TEST LOADS FOR POWER EQUIPMENT
DESCRIPTION

1. GENERAL

1.01 This section covers various types of electrical loads for machines.

1.02 This section is reissued to omit the information covering the use of generators as motors and job-made water-barrel rheostats and to revise the information covering ribbon-type resistors, the current-carrying capacities of various wires, and water rheostats.

1.03 Tests involving loading are usually covered in the test or requirements sections. In some cases, where special loading characteristics are essential, the equipment and circuit arrangement of the load is also specified. Where a specific load arrangement is not specified, the type best suited for the installation depends mainly on the electrical characteristics of the circuit, the number of times the load will be applied, the duration of each test and local conditions such as the charging routine, equipment available at the office, and the location of the equipment to be tested.

1.04 Various methods of loading follow.

(a) ***Battery charging loads*** are convenient for loading dc machines since they utilize the existing equipment and the load is steady. Use is generally restricted to infrequent tests of short duration, such as for adjustments, since it may involve excess charging or cycling the battery.

(b) ***Building loads,*** such as lighting, sump pumps, etc, may be used for either testing or routine operation of engine-alternator sets where such connections can be readily made.

(c) ***Resistors, Rheostats, Lamps, and Heater Units:*** Resistors are used for very small machines such as signaling types. Lamps or rheostats are also used for loading these and small charging machines. Heater units of the type commonly used in household heaters consist of uncovered resistor wire in coils ordinarily wound around an insulating spool or core of ceramic material arranged with a screw base. They are generally available in 660-watt capacity. They are used where more load is required than can readily be provided by lamps. Heater units or lamps may be connected in parallel or series-parallel, depending on the voltage and load required. Lamps may be used in parallel with heater units to obtain closer adjustment of the load provided. Lamps and heater units are suitable for temporary loading and in some instances may be desirable for routine loading.

(d) ***Commercial loading resistors*** are suitable for routine loading of engine generators or small alternators. They are also used as load for discharge tests of small batteries. For small loads, these would consist of a group of wound-tube resistors. For larger loads, they would consist of ribbon- or cast-grid-type resistors. These resistors have a long life and are available in fairly large capacities but are not arranged for close adjustment of the load. Although expensive for a single test, they are attractive for routine loading.

(e) ***Water rheostats*** are suitable for use in loading an engine-alternator set for routining or test. Western Electric Company has a group of water rheostats of various kw ratings suitable for this use.

(f) ***Permanent water rheostats*** (tank type) have been developed by the engineering department of the various operating companies. These rheostats have been found suitable for use in loading engine-alternators, provided there is a ready and expendable source of water available.

1.05 Although permanent or semipermanent loading arrangements should meet safety and Underwriters' requirements, the temporary test arrangements by their nature involve certain hazards such as the use of portable meters on high voltage (230 volts) or current transformers, moisture in combination with the high voltage with water rheostat operation, hot resistors, etc. ***Particular care should be exercised to guard against injury to personnel and equipment when applying test loads.*** The operating temperature of practically all of the loading resistors and especially the heater units will be above the ignition point of gasoline vapor. This must be considered when this equipment is in locations where such vapors may be present. Electric fans are helpful in dissipating excess heat.

2. GENERAL INFORMATION FOR WIRE CAPACITY AND FOR CALCULATION, CONNECTION, AND MEASUREMENT OF LOADING

2.01 Various methods of rating loading equipment are in use and the calculation for any particular type will depend on its ratings. Some loads, such as lamps and heater units, are rated in wattage at some nominal line voltage. Water rheostats are rated in wattage per unit. Commercial-type resistors are usually rated by resistance and current or resistance and wattage. For calculation purposes, all loads referred to herein, except motor loads, are considered noninductive and the power factor as unity. Although the wire-wound tube resistors are ordinarily slightly inductive, this would have negligible effect at low frequencies including 60 cycles.

DC Machines

2.02 The loading requirements for dc machines usually specify the current and voltage. From the following relationships, the resistance and the wattage can be readily calculated and the load equipment selected accordingly. For wire sizes, see 2.16.

V = volts $\qquad V = IR = \frac{W}{I}$

R = resistance (ω) in ohms $\qquad R = \frac{V}{I}$

I = current in amperes $\qquad I = \frac{V}{R} = \frac{W}{V}$

W = watts $\qquad W = IV = I^2R$

KW = kilowatts

1KW = 1000 watts

$$\frac{\text{number of watts}}{1000} = \text{number of kw}$$

AC Machines

2.03 The above formulae also apply to ac noninductive loads on single-phase machines or individual phase noninductive loads on polyphase machines.

2.04 ***The engine requirements sections*** specify the required load in ***per cent of full-load kw rating of the alternator.*** The test voltage would generally be that of the office regular service and not necessarily the nameplate voltage. In calculating loads, the test voltage specified is used rather than that given on the nameplate. In no case should the nameplate current or wattage rating be exceeded continuously. Alternator nameplate data usually include the full-load kw, the voltage between any two line wires, the kilovolt-amperes (kva), the power factor (pf), and the amperes in each line wire. The kw and current apply to inductive loads at the nameplate power factor. The kva, power factor, and current given are not involved in calculating noninductive loading, except that, if full load were specified and the kw value not given, it could be obtained by multiplying the nameplate kva by the nameplate power factor. The allowable load per phase is the total rated kw divided by the number of phases.

2.05 ***Routining an engine*** driving an alternator usually requires part load on the alternator. In some cases, the load arrangements may be simplified if the loading for a 3-phase machine is applied on one or two phases. Routine load may be placed on one or two phases but in this case the load per phase should not exceed approximately one-fourth of the total kw phase rating. However, initial tests on engines usually require up to full alternator load. In the case of polyphase alternators, this full load is divided approximately equally among the phases.

2.06 For ***single-phase loads,*** the required wattage and voltage being known, noninductive loading equipment may be calculated as above for dc machines. For wattage measurement and wire sizes, see 2.09 through 2.16.

2.07 ***Two-phase loads*** are calculated and connected as two separate single-phase loads, Fig. 1. For example, assume that 30 per cent of full load at 230 volts is required for a 60-kw machine with noninductive loading:

$$\text{Total load} = 0.30 \times 60 = 18\text{ KW} = 18{,}000\text{ watts}$$

$$\text{Load per phase} = \frac{18{,}000}{2} = 9000\text{ watts}$$

$$\text{Phase current} = \frac{W}{V} = \frac{9000}{230} = 39.1\text{ amp}$$

$$\text{Phase-load resistance} = \frac{V}{I} = \frac{230}{39.1} = 5.88\text{ ohms}$$

From these data, a suitable loading arrangement can be selected for each phase. It will be noted that the values in the figure were obtained from this example. If the two inner wires are run as a common wire, the current in the common wire for balanced loads would be 1.41 times the current in each of the outer wires and consequently that wire would probably be larger than the two inside wires. For wattage measurement and wire sizes, see 2.09 through 2.16.

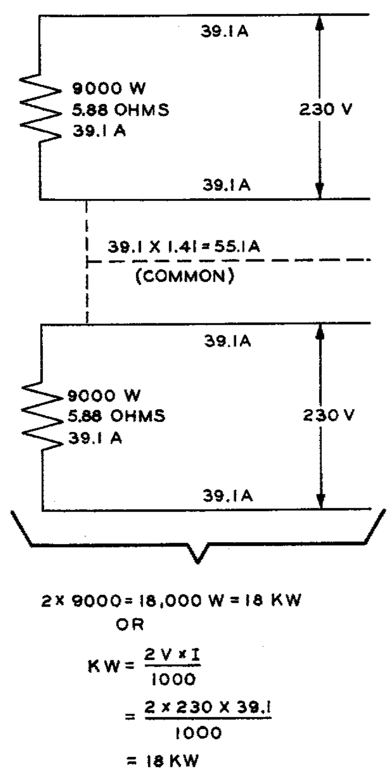

Fig. 1 — Typical Arrangement for 2-Phase 18-KW Balanced Noninductive Load

2.08 In calculating ***3-phase loads,*** it is convenient to divide the total desired wattage by three to obtain the individual phase loads and then calculate each phase load individually. The voltage across the line wires and the current in them is the same for a given output regardless of whether the three loads are connected in Y (also called star) or delta. See (a) and (b). However, the voltage and current for the phase loads will be different with the two arrangements.

(a) In delta connection, Fig. 2, the voltage across phase loads A, B, and C is, of course, the same as across the associated line wires. For balanced loads, the current in each phase load is the line current divided by 1.73. Delta connection is not convenient for connecting loads which must be adjusted such as water-rheostat loads, since the instruments are ordinarily connected in the line wires and the current in any line wire will be affected by more than one phase load. The most general application is for loads where the voltage or resistance with this connection is closer to the rated voltage or resistance of the available load equipment than would obtain with Y connection as covered in (b).

(b) In Y (also called star) connection, Fig. 3, the current in line wire L1, L2, or L3 is, of course, the same as in the associated phase loads A, B, or C. For balanced line voltage, the voltage across each phase load is the voltage across the line wires divided by 1.73. Since the instruments are connected in the line leads and the line and phase-load current is the same, 3-phase loads are usually connected in Y when current adjustment is necessary, such as with water rheostats. This connection is also applicable where the voltage or resistance with this connection is closer to the rated voltage or resistance of the available load equipment than would obtain with delta connection.

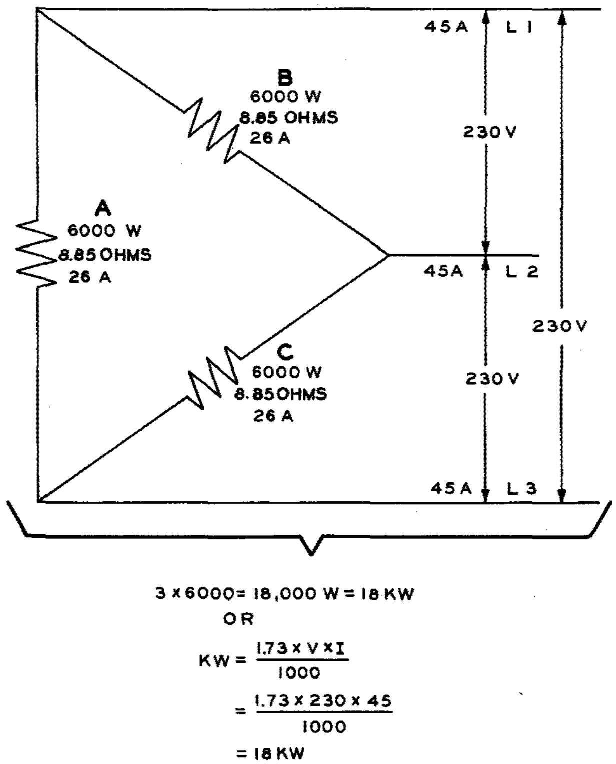

Fig. 2 – Typical Arrangement for 3-Phase 18-KW Balanced Noninductive Delta Connected Load

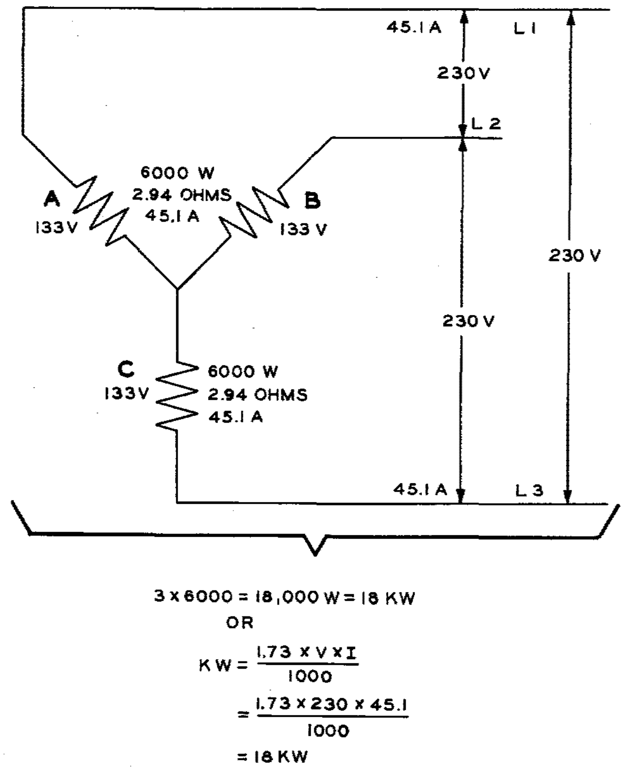

Fig. 3 – Typical Arrangement for 3-Phase 18-KW Balanced Noninductive Y Connected Load

As an example of calculating a 3-phase load, assume 30 per cent full load at 230 volts is required for a 60-kw machine, assuming non-inductive loading.

