SWITCHES FOR SPECIAL PANELS

Standard switches can be mounted on any thickness of panel up to the maximum specified. Switches can be had at somewhat increased cost with shafts or bushings made for mounting on any one of the following panel thicknesses: 1/16″, 1/8″, 1/2″, 3/4″, 1″, 1½″ and 2″.

SWITCHES WITH SPECIAL ROTATION OR OFF POSITION

Switches with less than the maximum number of taps are furnished ordinarily with the standard contact spacing of 30° (40° for Model 608). However, switches of limited number of taps, as shown in the table, can be supplied (at increased cost) with the contacts spaced 2 or 3 times standard. Switches can be made, also, without a stop so that there are no end positions to the shaft rotation. Switches with less than the maximum number of taps can be made with an off position.

Model	Maximum No. of Taps	Tap Spacing	Total Rotation (Maximum)
212, 312, 412	6	60°	300°
212, 312, 412	4	90°	270°
608	4	80°	240°
608	3	120°	240°

ELECTRICAL RATINGS

The ratings given for Ohmite Power Tap Switches are interrupting (and standstill) ratings for use only on alternating current circuits, either inductive or non-inductive, i.e., at any power factor. Switches may be used on voltages up to 600, and current ratings between 300 volts and 600 volts are proportional to the difference in voltage with the current reduced to 50% at 600 volts. The switches may be used on direct current *non-inductive circuits up to 20 volts* at full current ratings: recommendations for other conditions will be supplied on request.

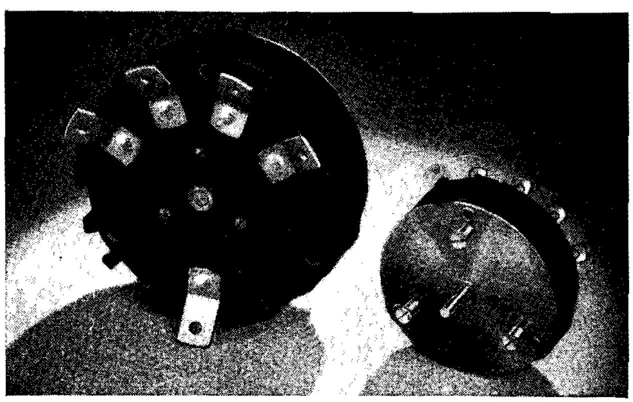
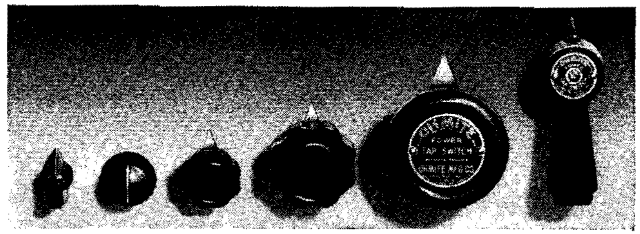


Fig. 138—Cat. No. 608-4 and No. 412-5 Switches

SWITCH INSULATION

All models of these switches withstand testing at 3000 volts A.C. with the voltage applied either between taps or to ground (between contacts and shaft), but such voltages should not be considered as the working voltage. The ceramic insulation is permanent in nature, unaffected by age and resistant to arcing.

TAP SWITCH KNOBS



4516 4500 4509 4510 4511 4512 4508, 4513 4514, 4517 4515

Fig. 139 Knobs for Tap Switches (see table for details)

These knobs are made of black bakelite. They fasten by means of two set screws except No. 4500 which has only one, and No. 4515 which requires a tapped hole and a driving pin as illustrated on the shaft of the Model 608 Tandem Assembly (Fig. 127). Pointers are nickel-plated. Numbers 4500, 4509, 4510 and 4516 are for use with Models 111, 212 and 312; the larger knobs are preferred for Model 412.

ORDERING: When ordering tap switches always specify: "With Knob Cat. No. —", or if none is wanted specify: "Without Knob". If the order does not state whether or not knobs are wanted, our standard knobs will be shipped on orders for tap switches up to 25 in quantity, and billed as a separate item.

Description	Knob Dia.	Hole Dia.	Cat. No.
Knurled Knob	1½″	¼″	4500
Handwheel with Pointer	3¼″	3/8″	4508
Finger-Grip with Pointer	1 5/8″	¼″	4509
Finger-Grip without Pointer	1 5/8″	¼″	4510
Finger-Grip with Pointer	2 3/8″	¼″	4511
Finger-Grip without Pointer	2 3/8″	¼″	4512
Handwheel with Pointer	3¼″	¼″	4513
Handwheel without Pointer	3¼″	¼″	4514
Bar Knob, 4¾″ long	......	3/8″	4515
Bar Knob, 1½″ long	......	¼″	4516
Handwheel without Pointer	3¼″	3/8″	4517

ALL PORCELAIN OPEN-TYPE TAP SWITCHES

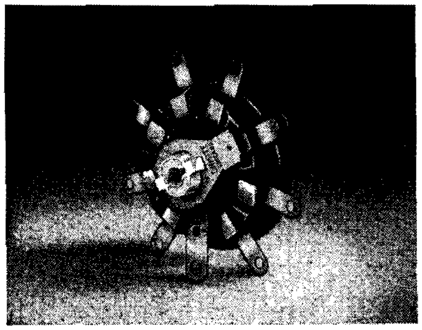


Fig. 140—A Non-shorting Switch (T-508)

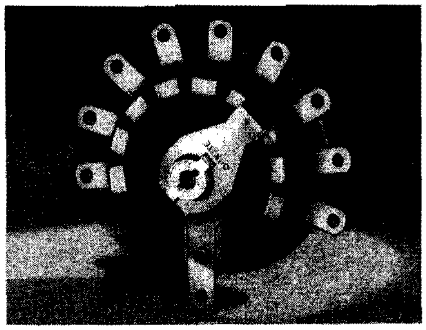


Fig. 141
A Shorting Type Switch (T-1009-S)

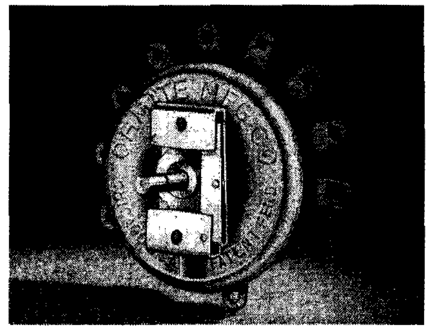


Fig. 142—Ratchet Action Mechanism in Place on a Tap Switch

These selector tap switches are designed to transfer currents of several amperes in circuits requiring high voltage insulation. They are ordinarily of the shorting type but non-shorting type switches are available also.

DESCRIPTION: The same type of all ceramic, vitreous enameled construction is used as in Ohmite Rheostats Models J and K, described on pages 38, 46 and 47. The bushing and shaft are insulated from the electrical circuit by ceramic parts which will withstand a *test voltage* of 3000 Volts A.C. Contact is made to the monel metal taps by a silver-graphite contact brush of very low resistance.

SHORTING TYPE SWITCH: The taps are set close together so that the contact brush smoothly bridges or shorts from one tap to the next as it is rotated. Thus the circuit is made with each succeeding tap before it is broken with the previous one. The switch arm is not indexed in any way and is free to stop in any position.

NON-SHORTING TYPE SWITCH: The circuit is opened as the moving contact leaves the tap. There is a modified snap action due to an indexing feature.

