OHMITE

MANUAL OF ENGINEERING INFORMATION

CONTENTS

GEORG SIMON OHM
1787-1854

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.

BULLETIN 1100

OHMITE MANUFACTURING COMPANY •

OHMITE

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:

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

The power formula is known as Joule's Law.

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 formulas. 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. 1: Table of Ohm's Law Formulas for Direct Current Circuits.

OHM'S LAW FOR ALTERNATING CURRENT

Ohm's Law in the forms given in Fig. 1 applies to direct current circuits. However, the same formulas can be used for alternating current circuits, provided the amount of inductance (because of coils) or capacitance (because of capacitors or distributed capacitance) 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 resistance.

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 "Non-Inductive Resistors" in "Resistor" catalog).

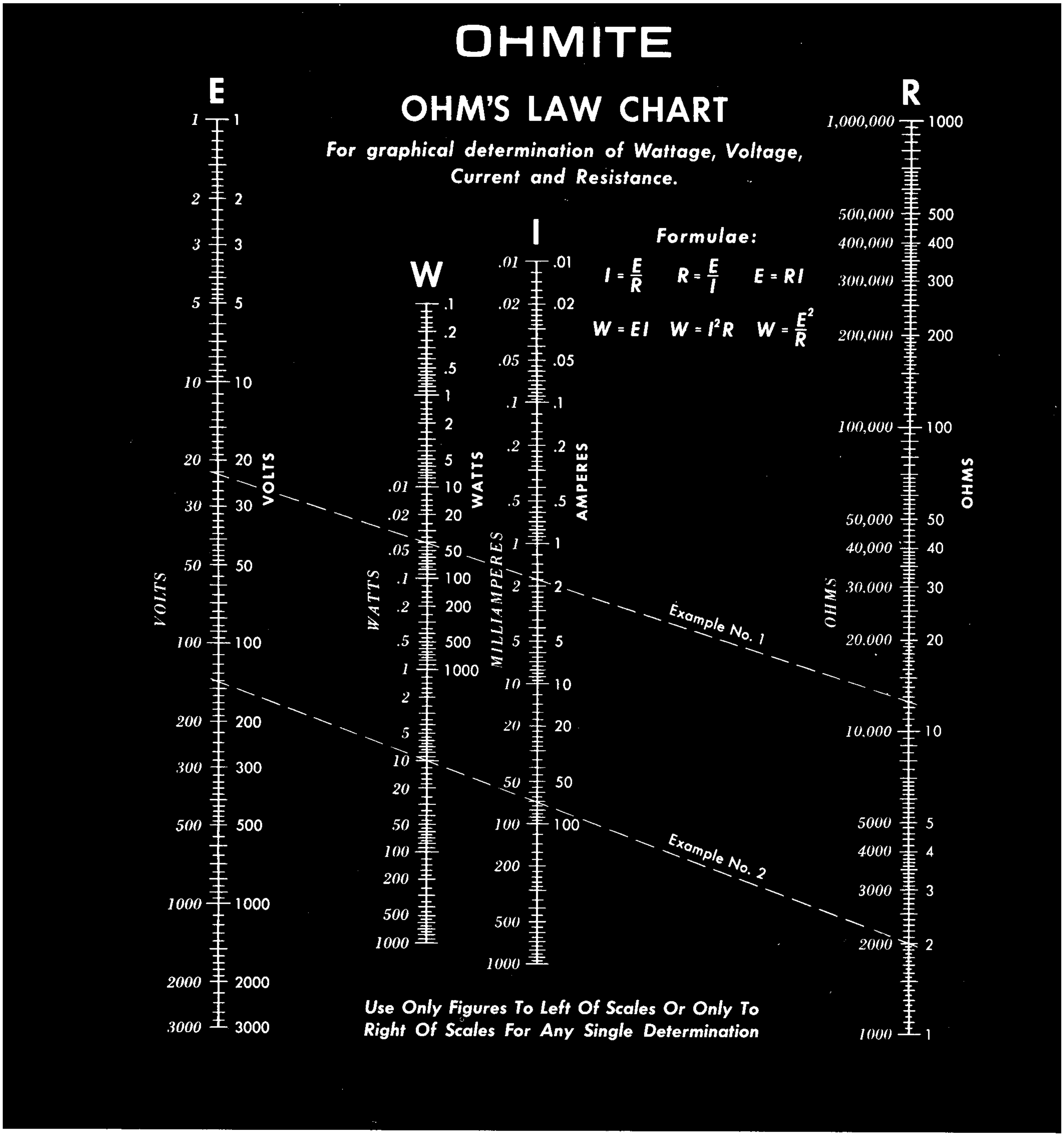
The formulas given in Fig. 2 apply to single-phase alternating current circuits containing reactance, such as circuits involving relays, magnets, solenoids, motors, chokes and filter circuits. It can be noted that these formulas reduce to the same form as the direct current formulas when the reactance 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
X_L = Inductive Reactance
X_C = Capacitive Reactance
f = Frequency in cycles per second
L = Inductance in henries
C = Capacitance in farads
Θ = Angle of lead or lag
ω = Angular velocity = $2\pi f$

Note: Power Factor is often expressed as a percentage.

Fig. 2: Table of Ohm's Law Formulas Modified for Alternating Current, Single Phase Circuits.

