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TEST LOADS FOR POWER EQUIPMENT

1. GENERAL

- 1.01 This section covers various types of electrical loads for machines.
- 1.02 This section is reissued to include new artificial loads which are now available to the operating companies and to revise load calculations to agree with the 30 per cent minimum load now required for the satisfactory operation of engine-alternator sets, and to revise wire size tables, and change part of, or add new figures.
- 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. Its 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) Generators run as motors (pumping back into the line) utilize the existing equipment and provide small or large loads quickly. Due to the possibility of high speed and burning the commutator, it is not generally recommended. However, this method may be used where no other methods of loading seem feasible and an experienced motor-generator man is present throughout the run. It is generally restricted to runs of short duration and should not be attempted with automatic power plants or diverter pole generators.
- (d) Resistors, Rheostats, Lamps and Heater Units: Resistors are used for very small machines such as signalling 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.

(e) 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.

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

(g) Water barrel rheostats (job made) are satisfactory for full-load test of large engine driven ac or dc machines. In view of the moisture condition and the large space required, a water rheostat is not suitable as a permanent setup for routine loading.

(h) Permanent water rheostats (tank type) have been developed by the engineering department of the various operating companies. These rheostats have been found suitable to 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. Also, operating generators

as motors involves some hazard. 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 barrel rheostats are rated in wattage per barrel. 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

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

R = resistance ( $\omega$ ) in ohms

$$R = \frac{V}{I}$$

I = current in amperes

$$I = \frac{V}{R} = \frac{W}{V}$$

W = watts

$$W = IV = I^2R$$

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 equal among the phases.

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

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

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

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

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

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

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 to 2.16.

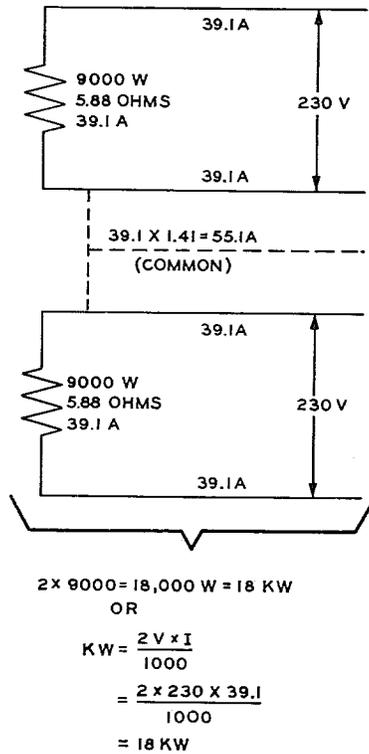


Fig. 1 - Typical Arrangement for 2-phase 18-kw Balanced Noninductive Load

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) below. 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. Its 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 below 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.

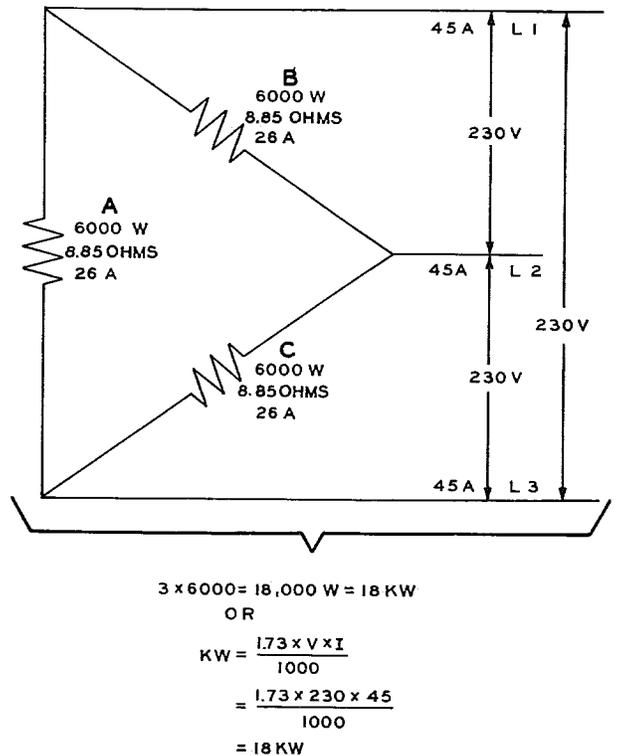


Fig. 2 - Typical Arrangement for 3-phase 18-kw Balanced Noninductive Delta Connected Load

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

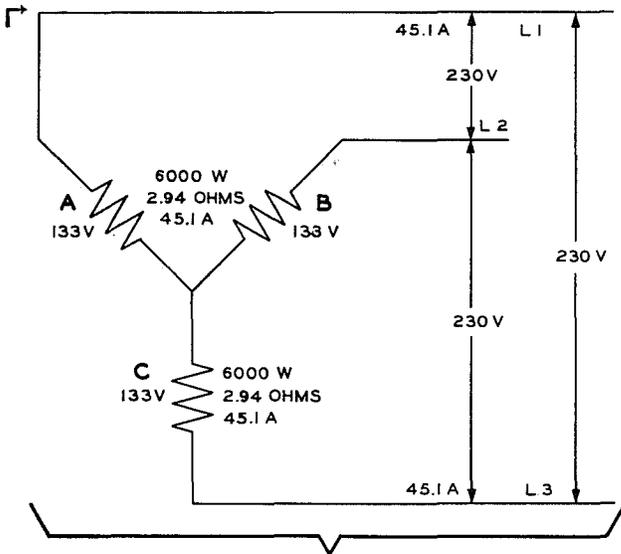
Total Load = 0.30 x 60 = 18 kw = 18,000 watts

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

For Delta Connection

Phase load voltage = 230 volts

Phase load current =  $\frac{W}{V} = \frac{6000}{230} = 26.1$  amps.



$$3 \times 6000 = 18,000 \text{ W} = 18 \text{ KW}$$

OR

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

$$= \frac{1.73 \times 230 \times 45.1}{1000}$$

$$= 18 \text{ KW}$$

Fig. 3 - Typical Arrangement for 3-phase 18-kw Balanced Noninductive Y Connected Load

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

$$\text{Line wire current} = 26.1 \times 1.73 = 45.1 \text{ amps.}$$

For Y Connection

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

$$\text{Phase load current} = \frac{W}{V} = \frac{6000}{133} = 45.1 \text{ amps.}$$

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

$$\text{Line wire current} = 45.1 \text{ amps.}$$

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 are unbalanced. For wattage measurement and wire sizes, see 2.09 to 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 con-

nected 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 at 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 were to be used.

$$\text{Current} = \frac{20,000 \text{ w}}{220 \text{ v}} = 90.9 \text{ amperes}$$

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 mul-

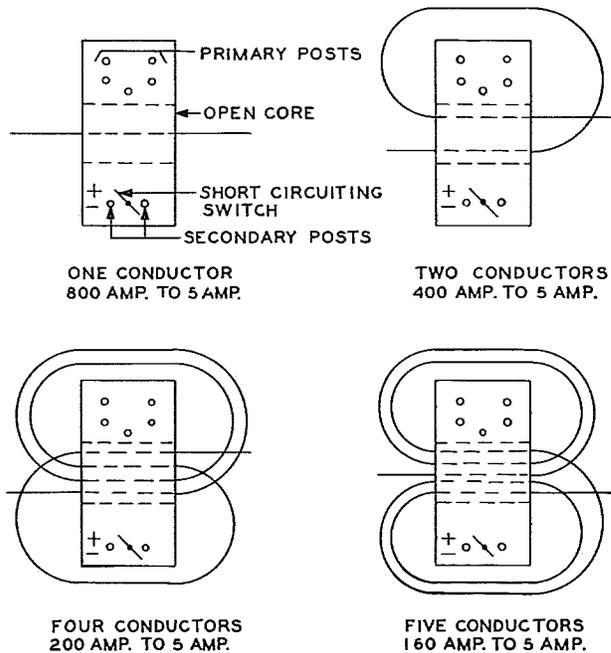


Fig. 4 - Typical Applications of Portable Current Transformer for Large Currents

tiplication 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.