RATCHET ACTION: A ratchet action indexing mechanism for shorting type switches definitely positions the contact over each tap. The mechanism adds $\frac{9}{32}$" to the depth behind the panel. The switch then mounts by two No. 10-32 screws located $\frac{3}{4}$" on each side of the shaft (see Fig. 142). The mechanism can be ordered so that the contact stops in position to bridge between pairs of contact.

Ratchet Action—Stopping on Lugs........................Code Word: RATAP
Ratchet Action—Bridging between Lugs..............Code Word: RATEB

TANDEM MOUNTINGS: Two, three, or more switches can be ganged by means of frames similar to those used for rheostats and illustrated on pages 52 and 53. Details on request.

MOUNTING: Single hole mounting by means of $\frac{3}{8}$" diameter bushing, accommodating panels up to $\frac{1}{4}$" thick (maximum). See page 49 for bushings for special panel thicknesses.

KNOB: Black bakelite knob Stock No. 4500, page 83, supplied with stock units. Other knobs with $\frac{1}{4}$" hole, as listed on page 83, can be used if desired.

SPECIAL SWITCHES: Switches with solid silver contact points, special angles between taps, larger switches with as many as 25 contact points, and switches with other special features can be furnished.

CURRENT AND VOLTAGE RATINGS: Maximum *standstill* current is 7 amperes. Maximum current which should be interrupted is 3 amperes at 120 V., Alternating Current. Current ratings are less for all direct current circuits above 20 volts, for inductive circuits and for high voltages. Recommendations given on receipt of details. The rating is also dependent upon the expected frequency of operation of the switch. Arcing in inductive circuits can often be greatly diminished by suitable condensers bridged across the contacts.

DIMENSIONS: Switches up to and including 8 points have the same dimensions as Fig. 79, Page 47; switches up to 12 points are similar to Fig. 75, Page 46.

SHORTING TYPE			NON-SHORTING TYPE		
No. of Contacts	Approx. Degrees Rotation	Cat. No.	No. of Contacts	Approx. Degrees Rotation	Cat. No.
4	90	T-504-S	4	180	T-504-A
5	120	T-505-S	5	180	T-505
6	150	T-506-S	6	296	T-506
7	180	T-507-S	7	270	T-507
8	210	T-508-S	8	296	T-508
9	210	T-1009-S	9	288	T-1009
10	236	T-10010-S	10	288	T-10010
11	262	T-10011-S	11	288	T-10011
12	288	T-10012-S	12	288	T-10012

See Page 33 for Band Change Switch for Radio Use.

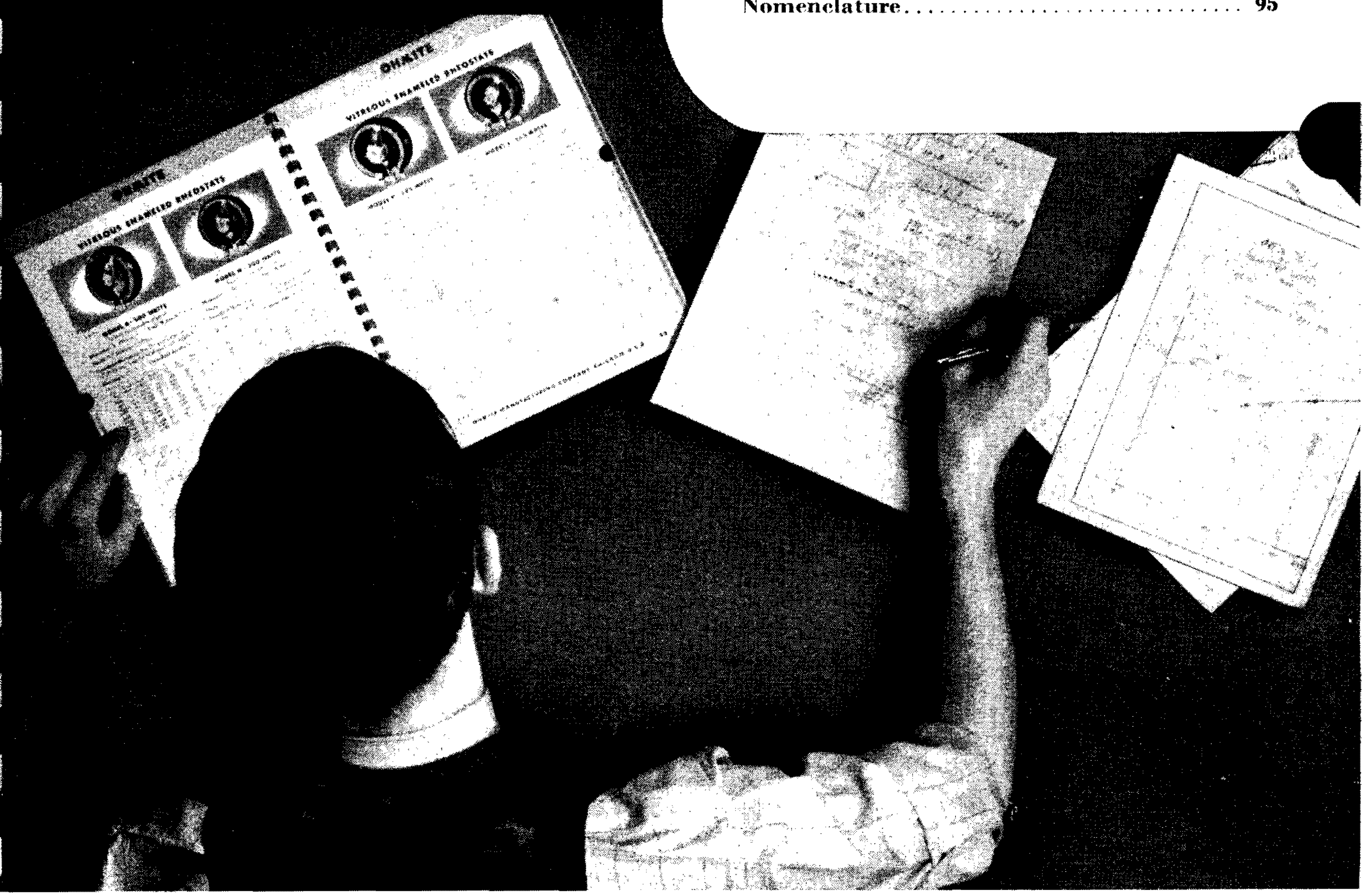
GEORG SIMON OHM

1789-1854

In 1827, Dr. Georg Simon Ohm mathematically demonstrated the relation between resistance, voltage and current in electrical circuits. Ohm's Law is fundamental in all resistance calculations, and is the basis for much of the computation in the pages which follow.

MANUAL

of Resistance Measurements and Engineering Information



HOW TO MAKE RESISTANCE CALCULATIONS

OHM'S LAW

The fundamental law of the electric circuit is Ohm's Law which has been stated as follows: *The current in a circuit is directly proportional to the E.M.F. (Electromotive Force) in the circuit and inversely proportional to the resistance.* In formula form it is:

$$I=\frac{E}{R} \text{ or } R=\frac{E}{I} \text{ or } E=IR$$

The following formula, also used in connection with resistor calculations, expresses the basic fact that the power in watts is equal to the product of the volts and amperes:

$$W=IE$$

Because $E=IR$ this can be written:

$$W=I\times IR \text{ or } W=I^2R \text{ or } W=\frac{E^2}{R}$$

Ohm's Law can be expressed in several different forms, all of which are conveniently tabulated below. Note that in working out any problem, all terms must be reduced to volts, amperes and watts when used in any of the formulae. For example, 30 milliamperes must be written as 0.030 amperes, 2.5 K.W. must be written as 2500 watts, 1 megohm as 1,000,000 ohms, and so forth.

