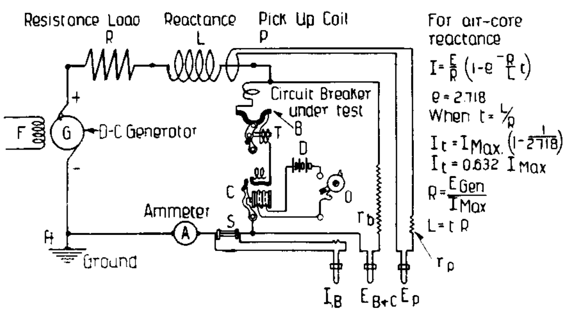


Fig. 17—Diagram of Connections for Studying Transient Phenomena of Circuit Switching

B = Circuit-breaker or switch under test.
T = Trip magnet of breaker.
C = Contactor used to close the circuit after start of film exposure.
O = Oscillograph remote control switch to start control apparatus.
D = Supply for contactor operating magnet.
S = Oscillograph, non-inductive shunt.
A = Ammeter for correct calibration of oscillograph and shunt.
I = "Amps."
E = "Volts".
G = D-C. Generator (with shunt field "F") voltage (e.m.f.)
R = Load resistance (total resistance of circuit should be used for figuring) "Ohms"
L = Load reactance (total reactance of circuit should be used for figuring) "Henrys".
P = Pick-up coil, about the core of the reactance (to show inductive kick).
H = Earth or ground connection, as a safety precaution.
t = Time, in seconds, as scaled from film "Seconds"
e = Natural base of logarithims (constant). 2.718

Most commercial apparatus is arranged for remote control. Where such is not the case, a magnetic contactor may be used to open or close the desired circuit; or a small magnet may be arranged to drop a weight which, in turn, closes a switch or driectly operates the mechanism in the desired way. The oscillograph switch may be set to compensate for the sum of all the lags entering into the controlling operation. The oscillograph switch may be placed directly in the exciting circuit of the electro-magnetic (or electro-pneumatic) control, such as is used on switchboard and electric car contactors, reversers, etc. As a safety precaution, when using larger contactors or higher voltages, it is advisable to insert a relay (or small contactor) in the control circuit. This is advisable for control potentials above 250 volts and for imputs above 100 watts. The oscillograph remote-control switch (see Fig. 14-B) may be used to either make or break the control circuit. When it is used to break the inductive circuit of the control apparatus, the operator should insert a condenser across the terminals leading to the oscillograph switch, so that the inductive kick will not cause a bad arc across the opening switch.

As an example of operation, assume it is desired to take a record of the transient that occurs when a contactor closes, thus starting a motor, or closing a field circuit, or throwing a short circuit onto a line containing a circuit-breaker. Open one of the leads passing to the electro-magnet and connect these ends to the oscillograph switch with one end to the binding post (below the shutter head) leading to the blade, and the other to the upper binding post. When the switch is set (held open by the trip-magnet arm) the circuit is open. Assume the contactor has a lag of approximately 0.10 second and that it will take approximately 0.12 second for the current to build up and trip the circuit-breaker (zero allowance for former in case breaker is tripped directly). Allow at least 10% for zero line (preceding transient) and at least 20% for possible extension of transient. Then the film exposure should be at least (0.12 + 0.012 + 0.024 =) 0.156 second. The fourth belt position, direct drive, would give a film speed of approximately (1700/7 =) 243 Rpm. when motor is operated on 60 cycles. For 25 cycle operation, the third belt position (3 to 1 reduction) would give approximately 230 Rpm. An exposure of 0.156 second on a 10 inch film (2/3 circumference), would correspond to ((60) / (0.156 x 3/2) =) 256 Rpm. Hence either of the above film speeds would be very satisfactory for this test.

Now assume the film drum is to be rotated at 243 Rpm. This corresponds to 0.247 second per revolution. Now if the brush contact (on driving head) is set for a lead of (0.10 ÷ 0.247 =) 0.40 revolution ahead of the position where the driving dog lines up with the optical slot ("D" position on film holder), then the transient will not appear on the film until after the exposure starts (allowing a slight lag for the oscillograph trip magnet).