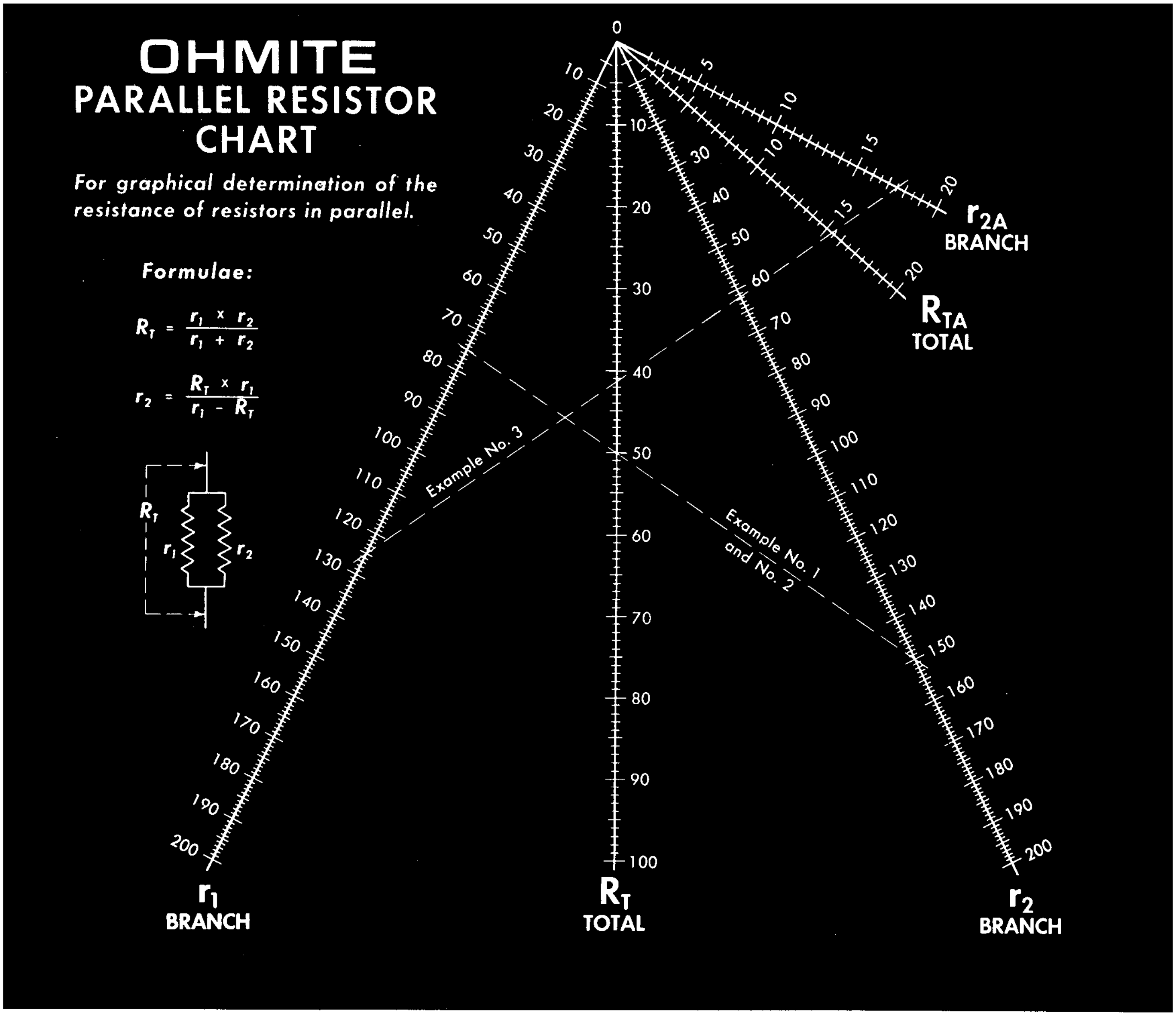


HOW TO USE THIS OHM'S LAW CHART

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 figures on the right of the scales cover another range. For a given problem, all values must be read on the left set or right set of numbers only, as required.

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.



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 CALCULATIONS

OHMITE

CURRENT, VOLTAGE AND POWER IN THREE-PHASE CIRCUITS

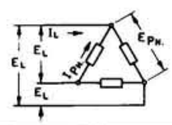
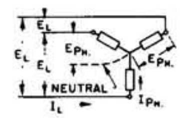
	3 PHASE CONNECTIONS (BALANCED LOAD)	
	DELTA	STAR—(Y)
		
E_L =	E_{Ph}	$\sqrt{3}\,E_{Ph} = 1.73\,E_{Ph}$
E_{Ph} =	E_L	$E_L/\sqrt{3} = E_L/1.73 = 0.577\,E_L$
I_L =	$\sqrt{3}\,I_{Ph} = 1.73\,I_{Ph}$	I_{Ph}
I_{Ph} =	$I_L/\sqrt{3} = I_L/1.73 = 0.577\,I_L$	I_L
Total Volt-Amperes =	$3 \times E_{Ph} \times I_{Ph} = \sqrt{3}\,E_L \times I_L = 1.73\,E_L I_L$	$3 \times E_{Ph} \times I_{Ph} = \sqrt{3}\,E_L \times I_L = 1.73\,E_L I_L$
Total Watts =	*PF × Total Volt-Amperes* or $PF \times 1.73\,E_L I_L$	
Power Factor (PF) =	*Cosine of angle by which E_L leads or lags I_{Ph}*	*Cosine of angle by which E_{Ph} leads or lags I_L*
	$\frac{\text{Total Watts}}{\text{Total Volt-Amps.}} = \frac{\text{Total Watts}}{\sqrt{3}\,E_L I_L}$	

Fig. 3: Table of Three Phase Relationships.

RESISTANCES IN SERIES

Total Resistance $R_T = R_1 + R_2 + R_3 \cdots + R_N$ *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 formula 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 4 can be used for quickly determining the approximate resistance of two resistors in parallel.

The resistance of any number of resistors in parallel can be determined readily by calculating the current in each resistor, adding the currents and dividing the voltage across the resistors by the total current.

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.

DISSIPATION AND STORAGE FACTORS—ADMITTANCE PARAMETERS

*D = Dissipation Factor	$\frac{R}{X}$	$\cot\theta$	$\frac{1}{Q}$	$\frac{G}{B}$
*Q = Storage Factor	$\frac{X}{R}$	$\tan\theta$	$\frac{1}{D}$	$\frac{B}{G}$
Y = Mhos Admittance	$\frac{1}{Z}$			
G = Mhos Conductance	$\frac{1}{R}$ (For $X=0$)	$\frac{R}{Z^2}$		
B = Mhos Susceptance	$\frac{1}{X}$ (For $R=0$)	$\frac{X}{Z^2}$	*D and Q are numbers	

Fig. 4: Table of Terms Used for Capacitors, Coils and Circuits.

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 1: 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 = (115-6) = 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.

The lamp resistance can be calculated by reference to the graph, "Average Curves for Tungsten Filament Lamps" in the "Lamp Dimming" portion of the "Rheostat" catalog.

Selecting a Resistor: (a) Using Stock Units. A total resistance of 54 ohms can be made up of two Catalog No. 0701 fixed resistors of 25 ohms each, connected in series with a Catalog No. 0362 Dividohm Adjustable Resistor of 5 ohms, which is to have the adjustable lug set at 4 ohms.