W=Watts	EI	I^2R	$\frac{E^2}{R}$			
E=Volts		IR		$\sqrt{WR}$		$\frac{W}{I}$
I=Amperes			$\frac{E}{R}$	$\sqrt{\frac{W}{R}}$	$\frac{W}{E}$	
R=Ohms	$\frac{E}{I}$				$\frac{E^2}{W}$	$\frac{W}{I^2}$

Fig. 143—Table of Ohm's Law Formulae for Direct Current Circuits

Ohm's Law for Alternating Current

Ohm's Law in the forms given in Fig. 143 applies to direct current circuits. However, the same formulae can be used for alternating current circuits, provided the amount of inductance (because of coils) or capacity (because of condensers or distributed capacity) in the circuit is negligible. Thus, for commercial frequencies (25 or 60 cycles) Ohm's Law can be used for the calculation of circuits involving heaters, lamps, vacuum tube filaments, etc., which for all practical purposes may be considered as pure resistances.

Even in circuits which have reactance, the direct current form of Ohm's Law still applies so far as the resistor itself is concerned (even at frequencies at the high end of the audio frequency range), because the reactance of the resistor, in that frequency range, is generally negligible when compared to the resistance. This is not true, however, at radio frequencies. Non-inductive type resistors are used at the radio-frequencies in order to minimize the changes due to frequency (see page 30).

The formulae given in Fig. 144 apply to single-phase alternating circuits containing reactance, such as circuits involving relays, magnets, solenoids, motors, chokes and filter circuits. It can be noted that these formulae reduce to the same form as the direct current formulae when the reactance is zero and cosine Θ thereupon becomes equal to 1.

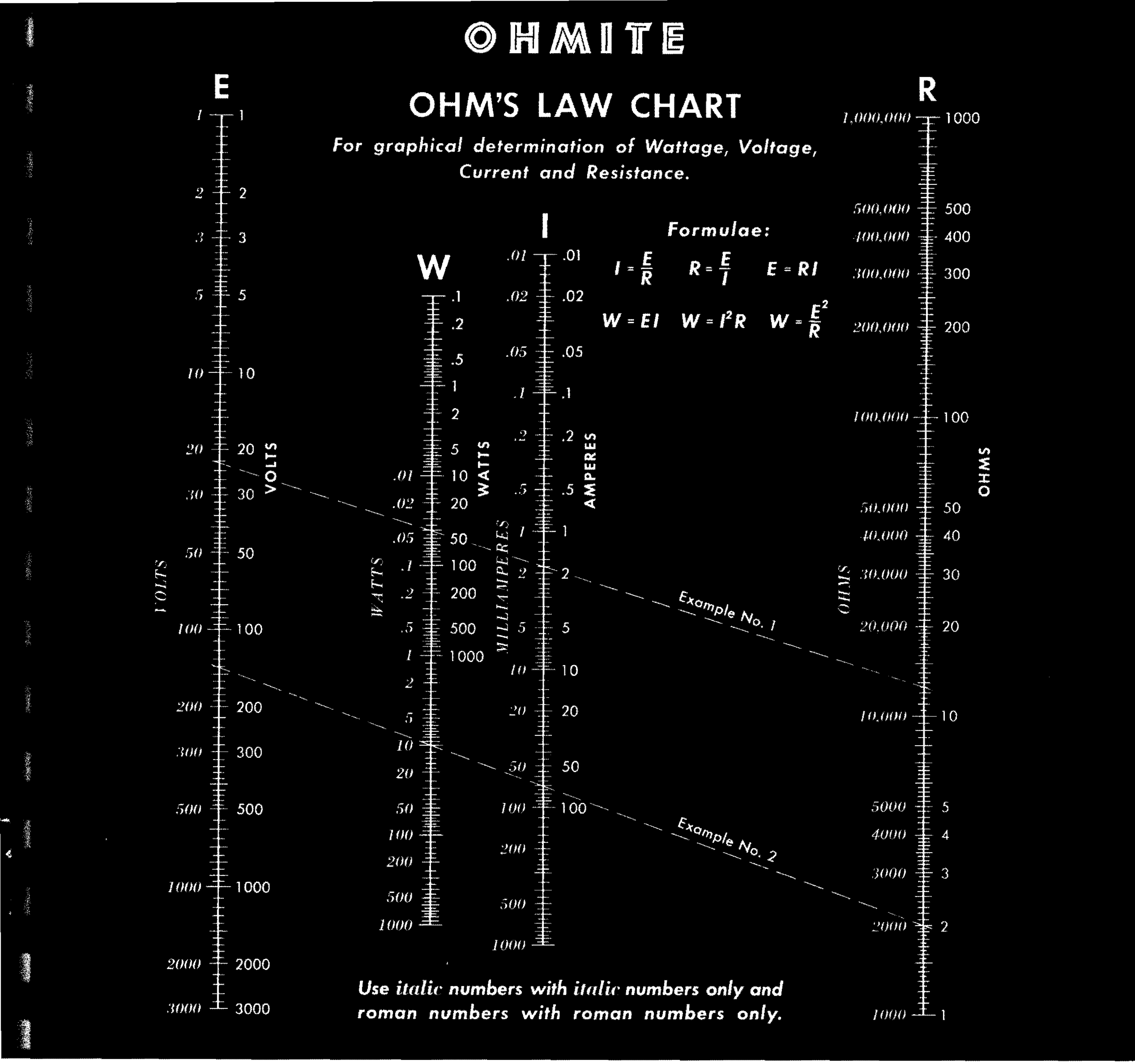
E= Volts		$\frac{W}{I\cos\Theta}$	IZ	$\frac{\sqrt{WR}}{\cos\Theta}$	$\sqrt{\frac{WZ}{\cos\Theta}}$	
I= Amperes	$\frac{W}{E\cos\Theta}$		$\frac{E}{Z}$	$\sqrt{\frac{W}{R}}$	$\sqrt{\frac{W}{Z\cos\Theta}}$	
Z= Ohms	$\frac{E}{I}$	$\frac{W}{I^2\cos\Theta}$		$\frac{R}{\cos\Theta}$	$\frac{E^2\cos\Theta}{W}$	$\sqrt{R^2+X^2}$
R= Ohms	$\frac{E^2\cos^2\Theta}{W}$	$\frac{E}{I}\cos\Theta$	$Z\cos\Theta$		$\frac{W}{I^2}$	$\sqrt{Z^2-X^2}$
W= Watts	$\frac{E^2\cos\Theta}{Z}$	$EI\cos\Theta$	$I^2Z\cos\Theta$	I^2R		
$\cos\Theta$= (Power Factor)	$\frac{IR}{E}$	$\frac{W}{I^2Z}$	$\frac{WZ}{E^2}$	$\frac{R}{Z}$	$\frac{W}{EI}$	$\frac{R}{\sqrt{R^2+X^2}}$
X= Ohms	(X_L-X_C)		$\left(2\pi fL-\frac{1}{2\pi fC}\right)$			$\sqrt{Z^2-R^2}$

Z=Impedance; L=Inductance in henries
X_L=Inductive Reactance; C=Capacity in farads
X_C=Capacitive Reactance; Θ=Angle of lead or lag
f=Frequency in cycles per second

Fig. 144—Table of Ohm's Law Formulae Modified for Alternating Current Single Phase Circuits

Resistance of Series Connections

Total Resistance $R_T=R_1+R_2+R_3\cdots+R_n$ Ohms



HOW TO USE THIS OHM'S LAW CHART

This alignment chart enables graphical solution of Ohm's Law problems. To use, place a ruler across any two known values on the chart; the points at which the ruler crosses the other scales will show the unknown values. The *italic* figures (on the left of the scales) cover one range of values and the roman figures cover another range. For a given problem, all values must be read **either** in the italic numbers or in the roman numbers.