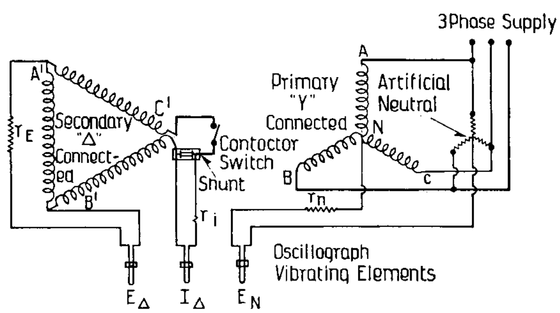


Fig. 18—Diagram of Connections for Studying Third-Harmonic Phenomena in Transformers Having Star Connected Primaries and Delta Secondaries; Before and After Closing Delta.

Oscillograph connections to show Third-harmonic Phenomena in Three-Phase Transformers (having high flux densities in cores) when Primary Coils are in Star and Secondary Coils in Delta.

Connect as per the above diagram. Connect contactor control-circuit through remote-control-switch of the oscillograph. Set adjustable contact, on driving-head of oscillograph, so that contactor-switch will close the "delta" a cycle (or two) after the film exposure begins.

The resulting oscillogram will show: (E_Δ) *The voltage wave distorted with a bad third-harmonic; the delta circulating current* (I_Δ), *at zero; the voltage between neutrals* (E_N), *three times the supply frequency; then, after the delta is closed, the voltage wave (in the secondary), similar in shape to that of the supply; the voltage between neutrals* (E_N), *practically zero; and the circulating current* (I_Δ) *three times supply frequency.*

#1 element, I_Δ = *Current circulating in delta connected secondary coils.*

#2 element, E_Δ = *e.m.f. across unopened side of delta secondary.*

#3 element, E_N = *e.m.f. from primary neutral to an artificial neutral.*

The same procedure is used for making oscillograms of transients as for recurrent phenomena, except that the remote-control switch must be set (after depressing trip-magnet arm) before the shutter is set.

Modern development in the electrical industry demands a larger and larger percent of transient oscillograms. Such work may be handled with ease with this outfit. The study of transient arc-rupture phenomena in switches, breakers, fuses, etc. is very important in the development of such apparatus, and very instructive to the student. See Fig. 21.

Inductive interference in telephone and telegraph lines, following transients in railway and power lines, may be studied very conveniently, with this outfit. The remote-controlled railway and power switches may be operated (through the medium of a contactor for safety) by the oscillograph remote-control switch.

Note—For inductive-interference work it is desirable to have the super-sensitive vibrator element.

Transients in transformers, reactances, choke-coils, electro-magnets, etc. can be readily studied with the aid of the remote-control switch.

E—The slow speed long-film attachment (Fig. 19) is very desirable for records of transient phenomena which persist for several seconds or minutes. With this outfit, one may take a continuous exposure about 58″ long. It may be instantly attached to the oscillograph in place of the rotating-drum film-holder. It has a possible speed variation from approximately 0.13″ per second to 6.3″ per second (when 25 and 60 cycles supply is available), thus taking continuous exposures

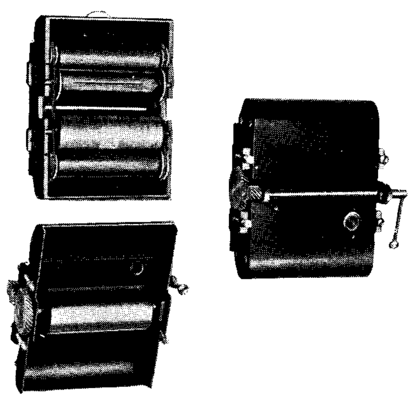


Fig. 19—Slow-Speed, Long, Film-Holder

from approximately 9.3 to 440 seconds (7 min. 20 sec.).

This slow-speed long-film attachment slips onto the face-plate of the oscillograph in place of the standard rotating-film holder. The shutter arm end should be above, when properly located on the oscillograph. In this position the larger of the internal pulleys will be located below and the smaller ones above the optical slot, so that when the film drum is turned so as to pass the film upward, the larger pulleys drive the smaller ones through spiral spring belts, thus rolling up the film after exposure.