Total Load $0.30 \times 60 = 18$ KW = 18,000 watts

$$\text{Load per phase} = \frac{18{,}000}{3} = 6000 \text{ watts}$$

For Delta Connection

Phase-load voltage = 230 volts

$$\text{Phase-load current} = \frac{W}{V} = \frac{6000}{230} = 26.1 \text{ amp}$$

$$\text{Phase-load resistance} = \frac{V}{I} = \frac{230}{26} = 8.85 \text{ ohms}$$

Line-wire current = 26.1×1.73 = 45.1 amp

For Y Connection

$$\text{Phase-load voltage} = \frac{230}{1.73} = 133 \text{ volts}$$

$$\text{Phase-load current} = \frac{W}{V} = \frac{6000}{133} = 45.1 \text{ amp}$$

$$\text{Phase-load resistance} = \frac{V}{I} = \frac{133}{45.1} = 2.95 \text{ ohms}$$

Line-wire current = 45.1 amp

From the above data, suitable load arrangements can be selected for each phase load. It will be noted that the values shown in Fig. 2 and 3 were obtained from these examples. The neutral wire from a machine is seldom run to the artificial load. It would make an additional wattmeter necessary if loads were unbalanced. For wattage measurement and wire sizes, see 2.09 through 2.16.

Wattage Measurement

2.09 ***Wattmeters*** should be connected as shown in Fig. 5, 6, 7, and 8, unless otherwise specified. The voltage coil leads may be connected on either side of the current transformer and it will not be necessary to correct for meter loss except for small machines such as ringing machines. Voltage posts on portable wattmeters are marked with the voltage which, in the absence of other information, should not be exceeded. Different current capacities are usually obtained by links. Information on operation of link and the factor by which instrument reading must be multiplied to give actual wattage vary with different instruments and is given on instruction furnished with the wattmeter. If a current transformer is used, its ratio must also be considered as covered below.

2.10 *Current transformers* are employed where the current is too large for the wattmeter to be connected directly which is the usual case.

> ***Caution: The voltage as the secondary, when open-circuited with the primary excited, is dangerously high. In connecting current transformers, make certain that the secondary side of the transformer (instrument side) is short-circuited at all times unless the primary side of the transformer is dead or the secondary is part of an external closed circuit.***

2.11 A current transformer similar to the Weston Model 461 multirange transformer is usually employed where a portable instrument is required. This instrument has four self-contained primary (line side) windings brought out to binding posts for current values of 10-20-50 and 100 amperes (40-ampere post in some instances). An opening through the transformer core provides a means for increasing the primary range to 800 amperes as illustrated below. The secondary (instrument side) has a rating of 5 amperes and is generally used with the 5-ampere range on the wattmeter. A short-circuiting switch is associated with the secondary posts and it should be open only when the posts are connected by a closed circuit externally.

To obtain the actual wattage, the wattmeter reading should be multiplied by the wattmeter ratio times the transformer ratio. As an example, assume a single-phase ac load of 20 kw at 220 volts and power factor unity and that a model 461 current transformer and model 310 wattmeter is to be used.

$$\text{Current} = \frac{20{,}000\ \text{W}}{220\ \text{V}} = 90.9\ \text{amp}$$

Run 5 conductors through transformer.

$$\text{Transformation ratio} = \frac{100\ \text{A}}{5\ \text{A}} = 20\ \text{to}\ 1$$

Use wattmeter current range 5 amperes. Use wattmeter voltage range 300 volts. From the data on the particular wattmeter instruction sheet, the wattmeter multiplication factor for this range would be 2. The over-all multiplication factor would be $20 \times 2 = 40$. The wattmeter would read 1/2 kw and the actual wattage would be $40 \times 1/2 = 20$ kw.

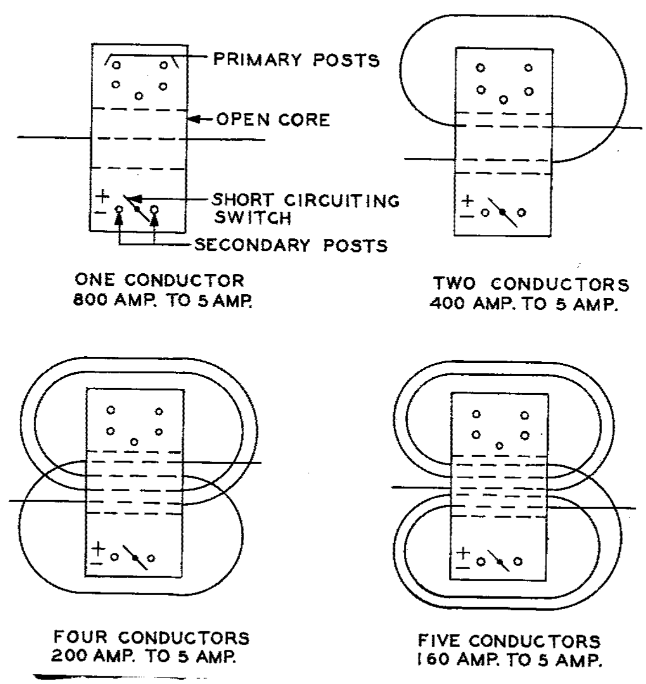

Fig. 4 – Typical Applications of Portable Current Transformer for Large Currents

2.12 The wattage of noninductive ***single-phase*** loads may be measured with a wattmeter or with an ammeter and a voltmeter. In the latter case, the product of the two readings is the wattage. If any of the load is inductive (motor load), a wattmeter should be used.

2.13 Although the ***wattage of 2-phase*** loads is usually measured with wattmeters, the wattage of all noninductive loads may be determined with ammeters and voltmeters. The current of a phase load times its voltage is the wattage of that load. The sum of the separate phase load wattages is the total wattage being delivered. If the two phase loads were connected as three wire, the current in each phase should not be read in the common wire as the common wire will carry the current of both phases which could not be added directly. For balanced noninductive 2-phase loads:

$$\text{Total KW} = \frac{2 \times \text{V phase per phase load} \times \text{I per phase load}}{1000}$$

For balanced noninductive loads, the line current (not common wire current) for any desired kw output is:

$$I = \frac{\text{total KW} \times 1000}{2V}$$

The wattage of two-phase inductive (motor load) loads is measured with one polyphase wattmeter or two single-phase wattmeters. It will be noted that the current coils are connected in the outside line wires and not in the common wire. A polyphase wattmeter will give the total wattage for all conditions of load. Where two single-phase wattmeters are used, the individual readings are added.

2.14 Although the wattage of ***3-phase, 3-wire*** loads is generally measured with wattmeters, as covered below, wattage of balanced noninductive 3-phase loads may be checked with ammeters and voltmeters usually furnished on the control board and connected in or across the line wires (not to neutral in the case of 4-wire service). For balanced noninductive loads, all of the ammeters and all of the voltmeters will read approximately the same. Under this condition, the total wattage drawn by the loading with either Y or delta connection is:

$$KW = \frac{1.73 \times \text{V between line wires} \times \text{I per line wire}}{1000}$$

and the line wire current for any desired kw output is:

$$I = \frac{\text{total KW} \times 1000}{V \times 1.73}$$

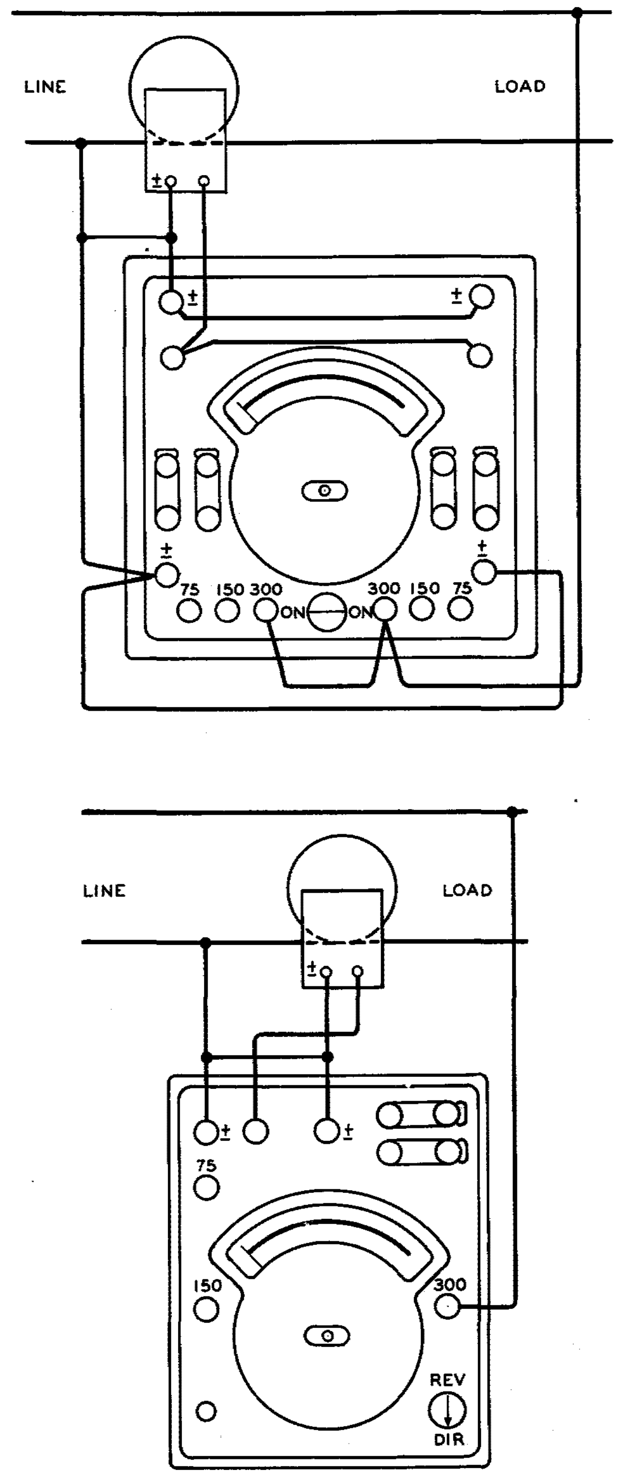

Fig. 5 – Typical Connections for Single-Phase Load Using a Polyphase or a Single-Phase Wattmeter

