NAVY SERVICE A

A-C OR D-C RESISTORS

TYPES HM, WM, TM, D, BAR, AND WX

EDGEWOUND (Types HM and WM) • WIREWOUND (Types TM, D, BAR, WX) • RIBFLEX (Type D)

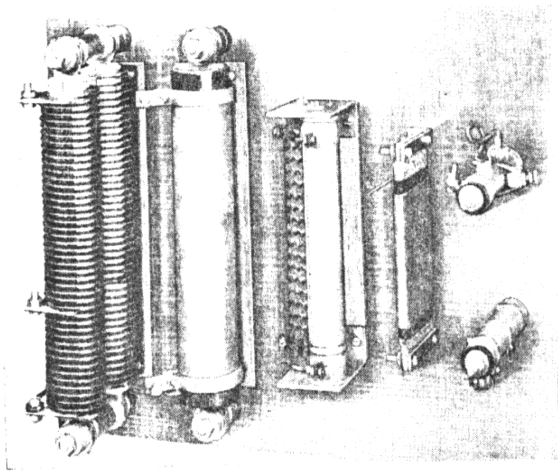


Fig. 1—Typical Resistor Assemblies

APPLICATION

The resistor units and mountings described and illustrated in this leaflet have been specifically designed for application to Navy Service A controllers. These resistor units and assemblies are applied to controllers to function as current-limiting, voltage-dividing, protective, field discharge, or heating devices.

The Types HM and WM edgewound, Type TM wirewound, bar wirewound, and Type D ribflex resistor assemblies are extensively used in d-c motor starters to limit the motor starting current. These resistor units are also often built into rheostat assemblies to provide d-c motor speed regulation by field control.

The Type WX and Type D wirewound resistor units are often employed in control circuits to limit contactor coil currents, to prevent short-circuiting of the voltage supply during switching, or to provide a means for varying the potential applied to a coil or to a voltage actuated device. Resistor units which have a sliding tap terminal are known as potentiometers.

Resistor units are sometimes used as radiant or immersion type of heaters. Condensation in a water-tight enclosure can be prevented by using a resistor unit as a heater to maintain the ambient temperature inside the enclosure at a temperature level at which moisture cannot form.

RATING

The rating of a resistor unit is generally given in the amperes that it can carry continuously or in the watts that it can dissipate indefinitely without the temperature rise of the resistance winding or the associated parts exceeding the maximum safe value. The proximity of a resistor unit to other heated bodies and the ventilation will also affect the rating of the unit in a particular resistor assembly. The physical size, thermal capacity, and the area of the radiating or heat dissipating surfaces are other factors that usually govern the resistor tube rating. The resistance of a wire or strap is directly proportional to its length, inversely proportional to its cross-section area, and depends upon the resistivity for the particular material used. The general characteristics and approximate ratings of the various types and sizes of resistor units are given in the rating table Fig. 2.

The resistor units and their mountings have sufficient creeping and arcing distances for 500 volt enclosed applications.

For many d-c motor starting or accelerating applications, the starting resistor units are selected and the resistor assemblies are designed on an intermittent rating basis. An intermittently rated starting resistor is much smaller in size and more economical to use than a continuously rated resistor assembly. As the rating of a d-c motor starting resistor is determined by its temperature rise after the completion of a certain number of starting cycles, most of the ratings are determined from actual test data.

The temperature rise of a resistor unit or an assembly for d-c motor starting service depends upon the resistor unit and support thermal capacity, arrangement of the resistor units in the assembly, the ventilation, the size or surface area of the controller enclosure, the energy to be dissipated, the time that current flows through the resistor during the starting period, the cooling time between starts, and the number of starts in a given time period.