With this attachment in place (on the oscillograph), remove the case cover (after loosening thumb screws). The gear train and main driving drum make a unit with the cover. Take a #3 A "Kodak" roll film and insert two of the spool shaft-extensions in ends of spool. Unseal cartridge and unroll about two inches; then insert the shaft-extensions of the spool in the grooves provided so that the cartridge is in place over the lower roller with the opaque paper extending up from the nearest side of the spool. Insert the tapered end of the opaque paper in the longitudinal slot of the empty spool (which should be located with its shaft extensions in the grooves under the upper roller). Give this empty spool a few turns so as to roll the opaque paper up from the unexposed spool over the forward (nearest) surface of the empty spool and thus on around it. This method of loading will result, later, in having the sensitive film facing the oscillograph. Replace the cover, with the main driving drum attached, so that the drum forces both spools back and into their respective vertical slots. At the same time, the drum will cause the opaque paper to unroll slightly from each spool and thus put the spiral spring belts (attached to pulleys at each end of each roller) in tension. The combined forces of the springs tend to force each spool tight against the driving drum. The unbalanced force of each spring tends to help wind up the exposed film and retard the unwinding of the unexposed film. The driving drum should be rotated so as to cause the film to pass up in front of the optical opening in the focal line of exposure. The figures printed on the opaque paper may be observed through the red window in the cover. When the printed hand appears, the edge of the film is ready for the exposure to start. For slow speed work, the film is usually started by closing the motor switch. The shutter must be propped open by the arm (extending from lower left-hand corner of trip-magnet core).

If desired, the shutter may be set (with crank in outward position); the trip magnet brushes shorted by the adjustable contact; the lamp-control switch held (by coin) in the 3.5 volt position; the motor switch closed; the d-c. field connected through the remote control switch; and the supply switch open, so that it is only necessary to close the supply switch (at any time) to start everything in a fraction of a second.

With this long-film attachment, the operator may take either a continuous exposure, over the whole 60″, or several intermittent exposures (the progress of the film being observed by noting the figures as they pass the red window).

The special features of this outfit keep the film tight and cause it to pass at uniform velocity and automatically roll up again, so that it may be removed without the help of a dark room.

F—Most commercial testing, especially on d-c. power circuits, requires shunts capable of handling the full line current. Station ammeter-shunts are too inductive to give true oscillograph records of quick changes in current. For slow speed oscillograph work, it is permissible to use a 50 or a 100 milli-volt shunt with a super-sensitive vibrator element. The standard vibrator element requires at least 200 milli-volts, shunt drop, to give a good deflection.

The variable non-inductive shunt, (Fig. 20) is designed to cover a very broad field of testing. It has a continuous capacity of 1000 amperes and will give a good deflection (with standard vibrator element) at currents from 20 amperes up (with strips all in series). Instantaneous currents as high as 25,000 amperes may be recorded with the help of this shunt. As seen from the photograph, this shunt has five non-inductive strips which may be instantly changed from a series to a parallel (or series parallel) arrangement to accommodate moderate or heavy currents. For certain work this unit may be re-connected for use as five separate shunts with 200 ampere capacity each (provided there is not much of a potential difference between any of the circuits).

For parallel connection of the strips, tighten the wing nuts on the longitudinal bus-bars. For series connection of the strips, tighten the upper left-hand wing-nut; then tighten as many additional wing-nuts on the slanting bus-bars as one desires additional units in series; then tighten the wing-nut on the lower bus-bar, below the last wing-nut which was tightened on the slanting bars.

If the sensitivity of the outfit is found with but one strip used in the shunt and with zero setting of the resistance dial switch, then:

$$C = (c/r)\ (r + R)\ (P/S)$$

approximately.

where C = sensitivity of unit in amperes (line) per each inch deflection.

R = resistance setting on dial.

r = resistance of element circuit when R = O

P = number of strips in parallel

S = number of strips in series.

c = current in amperes per inch deflection when P = 1, S = 1, and R = O

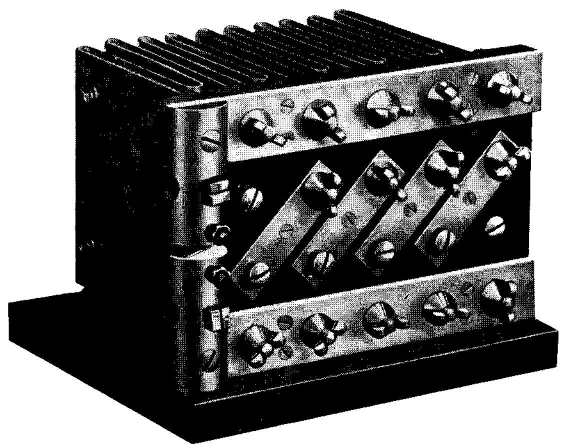


Fig. 20—Variable, Non-Inductive Shunt—20 to 1000 Amperes—(Continuous)

Thus "R", "P", and "S" may be varied to suit conditions, and "C" can be figured after determining "c" and "r". **Note**: "c" is approximately 40 and "r" may be as small as 1 ohm. Also "R" may be varied from 0 to 100 (ohms). For more accurate work, the true ratio of resistances for the various connections should be determined before figuring the results.