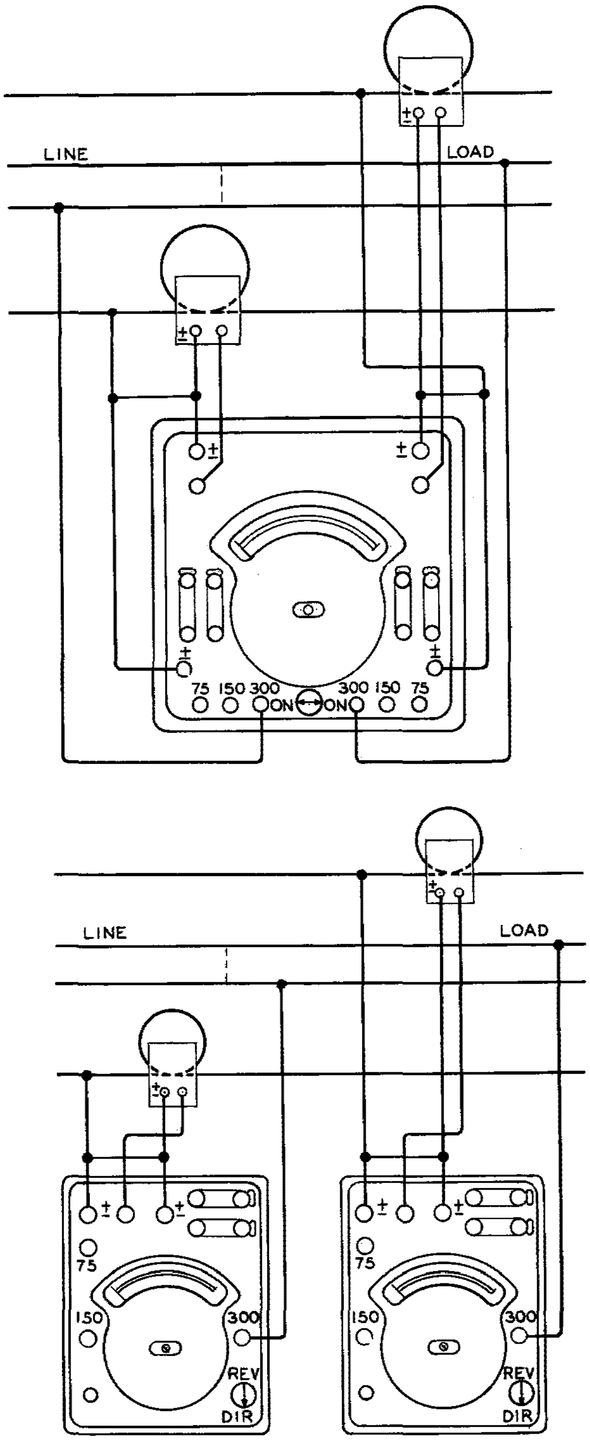

Fig. 6 – Typical Connections for 3- or 4-Wire, 2-Phase Loads Using One Polyphase Wattmeter or Two Single-Phase Wattmeters

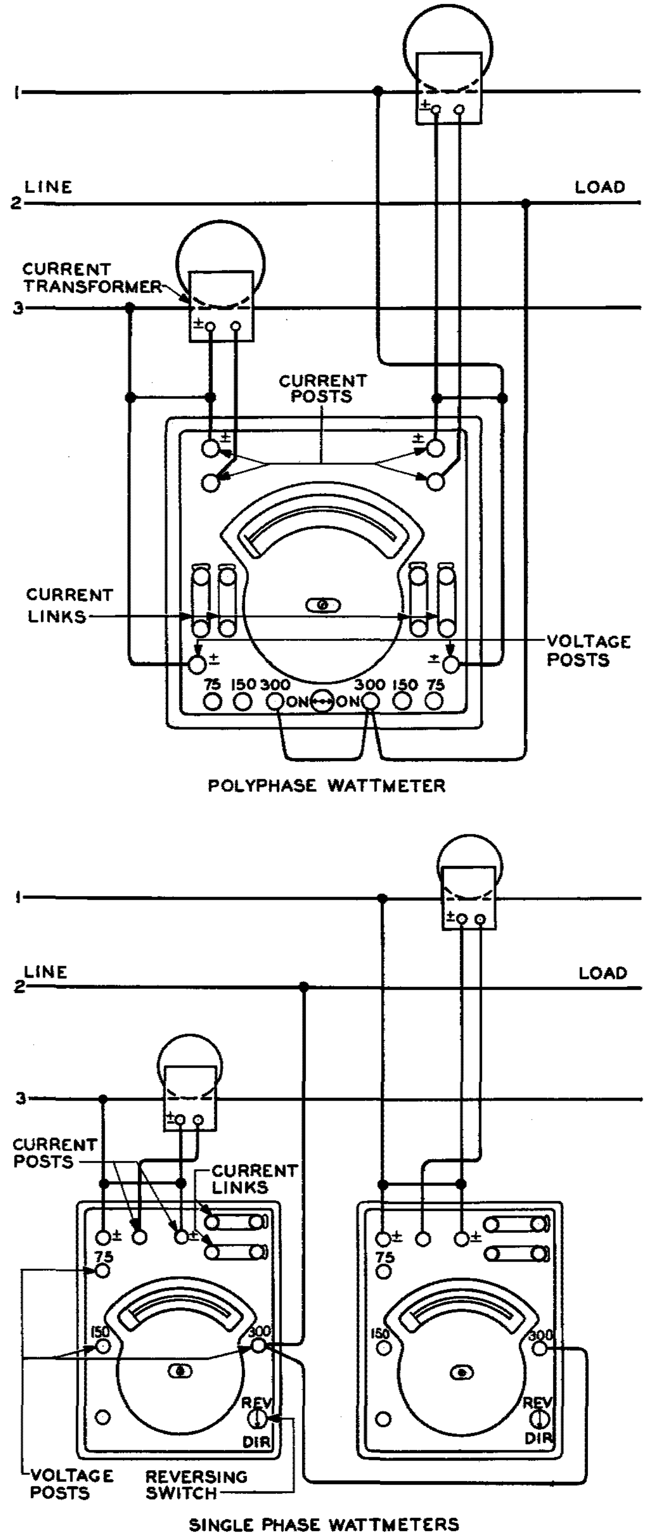

Fig. 7 – Typical Connections for 3-Phase, 3-Wire Loads Using One Polyphase Wattmeter or Two Single-Phase Wattmeters

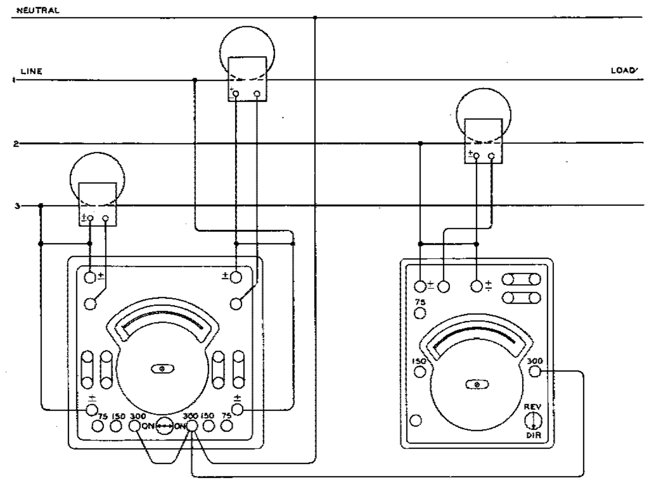

Fig. 8 – Typical Connections for 3-Phase, 4-Wire Loads Using One Polyphase Wattmeter and One Single-Phase Wattmeter

The wattage of unbalanced or inductive 3-phase, 3-wire loads is measured with one polyphase or two single-phase wattmeters. See Fig. 7. A polyphase wattmeter will indicate the total wattage for all conditions of load. Where two single-phase wattmeters are used, the individual readings are added. If it is necessary to reverse the current connection on the wattmeter or to turn the reversing switch to REV in order to obtain an up-scale reading, the total wattage is the difference between the two readings.

2.15 ***With a 3-phase, 4-wire service*** where four wires are run to the load, the neutral wire may carry current, in which case it is necessary to use one polyphase wattmeter and one single-phase wattmeter, three single-phase wattmeters or two polyphase wattmeters. All readings should be added if all wattmeters read up-scale. If it is necessary to reverse the current coil connections or the reversing switches in order to obtain an up-scale reading, add together the reading of reversed wattmeters and then add together the readings of the directly connected instruments. The total wattage is the difference between the two sums.

Wire Sizes

→**2.16** Table A agrees with the 1962 National Electric Code. The values are for Rubber Type RH, RH-RW, and RHW wire. With temporary wiring exposed to the air and under continuous supervision, current values up to 1-1/2 times (150 per cent) of the values may be used for full-load runs. The greater flexibility of small leads is of considerable advantage in pulling through the core of current transformers and in adjusting the electrodes of water rheostats. Any permanent or semipermanent wiring should meet the limits given in the table and be protected by fuses, as well as fused for temporary dc wiring.

TABLE A

SIZE	MAXIMUM CAPACITY IN AMPERES	SIZE	MAXIMUM CAPACITY IN AMPERES
14	20	00	225
12	25	000	260
10	40	0000	300
8	55	300,000	375
6	80	400,000	455
4	105	500,000	515
2	140	600,000	575
1	165	700,000	630
0	195	800,000	680

3. BATTERY CHARGING LOAD AND BUILDING LOADS

3.01 When loading a generator by ***charging the office battery,*** the fuseboard voltage is kept within limits by the regular office load, by connecting in countercells, by disconnecting one of duplicate batteries and charging it separately or by previously discharging the main battery sufficiently so that it will take the charge without exceeding the upper circuit limits. In scheduling tests involving motor operation on the outside service, the effect of this additional load on the demand factor should be considered.

3.02 In general, ***building loads*** are recommended as loading for alternators only where permanent wiring and switching equipment are installed for this purpose.

4. RESISTORS, RHEOSTATS (EXCLUDING WATER RHEOSTATS), LAMPS, AND HEATER UNITS

4.01 Western Electric resistors are designed for small current values and are satisfactory for small loads, such as the output of tone machines. Commercial tube resistors have appreciably higher current ratings and are described later under Commercial Loading Resistors. Adjustable rheostats (other than water rheostats covered later) are quite satisfactory if of the desired resistance and current rating to carry sufficient current. Unless already available, the cost of rheostats of high-current rating would seldom compare favorably with the cost of fixed resistors. Resistors, including rheostats, may be considered noninductive and can be used in any of the circuit arrangements described in the next paragraph.