EXAMPLE No. 1: The current through a 12.5 ohm resistor is 1.8 amperes. What is the voltage across it? The wattage? Answer: Dotted line No. 1 through $R = 12.5$ and $I = 1.8$ shows E to be 22.5 volts and W to be 40.5 watts.

EXAMPLE No. 2: What is the maximum permissible current through a 10 watt resistor of 2000 ohms? Answer: Dotted line No. 2 through $W = 10$ and $R = 2000$ shows I to be 70 milliamperes.

OHMITE

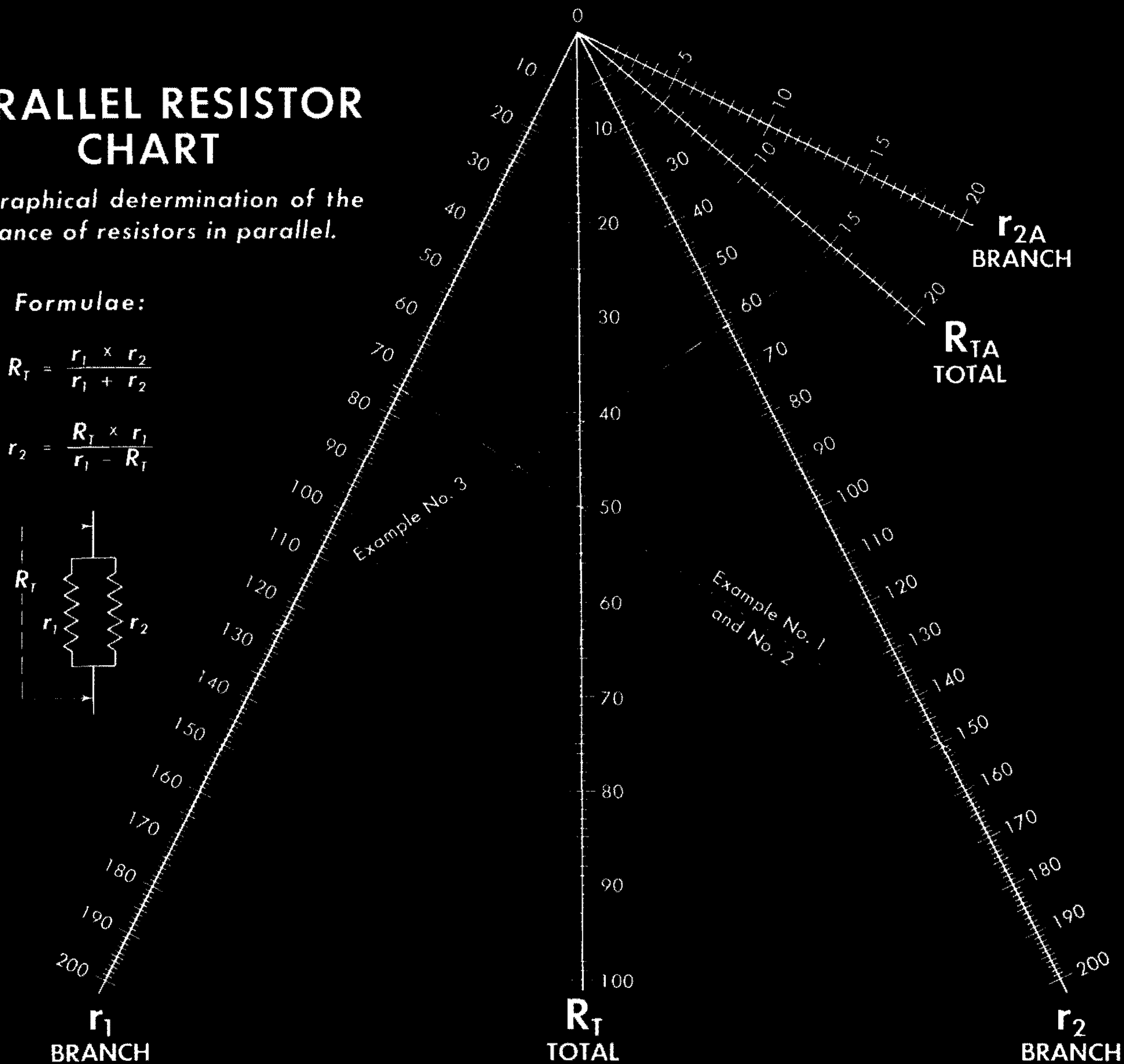
PARALLEL RESISTOR CHART

For graphical determination of the resistance of resistors in parallel.

Formulae:

$$R_T = \frac{r_1 \times r_2}{r_1 + r_2}$$

$$r_2 = \frac{R_T \times r_1}{r_1 - R_T}$$



HOW TO USE THIS PARALLEL RESISTOR CHART

This alignment chart enables graphical solution of problems involving resistances connected in parallel. The values of the parallel resistors r_1 and r_2 and of the total effective resistance R_T must be read on the scales marked with the corresponding letters. To use, place a ruler across the two known values; the point at which the ruler crosses the third scale will show the unknown value. Pairs of resistances which will produce a given parallel resistance can be obtained by rotating a ruler around the desired value on scale R_T. The range of the chart can be increased by multiplying the values on *all* the scales by 10, 100, 1000, etc., as required. Scales r_{2A} and R_{TA} are used with scale r_1 when the values of r_1 and r_2 differ greatly.

EXAMPLE No. 1: What is the total resistance of a 75 ohm resistor and a 150 ohm resistor connected in parallel? Answer: From dotted line No. 1, R_T is 50 ohms.

EXAMPLE No. 2: What resistance in parallel with 750 ohms will give a combined value of 500 ohms? Answer: From dotted line No. 1, r_2 is 1500 ohms.

EXAMPLE No. 3: What is the combined resistance of 1750 ohms and 12,500 ohms? Answer: Scales r_1 and r_{2A} are used and from dotted line No. 3, R_{TA} is 1535 ohms.

EXAMPLE No. 4: What is the combined resistance of 400, 600 and 800 ohm resistors in parallel? Answer: First find R_T for 400 ohms and 600 ohms. Then set the 240 ohms thus found as a new r_1 and 800 ohms as r_2 and the final answer is found to be 185 ohms.

Resistance of Parallel Connections

For resistances in parallel:

$$\text{Total Resistance } R_T = \frac{1}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_n}} \text{ Ohms}$$

For two resistances in parallel:

$$\text{Total resistance } R_T = \frac{R_1 \times R_2}{R_1 + R_2}$$

When one of the resistances and the total are known the formulae is conveniently written:

$$R_2 = \frac{R_T \times R_1}{R_1 - R_T}$$

When the resistances are all equal, the total parallel resistance is equal to the value of one resistance divided by the number of units. For example, the total resistance of two equal resistances in parallel is one-half that of one, the parallel resistance of three equal resistances is one-third that of one.

The handy chart on page 88 can be used for quickly determining the approximate resistance of two units in parallel.