(b) *Using Made-to-Order Units.* A single unit 1⅛" x 11¼", Code: 11¼ P46 F-54, of 54 ohms and operating at 94% load could be used; or two units 1⅛" x 8½", Code: 8½ P46F-27, each of 27 ohms and connected in series to operate at 63% of rated watts, 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:

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

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

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 "Rheostats"), 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. 5 showing the voltages and currents. Commence with Section A, which carries only the bleeder current I_A. By Ohm's Law:

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

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

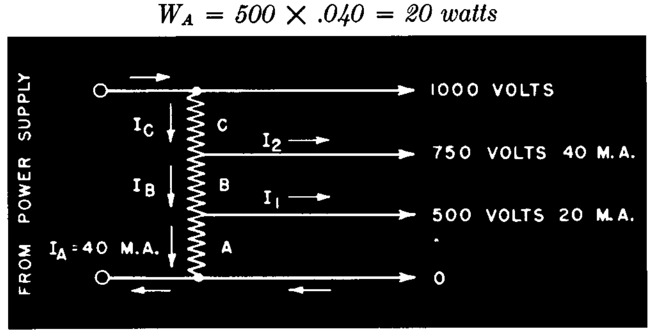


Fig. 5: Voltage Divider Diagram for Example 3.

HOW TO DETERMINE THE RESISTANCE REQUIRED FOR YOUR APPLICATION

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, 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″ x 6½″ core would be suitable. The winding space allowed for each section and the wire size would be determined by us according to the wattage and resistance.

SECTION 2. 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.

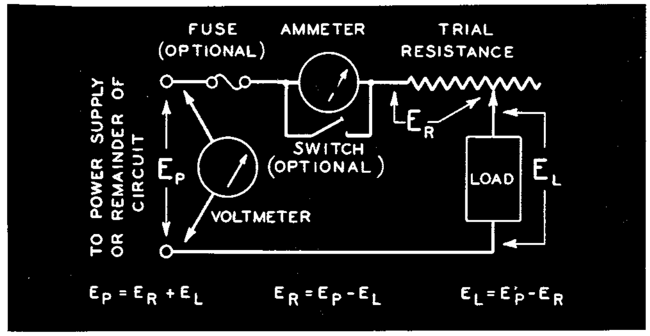


Fig. 6: Typical Test Circuit for Use in Determining Resistance and Current.

Circuit: Fig. 6 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. 7 illustrates a convenient way of inserting the trial resistance and ammeter by means of a series plug (such as Hubbell No. 7772).

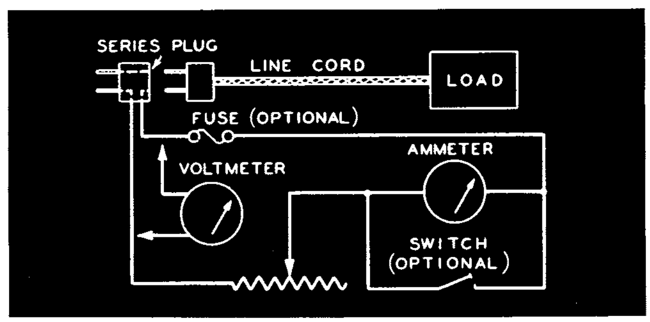


Fig. 7: Typical Test Circuit Using a Series Plug for Connection.

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.

HOW TO DETERMINE THE RESISTANCE REQUIRED FOR YOUR APPLICATION

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. 8 shows the measurements to be 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.

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" or rheostat) and a meter are connected in series as in Fig. 6. The resistance is then varied until the relay operates satisfactorily, with the voltage measured across the relay checking at 110V. Typical measured data might be as follows:

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 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	Res. = 3 or more Intermediate Values					

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

Fig. 8: Table of Tests and Data Required for Different Types of Controls and Loads.

HOW TO DETERMINE THE RESISTANCE REQUIRED FOR YOUR APPLICATION

OHMITE

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, show that approximately 10 ohms will be needed The circuit in Fig. 6 or Fig. 7 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. 8, Conditions 1 and 2, are taken.

Conditions	I Amps.	E_P Volts	E_R Volts	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 chapter, "Rheostat Control of Motor Speed" in the "Rheostat" catalog, 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. 6 or 7. Meters: From the name plate data on the motor, it is found that the full load current is 1.5 amperes.

The ammeter should be shorted while the motor is being started so as to protect the meter against the starting surge.

Procedure: From Fig. 8 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.

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.

OHMITE

ENVIRONMENTAL FACTORS— EFFECT ON THE POWER RATING OF COMPONENTS

All the components of an electrical apparatus—resistors, rheostats, capacitors, transformers, chokes, wiring, terminal boards, rectifiers, transistors, electronic tubes, etc.—have their own limitations as to the maximum temperature at which they can reliably operate. The attained temperature in service is the sum of the ambient temperature plus the temperature rise due to the heat dissipated in the apparatus. The temperature rise of a component is affected by a number of factors as explained in some detail in Resistor Catalog 100 and Rheostat Catalog 200. Maximum operating temperatures are given also in all of the other catalogs.

The graphs and discussions which follow, amplify and supplement the data previously referred to.

Note that the Multiplying Factors given on the Short Cut Chart, in the "Resistor" catalog, are the reciprocals of the "Percent Load Ratings" shown on the graphs in this section. The percent figures are, of course, expressed as decimals before finding the reciprocals.

AMBIENT TEMPERATURE DERATING

Fig. 9 shows the percent of full load which power resistors can dissipate for various high ambient temperatures. Curves for Rheostats, Riteohm Precision Resistors, and VT Variable Transformers are given in their respective catalogs.

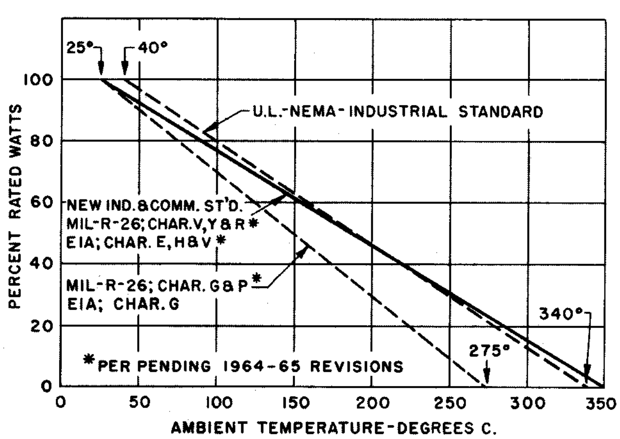


Fig. 9: Derating of Resistors for High Ambient Temperatures.