Many of the d-c general purpose controller starting resistors are designed for four repeated starts with a starting or accelerating cycle in

A-C OR D-C RESISTORS
TYPES HM, WM, TM, D, BAR, AND WX

RESISTOR UNIT

TYPE	LENGTH IN INCHES	RESISTANCE MATERIAL ▲	RANGE IN OHMS	MAX. CONTINUOUS WATTS		MAX. TEMP. RISE IN °C FOR A 50° C. AMBIENT
				1 UNIT (OPEN)	6 UNITS ★ (OPEN)	
HM	11	CrAl NiCr●	.05 to 1.15 1.4 to 4.3	600 500	530 430	
	14	CrAl NiCr●	.067 to 1.55 2.0 to 5.7	820 680	720 575	
	17¼	CrAl NiCr●	.085 to 1.95 2.5 to 7.1	1030 860	910 740	
	20¼	CrAl NiCr●	.10 to 2.34 3.0 to 8.6	1250 1040	1100 890	375
WM	11	CrAl NiCr●	.05 to 1.15 1.4 to 4.3	600 500	530 430	
	14	CrAl NiCr●	.067 to 1.55 2.0 to 5.7	820 680	720 575	
	17¼	CrAl NiCr●	.085 to 1.95 2.5 to 7.1	1030 860	910 740	
TM	11	CuNi NiCr	4 to 400 500 to 6400	310 350	270 310	300 375
	14	CuNi NiCr	5 to 500 640 to 8000	420 480	360 420	300 375
	17¼	CuNi NiCr	5 to 500 640 to 10000	545 625	470 540	300 375
D Ribflex	4¼ 6½ 8½	CuNi CuNi CuNi	.06 to 10 .10 to 15 .15 to 25	130 200 250	85 125 160	
D Wirewound	4¼ 6½ 8½	CuNi CuNi CuNi	15 to 5000 20 to 7000 25 to 10000	75 115 160	60 90 125	300
Bar	7¼	MnSiCu—CuNi—NiCr	.6 to 16	80	....	
WX	5	CuNi	25 to 6000	75	60	

▲CuNi = Copper-Nickel-Iron Alloy.
CrAl = Chromium-Aluminum-Iron Alloy.
NiCr = Nickel-Chromium-Iron Alloy (Nichrome).
MnSiCu = Manganese-Silicon-Copper-Iron Alloy.

● Less surface area than resistance elements used for the lower ohmic value range.

★Resistor units arranged in an assembly 2 units high and 3 units wide.

Fig. 2—Typical Resistor Unit Rating Table

accordance with the information shown in table Fig. 3.

After the accelerating cycle has been repeated four times, the temperature rise of open type resistor units (Types HM and WM) should not exceed 375°C. in an ambient temperature of 50°C. The temperature rise of the embedded type resistors (Types TM, D, WX, etc.) should not exceed 300°C. in a 50°C. ambient temperature.

The table in Fig. 4 shows the distribution of the resistance between steps and the starting current peaks for typical d-c motor starters of from one to four steps.

For a one step starter, the motor current will decrease from 500% at motor armature standstill to approximately 100% of full load current as the motor accelerates in speed. During this accelerating period, the heating effect on the resistor is

CONTROLLER SIZE			0	1	2	3	4	5	6
MAX. HP	Volts	115	½	3	5	10	20	40	75
		230	½	5	10	25	40	75	150
No. of Starting Resistor Steps			0	1	2	2	3	4	4
Cycle—Seconds time on out of each 80 second period			...	3	5	5	5	10	10
Rms Heating Test Current In % of Motor Full Load Current*	Step	First	...	190	125	125	110	90	90
		Second	...	...	160	160	125	115	115
		Third	...	...	...	...	150	125	125
		Fourth	...	...	...	...	...	140	140

*Resistor assemblies of more than one step are shunted with external resistors to secure the specified Rms current value for each step during the 5 or 10 second test.

Fig. 3—Typical Resistor Starting Cycles and Test Current Values Table in Accordance with Navy Specification 17-C-17 for D-c Controllers

STARTING RESISTOR

NO. OF STEPS	STARTING CURRENT ON 1st STEP IN % OF MOTOR FULL LOAD CURRENT	★TOTAL RESISTANCE IN % OF RESISTANCE (R) TO LIMIT MOTOR CURRENT TO THE FULL LOAD VALUE	% OF TOTAL RESISTANCE PER STEP			
			1ST STEP	2ND STEP	3RD STEP	4TH STEP
1	500	14 to 16	100	..	..	..
2	300	27 to 29	71	29	..	..
3	250	34 to 36	57	26	17	..
4	200	44 to 46	46	27	18	9

$\bigstar R = \frac{\text{Line Volts}}{\text{Full Load Amps.}}$ and the motor resistance is assumed to be 4 to 6%.