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

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

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

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

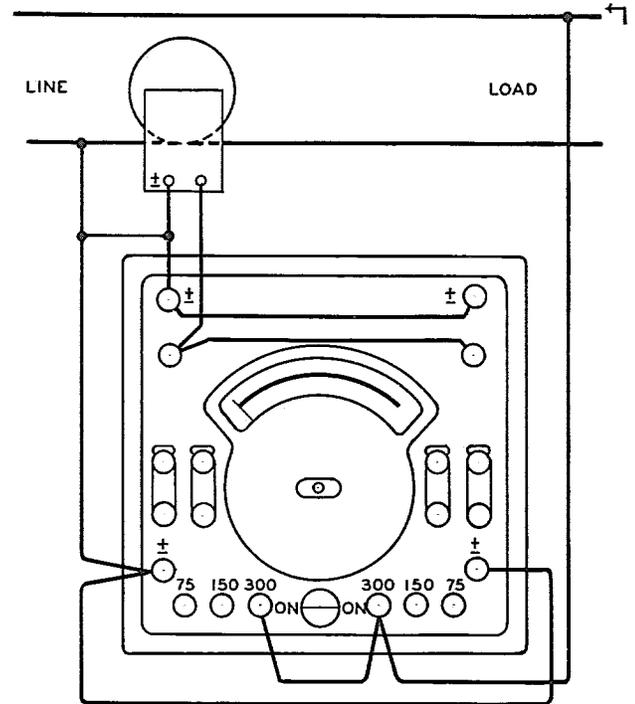


Fig. 5 - Typical Connections for Single-phase Load Using a Polyphase or a Single-phase Wattmeter

The wattage of two-phase inductive (motor load) loads is measured with one polyphase wattmeter or two single-phase wattmeters. It

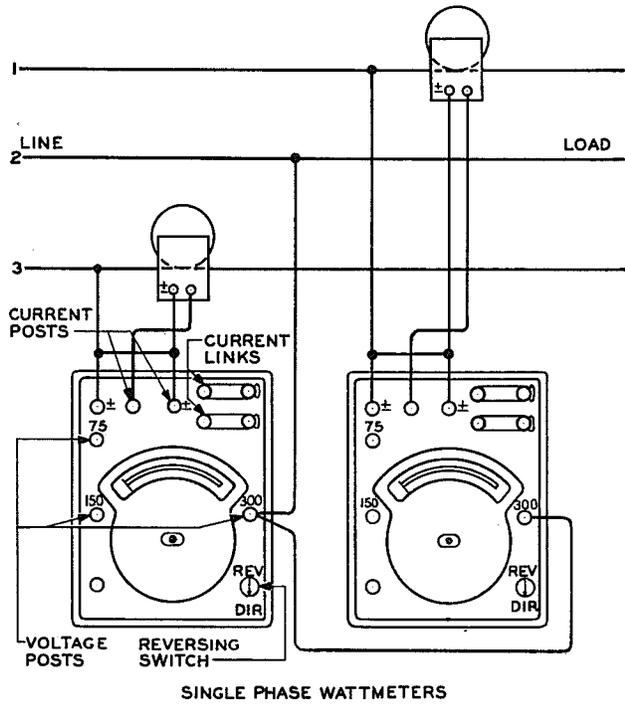
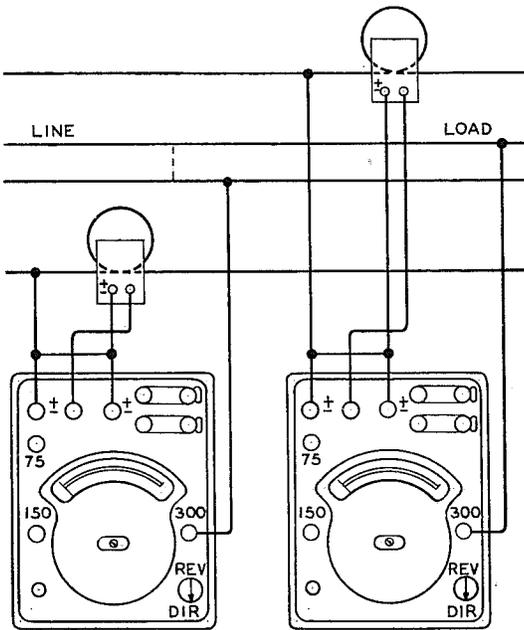
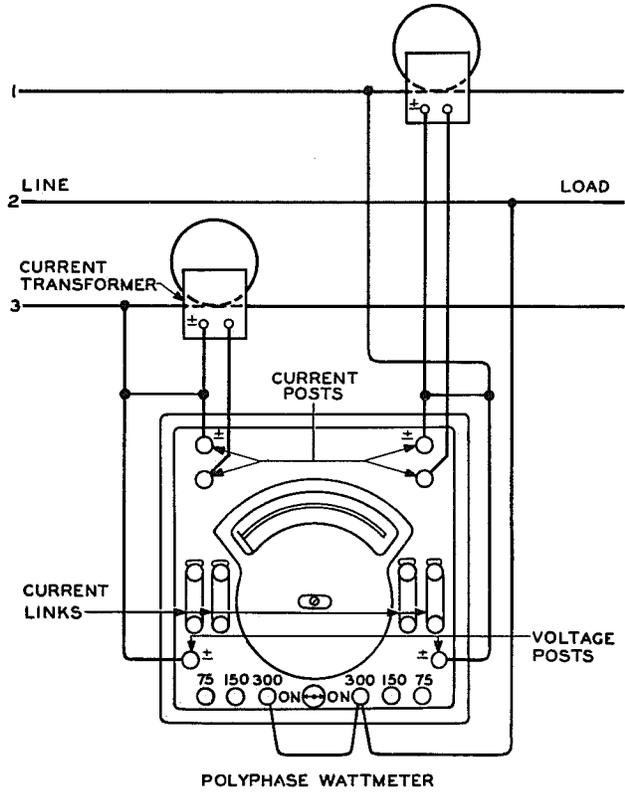
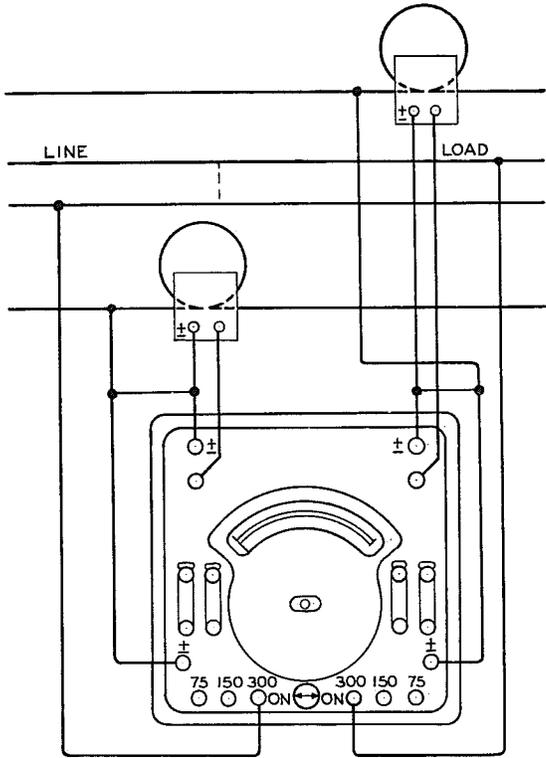