4.02 ***Lamps or heaters*** may be connected individually, or in parallel to increase the load, or in series when higher voltages are encountered or in series parallel to build up the load on higher voltages. Fig. 9 shows some schematic connections.

4.03 Lamps are available in various wattages in train-service type at 32 volts and the regular house lighting type at 110 to 125 volts. The heater units are generally available in 660-watt capacity at 110 to 125 volts and sometimes at 220 to 250 volts. The lamps and heater units have medium screw bases and may be mounted in the same receptacles. Some receptacles are arranged for wiring on the front of the mounting panel and some on the rear. They should be 660-watt, 250-volt type. The receptacles should be mounted on a fireproof panel such as sheet-rock asbestos board. Receptacles should be mounted on at least 6-inch centers so that the heat may be carried away from each unit. Where the panel is to be mounted vertically, it is preferable to arrange the receptacles staggered to reduce overheating the units in the top row. If the board is to be laid flat on some surface, the wiring arrangement may be followed as shown in Fig. 10 and 11.

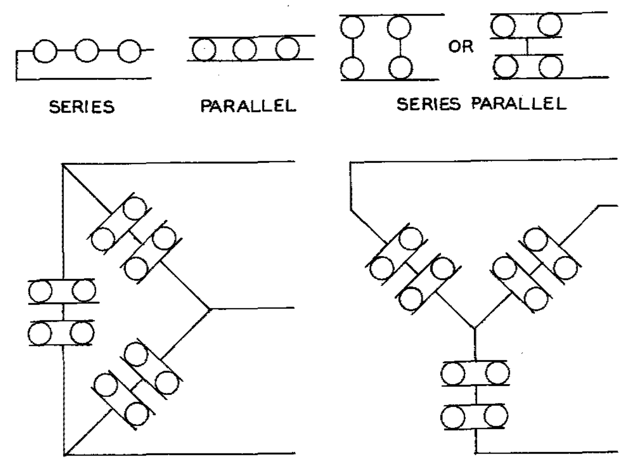

Fig. 9 — Schematic Connections

4.04 ***Lamps*** are designed primarily to operate across rated voltages and the wattage rating is based on rated voltage. Consequently, where it is essential to use a minimum number of lamps, the lamps are selected and connected for operation close to rated voltages. The number of lamps required for a load is conveniently estimated on a wattage basis. The current through any lamp circuit will be the total watts divided by the voltage across the circuits, whether it be a group in series or in parallel. The current is mainly of interest in determining wire sizes.

4.05 In estimating the number of ***lamps*** required for application at other than rated voltage, it will be necessary to consider the corresponding change in wattage. The approximate per cent of the rated watts drawn by lamps operated at from 50 to 120 per cent of the rated voltage is shown in Table B.

Table B — Wattage Variation of Lamps for Various Voltages

PER CENT OF RATED VOLTAGE	PER CENT OF RATED WATTS
120	133
110	118
100	100
90	85
80	70
70	57
60	45
50	35

As an example in applying Table B, assume a lamp load consisting of 32-volt lamps is required for a 45-ampere, 25-volt output.

Machine output = 45A × 25V = 1125 watts

Lamps will operate at $\frac{25V}{32V}$ = 78 per cent rated volts

At 78 per cent volts, lamps draw 70 per cent of the rated watts

Watts drawn per 100 watt lamp = 0.70 × 100W = 70 watts

Number of lamps = $\frac{1125W}{70W}$ = 16 in parallel

4.06 *Lamps* may be operated somewhat above rated voltage but this decreases lamp life. For series connection, lamps of the same rated voltage and wattage are generally used. If the circuit voltage were 240 volts, two 100-watt 120-volt lamps in series would each operate at rated voltage and wattage. The wattage for the two in series would be 200 watts and the current would be 200 watts divided by 240 volts equals 0.83 ampere. If 110-volt lamps were used, they would operate at 240 volts divided by 220 volts or 109 per cent of rated voltage. They would draw approximately 115 per cent rated wattage, or 200 times 1.15 equals 230 watts (from Table B). The current would be 230 watts divided by 240 volts equals 0.960 ampere per series circuit of two lamps.

4.07 ***Heater units,*** like lamps, draw rated wattage only at rated voltage. The number of units required for a load is conveniently estimated on a wattage basis. However, heater units operate at a luminous heat at rated voltage and the life in any case is relatively short. For longer life, they are operated at less than rated voltage at a sacrifice in wattage. The current through any heater unit circuit is the total watts divided by the voltage across that circuit whether the units be connected in series or in parallel. The current is mainly of interest in determining wire sizes.

4.08 The approximate per cent of the rated watts drawn by units operated at from 50 to 100 per cent of the rated voltage is shown in Table C and may be useful in estimating the number of units required for application at other than rated voltage.

Table C — Wattage Variation of Heater Units for Various Voltages

PER CENT OF RATED VOLTAGE	PER CENT OF RATED WATTS
100	100
90	80
80	65
70	50
60	35
50	25

As an example in applying Table C, assume a heater unit load consisting of 120-volt, 660-watt units is to be used for a 100-ampere, 60-volt output.

Machine output = 100A × 60V = 6000 watts

Units will operate at $\frac{60V}{120V}$ = 50 per cent rated volts

At 50 per cent volts, heaters draw 25 per cent rated watts

Watts drawn per 660-watt heater = 0.25 × 660W = 165 watts

Number of heaters = $\frac{6000W}{165W}$ = 36 in parallel

4.09 ***For series connection,*** units of the same rated voltage and wattage are generally used. Series circuits are connected in parallel to build up the load. As an example of series parallel connections, see Fig. 9, assume a heater-unit load consisting of 660-watt, 110-volt units is to be used for a 20-ampere, 160-volt output.

Machine output = 20A × 160V = 3200 watts

Over-all rated volts for 2 units in series = 2 × 110V = 220 volts

Units to operate at $\frac{160V}{220V}$ = 73 per cent rated volts

At 73 per cent voltage, heaters draw about 54 per cent rated watts

2 heaters in series will draw 2 × 660W × 0.54 = 713 watts

Series circuits required in parallel = $\frac{3200W}{713W}$ = 4.5

Four circuits could accommodate 4 × 713W = 2852 watts

The current would be $\frac{2852W}{160V}$ = 17.8 amp

Five circuits could accommodate 5 × 713W = 3565 watts

The current would be $\frac{3565W}{160V}$ = 22.3 amp

If a closer adjustment were required, four parallel strings of heaters (two units per string) would be used and the additional 348 watts (3200 minus 2852) would be taken up by two additional parallel strings, each consisting of two 110-volt, 150-watt lamps in series or three strings of 100-watt lamps. The size of lamps is calculated in accordance with 4.05.

4.10 As an example in applying ***heater units for routine load of an alternator,*** assume that approximately 30 per cent load is required for a 10-kw, 230-volt, 3-phase, 3- or 4-wire machine.

Total load required = 0.30 × 10 KW = 3 KW = 3000 watts

Load per phase = $\frac{3000}{3}$ = 1000 watts

For delta connection, Fig. 2, 9, and 10, the voltage would be 230

For 230V, use two 115-volt, 660-watt heaters in series

Over-all rated voltage would be 2 × 115 = 230 volts

Units to operate at full rated voltage

Two units in series will draw 2 × 660 = 1320 watts per phase load

Six units on 3-phase delta draw 3 × 1320 = 3960 watts

Total current through each string = $\frac{1320W}{230V}$ = 5.75 amp

The line current will be 1.73 times the current in one-phase load or 5.75 × 1.73 = 10 amp

Fig. 10 shows a typical panel layout and wiring for this load.

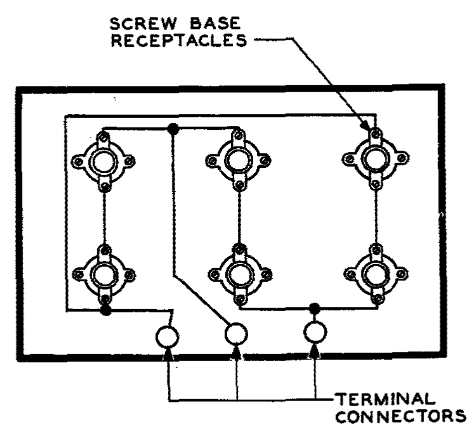

Fig. 10 – Typical Panel Layout of Six Receptacles Wired in Delta With Two Receptacles in Series per Phase

If the heaters were to be wired in Y connection, Fig. 3 and 9, for the above machine, the voltage per phase would be $\frac{230V}{1.73} = 133$ volts.

Two 115 volt units in series would operate at $\frac{133V}{230V} = 58$ per cent voltage.

From the table, each string of two heaters would draw $0.35 \times 2 \times 660 = 462$ watts.

Each phase would require $\frac{1250W}{462W} = 3$ strings of 2 units

The total number of units would be 18 as compared with 6 for delta connection.

4.11 For a 30 per cent load on a 20-kw machine, either two panels similar to Fig. 10 in parallel or one panel similar to Fig. 11 is suggested.

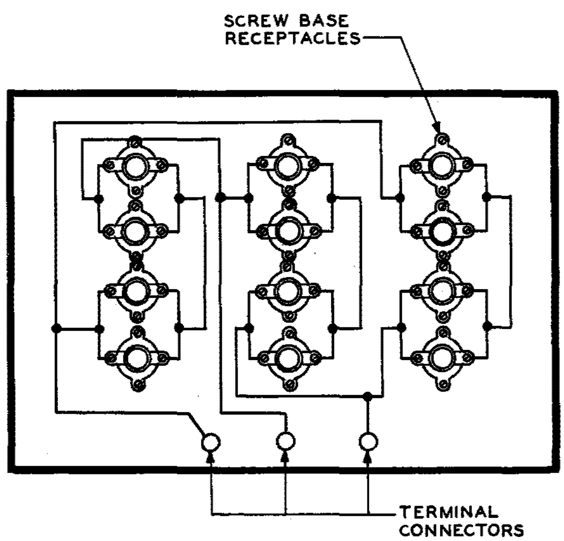

Fig. 11 – Typical Layout of Twelve Receptacles Wired in Delta With Four per Phase in Series Parallel

5. COMMERCIAL LOADING RESISTORS

5.01 For low-capacity applications, commercial ***tubular-wound resistors*** are available in various values of resistance and current capacity but are rarely stocked. Tubes are mounted and enclosed in groups as required for each application. For larger loads, ***ribbon- and cast-grid-type resistors*** are generally stocked commercially in certain fixed values of resistance and current capacity. The ribbon-type is more expensive than the cast-grid type but weighs less and is not subject to the breakage in handling which is characteristic of cast-grid-type resistors.

5.02 For ***dc loading,*** the voltage and current being specified, the wattage, and resistance may be readily calculated. See 2.02. If tubular-type resistors are to be used, tubes having a resistance closest to the calculated value would be selected from the manufacturer's information. Sufficient tubes will be required to build the load up to the desired wattage. From the manufacturer's information, it will be noted that the wattage allowed per tube decreases in value as the number of tubes in group increases. If a suitable resistor unit of the ribbon- or cast-grid type is available from stock, it will generally be less expensive for that application than a tubular-type built-up resistor.