Fig. 4—Typical Starting Current Peaks and Resistance Distribution for D-c Motor Starter Resistors

approximately the same as if a steady current of 190% of full load current (see Fig. 3) had been flowing through the resistor.

The temperature rise of a typical 25 hp, 230 volt d-c motor starting resistor in a drip-proof enclosure is shown by Fig. 5 for a series of starts in accordance with the requirements in Fig. 3 and Fig. 4 for a Size 3 starter.

From the curve it should be noted that the heating effect is cumulative and a cooling period of 75 seconds is not long enough for the resistor assembly to cool to its ambient temperature. This resistor assembly meets the temperature requirements as the temperature rise does not exceed 375°C. after four starts.

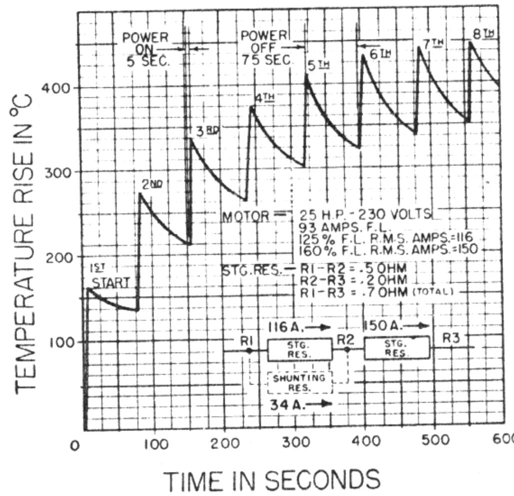


Fig. 5—Temperature Rise of a Typical Type HM Starting Resistor (Dwg. 13-D-6529)

CONSTRUCTION

1. TYPE HM RESISTOR—A Type HM Resistor unit consists essentially of an edgewound resistance element, a heat treated steel mounting bar and insulator support, and a set of refractory insulators. The connection and tap terminals are spot or tack welded directly to the resistance element. The refractory insulators are made of a material that will not shatter or break when subjected to mechanical and thermal shocks. All metal parts are either made of a material that is corrosion-resisting or are suitably protected against corrosion. The length of a resistor unit means the total or overall length of the mounting strap. For example, a 14 inch resistor unit is for mounting on studs or tie rods which are spaced 13 inches apart center to center. A typical resistor unit and its mounting are shown by Fig. 6.

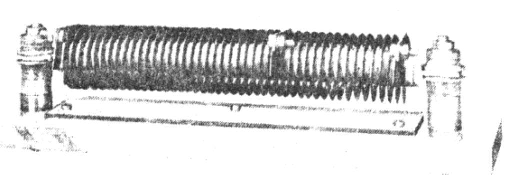


Fig. 6—Typical Type HM Resistor Unit and Mounting

The construction of a Type HM Resistor unit and its mounting is illustrated and shown in cross-section by Fig. 7.

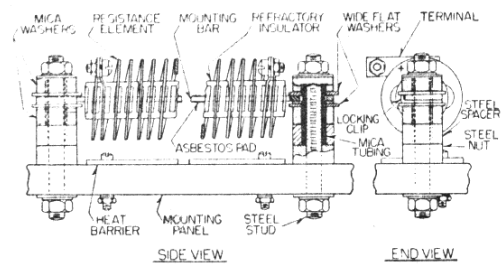


Fig. 7—Construction of a Type HM Resistor Unit and Mounting (Dwg. 5-C-2684)

2. TYPE WM RESISTOR—The Type WM Resistor unit is constructed the same as the Type HM unit except for the connection terminals. These units were designed especially for relatively high currents and a number of resistor units are often mounted in one assembly. The terminals are very sturdily constructed and their weight is rigidly supported by the mounting tie rods. This type of assembly prevents the ends of the resistance elements from being bent or distorted by the weight of the terminals when the resistor assembly is subjected to a high impact shock. The terminal clamp is held by two bolts and is of the solderless type.