Fig. 6 - Typical Connections for 3- or 4-wire, 2-phase Loads Using One Polyphase Wattmeter or Two Single-phase Wattmeters

Fig. 7 - Typical Connections for 3-phase, 3-wire Loads Using One Polyphase Wattmeter or 2 Single-phase Wattmeters

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:

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

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

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

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 direct connected instruments. The total wattage is the difference between the two sums.

#### Wire Sizes

2.16 The following table agrees with the 1953 National Electric Code. These 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.

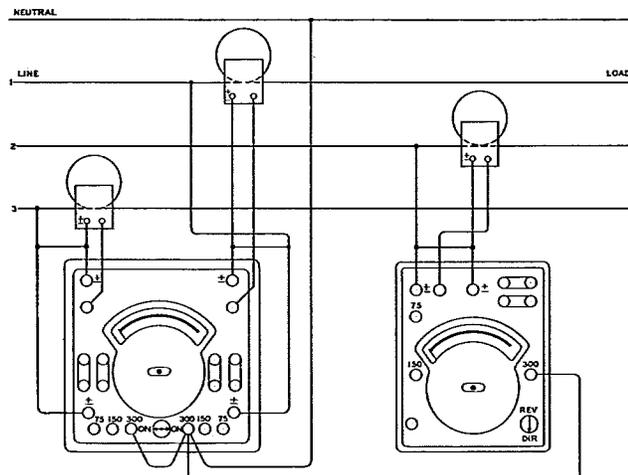


Fig. 8 - Typical Connections for 3-phase, 4-wire Loads Using One Polyphase-Wattmeter and One Single-phase Wattmeter

Size	Maximum Capacity in Amps.	Size	Maximum Capacity in Amps.
14	15	00	175
12	20	000	200
10	30	0000	230
8	45	300,000	285
6	65	400,000	335
4	85	500,000	380
2	115	600,000	420
1	130	700,000	460
0	150	800,000	490

**3. BATTERY CHARGING LOAD, BUILDING LOADS AND GENERATOR RUN AS A MOTOR**

3.01 When loading a generator by charging the office battery, the fuseboard voltage is kept down to within limits by the regular office load, by connecting in counter cells, 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.

3.03 If it is necessary to run a generator as a motor, select one considerably larger than the load required, if available, so that it may be run at less than full load. Also use an "M" type machine rather than an interpole machine where a selection can be made. The circuit breaker should be arranged to prevent opening on reverse current but should be left so that it can be opened quickly by the operator in case of trouble. All other automatic control equipment should be disconnected and the machine ammeter leads reversed at the most convenient point.

3.04 The set should be started from the line in the usual manner and after adjusting the voltage with the field rheostat to approximately the battery voltage, the generator should be connected to the battery. To draw current from the battery, turn the field rheostat one position at a time in the direction usually marked "lower voltage" to add field resistance. While the set is operating be prepared to open the circuit breaker quickly in case of high speed or current. If an "M" type machine is used, it will probably be necessary to shift the brushes to avoid sparking which would be injurious to the commutator. This may be done easily with the regular brush shifting mechanism on an "M" machine while the machine is operating. The brushes should be moved slowly and against the direction of rotation.

3.05 Any necessary shifting of the position of brushes on an interpole generator should be done with the machine stopped. In

shutting down the set the current from the battery should be reduced to approximately zero. The circuit breaker should be opened and then the motor line circuit should be opened. It should not be necessary to change the ammeter connections. The position marking of the brushes should be noted. The brushes should be shifted by about half the width of a commutator bar against the direction of rotation of the armature. The set may then be restored on the line and the circuit breaker closed when the voltage is adjusted to approximately that of the battery. The rheostat is again turned slowly to draw current from the battery. If necessary the brushes may be moved additional half segments at a time in the same manner.

**4. RESISTANCES, 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 illustrates some schematic connections.

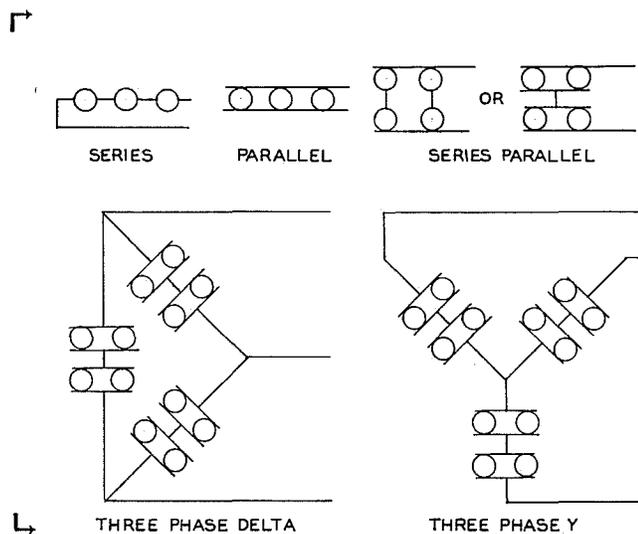


Fig. 9 - Schematic Connections

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.

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 following table shows the approximate per cent of the rated watts drawn by lamps operated at from 50 to 120 per cent of the rated voltage:

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 the above table, assume a lamp load consisting of 32-volt lamps were required for a 45-ampere, 25-volt output.

Machine output = 45A x 25V = 1125 watts

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

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

Watts drawn per 100 watt lamp = .70 x 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 amperes. 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 the above table). The current would be 230 watts divided by 240 volts equals 0.960 amperes 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 following table shows the approximate per cent of the rated watts drawn by units operated at from 50 to 100 per cent of the rated voltage and may be useful in estimating the number of units required for application at other than rated voltage:

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 the above table, assume a heater unit load consisting of 120 volt, 660 watt, units is to be used for a 100-ampere 60-volt output.