The fourth reflecting prism and adjustable slot (in optical box) were provided so that a timing mechanism (or a recorder) could be installed so as to give time dashes (or telegraphic dots and dashes) along one edge of the photographic film, in time phase with the oscillograph record. The operator may construct

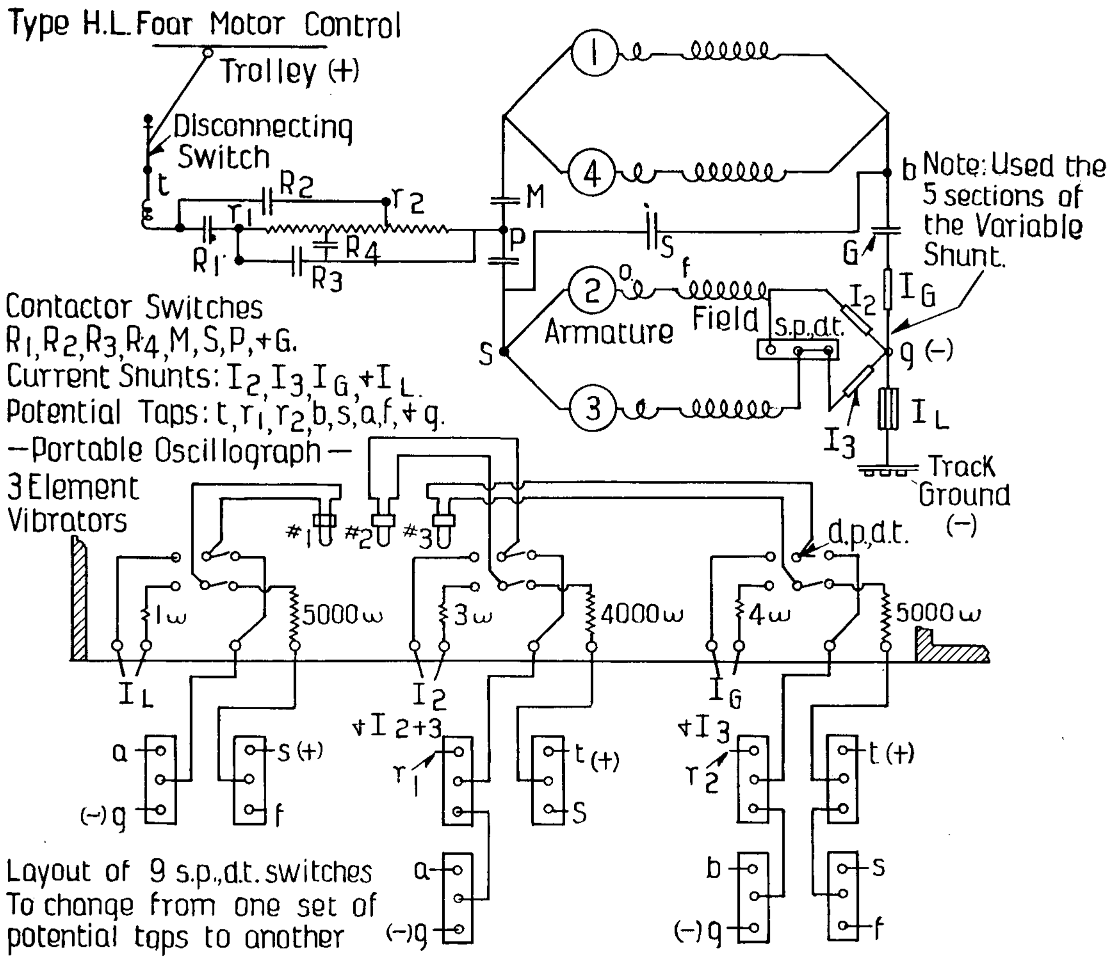


Fig. 21—Diagram of Oscillograph Test on Moving Electric Car Equipped With Type HL Control*

The work to be divided into the following classes:

Switching: Characteristics; Arc Division between various Switches.
Reversing: Reverse & Loop; Braking on Loop; Reversing with Power
Transition: "Series-Parallel" to "Parallel" connection of Motors.
Acceleration: Per Step; Complete Cycle.