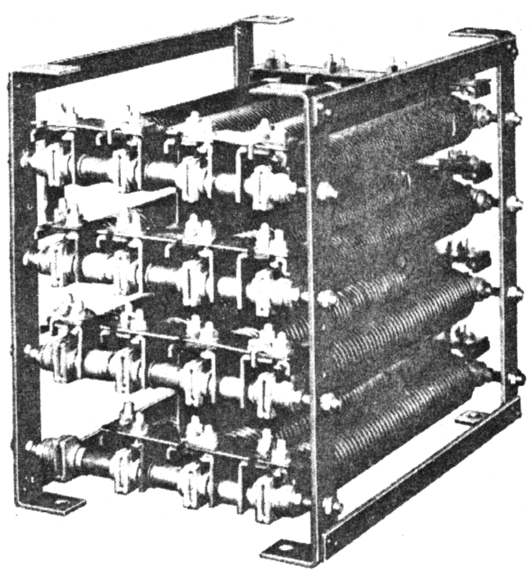


Fig. 8—Typical Type WM Resistor Assembly

One end of the resistor unit is rigidly clamped in the tie rod assembly and the other end is supported on the other tie rod in such a manner that it is free to slide longitudinally. This arrangement permits the resistor unit to expand without distortion when it is heated. A typical assembly of fifteen Type WM Resistor units in one frame is shown by Fig. 8.

The construction and method of supporting the connection terminals are shown by Fig. 9.

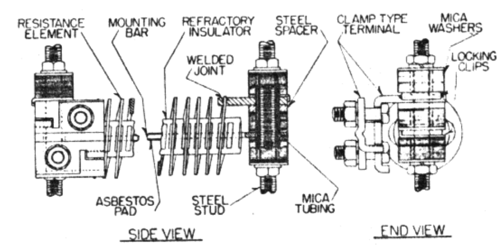


Fig. 9—Terminal Mounting for a Type WM Resistor Unit (Dwg. 5-C-2683)

3. TYPE TM RESISTOR—The Type TM Resistor is a wirewound unit which can be manufactured with resistance values which range from 4 to 10,000 ohms. A mica wrapping insulates the resistance wire winding from the steel tube support. Mounting lugs are spot welded to each end of the steel support tubing. The space between the turns of the resistance wire is filled with a refractory cement to support the turns and prevent them from coming in contact with each other. Connections to the resistance element are made with clamp-on terminals. Type TM and HM Resistor units may be supported in the same mounting assembly as the mounting stud and insulation assembly is exactly the same for either type of resistor unit. A Type TM Resistor unit and its mounting are shown by Fig. 10.

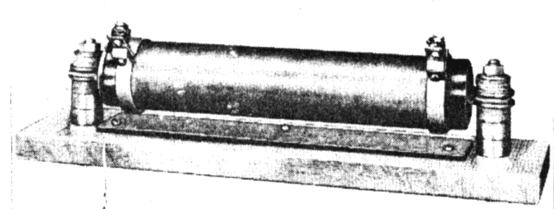


Fig. 10—Typical Type TM Resistor Unit and Mounting

A cross-section view of a Type TM Resistor tube and its mounting is shown by Fig. 11.

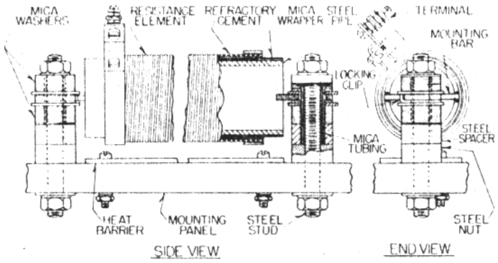


Fig. 11—Construction of a Type TM Resistor Unit and its Mounting (Dwg. 5-C-2685)

4. TYPE D RIBFLEX AND WIREWOUND RESISTORS—The resistance element of a Type D Ribflex Resistor unit is a crinkled edgewound strip which is wound around a refractory insulation tube support. The support tube and resistance winding are sealed and bonded together in an integral assembly by vitreous enamel. This unit has screw terminals and taps.

The Type D wirewound unit is similar to the ribflex type except a wirewound resistance element is used in place of the edgewound strip.

A Type D Ribflex Resistor unit and its mounting are shown by Fig. 12.

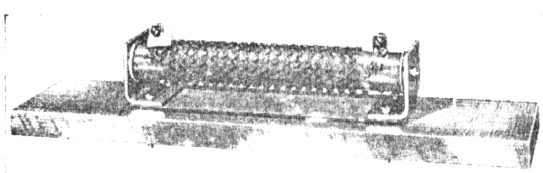


Fig. 12—Typical Type D Ribflex Resistor Unit and Mounting

The resistor tubes are usually mounted in the right-angle brackets by means of steel centering-washers and steel tie rods. Either type of tube may be used in the same mounting assembly. The mica washers provide additional insulation and give some flexibility to the mounting. Fig. 13 shows a cross-section view of a Type D Ribflex Resistor unit and its mounting.