SECTION A801.910

Machine output = 100A x 60V = 6000 watts

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

At 50% volts, heaters draw 25% rated watts

Watts drawn per 660 watt heater =  $.25 \times 660W = 165$  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 x 160V = 3200 watts

Over-all rated volts for 2 units in series =  $2 \times 110V = 220$  volts

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

At 73% voltage, heaters draw about 54% rated watts

2 heaters in series will draw  $2 \times 660W \times .54 = 713$  watts

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

Four circuits could accommodate  $4 \times 713W = 2852$  watts

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

Five circuits could accommodate  $5 \times 713W = 3565$  watts

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

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 approximately 30 per cent load is required for a 10 kw, 230-volt, three-phase, three or four-wire machine.

Total load required =  $0.30 \times 10 \text{ kw} = 3 \text{ kw} = 3000$  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  $2 \times 115 = 230$  volts

Units to operate at full rated voltage

2 units in series will draw  $2 \times 660 = 1320$  watts per phase load

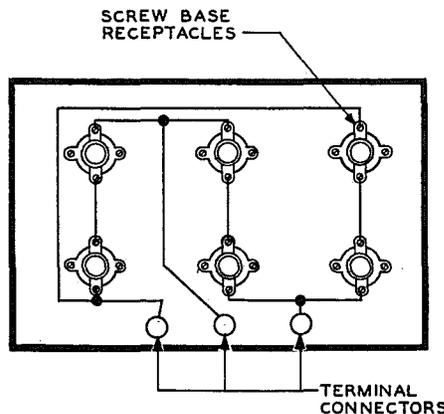
Six units on 3 phase delta draw  $3 \times 1320 = 3960$  watts

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

The line current will be 1.73 times the current in one-phase load or  $5.75 \times 1.73 = 10$  amperes

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  $\frac{133V}{230V} = 58\%$  voltage.

From the table each string of two heaters would draw  $.35 \times 2 \times 660 = 462$  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.

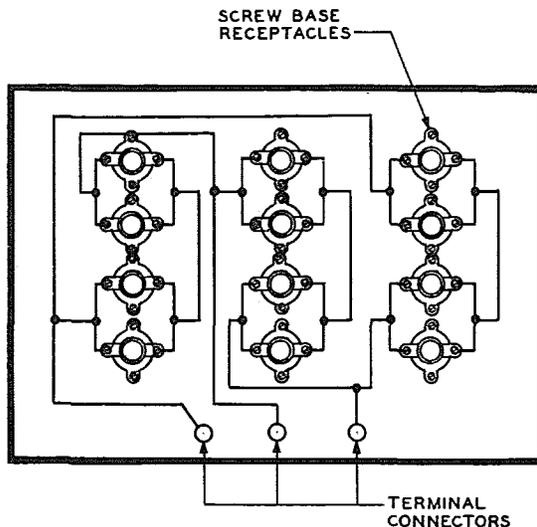


Fig. 11 - Typical Layout of Twelve Receptacles Wired in Delta With Four per Phase in Series Parallel

## 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 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 Table A shows some typical examples in ↙ the application of edgewise-wound, stainless-steel ribbon type resistors for routine loading at approximately 30 per cent rated capacity of 230 volt, 1- to 3-phase machines. 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. ↙

TABLE A

KW of Set	30% of KW	Per Phase KW	Method of Connection	Calculated Amperes Each Leg	Calculated Resistance Each Leg	Resistance Available See Note	Actual % of KW Load
10	3	3	1-Phase	13	17.7	17.5	29.6
20	6	6	1-Phase	26	8.8	8.8	29.7
25	7.5	3.75	2-Phase	16.3	14.1	15.0	31.8
30	9	4.5	2-Phase	19.5	11.2	11.32	28.7
40	12	4	Delta	17.4	13.2	13.2	30.0
50	15	5	Delta	21.7	10.6	10.38	29.3
60	18	6	Delta	26	8.8	8.8	29.7
70	21	7	Delta	30.4	7.6	7.0	27.7
75	22.5	7.75	Y	58.2	2.3	2.1	28.4

**Note:** General Electric Company CR 9I32 resistors are available in varying resistance and ampere ratings as listed in their catalog.

6.01 Listed below are water rheostats, under the following Western Electric Company tool numbers:

R-2759 6 KW Water Rheostat  
 R-2746 30 KW Water Rheostat  
 R-3104 120 KW Water Rheostat

Use only Western Electric Company R-3164, salt, sodium chromate, in these water rheostats. Sodium chromate will spot clothing and may only be removed by washing in water. Do not inhale or get into the eyes. Do not allow sodium chromate to remain on the skin. Wash the skin with warm water.

**Note:** In areas where there is a lack of sufficient running water to maintain the cooling system of a water rheostat, it is advisable to use a standard R-2759, 6 kw water rheostat. If it cannot be obtained, a job made water barrel rheostat should only be used if all other methods to obtain a standard Western Electric Company water rheostat have been exhausted.

6.02 R-2759 6-kw Water Rheostat: For locations where small loads are required the 6-kw water rheostat, see Fig. 12, is useful in that no running water is needed. Remove the two side covers which are attached to the shipping straps by removing the six screws. With side covers removed fill rheostat tank with water. Dissolve three tablespoons of sodium chromate in a glassful of warm water and add this solution to each rheostat. A larger amount of 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.

6.03 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.

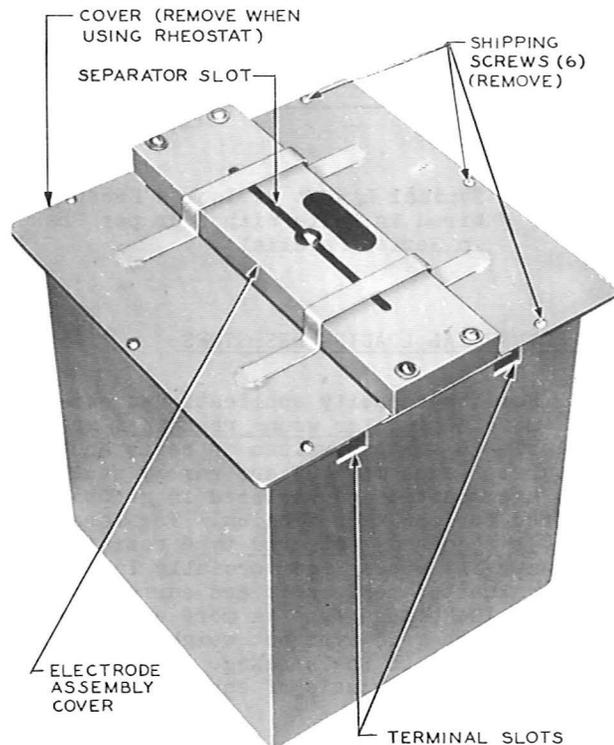


Fig. 12 - R-2759 6-kw Water Rheostat

6.04 R-2746 30-kw Water Rheostat: For larger loads the 30-kw water rheostat is available (see Fig. 14). This water rheostat employs a cooling coil mounted in the solution. The main tank is composed of wood and 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.

6.05 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.

6.06 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 as current flowing between them during operation would result in permanent damage to the assembly.