5.03 In calculating ***resistor loading for alternators,*** the wattage per phase load is determined by dividing the total wattage by the number of phases as illustrated in the discussion of general calculations, Part 2. The voltage per phase load in the case of 3-phase machines will depend on whether the loads are to be connected in Y or in delta, Fig. 2 or 3. The phase-load voltage is generally calculated for both methods and the corresponding current and resistance values determined for each method. Resistors are selected closest to these requirements.

5.04 Where ***tubular-type resistors*** are used, they would be wired to divide the load equally among the phases. Where the fixed resistor type units are used for large machines and each phase requires full capacity of one resistor, the load is also divided equally among the phases.

5.05 The wattage rating of one of the ***fixed*** resistors may be sufficient for the total required load on smaller machines. Since all of the fixed resistors of any type have practically the same wattage capacity and cost the same, regardless of resistance and current rating, a simpler and more economical arrangement may

TABLE D

KW OF SET	30 PER CENT OF KW	PER PHASE KW	METHOD OF CONNECTION	CALCULATED AMPERES EACH LEG	CALCULATED RESISTANCE EACH LEG	RESISTANCE AVAILABLE SEE NOTE	ACTUAL PER CENT OF KW LOAD
10	3	3	1-Phase	13	17.7	17	31
20	6	6	1-Phase	26	8.8	9	29.4
25	7.5	3.75	2-Phase	16.3	14.1	14	30.3
30	9	4.5	2-Phase	19.5	11.2	12	29.4
40	12	4	Delta	17.4	13.2	14	28.4
50	15	5	Delta	21.7	10.6	10.5	30.9
60	18	6	Delta	26	8.8	9	29.4
70	21	7	Delta	30.4	7.6	7.2	31.4
75	22.5	7.5	Y	56.4	2.4	2.2	28

Note: General Electric Company IC 9133 resistors are available in varying resistance and ampere ratings.

result if all of the load is placed on one or two phases of a 3-phase machine. There is no difficulty anticipated in doing this on machines where the purpose of the loading is to routine the engine and the exact amount of load is not important. With unbalanced loads of this type, not more than one-fourth of the 3-phase rating should be applied to any one phase.

5.06 Some typical examples in the application of edgewise-wound, steel-ribbon-type resistors for routine loading at approximately 30 per cent rated capacity of 230 volt, 1- to 3-phase machines are shown in Table D. These loads are calculated as covered in the discussion of general calculations in 2.08.

6. WATER RHEOSTATS

Note: Wattmeter measurements and wire capacities are covered in Part 2.

Caution: The moisture and voltage combinations subject an operator to possible shock. If work on a live load is necessary, stand on a dry insulating board or rubber mat and use only one hand. Provide for adequate ventilation of artificial loads to allow for heat dissipation, etc. Considerable foaming takes place and explosive mixtures of oxygen and hydrogen are given off when a water rheostat is loaded with direct current. Smoking or any other activity that could produce a spark or flame in the vicinity of the rheostat should be avoided.

6.01 Use only sodium carbonate or sodium chromate in the R-2759, R-2746, and R-3104 water rheostats. Sodium carbonate and sodium chromate in power and in a solution of water must be carefully handled. Avoid contacting the skin with either the powder or the solution because skin ulcers or rash may result. Avoid contact with the eyes and avoid inhaling. In case of contact, immediately flush skin or eyes with plenty of water for at least 15 minutes. After this, for eyes, obtain medical attention. Should powder or solution contact clothing, wash the clothing before re-use.

6.02 If water rheostats are to be left out-of-doors in freezing temperatures, drain the rheostats, when not in use, to prevent freezing. This includes draining the cooling system, when one is used, as well as the tank itself.

6.03 An accumulation of sodium-carbonate or sodium-chromate crystals in the bottom of these rheostats (particularly the R-3104) may result in an uncontrollable load. In this case, the solution should be drained and the tank refilled with fresh water. Fresh sodium-carbonate or sodium-chromate solution should then be added as required. In extreme cases, this procedure may not improve the operation. In such cases, if the load is still uncontrollable, it is recommended that the inside of the tank be steam cleaned if such facilities are locally available. See 6.31.

R-2759 6-KW Water Rheostat

6.04 The R-2759 water rheostat, see Fig. 12, has been designed for applications where a small load is needed. Running water for cooling this rheostat is not required. Remove the two side covers which are attached to the shipping straps by removing the six bolts. With side covers removed, fill rheostat tank with water to about 1 inch below the terminals. Dissolve three tablespoons of sodium carbonate or sodium chromate in a pint of warm water and add this solution to each rheostat. A larger amount of sodium carbonate or sodium chromate will be needed for dc loading. The terminals are then turned out and the electrical connections are made to them. See Fig. 13.

6.05 The load may be varied by raising or lowering the separator located in the slot on the electrode assembly cover. This separator may be held in any position by employing a pair of wooden-spring-type clips, one at each edge of the separator and allowing them to rest on the top of the electrode assembly cover.

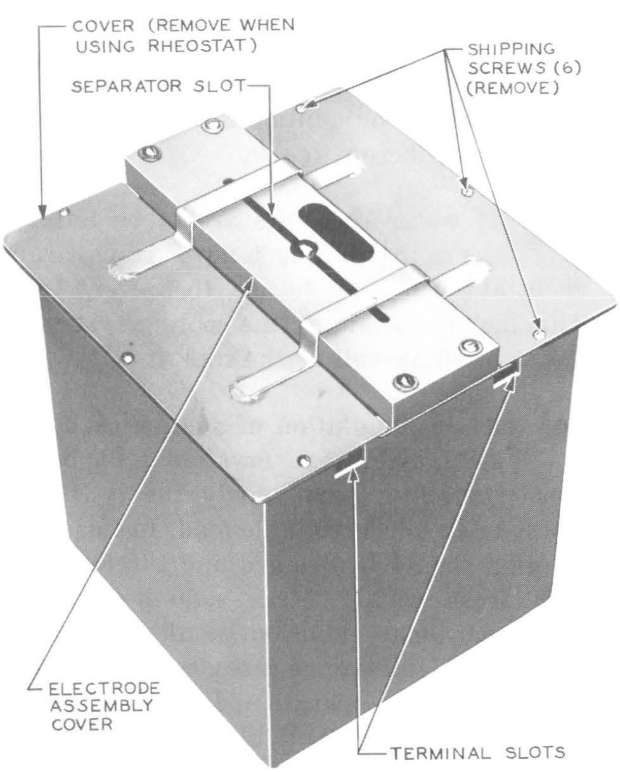

Fig. 12 – R-2759 6-KW Water Rheostat

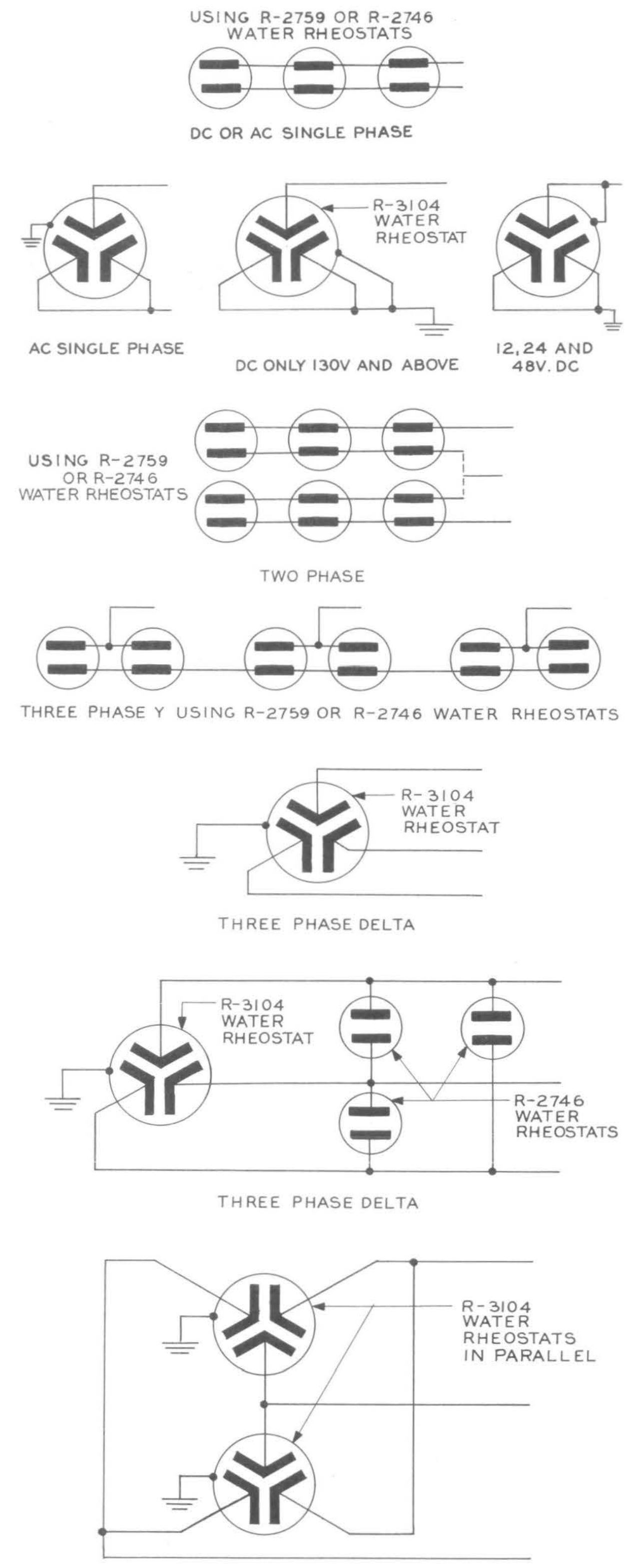

Fig. 13 – Typical Electrical Connections for Water Rheostats

R-2746 30-KW Water Rheostat

6.06 The R-2746 30-kw water rheostat, see Fig. 14, employs a cooling coil mounted in the solution. The main tank is composed of wood; careful operation and filling will prevent any undue leaks. If it is to be left out of doors in low temperatures, it should be drained. The location of the rheostat should be suitable for easy draining of the tank and cooling coils to prevent freezing.

6.07 Lower the separator to the bottom of the tank through the slot provided in the cover. The separator is maintained to any desired depth with the aid of wooden-spring-type clips, placed one at each edge of the separator, with the clips resting on the top cover of the rheostat. Electrical connections should be clean and tight. If a dc load is applied, the positive connection should be made to the plate nearest the cooling coil. On ac, either terminal may be connected. See Fig. 13.

6.08 The building water supply is connected to the IN coupling. This may be done by means of a garden hose capable of withstanding the local city water pressures which will be encountered at the various offices where these rheostats will be used. The water received must be from a hose 3/4 inch or larger and can be used to supply a maximum of six R-2746 rheostats. Another hose is connected from the OUT connection to a convenient drain for the purpose of carrying off the heated water from the cooling coil as well as draining the rheostat. The NEXT TANK valves are to be open except at the last rheostat in the group which is closed. See Fig. 15. Close all DRAIN and COOL valves. With the water supply on, open FILL valves and fill each rheostat to the level marked on the cooling coil. This may be observed through the opening at the top of the rheostat with the cover open. Do not allow water to touch the underside of the terminal assembly at the top of the rheostat since current flowing between them during operation would result in permanent damage to the assembly.