The # 1 vibrator element was used to show the following:

E.M.F. of # 2 armature	Potential Taps	s to a
E.M.F. across the "S" Contactor (# 2 motor)	Potential Taps	s to g
E.M.F. across the # 2 compensating field	Potential Taps	f to a
E.M.F. across the # 2 main series field	Potential Taps	f to g
Current in line	Shunt	I_L

The # 2 vibrator element was used to show the following:

E.M.F. across "R_1" Contactor	Potential Taps	t to r_1
E.M.F. from trolley to ground	Potential Taps	t to g
E.M.F. across # 2 armature	Potential Taps	s to a
Current in the # 2 motor circuit	Shunt	I_2
Current in # 2 and # 3 motor section	Shunt	I_2+3

The # 3 vibrator element was used to show the following:

E.M.F. across # 2 compensating field	Potential Taps	f to g
E.M.F. across "R_2" contactor	Potential Taps	t to r_2
E.M.F. across the "S" circuit breaker	Potential Taps	s to b
Current in "G" switch	Shunt	I_G
Current in # 3 motor	Shunt	I_3

*See article on Portable Oscillograph by J. W. Legg, in Electric Journal, December, 1920.

this apparatus, or any other device which may be desired, to meet particular commercial requirements. These devices should be constructed so as to have the intermittent motion cut off the light from a stationary mirror so as to give an intermittent line on one edge of the film. As an example: Cement a spare vibrator mirror on a small ball; have a knurled headed pin protrude at right angles to the mirror (for adjusting the beam to be reflected onto the edge of the film); mount the ball in clips and fasten same inside optical box on a level with the vibrator mirrors so as not to interfere with other beams; then mount the tuning-fork, buzzer, clock-work, or other mechanism, so that an extension from the moving part will interrupt the light intermittently. This enables the operator to tie up the oscillograph record with other apparatus (such as a graphic-meter, clock pendulum, etc.).

G—It may be desirable to have the oscillograph operate automatically to record the opening of a large oil breaker under a chance short circuit. This is possible with this outfit, especially in the case of a great power system, where it usually takes more than one or two-tenths of a second for the arcing contacts to part, after the short circuit has started. The only additional apparatus that is required is a quick-acting relay to operate from the secondary of a current transformer. The galvanometer field must be fed (at normal current) from 110 volts (more or less) through an external rheostat. This reduces the time-constant of the circuit so that the field current builds up much faster, reaching normal current in about one-twentieth the time it would have taken had normal voltage been applied. **Note**: If the field coil had been designed for 110 volts, it would take 2000 volts d-c. (through suitable additional resistance) to give the same effect.

To re-connect the oscillograph for automatic operation, remove the heavy leads from the lamp-extinguishing switch and connect them together; connect this switch in series with the supply (feeding lamp, trip-magnet, and motor) and also in series with the contacts on the quick acting relay (the relay must be adjusted so that it will remain closed when once actuated by a heavy overload on the power lines); place a 2 ampere fuse in the 3 ampere field circuit (so that the fuse will blow, and open the field circuit, soon after the oscillogram is taken) and insert the remote-control switch in this circuit, with switch open when set; slide film holder in place and have driving head in such a position that the slightest rotation will cause the arm to release the shutter (thus starting the exposure); set the adjustable contact so that it shorts the trip-magnet brushes in this position; secure lamp-control switch pointer (at proper abnormal voltage position) to the stop, electrically, so that the trip-magnet will operate the instant the supply circuit is closed; connect the vibrator elements to circuits to be studied, through proper resistances, shunts, etc.; then, when all else is ready, open film-holder shutter and place a large box (or other covering) over the whole oscillograph outfit, to protect it from dust and undue light.

The desired transient may not come until days or weeks later, but, nevertheless, if all is properly set, a heavy overload, or chance short circuit, will cause the quick-acting relay to connect in the supply; this will immediately start the motor, put abnormal voltage on the incandescent-filament lamp, and operate the trip-magnet; this will release the remote-control switch which will close the field circuit; the motor will rotate the film, through the driving head; the receding arm will release the shutter so that the exposure may start near the beginning of the film; a record will be made of the overload current before the arcing tips part; the arc voltage will then be recorded while the current is brought to zero; the open circuit voltage will be recorded, before the exposure ceases at the end of the film; the shutter will close and knock out the switch, which opens the supply circuit, thus stopping the motor and extinguishing the light; the overloaded fuse will then clear the field circuit and thus complete the automatic operation.