6.07 Dissolve three tablespoons of sodium chromate in a glassful of warm water and add this amount to each rheostat. More 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 chromate will be needed at lower voltages and higher loads.

6.08 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 to add more of the sodium chromate solution as required to stabilize rheostat to the desired load.

6.09 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.

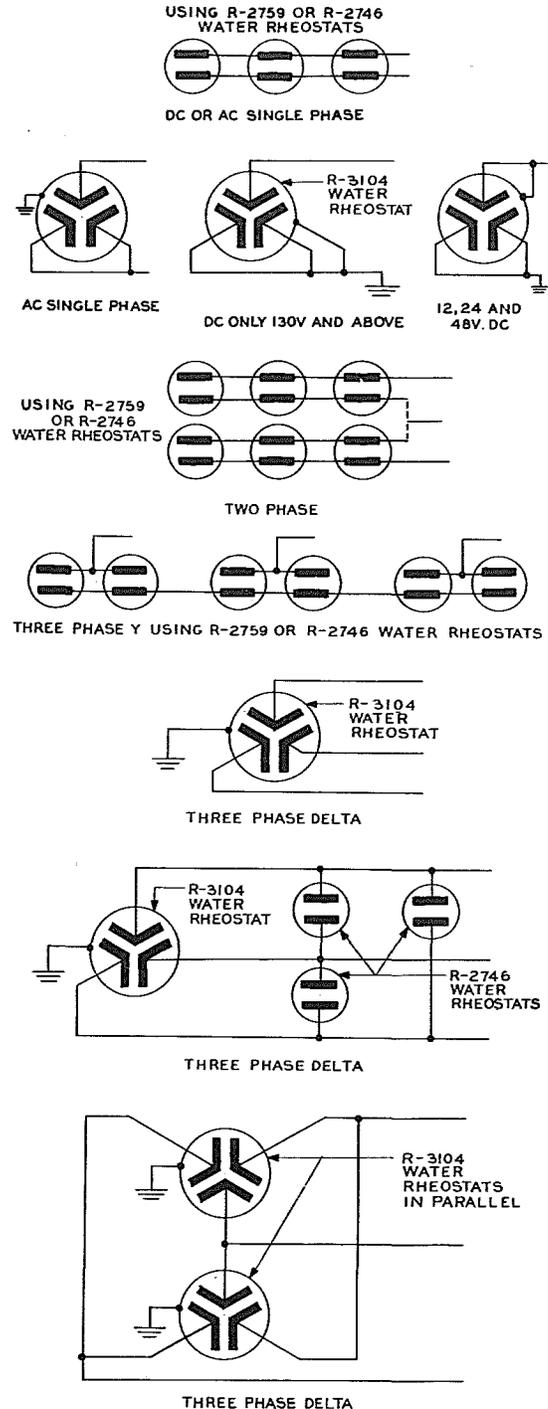


Fig. 13 - Typical Electrical Connections for Water Rheostats

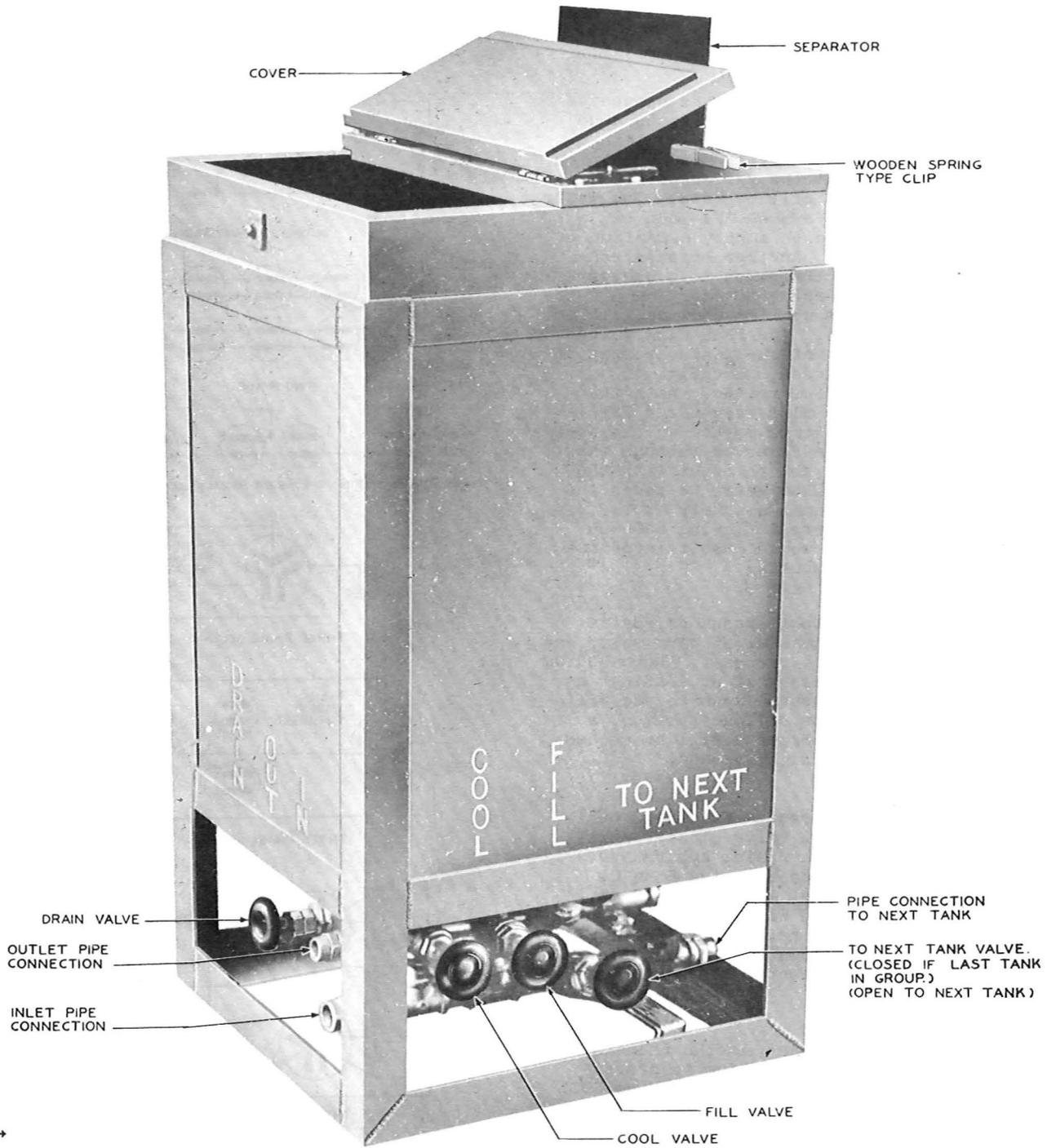


Fig. 14 - R-2746 30-kw Water Rheostat



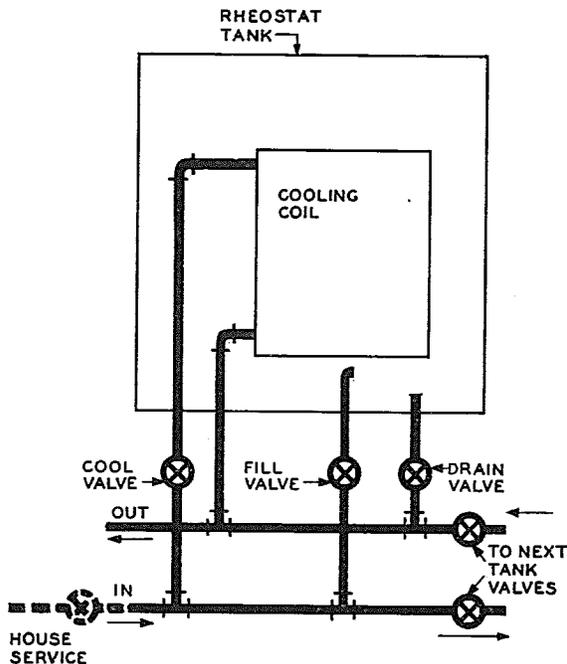


Fig. 15 - Piping Schematic of R-2746 30-kw Water Rheostat Cooling System

6.10 If the regulation obtained indicates that too much 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 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.

6.11 R-3104 120-kw Water Rheostat: 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 chromate foam to splatter in the vicinity of the water rheostat thereby endangering personnel.

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

6.12 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.

6.13 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.

6.14 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 its 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 their 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.

6.15 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.