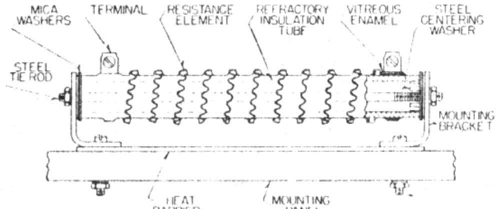


Fig. 13—Cross-section View of a Type D Ribflex Resistor Unit and its Mounting (Dwg. 5-C-2681)

5. WIREWOUND BAR RESISTOR—This type of resistor unit consists essentially of a resistance wire element which is wound on a mica insulated flat rectangular steel bar. The steel bar provides a very rigid support and also increases the thermal capacity of the unit. A refractory cement fills the space between the turns and prevents the turns from touching each other. Connections are made to extensions of the resistance winding. A typical bar type resistor unit is shown by Fig. 14.

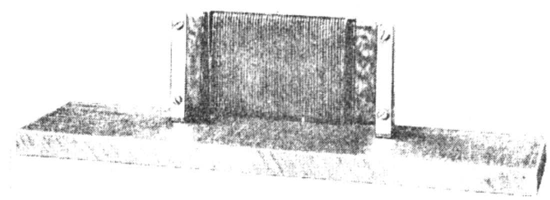


Fig. 14—Bar Type Resistor Unit and Mounting

6. TYPE WX WIREWOUND RESISTOR—The resistance wire element of a Type WX Resistor unit is wound on a refractory insulating tube. The complete assembly is sealed and coated with vitreous enamel. A resistor unit for use as a potentiometer is only partially coated with enamel so that the sliding tap can make electrical contact with the resistance winding at any point. These resistor units have screw terminals. The steel tie rod may be used for making an electrical connection from the resistor unit front terminal to the rear of the mounting panel. A fixed resistance and a potentiometer unit are shown by Fig. 15.

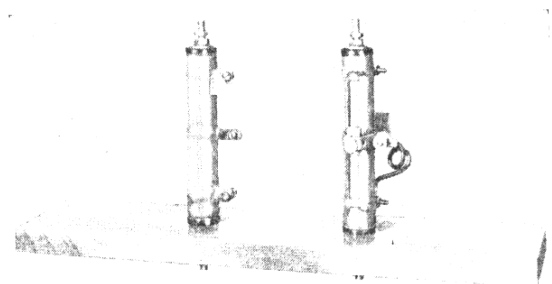


Fig. 15—Type WX Resistor Units and Mountings

This resistor unit is usually mounted in a position perpendicular to the mounting panel. A cross-section view of a typical resistor unit and mounting is illustrated by Fig. 16.

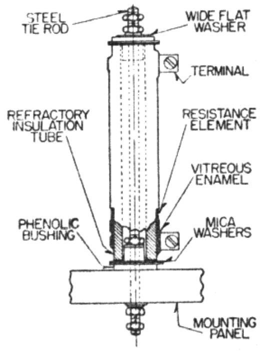


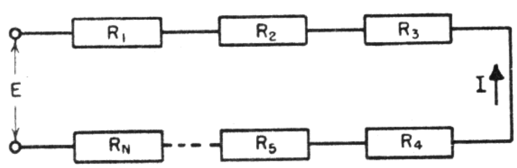
Fig. 16—Construction of a Type WX Resistor Unit and Mounting (Dwg. 5-C-2682)

OPERATION

1. **NORMAL**—The primary function of a resistor is to provide resistance to an electrical current. In d-c and low frequency a-c circuits the magnitude of the current that will flow when a voltage is applied to a resistor can be calculated by Ohm's law which is given below:

$$I = \frac{E}{R} \text{ where } \begin{cases} I = \text{Current in amperes} \\ E = \text{Potential in volts} \\ R = \text{Resistance in ohms} \end{cases}$$

The total resistance in a series circuit is equal to the sum of all the resistor units as shown by Fig. 17.