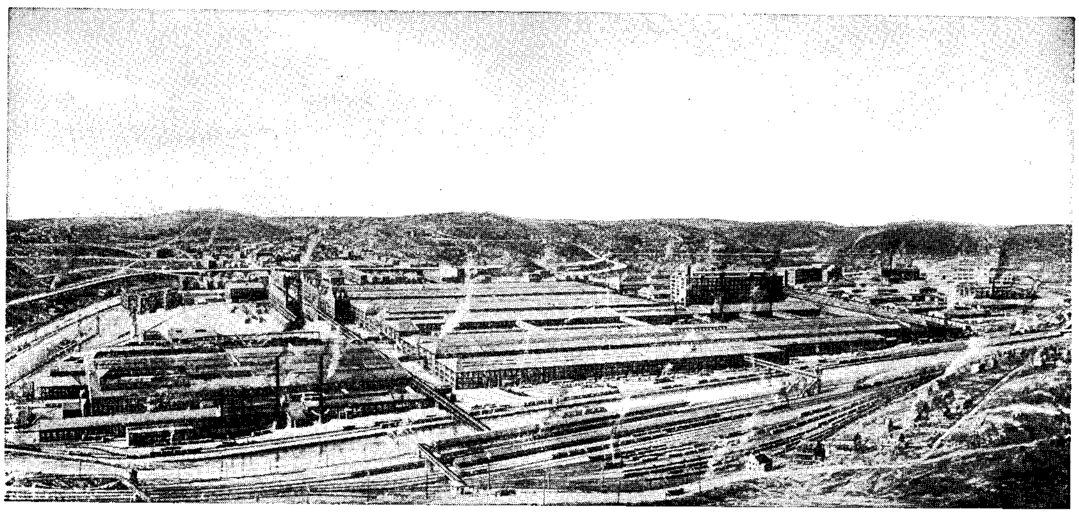
When the supply is 25 cycles, the motor comes up to speed in a very short time so as to start the exposure in from 0.1 to 0.2 second from the closing of the quick acting relay, and give the film a uniform velocity for an exposure of one-half second (or more) on a ten-inch film.

H—Several portable oscillographs may be operated simultaneously to show different phases of the same transient. These osillographs may be located on the same table or they may be scattered in different towns or different sub-stations along the same net-work of power lines. Each oscillograph can be set zero. All of these are indications of a loose mirror. In such a case, remove the old mirror, with a razor blade, and clean the vibrator strips with a little alcohol on the end of one

it is well to have a spare element ready at all times.

XVIII—REMOVAL OF PARTS

It is seldom necessary to remove any part



The Company's Works at East Pittsburgh, Pa.

Westinghouse Products

A few of the Westinghouse Products are listed below and will furnish some idea of the great variety of electrical apparatus manufactured by the Company and the many extensive fields for their use.

For Industrial Use

Instruments
Motors and controllers for every application, the more important of which are: Machine shops, woodworking plants, textile mills, steel mills, flour mills, cement mills, brick and clay plants, printing plants, bakeries, laundries, irrigation, elevators and pumps.
Welding outfits
Gears
Industrial heating devices, such as: Glue pots, immersion heaters, solder pots, hat-making machinery and electric ovens.
Lighting Systems
Safety switches

For Power Plants and Transmission Lines

Solder and soldering fluids
Stokers
Substations, portable and automatic
Switchboards
Synchronous converters
Transformers
Turbine-generators

For Transportation

Locomotives
Railway equipment
Marine equipment

For Mines

Lamps
Locomotives
Motors for hoists and pumps
Motor-generators
Portable substations
Switchboards

Incandescent lamps
Small motors for driving addressing machines, dictaphones, adding machines, cash carriers, moving window displays, signs, flashers, envelope sealers, duplicators, etc.
Ventilating outfits

For Electric and Gasoline Automobiles and the Garage

Battery charging outfits
Charging plugs and receptacles
Lamps
Instruments
Motors and controllers
Small motors for driving lathes, tire pumps, machine tools, polishing and grinding lathes.
Solder and soldering fluids
Starting, lighting and ignition

Westinghouse Electric & Manufacturing Company

East Pittsburgh, Pa.