6.16 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 60F the water is shut off or reduced to a trickle. As the temperature of the water in the tank reaches approximately 180 to 190F 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.

6.17 Remove the mason jar, see Fig. 16, which is the "salt" dispenser from its holding clamp located at the top of the rheostat assembly. Remove the lid from the jar and prepare a mixture of sodium chromate solution as follows:

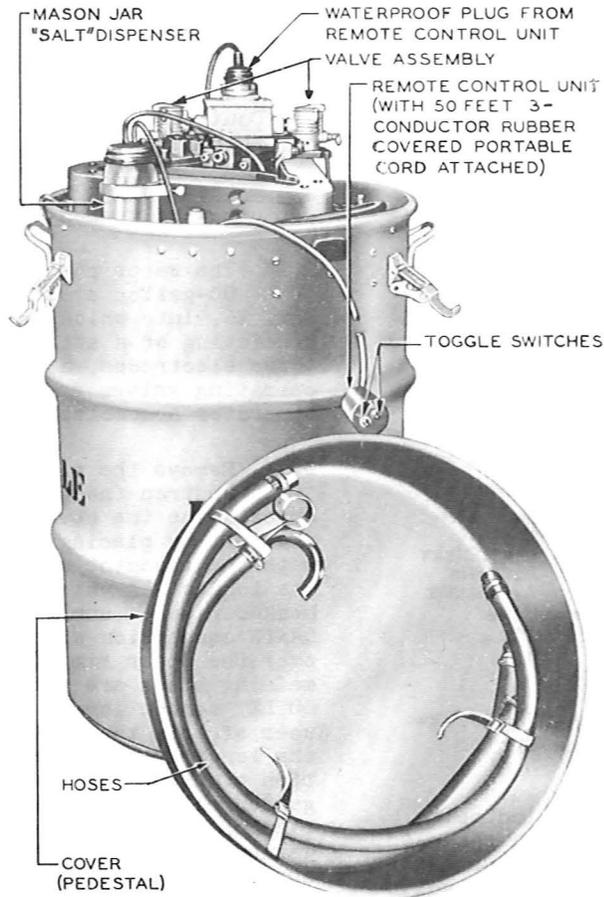


Fig. 16 - R-3104 120-kw Water Rheostat With Cover Removed

- (1) Fill the jar to within one inch of the top preferably with hot water.
- (2) While stirring the water, slowly add six level tablespoons of sodium chromate into the hot water until all the crystals have been dissolved. For dc loads more sodium chromate will be needed, see 6.26.
- (3) Replace the jar in its holding clamp taking care not to spill any of the sodium chromate solution into the barrel. Replace the lid of the dispenser.

6.18 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.

6.19 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. Connect a ground lead

from the ground lug at the side of the barrel with office ground.

6.20 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.

6.21 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

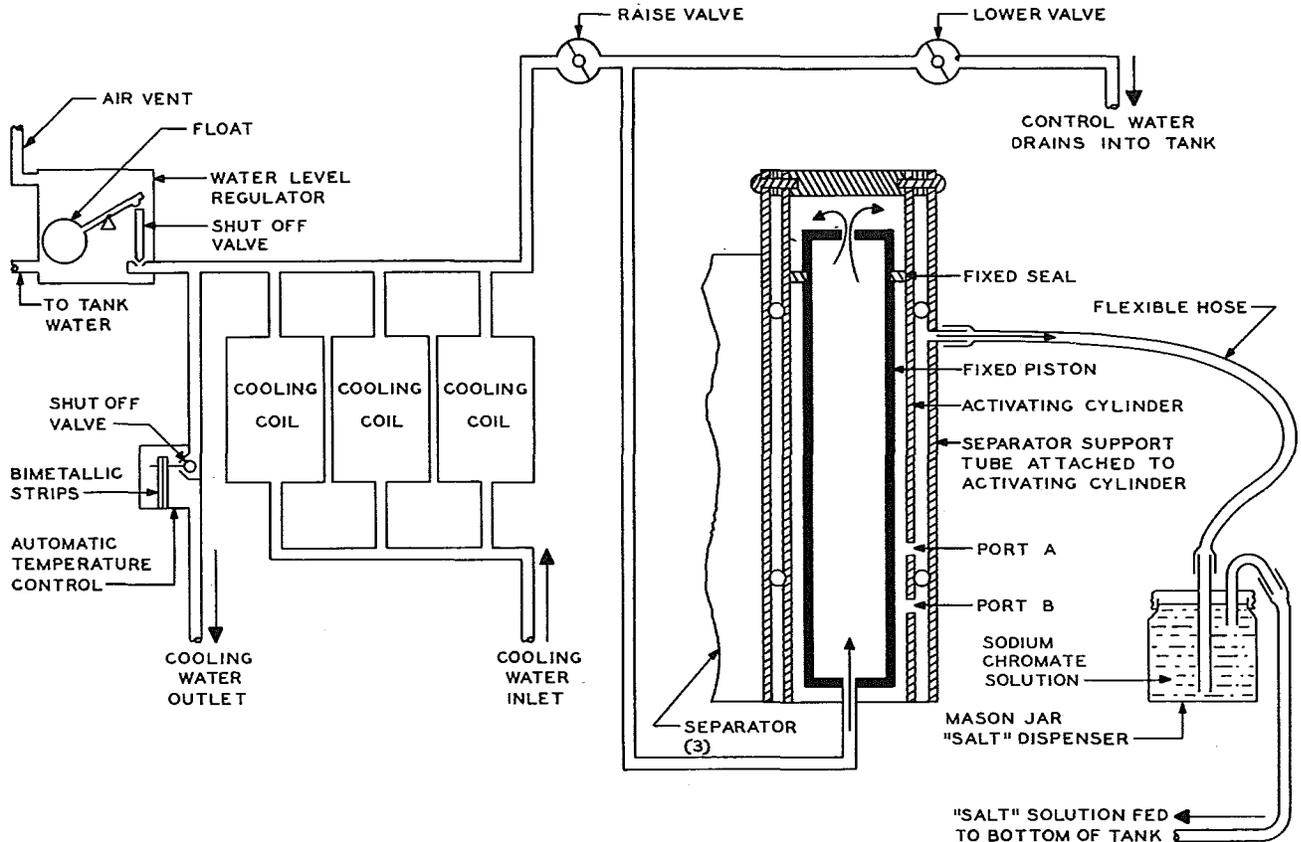


Fig. 17 - Cooling and Hydraulic System of R-3104  
120-kw Water Rheostat-Schematic Diagram

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 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.