DERATING DUE TO ENCLOSURE

The amount of derating required, if any, because of enclosure is affected by a number of factors, most of which are hard to determine accurately. The watts per square inch of surface, size, shape, orientation, wall thickness, material, finish and amount and location of ventilating openings all play a part. Fig. 10 serves to indicate for a particular set of conditions how the temperatures varied with the size of enclosure for a moderate size power resistor.

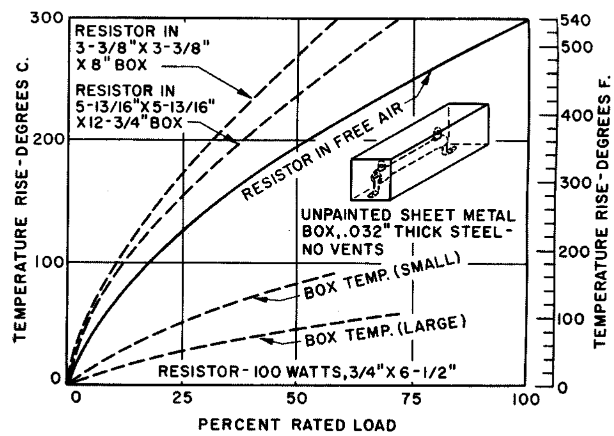


Fig. 10: Example of Effect of Size of Enclosure on Temperature Rise of An Enclosed Resistor.

DERATING DUE TO GROUPING

The temperature rise of a component is affected by the nearby presence of other heat-producing units, such as resistors, electronic tubes, etc. The curves in Fig. 11 show the power rating for groups of resistors with various spacings between the closest points of the resistors, assuming operation at maximum permissible hot spot temperature. If resistors are to be operated at lower hot spot temperatures, the amount of derating for grouping can be reduced.

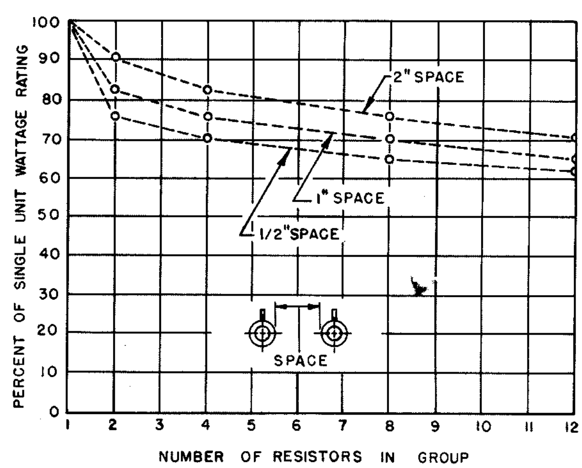


Fig. 11: Derating of Resistors to Allow for Grouping.

ENVIRONMENTAL FACTORS— EFFECT ON THE POWER RATING OF COMPONENTS

OHMITE

DERATING FOR ALTITUDE

The curve in Fig. 12 shows the proportional watts for various altitudes, assuming standard atmospheric conditions.

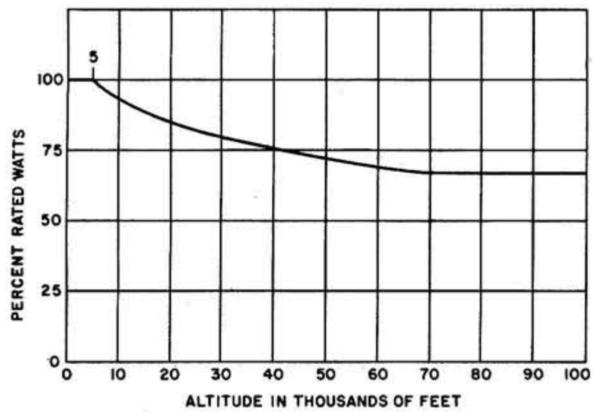


Fig. 12: Derating for Altitude.

PULSE OPERATION

Unlike the environmental factors, which result in reduction of the watt rating, pulse operation may permit higher power in the pulses than the continuous duty rating.

The NEMA has set up certain standard duty cycles for motor control resistors and the resistor ratings for some of these conditions are shown in Fig. 13.

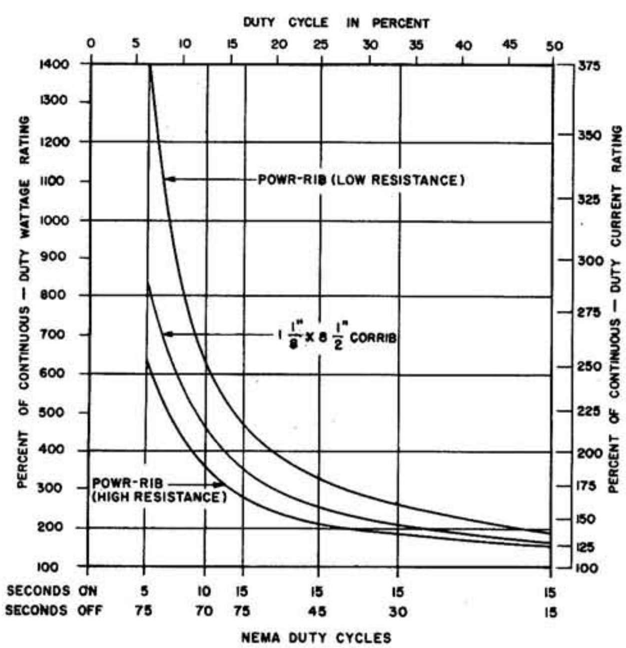


Fig. 13: Percent of Continuous Duty Rating for Resistors for Typical NEMA Duty Cycles.

The curves in Figures 15, 16, 17 and 18 illustrate the more general case of various combinations of on and off time for specified loads up to 1000% for a continuous series of pulses. Intermediate loads can be approximated by interpolation. The "on-time" at which each curve flattens out also indicates the maximum on-time for single pulses (with enough off-time for cooling to ambient). Additional data on single pulses is given by Fig. 14. Resistors will reach about 75% of the rated maximum temperature rise in approximately 5 to 8 pulses and level off at maximum rise in another 10 to 20 cycles, depending on percent load, size, type, etc. Any curve passing above the intersection of the designated on and off-times indicates a percent load which can be used. A resistor operated at the rating of an interpolated curve through the point of intersection would operate at maximum rated temperature rise.