6.09 Dissolve 3 tablespoons of sodium car-← bonate or sodium chromate in a pint of← warm water and add this amount to each rheostat. More sodium carbonate or sodium chromate← will be necessary if dc loading is required. This will depend upon the dc voltage as well as the size of load desired; a great deal of sodium car-← bonate or sodium chromate will be needed at← lower voltages and higher loads.

6.10 With the separators in full-down position and the COOL valve closed, apply load voltage. Gradually raise separators towards full-up position, allowing 5 to 20 minutes for the rheostat load to build up. If load is not obtained with separators in position when they are fully extended, add more of the sodium-carbonate or← sodium-chromate solution as required to stabilize rheostat to the desired load.

6.11 The water temperature in the rheostat must be kept below boiling to prevent steaming and excessive vapors. Open the COOL valve as needed to reduce this temperature. By regulating this cooling water, the tank water can be kept at a point below boiling. Boiling temperatures would permanently damage the wooden tank of the water rheostat.

6.12 If the regulation obtained indicates that too much sodium carbonate or sodium← chromate was used, remove the load. Close the COOL valve and open the DRAIN valve. Close the DRAIN valve when the desired amount of sodium-carbonate or sodium-chromate solution← has drained. Replace the drained solution by opening the FILL valve, filling to the proper level and closing the FILL valve when the level required for the tank water is reached. The COOL valve is then operated to regulate the flow of water to keep the rheostat cool after the load has been restored.

R-3104 120-KW Water Rheostat

6.13 The R-3104 water rheostat has been designed for applications where a heavy duty load is needed. The water rheostat may be used as an artificial load for engine-alternators and large dc power plants.

> ***Caution:** In dc operation there is a tendency for sodium-carbonate or sodium-chro-← mate foam to splatter in the vicinity of the water rheostat, thereby endangering personnel.*

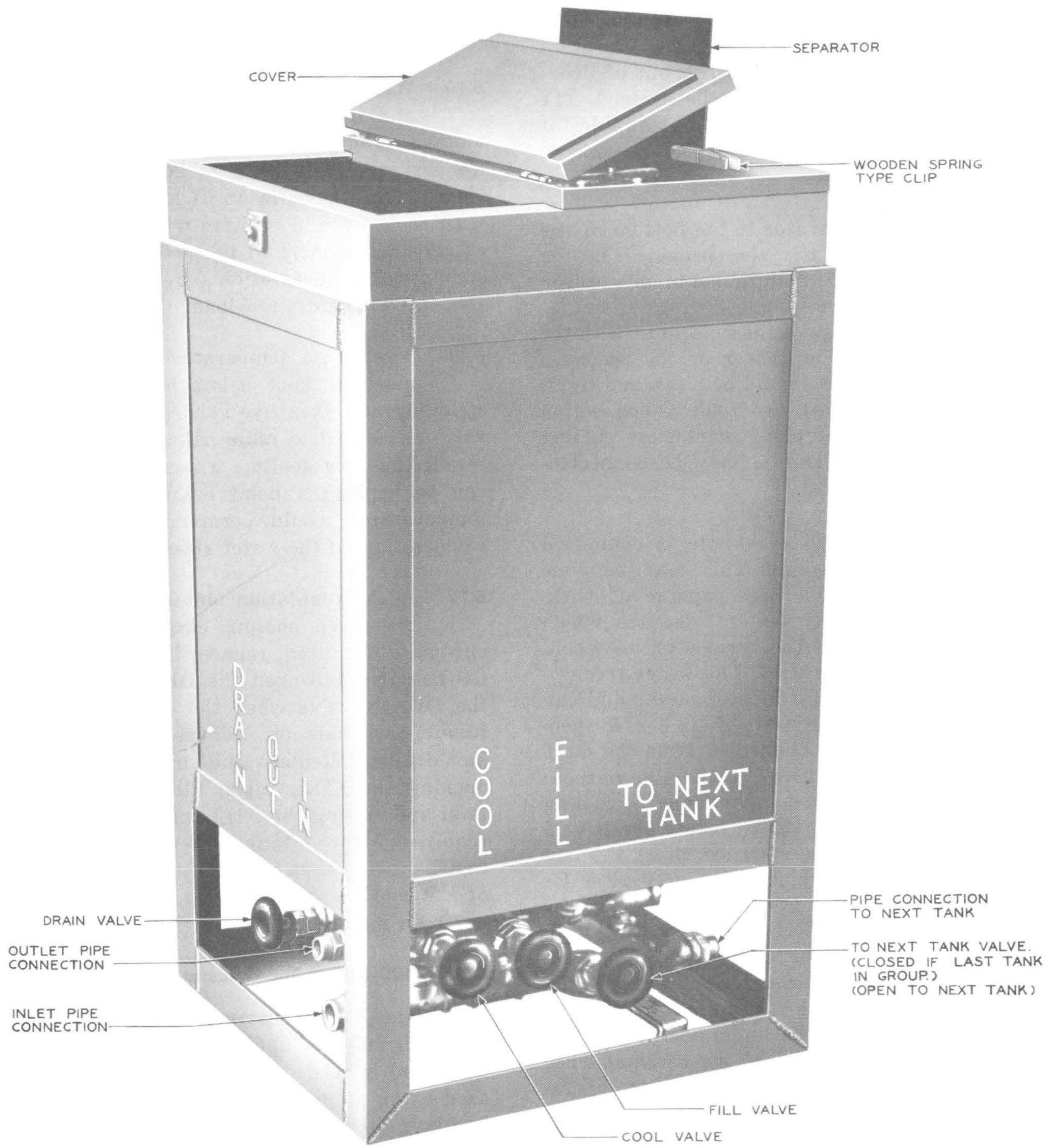

Fig. 14 – R-2746 30-KW Water Rheostat

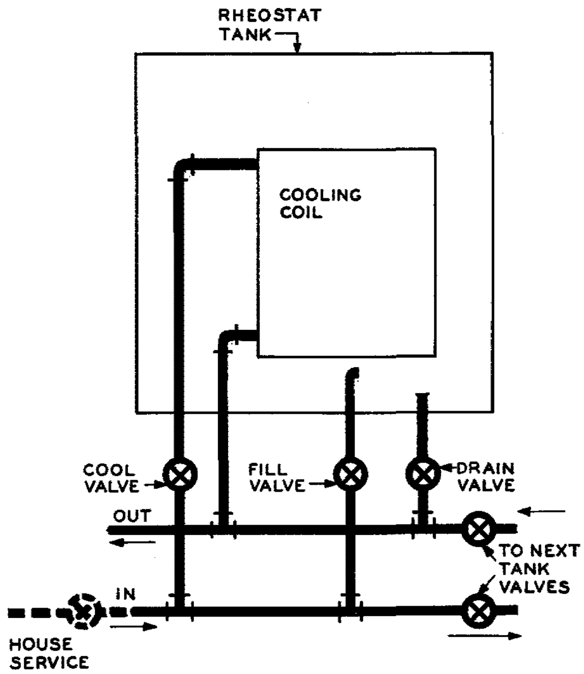

Fig. 15 – Piping Schematic of R-2746 30-KW Water Rheostat Cooling System

This condition is caused by the gases that form under a blanket of foaming sodium carbonate or← sodium chromate. When there is a sufficient buildup of pressure in these gases, the foaming sodium carbonate or sodium chromate ruptures,← splattering the foam in the immediate area around the water rheostat.

6.14 The water rheostat may be located indoors but preferably out of doors where it will be most convenient to a supply of running water, drainage, the machine under test, and a 115-volt ac outlet. A location which is suitable for visual observation as well as protection of passing personnel is also recommended.

> ***Caution:*** ***Smoking or any other activity which might produce a spark, flame, or a concentration of heat should not be permitted in the vicinity of the rheostat, especially when operated as a dc load.***

6.15 The water rheostat is composed of a 50-gallon size large steel drum, see Fig. 16, into which is mounted an assembly consisting of a set of three cooling coils, three electrodes, a bracket containing the operating valves, and a hydraulic-ram-operated separator assembly.

6.16 Remove the cover of the rheostat and unstrap the three hoses held inside the cover. Use the cover as a pedestal for the rheostat by placing it flange side down with the rheostat standing on top of it. The longest of the three hoses (with the hooked pipe on one end) is attached to the DRAIN connection with the hooked end placed over the upper rim of the barrel. The remaining hoses are attached to the INLET and OUTLET connections. It is suggested that the user of this rheostat purchase garden hose of the length required for his particular location of the water rheostat. The standard garden hose couplings may be used with particular attention paid to the ability of the garden hose to withstand the local water pressure anticipated at the water rheostat site.

6.17 With the garden hose connected to the water supply, fill the barrel from the top to within 4 inches of the top. After filling, shut off the water supply and connect the garden hose to the INLET hose. Run another hose, if necessary, from the DRAIN to a convenient source of drainage.

6.18 The city water circulates through the cooling coil, extracting the heat dissipated by the electrodes which are immersed in the barrel water, see Fig. 17. A cooling-water flow regulator located in the outlet line restricts the flow of cooling water. At 60 F the water is shut off or reduced to a trickle. As the temperature of the water in the tank reaches approximately 180 to 190 F, a full flow of circulating water through the cooling coils is obtained, thereby causing a balanced condition of temperature and load. A water level regulator is also used. This automatically maintains the proper water level in the barrel, by a float and valve device to replace the water lost by evaporation.

6.19 Prepare a mixture of sodium-carbonate or← sodium-chromate solution as follows.

(a) ***For AC Loads***

(1) ***R-3104 Water Rheostat Equipped With the Mason Jar Salt Dispenser:*** Remove the mason jar which is the salt dispenser, see Fig. 16, from its holding clamp located at the top of the rheostat assembly. Remove the lid from the jar. Fill the jar to within 1 inch of the top, preferably with hot water.

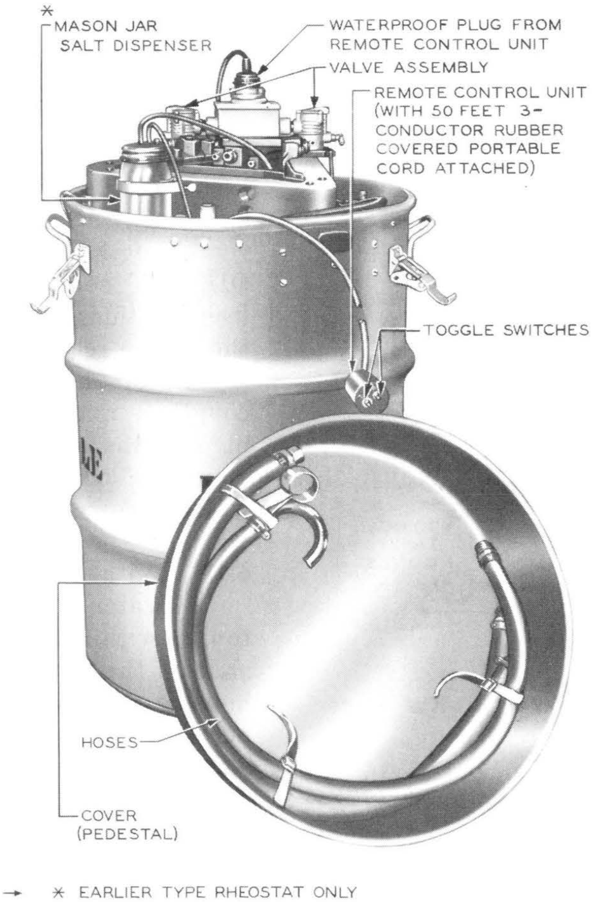

Fig. 16 – R-3104 120-KW Water Rheostat With Cover Removed

While stirring the water, slowly add 6 tablespoons (1/2 cup) of sodium carbonate or sodium chromate into the hot water until all the crystals have been dissolved. Replace the jar in its holding clamp, taking care not to spill any of the sodium-chromate or sodium-chromate solution into the barrel. Replace the lid of the dispenser.