KIRCHHOFF'S LAWS

Kirchhoff's laws are extremely useful for the calculation of circuits containing more than one source of voltage or containing parallel paths.

FIRST LAW: *"The algebraic sum of the potential drops around every closed circuit is always equal to zero."*

Note that one direction is assumed positive for voltages and currents, and that opposing voltages, or circuits which are traversed in the opposite direction, take negative signs. A resistance drop is always negative with respect to the direction of the impressed voltage.

$$E_1 \pm E_2 \cdots \pm E_n - IR_1 - IR_2 \cdots - IR_n = 0$$
$$\text{or } E = \Sigma IR$$

SECOND LAW: *"The algebraic sum of the currents at any junction of the conductors is always zero."*

That is, the total current flowing towards a junction point of several conductors must be equal to the sum of the currents flowing away from the point.

HOW TO DETERMINE THE RESISTANCE REQUIRED FOR YOUR APPLICATION

Section I. By Calculation

When the current through, and the voltage across a resistor are known from the given conditions of a circuit, the resistance can be readily calculated by Ohm's Law. Cases which are calculable, rather than determinable only by test, are most often those in which the resistance is used as a voltage dropper to operate a low voltage device from a higher voltage source, or to limit the amount of current passing. Typical cases are: operation of low-voltage lamps or devices from 110 or 220 volt lines; dropping or bias resistors in radio circuits; current limiting heater control.

EXAMPLE I: It is desired to operate a 6 volt, 15 C.P. lamp drawing 2.02 amperes from the 115 volt power line. What resistance is required?

Method: Volts across resistor $= (115\text{-}6) = 109$

By Ohm's Law: $R = \frac{E}{I} = \frac{109}{2.02} = 54$ ohms

Also Watts $= EI = 109 \times 2.02 = 220$ *watts*

Note: If the lamp were to be operated at less than 6 volts, the fact that the lamp resistance is not a constant would have to be taken into account. While the variation of lamp resistance with current follows certain definite curves, the resistance variation is often most readily determined by test.

Selecting a Resistor: (*a*) *Using Stock Units.* A total resistance of 54 ohms can be made up of two Catalog No. 0701 (page 10) fixed resistors of 25 ohms each, connected in series with a Catalog No. 0362 (page 15) Dividohm Adjustable Resistor of 5 ohms, which is to have the adjustable lug set at 4 ohms. Note that all units selected have a current rating greater than 2.02 amperes. The percentage of full load is

$$\frac{2.02^2 \times 25}{160} \times 100 = 64\%$$

for the two fixed units. The percentage load for the Dividohm is $\frac{2.02^2 \times 4}{4/5 \times 25} \times 100 = 81\%$

(*b*) *Using Made-To-Order Units.* A single unit $1\frac{1}{8} \times 11\frac{1}{4}''$, Code Word AAVOR, page 18, of 54 ohms and operating at 100% load could be used: or two units $1\frac{1}{8} \times 8\frac{1}{2}''$, Code Word: ABABI, each of 27 ohms and connected in series to operate at 69% might be chosen.

EXAMPLE 2: It is desired to control a 500 watt, 115 volt heater by means of a rheostat so that the amount of heat (number of B.T.U. per hour) may be reduced 50%. What rheostat resistance is required?

Calculation:

Maximum current $I = \frac{W}{E} = \frac{500}{115} = 4.35$ *amperes*

Heater resistance is $\frac{E}{I} = \frac{115}{4.35} = 26.4$ *ohms*

Because the amount of heat produced is directly proportional to the watts, the heater watts must be reduced to 250. The current is then:

$$I = \sqrt{\frac{W}{R}} = \sqrt{\frac{250}{26.4}} = \sqrt{9.47} = 3.08 \text{ amps.}$$

$$R_{Total} = \frac{115}{3.08} = 37.4 \text{ ohms.}$$

$$R_{Rheostat} = R_{Total} - R_{Heater} = 37.4 - 26.4 = 11.0 \text{ ohms.}$$

Selecting a Rheostat: (a) From Stock.

The smallest rheostat available from stock for this particular case (see pages 43 to 47) is a Model N, 300 watt unit of 15 ohms, Catalog No. 0657. This rheostat is selected because it is the nearest stock unit that has a current rating (4.47 amps.) greater than the 4.35 amperes maximum required for this application.

(b) Made-to-Order

A Model P with uniform winding can be used for this application.

TAPPED RESISTORS—VOLTAGE DIVIDERS—POTENTIOMETERS

The procedure for calculating a typical voltage divider is given in Example 3. The same method can be extended to cover a voltage divider of any number of sections. When a rheostat or "Dividohm" adjustable resistor is used as a potentiometer, it is in effect a voltage divider with variable sections and can be calculated in the same way.

EXAMPLE 3: To find the resistance and wattage of each section of a voltage divider for a radio transmitter. *Conditions:* Rectifier voltage (maximum across bleeder) = 1000 volts. To be provided with taps at 750 volts, 40 milliamperes, and 500 volts, 20 milliamperes. Bleeder current to be 40 milliamperes.

Method: The first step is to make a sketch similar to Fig. 145 showing the voltages and currents. Commence with Section A, which carries only the bleeder current I_A. By Ohm's Law:

$$R_A = \frac{500}{.040} = 12{,}500 \text{ ohms}$$

$$W_A = 500 \times .040 = 20 \text{ watts}$$

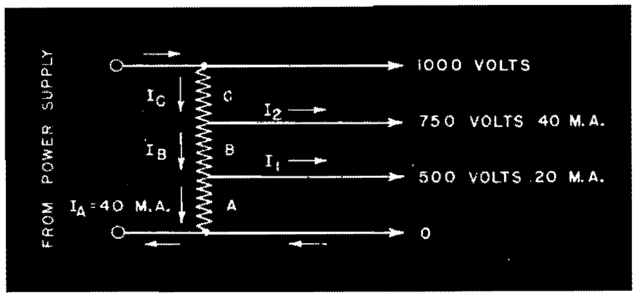


Fig. 145—Voltage Divider Diagram for Example 3

Section B carries the bleeder current I_A plus the current I_1 drawn at the 500 volt tap or

$$I_B = 40 + 20 = 60 \text{ milliamperes}$$

$$R_B = \frac{250}{.060} = 4{,}166 \text{ ohms}$$

$$W_B = 250 \times .060 = 15 \text{ watts}$$

Section C carries the current in Section B plus the current drawn at the 750 volt tap.

$$I_C = I_B + I_2 \text{ or } I_C = 60 + 40 = 100 \text{ milliamps. or } 0.1 \text{ amp.}$$

$$R_C = \frac{250}{.1} = 2500 \text{ ohms}$$

$$W_C = 250 \times .1 = 25 \text{ watts}$$

$$R_{Total} = 12500 + 4166 + 2500 = 19{,}166 \text{ ohms}$$

$$W_{Total} = 20 + 15 + 25 = 60 \text{ watts.}$$

Note that the voltage between the taps of a voltage divider will change if the currents drawn from the various taps change, and that the bleeder current (section A) is increased under no-load conditions and is then equal to supply voltage divided by total bleeder resistance. All sections should be designed to carry the maximum current which would occur under the different conditions of use.

Selecting the Resistor (A) From Stock.

The total resistance required is 19,166 ohms; hence a Dividohm adjustable resistor of 20,000 ohms can be used. Three adjustable lugs will be needed to form the divider. The current rating of the Dividohm must not be exceeded in any section regardless of the watts to be dissipated in that section. Hence, a Dividohm with a rating equal to, or larger than, the maximum current (0.1 amp.) must be selected. This is Stock No. 1367, page 13, equipped with two lugs No. 2158 in addition to the one regularly supplied with the resistor.