The *exact* temperature rise, of course, varies with each resistor, depending on size, ohms winding, etc. The curves shown indicate the approximate rise for *typical*

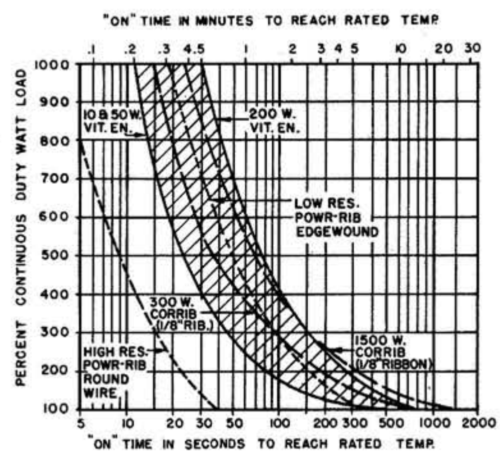


Fig. 14: Time Required for Typical Resistors to Reach Rated Operating Temperature at Various Watt Loads.

units only, as a band or range of values actually exists for each percent load.

Ratings at over 1000% are not recommended except for POWR-RIB resistors. Curves for intermediate size resistors can be roughly estimated by comparison with the sizes given.

Ratings for single pulses in the milli-second range (and up to 1 to 2 seconds) require individual calculation. This is because the ratings vary greatly with the resistance, or more specifically with the actual weight and specific heat of the resistance alloy used. Calculation is based on the assumption that all of the heat generated in the pulse goes to raise the temperature of the resistance wire.

OHMITE

PULSE OPERATION—COOLING—LIMITED TEMPERATURES

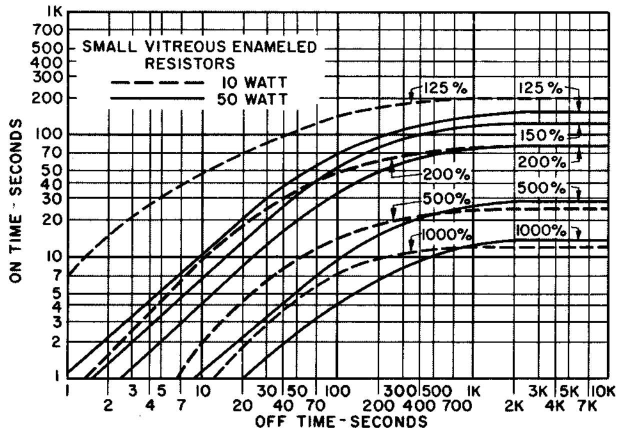


Fig. 15: Percent of Continuous Duty Rating for Pulse Operation of Small to Medium Size Vitreous Enameled Resistors.

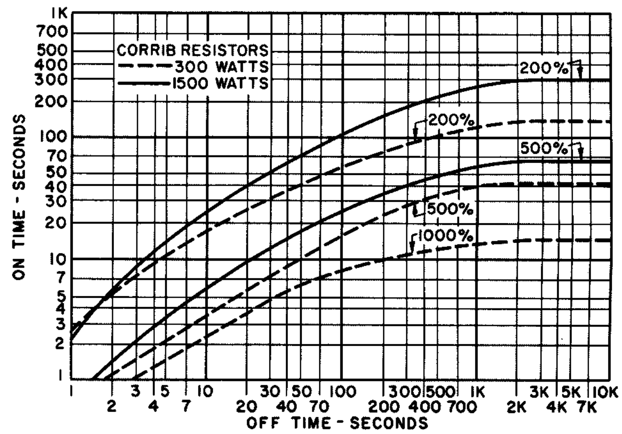


Fig. 17: Percent of Continuous Duty Rating for Pulse Operation of CORRIB, Corrugated Ribbon Resistors.

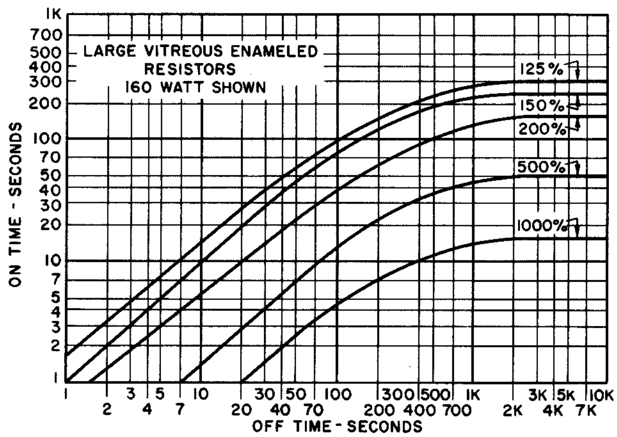


Fig. 16: Percent of Continuous Duty Rating for Pulse Operation of Large Vitreous Enameled Resistors.

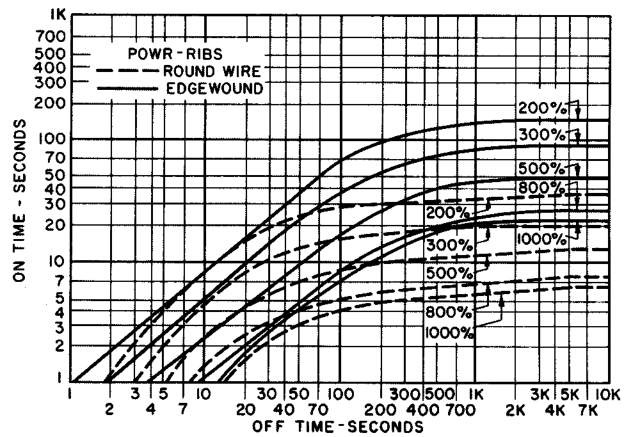


Fig. 18: Percent of Continuous Duty Rating for Pulse Operation of POWR-RIB, Bare Resistors.