WESTINGHOUSE DISTRICT OFFICES

ALBANY, N. Y., Journal Building.
ATLANTA, GA., Candler Bldg., 127 Peachtree St.
BALTIMORE, MD., Westinghouse Bldg., 121 E. Baltimore St.
BIRMINGHAM, ALA., Brown-Marx Bldg., First Ave. and Twentieth St.
BLUEFIELD, W. VA., Law and Commerce Building, Federal and Raleigh Sts.
BOSTON, MASS., Rice Building, 10 High St.
BUFFALO, N. Y., Ellicott Square Bldg., Ellicott Square.
BUTTE, MONT., Montana Electric Co. Bldg., 52 East Broadway.
CHARLESTON, W. VA., Kanawha National Bank Bldg., Capitol and Virginia Sts.
CHARLOTTE, N. C., Commercial Bank Bldg., Rooms 409-10-11.
CHATTANOOGA, TENN., Hamilton National Bank Building, 701 Market St.
CHICAGO, ILL., Conway Bldg., 111 W. Washington Street.
CINCINNATI, O., Westinghouse Bldg., Third and Elm Sts.
CLEVELAND, O., Swetland Bldg., 1010 Euclid Ave.
COLUMBUS, O., Interurban Terminal Bldg., Third and Rich Sts.
DALLAS, TEX., Exchange Bldg., Akard and Wood Street.
DAYTON, O., Reibold Bldg., South Main St.
DENVER, COLO., Gas and Electric Bldg., 910 Fifteenth St.
DES MOINES, IOWA., 608 Securities Bldg., 412 W. Seventh St.
DETROIT, MICH., Dime Savings Bank Bldg., Fort and Griswold Streets.
DULUTH, MINN., Alworth Bldg., 306 West Superior St.
EL PASO, TEX., Mills Bldg., Oregon and Mills St.
FRESNO, CAL., J and Mariposa Streets.
HOUSTON, TEX., Union National Bank Building, Main and Congress Streets.
INDIANAPOLIS, IND., Traction Terminal Bldg., Illinois and Market Sts.
JACKSONVILLE, FLA., Union Terminal Warehouse, East Union and Ionia St eets
KANSAS CITY, MO., Orear-Leslie Bldg., 1012 Baltimore Ave.
LOUISVILLE, KY., Paul Jones Bldg., 312 Fourth Ave.
LOS ANGELES, CAL., I. N. Van Nuys Bldg., Seventh and Spring Streets.
MEMPHIS, TENN., Exchange Bldg., 6 N. Second St.
MILWAUKEE, WIS., First National Bank Bldg., 425 E. Water St.
MINNEAPOLIS, MINN., Met. Life Insurance Bldg., 119- S Third St.
NEW ORLEANS, LA., Maison Blanche Bldg., 921 Canal St.
NEW YORK, N. Y., City Investing Bldg., 165 Broadway.
NIAGARA FALLS, N. Y., 205 Falls Street.
PHILADELPHIA, PA., Widener Bldg., 1325-1329 Chestnut St.
PITTSBURGH, PA., Union Bank Bldg., 306 Wood St.
PORTLAND, ORE., Northwestern Bank Bldg., Broadway and Morrison Sts.
ROCHESTER, N. Y., Chamber of Commerce Bldg., 119 E. Main Street.
ST. LOUIS, MO., 300 N. Broadway.
SALT LAKE CITY, UTAH. Walker Bank Bldg., Second Street South and Main Sts.
SAN FRANCISCO, CAL., First National Bank Bldg., 1 Montgomery St.
SEATTLE, WASH., Westinghouse Bldg., W. Spokane Street and E. Marginal Way.
SYRACUSE, N. Y., University Bldg., 120 Vanderbilt Square.
TOLEDO, O., Ohio Bldg., Madison Ave and Superior St.
TUCSON, ARIZ., Immigration Bldg., 90 Church Street.
WASHINGTON, D. C., *Hibbs Bldg., 723 Fifteenth St., N. W.
WILKES-BARRE, PA., Miner's Bank Building, W. Market and Franklin Streets.
The Hawaiian Electric Company, Ltd., Honolulu, T. H.—Agent

*Government business exclusively.