The divider could be assembled also by using one of No. 0208, No. 0382 and No. 0583 resistors in series.

(b) From Made-To-Order Sizes. A tapped resistor on a ¾"x6½" core would be suitable (see page 18). The winding space allowed for each section and the wire size would be determined by us according to the wattage and resistance.

HOW TO DETERMINE THE RESISTANCE REQUIRED FOR YOUR APPLICATION

Section II. By Trial or Substitution

When the amount of control or change to be produced by a resistance unit is not or cannot be known without trial, a temporary or substitute resistance and suitable meters must be connected in the actual circuit; then the resistance is varied until the desired results are secured and the amount of resistance and current noted.

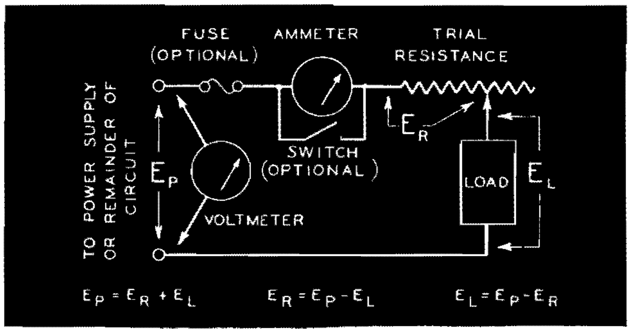


Fig. 146—Typical Test Circuit for Use in Determining Resistance and Current

CIRCUIT: Fig. 146 illustrates a typical test circuit (which may be only part of a larger circuit). The power supply may be the commercial 115 V. or 230 V. outlet, batteries or a generator. The load may be any device such as a motor, generator field, lamp, or heater. The adjustable trial resistance may be an Ohmite rheostat, or it may consist of a number of Ohmite fixed resistors, or one or more Ohmite adjustable Dividohm resistors. Fig. 147 illustrates a convenient way of inserting the trial resistance and ammeter by means of a series plug (such as Hubbell No. 7772).

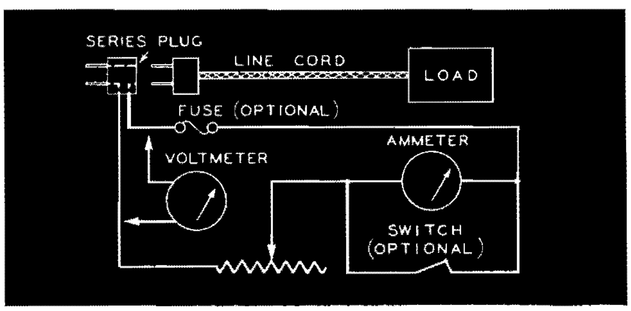


Fig. 147—Typical Test Circuit Using a Series Plug for Connection

Practical Points on Selecting Meters and Wiring

Before connecting any meter to a circuit, the meter range should be compared with the maximum current or voltage expected, to make sure that the meter range exceeds the values which are to be measured. The expected values can be obtained from the name plate data of the apparatus under test or by calculation from the wattage and voltage. It is well to include a fuse in the circuit to protect the meters and apparatus against accidental overload.

When possible, select meters on which the indications will occur in the upper half of the scale in order to obtain the most accurate reading. When the range between maximum and minimum current is very great, it may be necessary to substitute a lower range ammeter for the minimum values. Because of the non-uniform calibration of the scale, alternating current instruments generally cannot be used below approximately 20% of full scale value (except for rectifier type instruments). Small direct current meters commonly have an accuracy of 2% of full scale readings. Alternating current meter accuracy varies, (in descending order), according to the type as follows: electro-dynamometer, iron vane and rectifier (5%).

When the load current amounts to several amperes, as in most power applications, the effect of the current drawn by the voltmeter (when connected across the resistance or the load) generally can be ignored. But as alternating current voltmeters are quite generally of low resistance, the amount of current drawn by the meter should be considered whenever the load currents are small. In the case of high resistance, low current circuits (as in radio apparatus), high resistance rectifier type voltmeters or vacuum tube voltmeters must be used to avoid upsetting circuit conditions.

PULSATING DIRECT CURRENT: Conventional permanent magnet (D'Arsonval) direct current meters read average values. When used on pulsating D.C., the average value indicated is not the true measure of the heating effect or power. For battery charging circuits, the average values are used, but for lighting or heating circuits, the R.M.S. (root-mean-square) value must be used. For unfiltered half-wave rectification, this is 1.57 times the average value; for unfiltered full-wave rectification, it is 1.11 times the average. For filtered circuits where the amount of ripple is less than one-third of the maximum, the difference between the average and R.M.S. is less than 1%.

WIRING: Copper wire of large enough gauge to carry the current without appreciable heating should be used so that the resistance of the connecting wires can be neglected.

Measurements Required

The number of measurements necessary to determine the required resistor depends upon whether the control resistance is to be fixed or adjustable and upon the nature of the load (i.e., of constant or varying resistance). Fig. 148 shows the measurements to be

Type of Control and Load				Conditions for Each Test	Measure Any Two (or Three to Provide a Check)			Measure in Each Case	Measure or Calculate
Type 1	*Type 2	*Type 3							
Fixed Resistance Control—Any Load	Rheostat Control—Constant Resistance Load	Rheostat Control—Varying Resistance Load		For Type 3 Loads, More Than 5 Tests Are Often Taken to Obtain More Detailed Information.	E_P	E_R	E_L	I	R
Minimum Tests Required					Line Volts	Volts Across Resistance	Volts Across Load	Amps. Current	Ohms Control Resistance
	√	√	1	Resistance = 0 Current = $I_{max.}$ = Maximum					
√	√	√	2	Res. = Max. Value Used. Current = $I_{min.}$ = Minimum		*Your test data may be arranged in tabular form similar to this.*			
		√	3	Resistance = 25% of Maximum (Approximately)					
		√	4	Resistance = 50% of Maximum (Approximately)					
		√	5	Resistance = 75% of Maximum (Approximately)					

*Measurements for Type 2 Loads are sufficient for Type 3 Loads if a uniformly wound rheostat is to be used.

Fig. 148—Table of Tests and Data Required for Different Types of Controls and Loads

taken for each of the different possibilities. The intermediate tests for Type 3 Control are taken to obtain a curve showing how the current varies between the maximum and minimum. The table given on page 42 presents in another form the combinations of circuit constants which must be known.

OVER VOLTAGE: If there is any possibility of operating voltages exceeding the test voltages, it is well to consider the effect on the current rating and resistance required to be certain of obtaining the desired amount of control under the most adverse operating conditions.

Type 1. Fixed Resistor Control

EXAMPLE 4. An A.C. relay intended for operation on 110 volts is to be operated from a 220 volt line. The operating current is unknown. What resistance is required?

Method: The relay, a trial resistance (Ohmite "Dividohm") and a meter, 0-500 milliamperes (0.5 amperes), are connected in series as in Fig. 146. As A.C. relays of the type at hand rarely draw over .250 amperes, a "Dividohm" with this ampere rating will be satisfactory for trial use. A preliminary calculation is helpful in selecting the trial resistance. If the current required is as high as .250 amperes, the resistance required would be:

$$\frac{110}{.250} = 440 \text{ ohms}$$

But, if the current should be as little as 50 milliamperes (also a possibility), the resistance required would be $\frac{110}{.050}$ or 2200 ohms. Hence a safe trial resistor would be one of more than 2200 ohms and capable of carrying .250 amperes. Turning to page 13, we note that Cat. No. 1163 "Dividohm" (2500 ohms, 0.253 amperes) would be satisfactory (or any other Ohmite adjustable resistance of greater or equivalent rating).