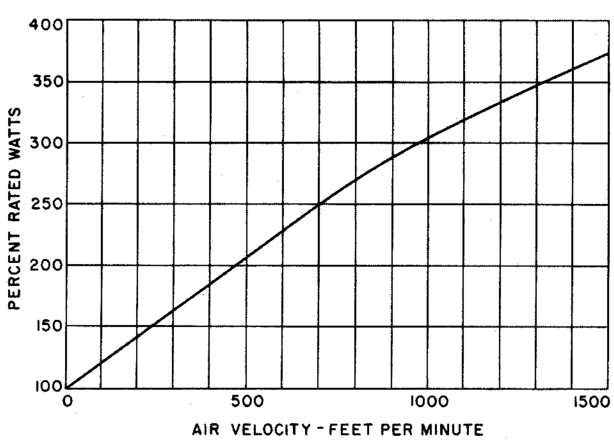


Fig. 19: Percent of Free Air Rating for Typical Resistor or Rheostat Cooled by Forced Air Circulation.

COOLING AIR

Resistors, rheostats and other components can be operated at higher than rated wattage when cooled by forced circulation of air. A typical curve is illustrated in Fig. 19. The curve tends to level off at higher velocities, as excessive hot spots develop where the air flow does not reach all parts uniformly.

LIMITED TEMPERATURE RISE

When it is desired to operate a resistor or rheostat at less than maximum temperature rise, the percent watts for a given rise can be read from "Temperature Rise vs. Load" graphs in each catalog.

RESISTOR DESIGN
Resistance Alloys and Uses

A number of different resistance alloys are used in winding resistors and rheostats as shown in Fig. 20. The general use for each alloy is indicated by the column headed, "Resistance Range for Which Used." Whether a particular alloy can be used on a specific resistor can be estimated by dividing the given resistance by the area of the given winding space and determining whether the quotient falls within the limits given hereafter. The "high resistance" alloys cover the range from approximately 10 to 25,000 ohms per square inch of winding area, the "low to medium" type from 5 to 400 ohms and the "very low resistance" alloys from less than an ohm to 250 ohms. It should be noted that the "Ohms per Square Inch" ranges overlap considerably, indicating that in many instances a given resistor could use any of several alloys. Both the upper and lower limits of the ranges are only approximate and in general can be extended somewhat when necessary.

The actual temperature coefficient of a complete resistor is generally greater than the nominal for the wire alone. The approximate change in overall resisttance at full load is shown in the table.

Other Alloys: In addition to the alloys tabulated which show small changes in resistance with temperature, there are others which sometimes have to be used for very low resistance units. These alloys have higher temperature coefficients, which limit their use to applications where the change in resistance with load is not important. An example is No. 60 alloy, which has a resistance of 60 ohms per circular-mil-foot and a temperature coefficient of +700ppm/°C.

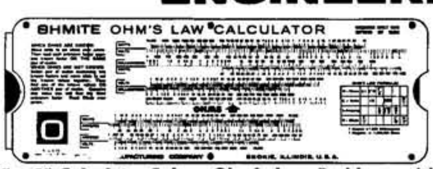
Ballast Wire: There are other alloys which are selected especially for their high temperature coefficient of resistance. These are used for so-called "ballast" resistors where a large change in resistance is desired with a change in load. A typical ballast wire is Nickel, which has 58 ohms/cmf and a temperature coefficient of +4800ppm/°C. Others are "Hytemco" and "Balco" at 120 ohms/cmf and a TC of +4500ppm/°C.

ASTM Alloy Class*	Alloy Composition (Approximate)	Ohms per CMF	Trade Names	Mean Temperature Coeff. of Res. ppm/°C	Temperature Range for TC °C	Resistance Range for Which Used	†Average Resistance Change at Full Load
1a	Nickel base, non-magnetic Ni 75%, Cr 20% plus Al, Cu, Fe, etc.	800	Evanohm Karma Moleculoy Nikrothal L	0 ± 20	−65 to +250	Very high, medium and up, for low temp. coeff.	Under ±1% to ±2%
1b		800		0 ± 10	−65 to +150		
2a	Iron base, magnetic Fe 73%, Cr 22.5%, Al 4.5% (plus Co in one alloy)	800	Alloy 815-R Kanthal DR Mesaloy	0 ± 20	−65 to +200	Alternate sometimes for Class 1	Under ±1% to ±2%
2b		800		0 ± 10	0 to +150		
3a	Nickel-Chromium 80%—20%	650	Chromel A Nichrome V Nikrothal B Protoloy A Tophet A	+80 ± 20	−65 to +250	High and medium	+4 to +6%
3b		675		+60 ± 20			
4	Nickel—Chromium—Iron 60%—16%—24%	675	Chromel C Electroloy Nichrome Nikrothal 6 Tophet C	+140 ± 30	−65 to +200	High and medium	+5 to +8%
5a	Copper-Nickel 55%—45%	300	Advance Copel Cupron Cuprothal 294 Neutroloy	0 ± 20	−65 to +150	Low and low to medium for low temp. coeff.	Under ±1% to ±2%
5b				0 ± 40			
6	Manganin 13% Mn, 87% Cu	290	Manganin	0 ± 15	+15 to +35	Low and low to medium for low TC near 25°C	Under ±1% to ±2%†
7	Copper-Nickel 77%—23%	180	180 Alloy Cuprothal 180 Midohm	+180 ± 30	−65 to +150	Very low	+5% to +8%
9	Copper-Nickel 90%—10%	90	90 Alloy 95 Alloy Cuprothal 90	+450 ± 50	−65 to +150	Very low	+5% to +10%

*American Society for Testing Materials, Tentative Specification B267-60T. †—For resistor with 300°C hot spot rise from 25°C ambient except 54°C rise for Manganin.

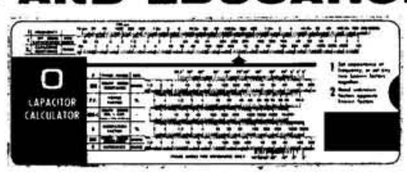
Fig. 20: Table of Resistance Alloys Generally Used for Resistors and Rheostats.

ENGINEERING AND EDUCATIONAL AIDS



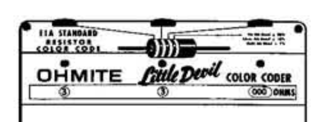
9" x 3" Calculator Solves Ohm's Law Problems with one setting of slide. Two types (1) heavy varnished cardboard and (2) deluxe Vinylite. Has parallel resistance computing scales. Ohm's Law resistance scale ranges from 0.01 ohms to 100 megohms. Current scales provided both in amperes and milliamperes. Also includes A, B, C and D slide rule scales.