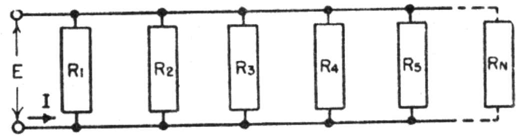


$$R_T = R_1 + R_2 + R_3 + R_4 + R_5 + \cdots + R_N$$

$$I = \frac{E}{R_T}$$

Fig. 17—Series Resistor Circuit (Dwg. 13-D-6527)

In parallel circuits the total resistance is always less than that of the unit with the lowest resistance value. The parallel circuit resistance can be calculated by the formula given in Fig. 18.

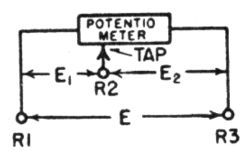


$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} + \cdots + \frac{1}{R_N}}$$

$$I = \frac{E}{R_T}$$

Fig. 18—Parallel Resistor Circuit (Dwg. 13-D-6530)

A resistor unit with a sliding or adjustable tap terminal is usually known as a potentiometer. A resistance winding with equal resistance per unit length will have a uniform voltage drop per unit length when a potential is impressed upon the terminals of the winding. The potentiometer utilizes this characteristic and can be used to secure a variable and reduced voltage from a constant voltage source. The circuit diagram for a typical potentiometer circuit is shown by Fig. 19.



$$E = E_1 + E_2$$

Fig. 19—Potentiometer Circuit (Dwg. 13-D-6526)

When the tap is moved from the "R_1" end of the potentiometer to the other end, the voltage "E_1" between the terminal "R_1" and the tap will vary from 0 to 100% of the total applied voltage "E". For a high resistance load connected between the tap and "R_1" terminals, the percentage of the total applied voltage on the load will be approximately equal to the percentage of the resistance winding that is in parallel with the load. For a low resistance load, the voltage distribution will be proportional to the combined load and "R_1" to the tap resistances with respect to the total resistance.

2. **UNDER SHOCK**—When a resistor unit is subjected to a high impact shock, it will function the same electrically as it does during normal operation. However, the shock forces will subject the resistor unit to severe bending, compressional, and torsional mechanical stresses.

If the Types HM and WM Resistor units are subjected to a high impact shock, the weight of the edgewound resistance strip and the refractory insulators will cause the center section of the unit to deflect in a direction parallel to the mounting supports. The resistor unit steel mounting support strap is case hardened to reduce the deflection and prevent permanent distortion of the parts. The refractory insulators are relatively short and their ends are shaped in such manner that very little stress is applied to them when the mounting strap is deflected. This arrangement provides a flexible resistor assembly which can withstand mechanical shock forces.

The Type TM and the bar type wirewound resistor units have mica insulation and are supported on very rigid mounting tubes or bars. As the mounting supports do not deflect appreciably during shock, the mica insulation and the refractory cement will not be broken or shattered.

The mounting assembly for Type D Resistor units provides a very rigid support and prevents the unit from being subjected to bending or torsional stresses. The centering washers and the mica washers provide some flexibility and damping of the shock forces.

The Type WX Resistor units are supported in such a manner that deflection of the mounting panel will not subject the unit to bending or torsional stresses. The phenolic centering bushings and mica washers provide some cushioning against shock forces.

INSTALLATION—MAINTENANCE—REPLACEMENT OF PARTS

1. GENERAL—Reference can be made to Instruction Leaflet 6000-1 for general instructions and suggestions on installation and maintenance. A periodic inspection should be made to insure that all screws, bolts, and nuts are as tight as possible.

All current carrying connections should be clean and fastened as tight as possible. Loose connections will usually cause overheating at the joints.

Care should be exercised to make certain that the resistor units are not hot when any inspection or maintenance work must be done. Some starting resistor units will reach a temperature of 400 to 500° C. (near red hot heat) or more after a starter has been operated repeatedly in a short interval of time. Resistor assemblies with a relatively large mass will have a large thermal capacity and may require a rather long time to cool to a safe handling temperature.

Compressed air should be used periodically to remove accumulations of dirt and dust which may collect on the resistor units and connectors. It is particularly important to clean resistors that are used only occasionally. When resistors are used frequently, some of the dust and dirt is either carried away by the thermal air currents or burned off by the high temperature of the resistance elements.