With the "Dividohm" adjustable lug set at the maximum resistance, the current is turned on. Assuming that the relay fails to operate, the voltage is then turned off, the adjustable lug is loosened, moved to a new position and retightened, and the relay operation again tested. For greater convenience an Ohmite rheostat may be used. This process is repeated until the relay operation is satisfactory, at which time the voltage across the relay should be 110 volts.

As indicated in Fig. 148, only the current at the operating condition and the control resistance ohms are required. The control resistance can be obtained as follows: approximately, from the scale on the Dividohm;" or accurately, by measuring the resistance with a Wheatstone bridge or an Ohmmeter; or by calculation from the voltage and current measurements.

Measured Data for Example 4

I	E_P	E_R	$R_{Res.}$
.105 Amp.	220 V.	110 V.	$\frac{110}{.105} = 1045$ ohms

Wattage in Resistor $= EI = 110 \times .105 = 11.55$ *watts.*

Selection of Resistor: A Stock No. 0375B, 1250 ohm "Dividohm" or 1000 ohm 20 watt Brown Devil.

Type 2. Rheostat Control of a Constant Resistance Load

TYPICAL APPLICATIONS: The temperature control of heaters, such as drying ovens, solder pots, glue pots, electric furnaces, machine spot-heaters, soldering irons, etc.; field control of generators, balancing of control circuits; etc.

EXAMPLE 5. A drying oven of 500 watts, 115 volt rating, is to be controlled between its maximum temperature and some lower value (to be determined during the test).

Method: From $I = \frac{W}{E} = \frac{500}{115} = 4.35$ *amperes*, it can be seen that a 5 ampere meter will handle the maximum current. The trial rheostat, of course, should be rated to carry this current or more.

Assuming that the temperature will fall at a somewhat lesser rate than the wattage, and that the desired minimum temperature is approximately 75% of the maximum, select a trial rheostat which will reduce the wattage by about one half.

Calculations similar to those given in Example 2, page 90, show that approximately 10 ohms will be needed. The circuit in Fig. 146 or Fig. 147 can be used. The trial resistance is increased step by step and time allowed for the oven temperature to stabilize itself until the desired operating temperature is reached.

Data as called for in Fig. 148, Conditions 1 and 2, are taken.

Conditions	I Amps.	E_P Volts	E_R Ohms	R Ohms
Maximum	4.35	115	0	0
At desired temperature	3.5	115	22.4	$\frac{22.4}{3.5} = 6.4$ ohms

Selecting a Rheostat: Proceed as given under Example 2. Stock Rheostat: Model L, Cat. No. 0529, 7.5 ohms, 150 watts, 4.47 amps. maximum current.

Type 3. Rheostat Control for a Varying Resistance Load

TYPICAL APPLICATIONS: Lamp dimming, motor speed control, etc.

EXAMPLE 6: A ventilating fan is directly driven by a 1/6 H.P., 115 Volt D.C. series motor. It is desired to control the speed of the fan from the maximum down to a value determined by trial. From the data on page 61, it is ascertained that a series rheostat will provide satisfactory control.

Test Must Be Made With Motor Loaded: All tests on motors must be run while they are connected to their normal loads.

Circuit: Fig. 146 or 147. Meters: From the name plate data on the motor, it is found that the full load current is 1.5 amperes. Hence, a 0-3 ampere meter is the smallest standard range instrument which should be used. The ammeter should be shorted while the motor is being started so as to protect the meter against the starting surge. A 0-150 Volt D.C. voltmeter is also required.

Procedure: From Fig. 148 it can be seen that for complete data, measurements must be taken under at least five different conditions. The first condition is that of full speed, when the load current is at maximum and the control resistance is at zero.

The temporary resistances for the test should be selected so that their maximum current ratings are equal to, or greater than, the load current when they are in the circuit. Therefore, the first adjustable resistance to be inserted in the circuit should have a current rating of more than 1.5 amps. If the control resistance can be adjusted easily, condition No. 2 for maximum resistance should be determined next by adjusting the resistance until the speed of the fan has been reduced to give the least amount of ventilation desired (rarely over 50% reduction in speed). Then the intermediate conditions, 5, 4 and 3 should be obtained. If the adjustment of the test resistance is not easy, time may be saved by taking the readings in the order, 1, 3, 4, 5 and 2, spacing the readings as best as possible to divide the total range into approximately equal intervals; or the readings may be spaced at equal intervals of amperes change in current or ohms change in resistance. It may be desirable, also, to take more than three intermediate values.

Measured Data for Example 6

Condition	Speed R.P.M.	E_P Line Volts	E_R Volts Across Rheostat	I Amps.	R (Calculated) Ohms
1	1725	115	0	1.50	0
2	1500	115	22.0	1.29	17.1
3	1300	115	39.0	1.11	35.1
4	1100	115	51.8	0.96	54.0
5	900	115	66.7	0.82	81.2

Your test data, including complete name plate description of the motor should be sent to us to permit calculation of the taper-wound rheostat best suited for the application.

Selecting a Rheostat: Proceed as given under Example 2. Stock Rheostat: Model N, Stock No. 0661, 100 ohms, 1.73 amps. maximum current. Tapered Rheostat: A Model L of 82 ohms can be used.

REFERENCE DATA

TEMPERATURE CONVERSION

To convert degrees Fahrenheit (F°) into degrees Centigrade (C°):

$$C° = \frac{5}{9}(F° - 32) \quad \text{or} \quad C° = .555(F° - 32)$$

To convert degrees Centigrade into degrees Fahrenheit:

$$F° = \frac{9}{5}C° + 32 \quad \text{or} \quad F° = 1.8C° + 32$$

When a temperature *rise* (not the temperature attained) is to be converted from one system to the other, the 32° terms in the above formulae are omitted.

INCHES TO MILLIMETERS

Inches	mm	Inches	mm	Inches	mm
1/64	.397	25/64	9.922	49/64	19.447
1/32	.794	13/32	10.319	25/32	19.844
3/64	1.191	27/64	10.716	51/64	20.241
1/16	1.588	7/16	11.113	13/16	20.638
5/64	1.984	29/64	11.509	53/64	21.034
3/32	2.381	15/32	11.906	27/32	21.431
7/64	2.778	31/64	12.303	55/64	21.828
1/8	3.175	1/2	12.700	7/8	22.225
9/64	3.572	33/64	13.097	57/64	22.622
5/32	3.969	17/32	13.494	29/32	23.019
11/64	4.366	35/64	13.891	59/64	23.416
3/16	4.763	9/16	14.288	15/16	23.813
13/64	5.159	37/64	14.684	61/64	24.209
7/32	5.556	19/32	15.081	31/32	24.606
15/64	5.953	39/64	15.478	63/64	25.003
1/4	6.350	5/8	15.875	1	25.400
17/64	6.747	41/64	16.272	2	50.8
9/32	7.144	21/32	16.669	3	76.2
19/64	7.541	43/64	17.066	4	101.6
5/16	7.938	11/16	17.463	5	127.0
21/64	8.334	45/64	17.859	6	152.4
11/32	8.731	23/32	18.256	7	177.8
23/64	9.128	47/64	18.653	8	203.2
3/8	9.525	3/4	19.050	9	228.6