Cardboard............Stock No. 5180—Net $0.25
Plastic................Stock No. 5182—Net $1.50



7" x 2⅜" Calculator Solves Capacitance Problems involving frequency, reactance, power factor, dissipation factor, equivalent series resistance, impedance and phase angle with one setting of slide. Includes A, B, C, D slide rule scales. Lists capacitance formulae and a comparison chart of different types of capacitors. In heavy, varnished cardboard.

Stock No. 5184........................Net $0.25



4¾" x 2" "Color Coder" decodes the resistance and tolerance of EIA (RETMA) color coded composition resistors. Just turn the color wheels until the colors correspond to the color bands on the resistor and read resistance value directly in ohms in the windows.

Stock No. 5190...........Net $0.10

COMPONENT APPLICATION PROBLEMS

TAP SWITCH CONSIDERATIONS

Few problems arise in the choice of a tap switch to be used within its normal, published rating. Questions are frequently asked, however, about applications in which one of the normal factors has been altered. Typical variations involve standstill currents higher than rated load-break values, high current surges, operation on 400 cycles, higher voltages, operation of switches in parallel, operation in instrument type applications involving very low currents and voltages, DC ratings and operation at high altitude or high ambient temperature.

Other variations involve mechanical problems such as rotation at many RPM or life when subjected to an abnormally high number of operations.

Only a few of these questions have general answers, such as that switches can be operated on 400 cycles. Practical answers to the other questions depend on the circumstances. Ohmite engineers will be glad to answer specific requests as completely as possible. In many cases an actual trial is necessary to evaluate the suitability of a particular switch.

RELAY APPLICATIONS

Relays are used as basic parts of such a limitless variety of control circuits that many relay types have evolved to handle the different needs. In many cases several different types of relays can be used and the designer's task is to select the one which provides the best balance of performance, mechanical convenience and cost.

Coil operating characteristics constitute one set of conditions, contact load another and mechanical or environmental conditions yet another. AC or DC operation and the amount of power required are the essentials to be considered for the coil. In pulse circuits the operate and release times may be important.

Contact loads and "dry circuit" operation set the requirements on the contacts although expected life (number of operations) is also a factor.

Mechanical considerations include method of mounting, desirability of plug-in connection, dust proof enclosures, hermetic sealing, and special requirements (generally according to military specifications) as to ability to withstand vibration, acceleration and shock, etc. Humidity and ambient temperatures are still other factors.

Ohmite engineers will make recommendations of relays for specific applications upon receipt of full information.

TANTALUM CAPACITOR CONSIDERATIONS

All tantalum capacitors are "electrolytic capacitors" and therefore differ in some characteristics from the "classical" capacitor consisting of two plates (or sets of plates) separated by air or a solid dielectric. In a tantalum capacitor (regardless of type—wire, slug or foil) the dielectric is the thin oxide-layer formed on the tantalum. This layer acts as a dielectric or insulator only as long as the surface it is formed on is electrically positive (the anode).

The following basic formulas apply:

$$\text{Capacitance } C = 0.224\,\frac{KA}{d \times 10^{6}}\ \textit{microfarads}$$

K = Dielectric constant A = Area of one plate in inches
d = thickness in inches

$$\text{Charge } Q = CE \times 10^{-6}$$

Q = Coulombs C = Capacitance in microfarads
E = Volts Coulombs = Amperes × seconds

$$\text{Stored Energy} = \frac{CE^{2}}{2} \times 10^{-6}\ \textit{joules}$$

$$\text{Joules} = \textit{Watts} \times \textit{seconds}$$

In the application of tantalum capacitors to circuits, the differences between electrolytic and other capacitors must be taken into consideration. Basically, tantalum capacitors are used in typical electrolytic capacitor applications in filter and by-pass circuits where the capacitors are subjected to a constant DC bias and a small AC ripple voltage. This comes about because electrolytic capacitors are generally polar, i.e., act as capacitors only when the voltage does not reverse across them. However, foil type tantalum capacitors (Ohmite Tan-O-Mite Type TF) are also available as non-polar types and can be used on AC within their rating.

All types of capacitors show some changes in capacitance and power-factor or leakage current with temperature, frequency, voltage and time. All of these factors should be considered in the application of tantalum capacitors. Tantalum capacitors which are to be connected in series, require special consideration. On DC, the voltage will divide according to the ratio of leakage currents rather than the capacitances. Also, a series combination of polar and non-polar types on AC shows differences on each half-cycle. Instruments particularly suited for the purpose must be used for measuring tantalum capacitors as the relative amount of AC compared to the DC bias may affect the observed measurement results.

COMPONENT APPLICATION PROBLEMS - REFERENCE DATA

OHMITE

VARIABLE AUTOTRANSFORMER USES

Variable autotransformers provide a convenient means of voltage control of AC operated devices. As applied in Ohmite *"v.t."* Transformers, they enable control of voltage from zero to 110% or 117% of line voltage (depending on the model). Apparatus requiring 240 volts can also be operated from a 120 volt source, by use of the transformers.

Where no step-up of voltage is required, a rheostat or potentiometer can generally be used, rather than a variable transformer, to do the same control job and the question therefore arises as to what determines the choice between them. A survey of each type of control discloses that transformers and rheostats each have their own advantages such that the details of the application determine the choice.

Variable autotransformers are of course limited to alternating current use, have excellent regulation under changing load, have high efficiency, produce little heat, and are fairly universal in application within their current rating. Current ratings (in general) go hand in hand with physical size, so that large currents require large transformers.

Rheostats can be connected as potentiometers or voltage dividers so as to be able to control the load from zero to line voltage, like the transformer. They are more generally used as series resistances however. Unlike the transformers, rheostats work on DC as well as AC and can be provided to handle large currents on any size rheostat. They can also operate at higher ambient temperatures than the transformers. In a large percentage of applications, especially where the current or voltage does not have to be reduced to less than 25 to 50%, the rheostat provides the desired amount of control and is smaller, lighter and cheaper.

Tapered windings can also be provided on the rheostats so as to obtain special relationships between the angle of rotation and the controlled effect.

Special circuit arrangements with the load permit variable transformers to be used also for such purposes as providing a variable load of constant power factor, or to provide controlled phase shift.