2. INITIAL OPERATION—When a starter or resistor is first operated, the oil, grease, or dust on the resistor units may burn and create considerable smoke. This is generally of no consequence as the resistor units will be cleaned off after a few operations or when the units reach a temperature which is sufficient to volatize the foreign matter. This is particularly true of Types HM and WM Resistor units as the resistance strap is lubricated while it is being wound into a helical coil.

3. ELECTRICAL AND MECHANICAL CLEARANCE—As most resistor units deflect or move when they are subjected to a shock, sufficient mechanical and electrical clearance should be maintained between the resistors and the enclosure or associated apparatus. In general, there should be a mechanical clearance of at least one inch between current carrying parts of opposite polarity and grounded parts or enclosures.

4. REPLACEMENT OF RESISTOR UNITS—The mounting straps of the Types HM and TM Resistor units are slotted so that the resistor units may be slipped off the mounting supports or tie rods after those assemblies are loosened by backing off the nut which holds the steel washers, mica washers, locking clips, etc., tight on the mounting stud. When a resistor unit is replaced, the locking clip which has a right-angle flange on one side should always be re-assembled so that it prevents the resistor mounting strap from slipping off the tie rod. The flange on the locking clip should be located at the closed side of the slot of the resistor unit mounting strap.

On the Type WM Resistor units, the locking clip is usually tack welded to the resistor connection terminal. This clip should be cut or broken loose before any attempt is made to remove the resistor unit. After the clip has been disengaged, the resistor units can be removed by the same method as described for the Types HM and TM units. When a Type WM Resistor unit is re-assembled, the locking clip should be tack welded to the terminal strap. The welding will prevent the resistor tube terminal from being jarred out of its mounting when the resistor frame is subjected to a shock.

The Type D Resistor units can be removed from the mounting brackets by disconnecting the leads and removing the steel tie rods.

The bar type resistor units are held to their mounting straps by four bolts.

The Type WX Resistor tubes can be removed after the leads are disconnected and the front mounting nuts have been removed.

5. EMERGENCY REPAIR OF EDGEWOUND RESISTOR UNITS—If a replacement resistor unit is not available, emergency repairs can usually be made to a Type HM or WM Resistor unit that is not severely damaged by welding or brazing the burned ends of the resistance strap together. Jumpers or straps can also be welded between turns to bridge or shunt out the damaged section.

When the edgewound resistance element is very thin, it is sometimes very difficult to weld the ends of the strap together. A very satisfactory connection can usually be made by welding each end of the resistance winding to a steel strap or spacer. A ⅛ inch thick steel strap is generally suitable for this purpose.

While this method of repair may make it possible to operate during an emergency, it is usually best to replace the repaired unit at the first opportunity. This type of repair will decrease the ohmic value of the resistor unit and may not give the most satisfactory operation.

6. HEAT BARRIERS—When resistor units are mounted near apparatus or mounting panels that are subject to damage if they are overheated, it is recommended that asbestos or refractory barriers be installed to protect the insulation parts. Asbestos lumber plates are frequently used for this purpose.

WEIGHT OF TYPICAL RESISTOR UNITS

DESCRIPTION	WEIGHT
TYPE HM —11 inch length	1 lb. —12 oz.
14 inch length	2 lbs.— 6 oz.
17¼ inch length	3 lbs.
20¼ inch length	3 lbs.—10 oz.
TYPE WM—11 inch length	2 lbs.
14 inch length	2 lbs.—14 oz.
17¼ inch length	3 lbs.— 8 oz.
TYPE TM —11 inch length	2 lbs.—12 oz.
14 inch length	3 lbs.—10 oz.
17¼ inch length	4 lbs.— 8 oz.
TYPE D — 4¼ inch length	9 oz.
6½ inch length	12 oz.
8½ inch length	1 lb.
BAR TYPE— 7¼ inch length	1 lb.— 3 oz.
TYPE WX — 5 inch length	9 oz.

Fig. 20—Weight Table

CIRCUIT DIAGRAM SYMBOLS

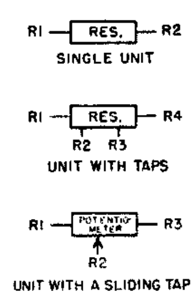


Fig. 21—Typical Resistor Unit Diagram Symbols (Dwg. 13-D-6528)

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