TABLE OF WIRE SIZES

American Wire Gauge (B&S)

Gauge A.W.G. (B&S)	Diameter Inches	Area Circular Mils	Gauge A.W.G. (B&S)	Diameter Inches	Area Circular Mils
1	.28930	83,700.0	21	.02846	810.0
2	.25763	66,400.0	22	.02535	642.0
3	.22942	52,600.0	23	.02257	510.0
4	.20431	41,700.0	24	.02010	404.0
5	.18194	33,100.0	25	.01790	320.0
6	.16202	26,300.0	26	.01594	254.0
7	.14428	20,800.0	27	.01420	202.0
8	.12849	16,500.0	28	.01264	160.0
9	.11443	13,100.0	29	.01126	127.0
10	.10189	10,400.0	30	.01003	101.0
11	.09074	8,230.0	31	.00893	79.7
12	.08081	6,530.0	32	.00795	63.2
13	.07196	5,180.0	33	.00708	50.1
14	.06408	4,110.0	34	.00630	39.8
15	.05707	3,260.0	35	.00561	31.5
16	.05082	2,580.0	36	.00500	25.0
17	.04526	2,050.0	37	.00445	19.8
18	.04030	1,620.0	38	.00397	15.7
19	.03589	1,290.0	39	.00353	12.5
20	.03196	1,020.0	40	.00315	9.9

To find the resistance per foot of any size wire of any metal or alloy divide the ohms per circular mil foot by the area, in circular mils, of the gauge chosen. See table at bottom of page.

ALLOWABLE CURRENT FOR COPPER WIRE

From National Electric Code

A.W.G. or B&S	Rubber Insulated	Asbestos Insulated	A.W.G. or B&S	Rubber Insulated	Asbestos Insulated
	Amperes	Amperes		Amperes	Amperes
18	3	* 6	6	50	70
16	6	*10	5	55	80
14	15	20	4	70	90
12	20	30	3	80	100
10	25	35	2	90	125
8	35	50	1	100	150

*No. 18 is rated at 10 amperes and No. 16 at 15 amperes when in cords for portable heaters, U.L. Type Nos. HC and HPD.

PROPERTIES OF VARIOUS METALS AND ALLOYS

MATERIAL	Ohms Per Circular-Mil-Foot At 20° C. (68° F.)	Relative Resistance With Copper = 1	Approx. Temperature Coefficient 20° C.	Approximate Melting Point Degrees Centigrade	Maximum Working Temperature Degrees Centigrade	Specific Gravity	Weight in Pounds Per Cubic Inch
Silver	9.796	0.95	.0038	960		10.5	.3793
Copper	10.37	1.00	.00393	1085		8.89	.3212
Aluminum	17.0	1.64	.00446	660		2.70	.0975
No. 30 Alloy	30.00	2.89	.00118	1100	350	8.92	.322
Brass (Spring)	36.30	3.50	.0020	965		8.55	.309
Beryllium Copper (Heat Treated)	41.5 to 57.6	4.0 to 5.55		955		8.21	.297
Phosphor Bronze—5% (Grade A)	56.5	5.45	.0018	1050		8.88	.320
Nickel	58.0	5.60	.0048	1445	500	8.90	.321
Pure Iron	61.1	5.90	.0062	1575		7.7	.278
No. 60 Alloy	60.0	5.78	.00046	1100	350	8.9	.321
Platinum	63.8	6.15	.0030	1755		21.45	.775
No. 90 Alloy	90.0	8.68	.00038	1100	400	8.96	.324
Lead	132.0	12.7	.0039	327		11.4	.412
Everdur No. 1010	155.0	15.0	.00034	1019		8.52	.308
No. 180 Alloy	180.0	17.3	.00016	1130	400	8.95	.323
18% Nickel Silver	190.0	18.3	.00019	1110	260	8.50	.307
Monel	256.0	24.7	.00145	1360	500	8.9	.321
Manganin	290.0	28.0	±.00002	1020	100	8.39	.303
Copper-Nickel (55%-45%)	294.0	28.4	±.00002	1290	500	8.9	.321
Nickel-Chromium (80%-20%)	650.0	62.7	.00013	1400	1150	8.412	.304
Nickel-Chromium-Iron (60%-16%-24%)	675.0	65.0	.00017	1350	1000	8.247	.298

THE OHMITE NEWS

"The Ohmite News", our monthly publication contains technical data on the use of resistors, rheostats, tap switches and other products; descriptions of interesting applications; historical and biographical accounts pertaining to electricity and to its pioneers; and announcements of our new developments. Upon request (please use your company letterhead), we will be glad to enter your name on the circulation list.

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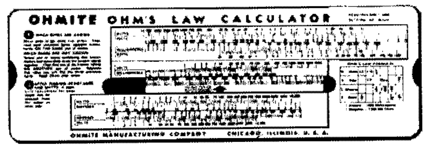

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OTHER LITERATURE

Bulletins on the following subjects are available upon request by specifying the bulletin number: Power Line Chokes—No. 105; Dummy Antenna Resistors—No. 111; Heat Control of Soldering Irons and Melting Pots—No. 116; Rheostats and Resistors for Army-Navy Aircraft—No. 120; Slide Wire Rheostat-Potentiometer—No. 121; AN3155 Army-Navy Aircraft Rheostats—No. 124; "RITEOHM" Precision Resistors—No. 126; Direction Indicator Potentiometer—No. 128; 2 Watt Molded Composition Potentiometer—No. 131; "BROWN DEVIL" Fixed Resistors—No. 132; Radio Frequency Plate Chokes—No. 133; Model Train Control Rheostats—No. 134; "LITTLE DEVIL" Insulated Composition Resistors—No. 135.

NOMENCLATURE

Definitions of Resistance Terms

To avoid misunderstanding when making inquiries, we suggest that the following terms *be used only with the same sense as given in the definitions* which follow. The terms are used in this catalog in accordance with these definitions.

RESISTANCE: A general term used in electricity and meaning that property of a substance which impedes the flow of current and results in the dissipation of power in the form of heat. Its relation to current and voltage is given by Ohm's Law. Resistance is measured in ohms. The term "resistance" is sometimes used as a noun meaning "a resistance unit" but it is better to use the more explicit terms given hereafter.

RESISTOR: The general name for a device used for the purpose of introducing resistance into a circuit.

FIXED RESISTOR: A form of resistor the resistance of which is not intended to be adjusted by the user—except by the use of intermediate taps. The latter type of unit is known as a *Tapped Resistor.*

ADJUSTABLE RESISTOR: A resistor which has the resistance wire partly exposed to enable the amount of resistance in use to be adjusted *occasionally* by the user. Adjustment is made *with the circuit electrically open.* Adjustment requires the loosening of a screw, the subsequent moving of the lug, and retightening of the screw.

RHEOSTAT: The general name for a device which has the resistance element partly exposed to enable the amount of resistance in use to be *easily adjusted by the simple movement of a control knob.* A rheostat enables frequent and immediate change *with the circuit electrically alive.*

POTENTIOMETER (ADJUSTABLE): A rheostat equipped with a terminal at each end of the resistance winding and a connection to the moving arm so that a voltage-divider type of circuit can be used.

RHEOSTAT-POTENTIOMETER: A rheostat equipped with three terminals so that it may be used either as a rheostat or as a potentiometer. It is identical with a potentiometer.

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