RADIO FREQUENCY CHOKE PROBLEMS

Problems involving the application of radio-frequency chokes become too involved in radio theory to permit adequate treatment in this manual. Suffice it to say, that while the standard series of Ohmite R.F. "plate" chokes covers a wide range of frequencies, it is of course possible to design chokes to fit other requirements. Recommendations for special chokes will be made by Ohmite engineers upon receipt of full information as to circuit and other considerations.

REFERENCE DATA

PROPERTIES OF VARIOUS METALS AND ALLOYS

MATERIAL	Ohms Per Circular-Mil-Foot At 20° C. (68° F.)	Relative Resistance With Copper = 1	Approximate Temperature Coefficient 20° C.	Approximate Melting Point Degrees Centigrade	Maximum Working Temperature Degrees Centigrade	Specific Heat	Specific Gravity	Weight in Pounds Per Cubic Inch
Silver	9.796	0.95	.0038	960		.057	10.5	.379
Copper	10.37	1.00	.00393	1085		.10	8.89	.321
Aluminum	17.0	1.64	.00446	660		.23	2.70	.096
No. 30 Alloy	30.00	2.89	.00118	1100	350	.092	8.92	.322
Brass (Spring)	36.30	3.50	.0020	965		.10	8.55	.309
Beryllium Copper (Heat Treated)	41.5 to 57.6	4.0 to 5.55		955		.10	8.21	.297
Phosphor Bronze—5% (Grade A)	56.5	5.45	.0018	1050		.09	8.88	.320
Nickel	58.0	5.60	.0048	1445	500	.11	8.90	.321
Iron	61.1	5.90	.0062	1575		.11	7.7	.278
Lohm Alloy	60.0	5.78	.0008	1100	350	.092	8.9	.321
Platinum	63.8	6.15	.0030	1755		.032	21.45	.775
No. 90 Alloy	90.0	8.68	.00045	1100	400	.092	8.96	.324
Lead	132.0	12.7	.0039	327		.031	11.4	.412
Everdur No. 1010	155.0	15.0	.00034	1019		.09	8.52	.308
No. 180 Alloy	180.0	17.3	.00018	1130	400	.092	8.95	.323
18% Nickel Silver	190.0	18.3	.00019	1110	260	.09	8.50	.307
Monel	256.0	24.7	.00145	1360	500	.127	8.9	.321
Manganin	290.0	28.0	±.00002	1020	100	.09	8.39	.303
Copper-Nickel (55%-45%)	294.0	28.4	±.00002.or'4	1290	500	.094	8.9	.321
Stainless Steel—Type 416	343	33.1	.0014	1500	677	.11	7.75	.280
Stainless Steel—Type 302 or 303	433	41.8	.0011	1410	760	.12	8.03	.290
Nickel-Chromium (80%-20%)	650	62.7	.00008	1400	1150	.104	8.412	.304
Nickel-Chromium-Iron (60%-16%-24%)	675	65.0	.00014	1350	1000	.107	8.247	.298
Stainless Steel—Type 1-JR	720	69.4	.00015	1400	870	.11	7.34	.265
Nickel-Chromium-Al-Cu (74.5-20-2.75-2.75)	800	74.5	±.00002 or'1		300	.104	8.10	.293

OHMITE

REFERENCE DATA

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

Wire Table Relations

The following approximate relations are convenient for rapid mental computations:

Increase in AWG No. By	Multiplies Resistance By
1	1.25
2	1.6
3	2.0
10	10.

To find the resistance per foot of any size wire of any alloy: *OHMS/FOOT=OHMS per CMF/CM*

To find the weight per 1000 feet of any bare wire of any alloy:

$$POUNDS/1000\ FEET = .003 \times CM \times SP.\ GR./.321$$
$$= .000342 \times CM \times SP.\ GR.$$

ALLOWABLE CURRENT‡ FOR COPPER WIRE

From National Electric Code 1962

AWG or B&S	Rubber or Plastic		Asbestos	
	1 Cond.* Amps	To 3 Cond.† Amps	1 Cond.* Amps	To 3 Cond.† Amps
18	—	7	—	10
16	—	10	—	15
14	20	15	30	25
12	25	20	40	30
10	40	30	55	40
8	55	40	70	50
6	80	55	100	70
4	105	70	135	90
3	120	80	155	105
2	140	95	180	120
1	165	110	210	140
0	195	125	245	155

*—In free Air. †—In raceway or cable.
‡—Ratings apply only to certain wire insulation systems. Consult N.E. code for details.

TEMPERATURE CONVERSION

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

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

To convert degrees Centigrade into degrees Fahrenheit:

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

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.

OTHER USEFUL DATA

Inches to Centimeters and Millimeters

1 inch = 2.54 cm. = 25.4 millimeters

Pounds and Ounces to Grams

1 pound = 454 grams   1 ounce = 28 grams

SCREW SIZES

No.	Dia.	No.	Dia.	No.	Dia.
0	.060	4	.112	10	.190
1	.073	5	.125	12	.216
2	.086	6	.138		
3	.099	8	.164		

DECIMAL EQUIVALENTS

				1/64	.015625
			1/32		.03125
				3/64	.046875
		1/16			.0625
				5/64	.078125
			3/32		.09375
				7/64	.109375
	1/8				.125
				9/64	.140625
			5/32		.15625
				11/64	.171875
		3/16			.1875
				13/64	.203125
			7/32		.21875
				15/64	.234375
1/4					.25
				17/64	.265625
			9/32		.28125
				19/64	.296875
		5/16			.3125
				21/64	.328125
			11/32		.34375
				23/64	.359375
	3/8				.375
				25/64	.390625
			13/32		.40625
				27/64	.421875
		7/16			.4375
				29/64	.453125
			15/32		.46875
				31/64	.484375
1/2					.5
				33/64	.515625
			17/32		.53125
				35/64	.546875
		9/16			.5625
				37/64	.578125
			19/32		.59375
				39/64	.609375
	5/8				.625
				41/64	.640625
			21/32		.65625
				43/64	.671875
		11/16			.6875
				45/64	.703125
			23/32		.71875
				47/64	.734375
3/4					.75
				49/64	.765625
			25/32		.78125
				51/64	.796875
		13/16			.8125
				53/64	.828125
			27/32		.84375
				55/64	.859375
	7/8				.875
				57/64	.890625
			29/32		.90625
				59/64	.921875
		15/16			.9375
				61/64	.953125
			31/32		.96875
				63/64	.984375
1					1.