(2) ***R-3104 Water Rheostat Not Equipped With the Mason Jar Salt Dispenser:*** Slowly add 6 tablespoons (1/2 cup) of sodium carbonate or sodium chromate to 1/2 gallon of water (preferably hot) and stir the water to dissolve all the crystals. Pour the solution into the barrel around the side of the barrel.

(b) ***For DC Load:*** The limit of dc load current is 850 amperes for this rheostat. The following amounts of sodium carbonate or sodium chromate should produce about 850 amperes at the dc voltages listed: 130 volts - 1/2 cup; 48 volts - 2 cups; 24 volts - 4 cups; and 12 volts - 8 cups. The amount required for any other value of load current may be estimated from these figures. Mix the estimated amount of sodium carbonate or sodium chromate in 1/2 gallon of water (preferably hot) and pour this solution into the barrel around the side of the barrel.

6.20 Check to see that the ac lead from the rheostat control panel reaches an ac outlet, but do not plug it in until ready to operate the water rheostat.

6.21 The power wires may now be connected to the lugs located at the top of the rheostat, see 2.16. Each of these wires must be fused so as not to exceed 125 per cent of the anticipated maximum current of the wire. Dress leads radially from each lug to prevent any restriction in the vertical movement of the separator assembly. Where the rheostat is connected to an ac load, connect a ground lead from the ground lug at the side of the barrel with office ground. Where the rheostat is connected to a dc load, two of the electrodes are electrically joined. A jumper is used between any two of the three electrode lugs and connected to the grounded side of the dc power source. Connect the other electrode through a fuse to the ungrounded side of the dc power source. It is advisable to alternate the electrodes which will be used for ground. This is done to lengthen the life of all the electrodes because of the corrosive action which tends to damage the electrodes used as ground.

6.22 The remote control unit is used to raise and lower the separators. One end plugs into the waterproof socket of the valve assembly located on the top of the barrel. See Fig. 18. The ac lead is plugged into a convenient 115-volt ac outlet. The long third lead terminates in the remote control unit which has two toggle switches R (raise) and L (lower). The electric circuit schematic of this remote control unit is shown in Fig. 19. The long lead of the remote control unit allows for greater flexibility in the safe operation of the water rheostat.

6.23 The circuit of the remote control unit is so designed that the R and L valves are always held closed. If either of the R or L toggle switches is held in position, that particular valve will open and raise or lower the separators respectively. By holding the R toggle switch in R position, the RAISE valve will open and allow the city water, which is available under pressure at one side of the RAISE valve, see Fig. 17, to flow through the hollow fixed piston and cause the activating cylinder to move upward. The separators are mounted to the support tube which is attached to the activating cylinder. If the R toggle

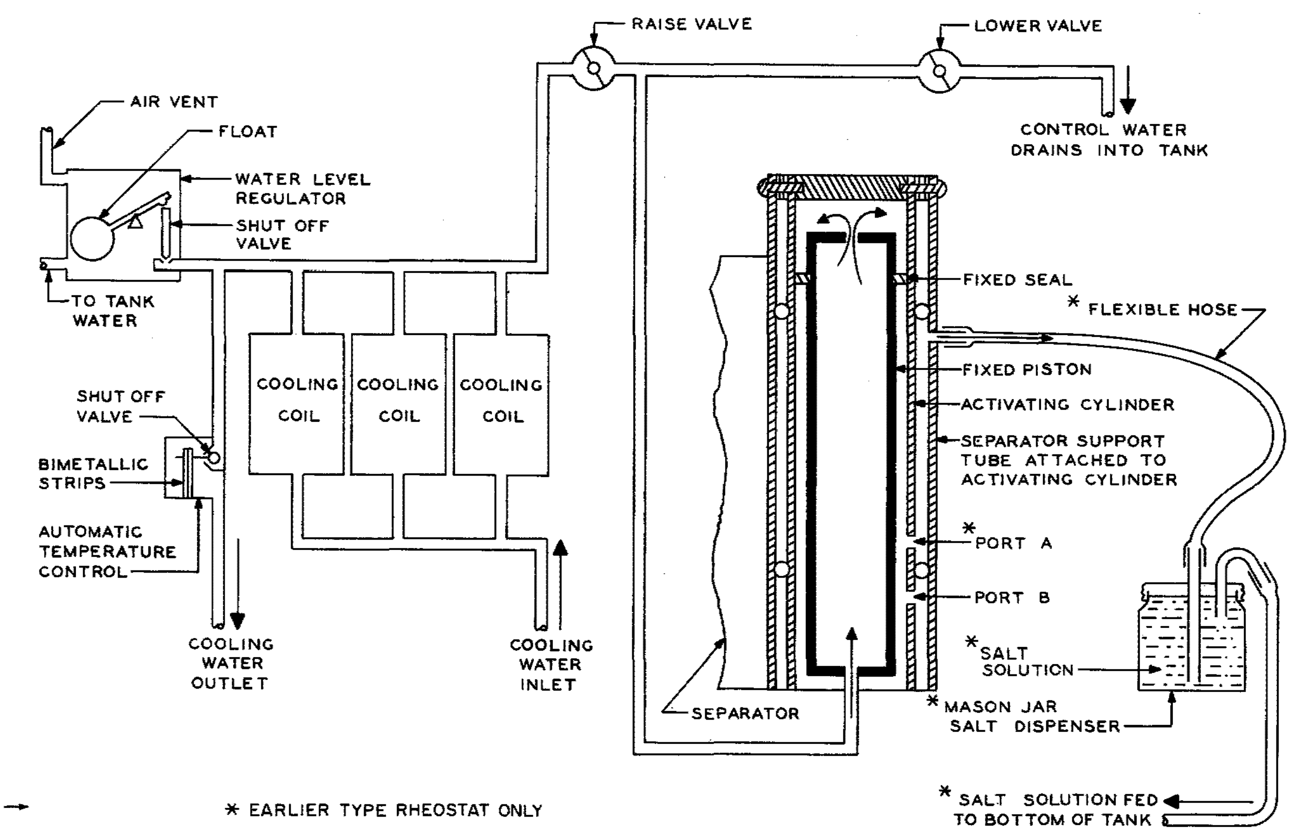

Fig. 17 – Cooling and Hydraulic System of R-3104 120-KW Water Rheostat — Schematic Diagram

switch is released, the RAISE valve closes and traps the water between the valves and the cylinder, causing the separators to remain stationary. Operation of the L toggle switch will open the LOWER valve and the trapped water will be expelled through the LOWER valve due to the weight of the separator assembly, thus lowering →the separators. Port B prevents excessive rising →of the separators.

6.24 Operating the R or L toggle switches will raise or lower the separator and respectively increase or decrease the load.

6.25 ***AC Load — R-3104 Water Rheostat Equipped With Mason Jar Salt Dispenser:*** →The load may be increased by adding a sodium- →carbonate or sodium-chromate solution to the barrel water. This is accomplished by operating the R toggle switch and therefore raising the separators to their maximum height. When this maximum height is reached, port A of the activating cylinder rises above the sliding seal of the fixed piston, causing the water to move through port A and into the salt dispenser through a flexible tube. The sodium-carbonate or sodium-chromate solution, which is in the jar attached to the tube, will overflow and feed the solution into the barrel at the bottom of the tank. To prevent the separator assembly from rising excessively, port B will expel the water back into the tank. This safety device is used in the event that port A or one of the salt dispenser tubes should become plugged or blocked. See Fig. 17.

6.26 To operate the water rheostat, insert the three prong waterproof plug from the remote control unit into the outlet box on the valve assembly located on top of the rheostat. See Fig. 18. Plug in the power cord of the remote control unit to a convenient 115-volt ac supply and then slowly turn on the water supply

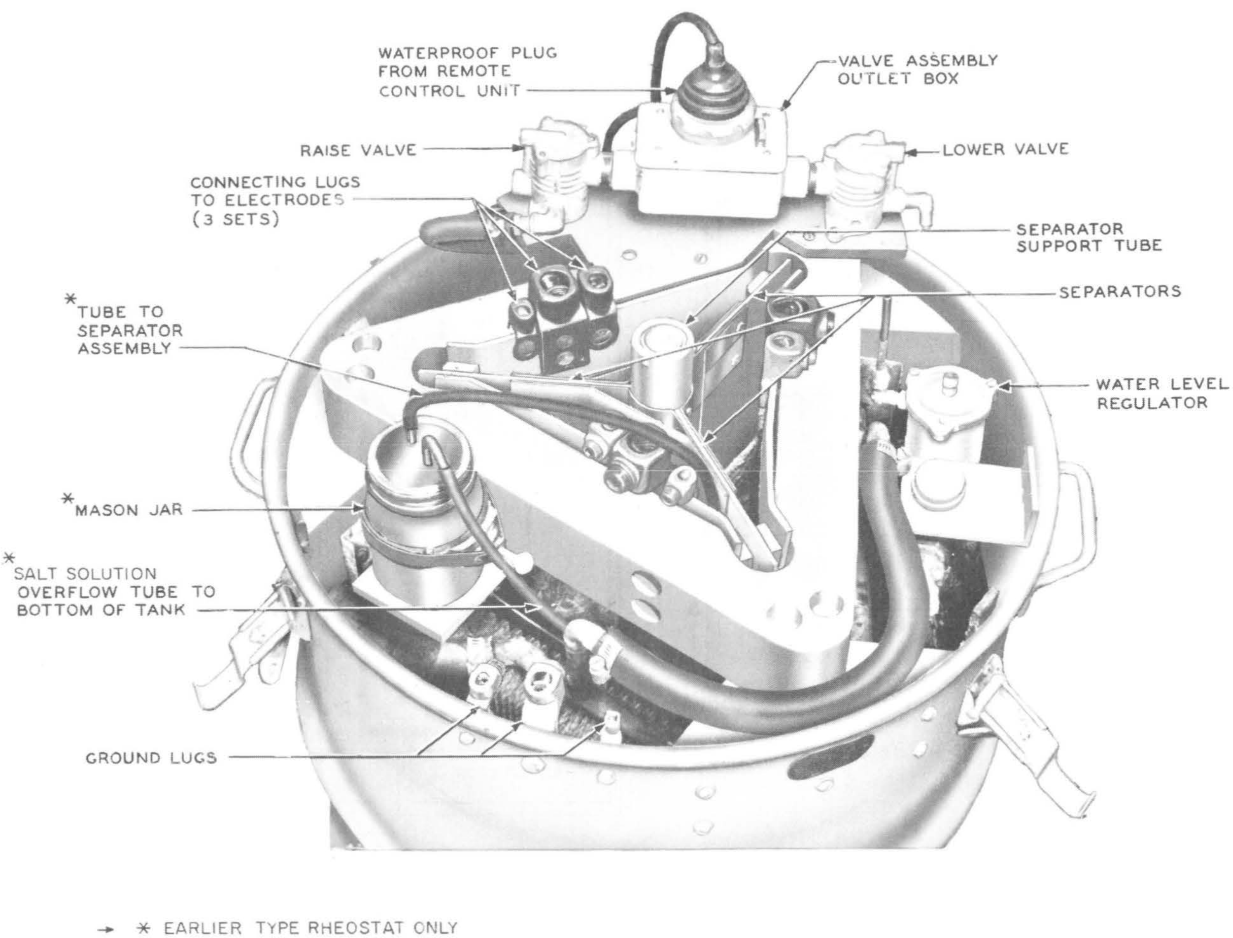

Fig. 18 – R-3104 120-KW Water Rheostat — Top View

to which the cooling water inlet hose is connected.