6.22 Operating the R or L toggle switches will raise or lower the separator and respectively increase or decrease the load. The load may be increased further by adding a 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 chromate solution, which is in the jar attached to the tube, will overflow and feed the sodium chromate solution into the barrel at the bot-

tom 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.

6.23 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 to which the cooling water inlet hose is connected.

6.24 To apply the load, operate R toggle switch on the remote control unit thereby raising the separators. See Fig. 19. When the separators have reached their maximum height, the water should overflow through the tube into the "salt" dispenser. This will cause the sodium chromate solution to feed into the bottom of the tank and steadily increase the load as long as the R toggle switch is operated. Release R toggle switch when sufficient load is obtained.

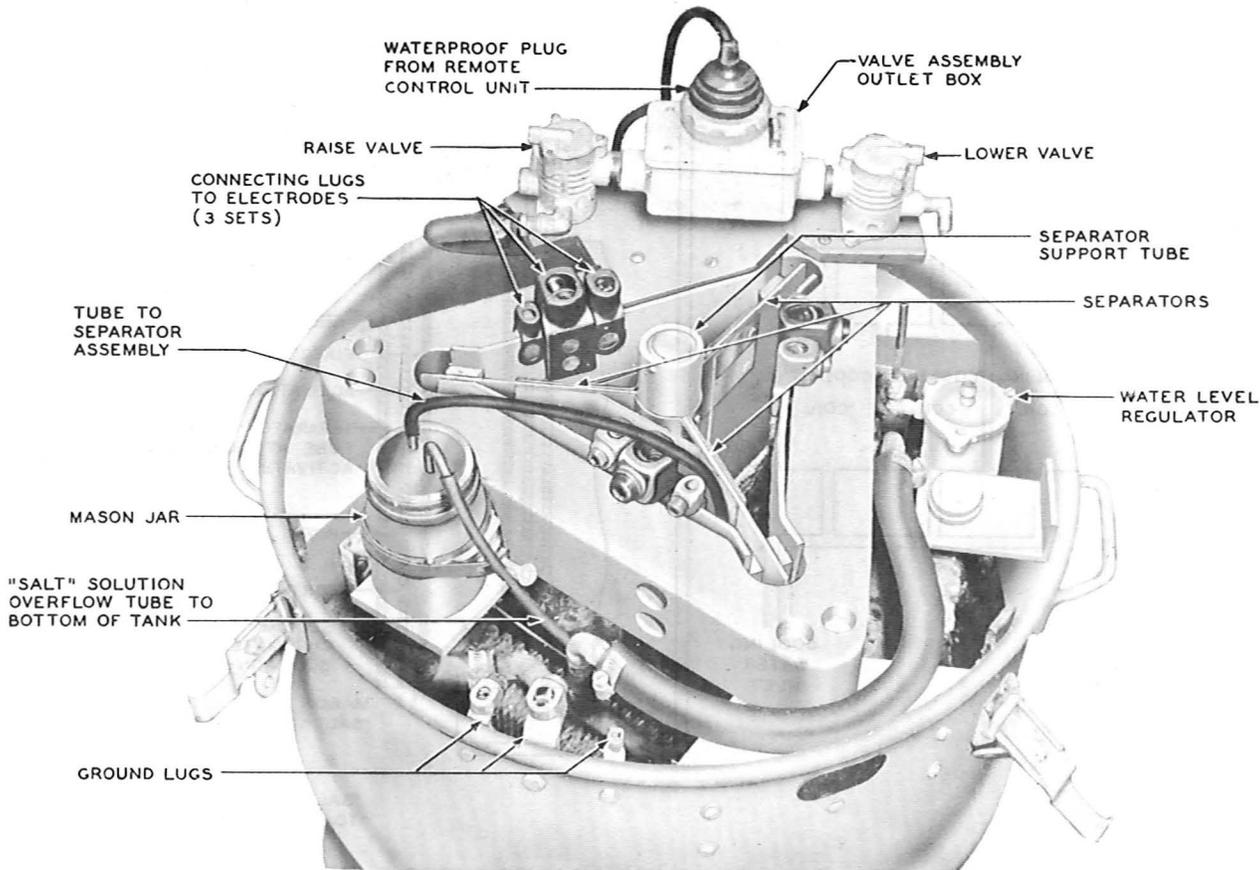


Fig. 18 - Top View - R-3104 120-kw  
Water Rheostat

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.

6.25 The water rheostat may be used as a dc load and its operation is similar to that of an ac load, with the exception that 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.

6.26 Large dc loads will require additional amounts of sodium chromate solution to be added directly into the rheostat barrel water. Approximately 2 measuring cups (16 ounces by volume) of sodium chromate should produce an 850-ampere load at 48 volts. The

maximum capacity of the R-3104 water rheostat is as follows:

Type of Power	KW	Amperes Per Line Wire
AC (at 208V, 3 phase)	120	333
130 Volt DC	110	850
48 Volt DC	42	850
24 Volt DC		Maximum obtainable
12 Volt DC		not yet determined.
		Do not exceed 850 amps.

6.27 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.

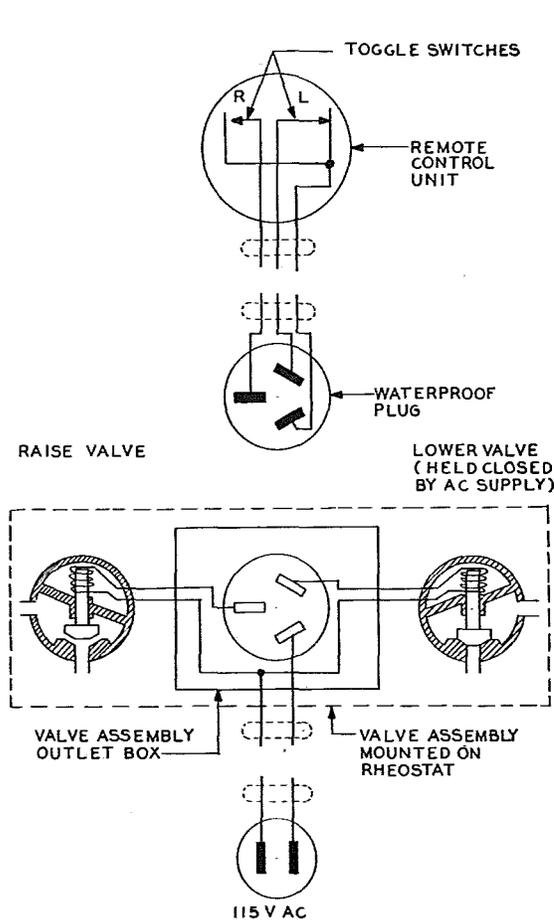


Fig. 19 - Remote Control Panel Wiring Diagram

Cleaning the water rheostat after dc loading is urgently recommended, because of the possibility of destructive short circuit from excessive sodium chromate. It will be noted that the water rheostat will require more than 30 times as much sodium chromate in the solution when operating at 48 volts dc, as the same ac load operating at 230 volts.