WESTINGHOUSE AGENT JOBBERS

ATLANTA, GA., Gilham Schoen Electric Co.
BIRMINGHAM, ALA., The Moore-Handley Hardware Co.
BLUEFIELD, WEST VIRGINIA, Superior Supply Co.
BUFFALO, N. Y., McCarthy Bros. & Ford
BUTTE, MONTANA, The Montana Electric Co.
CHICAGO, ILL., Illinois Electric Co.
CINCINNATI, OHIO, The Johnson Electric Supply Co.
CLEVELAND, OHIO, The Erner Electric Co.
DENVER, COLO., Mine & Smelter Supply Co.
DETROIT, MICH., Commercial Electric Supply Co.
EL PASO, TEXAS, Mine & Smelter Supply Co.
EVANSVILLE, IND., The Varney Electrical Supply Co.
HOUSTON, TEXAS, Tel-Electric Co.
HUNTINGTON, WEST VIRGINIA, Banks Supply Co.
INDIANAPOLIS, IND., The Varney Electrical Supply Co.
JACKSONVILLE, FLA., Pierce Electric Co.
KANSAS, CITY, MO., Satterlee Electric Co.
LOS ANGELES, CAL., Illinois Electric Co.
LOUISVILLE, KY., Tafel Electric Co., Inc.
MEMPHIS, TENN., Riechman-Crosby Co.
MILWAUKEE, WIS., Julius Andrae & Sons Co.
NEW HAVEN, CONN., Hessel & Hoppen Co.
NEW ORLEANS, LA., Electrical Supply Co.
NEW YORK, N. Y., Alpha Electric Co.
OKLAHOMA CITY, OKLA., United Electric Co.
OMAHA, NEB., The McGraw Co.
PHILADELPHIA, PA., H. C. Roberts Electric Supply Co.
PITTSBURGH, PA., Robbins Electric Co.
PORTLAND, ORE., Fobes Supply Co.
RICHMOND, VA., Tower-Binford Electric & Mfg. Co.
ROCHESTER, N. Y., Rochester Electrical Supply Co.
SALT LAKE CITY, UTAH, Intermountain Electric Co.
SAN FRANCISCO, CAL., Electric Rwy. & Mfrs. Supply Co.
SCRANTON, PA., Penn. Electrical Engineering Co.
SEATTLE WASH., Fobes Supply Co.
SIOUX CITY, IOWA, The McGraw Co.
SPOKANE, WASH., The Washington Electric Supply Co.
ST. JOSEPH, MO., Columbian Electrical Co.
ST. LOUIS, MO., Central Telephone & Electric Co.
ST. PAUL, MINN., St. Paul Electric Co.
SYRACUSE, N. Y., H. C. Roberts Electric Supply Co.
TAMPA, FLA., Pierce Electric Co.
TULSA, OKLA., United Electric Co.
WICHITA, KANSAS, United Electric Co.

WESTINGHOUSE SERVICE SHOPS

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BALTIMORE, MD.	501 East Preston St.
BOSTON, MASS.	12 Farnsworth St.
BUFFALO, N. Y.	141-157 Milton St.
CHICAGO, ILL.	32 South Peoria St.
CINCINNATI, O.	Third and Elm Sts.
CLEVELAND, O.	1255 West Fourth St.
DENVER, COLO.	1909-11-13-15 Blake St.
DETROIT, MICH.	Westinghouse Bldg., 6th St.
HARTFORD, CONN.	220 Market St.
LOS ANGELES, CAL.	2019 Bay St.
NEW YORK, N. Y.	467 Tenth Ave.
PHILADELPHIA, PA.	214-220 North 22nd St.
PITTSBURGH, PA.	6905 Susquehanna St.
ST. LOUIS, MO.	1906 Pine St.
SALT LAKE CITY, UTAH	573 W. 2nd St. So.
SAN FRANCISCO, CAL.	1400 Fourth St.
SEATTLE, WASH.	3451 East Marginal Way.
SPRINGFIELD, MASS.	82-86 Worthington St.

WESTINGHOUSE MARINE SERVICE PORT ENGINEERS

BALTIMORE	109 South Street
NEWPORT NEWS	Foot Warwick Pier
NEW ORLEANS	921 Canal Street
NEW YORK	596 Court Street, Brooklyn
PHILADELPHIA	1442 Widener Bldg.
SAN FRANCISCO	141 Second Street
SAVANNAH	406 E. 39th Street

CANADIAN COMPANY

CANADIAN WESTINGHOUSE COMPANY, LTD., Hamilton, Ontario

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