6.27 ***Caution: The remote control panel should not be operated at a distance of less than 5 feet from the water rheostat while it is under load.***

(a) To apply the load, operate R toggle switch on the remote control unit, thereby raising the separators. See Fig. 19. If the desired amount of load is obtained before separators are full up, release R toggle switch at that time.

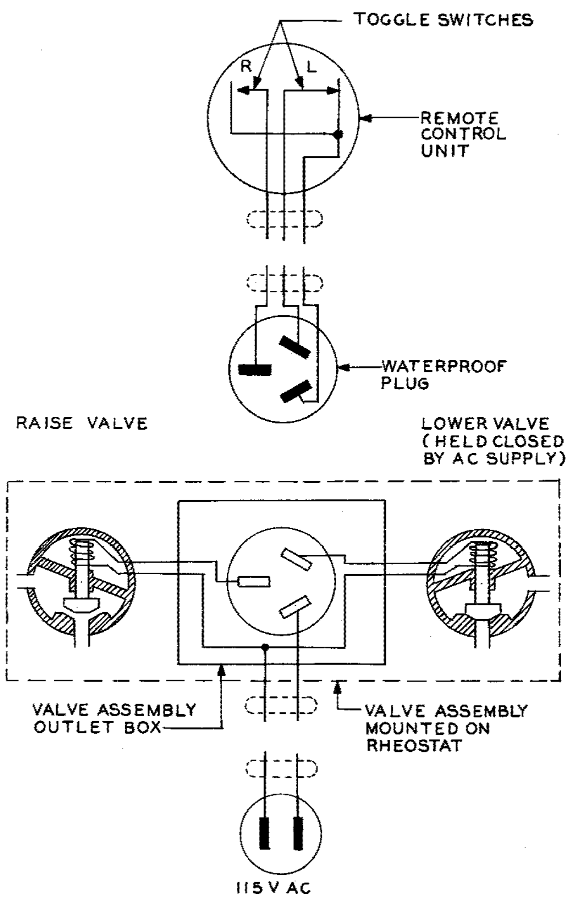

Fig. 19 — Remote Control Panel Wiring Diagram

6.28 ***AC Load — R-3104 Water Rheostat Equipped With Mason Jar Salt Dispenser:*** When the separators have reached their maximum height, the water should overflow through the tube into the salt dispenser. This will cause the sodium-carbonate or sodium-chromate solution to feed into the bottom of the tank and seadily increase the load as long as the R toggle switch is operated. Release R toggle switch when sufficient load is obtained.

6.29 The rheostat will provide very little load until the solution in the tank heats up. The lower the voltage the longer it takes to heat up the solution. It may take as long as 20 minutes on ac to an hour on low voltage dc. If sufficient load current is not obtained on dc after about 30 minutes, make another half gallon of the solution as covered in 6.19(b) and pour some of this solution into the barrel around the side. The maximum capacity of the R-3104 water rheostat is shown in Table E.

TABLE E

TYPE OF POWER	KW	AMPERES PER LINE WIRE
AC (at 440-480V, 3 phase)	120	170
AC (at 208-240V, 3 phase)	120	333
AC (at 230-240V, 1 phase)	80	348
130 Volt dc	110	850
48 Volt dc	42	see note 1
24 Volt dc	21	see note 1

Note 1: Do not exceed 850 amperes.

6.30 Reduce load current by operating the L (lower) toggle switch to lower the separators. If the load current is too high with separators all the way down, too much sodium carbonite or sodium chromate has been used and it will be necessary to dilute the solution in the tank. For this operation, either disconnect the load or shut down the equipment that is being loaded. Remove the clip of the overflow hose from where it is attached and lower the end of the hose to drain out some of the water. The water level regulator in the barrel will automatically supply water to the barrel.

6.31 After a water rheostat has been used as a dc load, the interior of the barrel and the associated assembly must be thoroughly cleaned.

Caution: Never use a rheostat for ac loading that has been used as a dc load without first cleaning the inside of the rheostat. Never change from one dc load to one of a

higher voltage dc load without first cleaning the inside of the rheostat.

Cleaning the water rheostat after dc loading is urgently recommended, because of the possibility →of destructive short circuit from excessive sodi- →um carbonate or sodium chromate.

7. PERMANENT WATER RHEOSTAT (TANK TYPE)

7.01 Many operating companies have found it advantageous, where there is an expendable supply of fresh water, to install permanent water rheostats in their engine rooms. These units have been found practical for use when routining or testing an engine-alternator set. Being permanently installed and the load calculated for the engine or engines in the power room, a permanent switchboard can be installed and a variety of artificial loads may be made available to any engine.

7.02 The permanent water rheostat consists of a glass-lined tank, water inlet, water outlet, Nichrome V wire coils, see Fig. 20, and associated wiring which runs to the artificial load switching panel. See 2.16. A typical example of a permanent water rheostat handling a 4-step noninductive load of 100- to 400-kw is explained in the following paragraphs.

7.03 A glass-lined steel tank 2 feet high, 2 feet wide, and 4-1/2 feet long is mounted in a convenient location in the engine room. The location of this tank should be considered in relation to a ready source of water and its disposal as well as the electrical connection to the artificial load switching panel. A 1-1/2 inch pipe connection for the inlet water and a 2-inch pipe connection for the outlet water should be installed centrally on the end panels of the tank. The inlet is at the opposite end of the tank from the outlet. A 1-1/2 inch globe valve should be installed in the inlet side of the water piping to control the flow of water over the Nichrome V coils. The outlet side should connect directly to the sewerage or drain-off system.

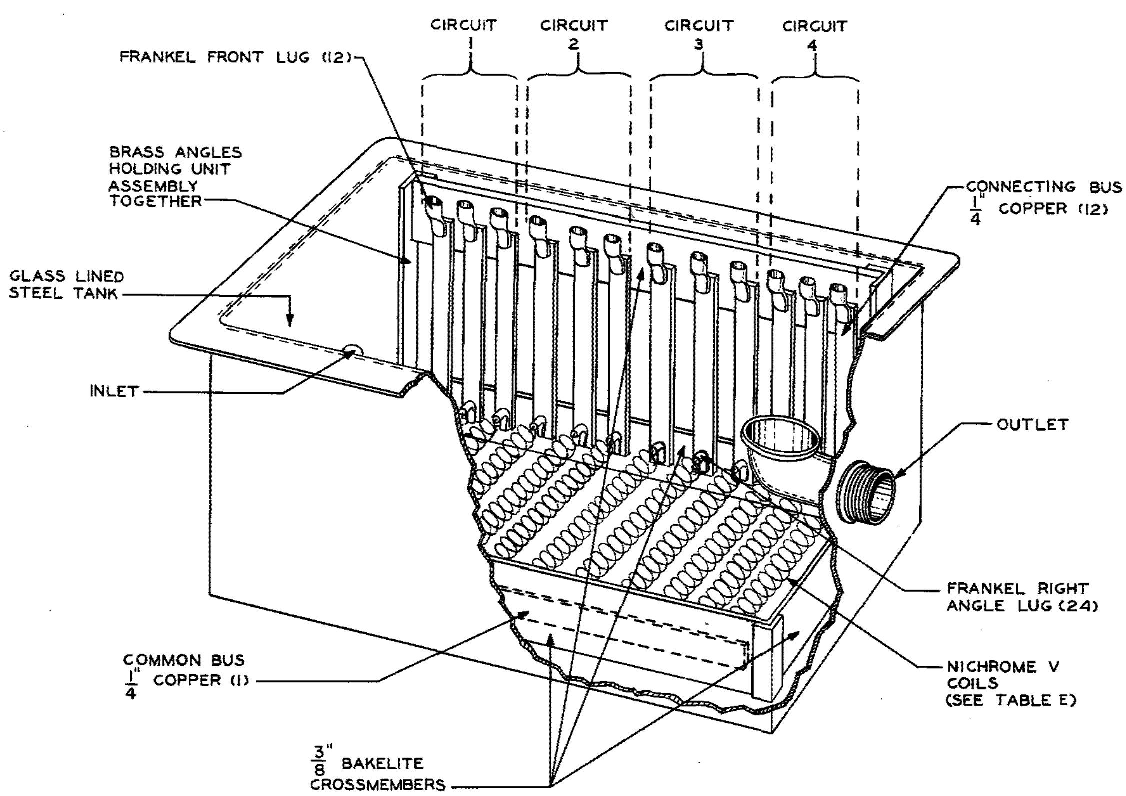

Fig. 20 — Typical Permanent Water Rheostat (tank type) With Section Removed to Show Nichrome V Wire Coils

7.04 The Nichrome V coils are mounted as a unit assembly and placed into the tank. The structural crossmembers of this assembly are paper bakelite 3/8 inch thick. Extending vertically between two of the bakelite crossmembers are 12 equally spaced 1/4-inch copper bus bars. At the top end of the bus bars are fastened Frankel front lugs; at the bottom are fastened Frankel right-angle lugs. Each set of three top lugs is used to fasten the wires from the artificial load switching panel and the bottom right angle lugs are used to hold one end of the Nichrome V coils.

7.05 The other end of the coils, which run along at the bottom of the assembly, is attached to right-angle lugs which in turn are connected to a common bus extending the length of the assembly. It can be seen that this assembly presents four circuits, each containing three coils connected in Y. See Fig. 20.

7.06 The coils of Nichrome V wire may be formed on a cylinder in order to bring the ends of the calculated length of wire within the dimension of the distance between the bottom right angle lugs.

7.07 Table F shows some of the gauges of Nichrome V wire used for various artificial loads.

TABLE F

B & S GAUGE NO.	TURNS ON 1-1/2 INCH DIA. FORM	LENGTH DEVELOPED	KW
6	32	16 feet	415
8	28	14 feet	300
10	32	16 feet	165

The Driver-Harris Company of Harrison, N.J. may be consulted on the gauge and length of Nichrome V wire needed for a particular artificial load while submerged in running water.