## 7. JOB-MADE WATER BARREL RHEOSTAT

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

**Caution:** The moisture and voltage combinations, subject an operator to possible electric shock. The voltage should be entirely cut off from the plate electrodes by either opening the circuit or shutting down the machine when working on the setup other than moving the adjustable plate vertically to adjust the load or adding salt not in solution. The control of the adjustable plates should be made with dry rope with the operator standing

on dry insulation, preferably wearing good rubbers. The barrel should be within the view of the operator adjusting the load. Care should be taken to avoid accidental contact with conducting material at all times.

7.01 Job-made water barrel rheostats require ← considerable space and should be set up out-of-doors because of the fumes given off and the moisture conditions. It is advisable to close the windows and doors near the setup while operating. When direct current is used on a water rheostat with common salt in solution, chlorine and an explosive mixture of oxygen and hydrogen are given off. Since the salt solution will destroy grass, it should be kept away from lawns. The arrangement consists of one or more wooden barrels containing a common salt solution. There are two metal plate electrodes usually iron. These plates are hung vertically in the barrel. One of them is adjustable vertically by raising or lowering in the solution (referred to as the adjustable plate) and the other is adjustable horizontally by moving close or farther from the other plate (referred to as the stationary plate).

7.02 The amount of energy to be dissipated per barrel depends on the quality of the test results desired. For low currents the temperature of the entire barrel of water will not be raised to the boiling point. Small bubbles may develop at the plates but will not affect the current appreciably and may be absorbed before they reach the top of the water. If the current is further increased so that the heat developed is greater than the barrel can dissipate into the surrounding air, the water will be raised to the boiling point and the excess energy will be expended in boiling. As the current is further increased the boiling and gassing will become more vigorous. This will cause the current to be less stable and give less satisfactory test results. If the current is further increased it will become so erratic that it will be impossible to obtain satisfactory meter readings.

7.03 In addition to the above, the temperature of the air, the design of the rheostat, the load current and voltage and the strength of the solution affect the kw dissipation for satisfactory operation. In some instances alternator rheostat setups operate smoothly for two or three hours on full load, and then develop hunting or surging. This sometimes occurs after a setup has been idle for a few days. Although the trouble is often attributed to the engine or alternator control, it may be due to dirty solution, rusty plates or too much current for the connections. Considerable expense and delay is involved in clearing such troubles which can be reduced to a minimum by using an ample number of barrels and making good connections.

7.04 In order to insure good test results with a minimum of trouble due to the loading, it is recommended that the dissipation per 50-gallon barrel be limited to a maximum of 12.5 kw for alternating current and 7 kw for direct current.

7.05 If full load were required for a 200-ampere, 60-volt dc machine, the wattage would be 200 times 60 equals 12,000 watts or 12 kw which would require 12 divided by 7 equals 2 barrels connected in parallel.

7.06 For alternators, the number of barrels are calculated on a phase basis. Assume full kw load at 220 volts were required for an engine-driven alternator with nameplate data, "3 phase, 4 wire, 75 kw, 230 volts, 93.75 kva, 0.8 p.f., 235.6 amperes." If the kw were not given, it could be obtained as kva times the power factor.

$$\text{Load per phase} = \frac{75}{3} = 25 \text{ kw}$$

$$\text{Barrels per phase} = \frac{25 \text{ kw}}{12.5 \text{ kw per barrel}} = 2$$

$$\text{Total number of barrels} = 6$$

The current per line wire for approximately balanced load will be

$$\frac{\text{kw} \times 1000}{1.73 \times \text{voltage}} = \frac{75 \times 1000}{1.73 \times 220} = 197 \text{ amperes}$$

It will be noted in this example that the voltage is the specified value which is not necessarily the nameplate value. The 3-phase loads should be connected in "Y" and the neutral wire should not be run to the load. Typical schematic connections of barrels are shown in Fig. 20.

7.07 The 2-phase, 4-wire alternators, are connected to the load by either three or four wires. If by three wires, the combined wire is generally called the common wire.

Current (I) for approximately balanced loads,

$$\text{per common wire} = \frac{\text{kw} \times 1000}{1.41 \times V}$$

$$\text{Current (I) per wire other than common} = \frac{\text{kw} \times 1000}{2 \times V}$$

7.08 Although Fig. 22 shows a typical setup, there are many methods of arranging the barrels, electrode supports and electrical connections, depending on the number of barrels used, the materials available and local conditions. The following general suggestions should be of assistance in preparing a water rheostat.

(a) The barrels should be reasonably clean. The top hoop of each barrel should be removed to avoid short circuit at this point.

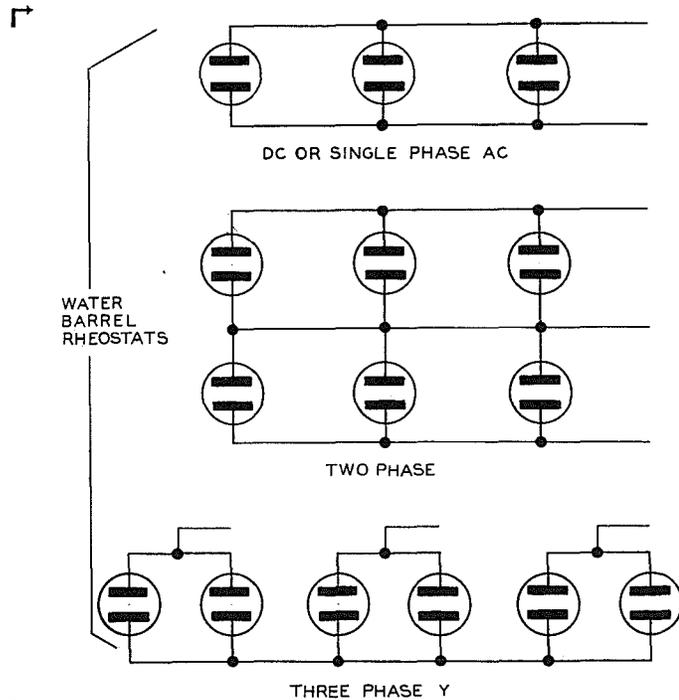


Fig. 20 - Typical Electrical Connections

(b) The plates are usually iron and should be reasonably clean and free from paint (including aluminum paint). For best results the plates are fairly large (one side of surface under water at least one square foot). They usually are long enough to nearly reach the bottom of the barrel. For best results in obtaining light load adjustment, the lower end of the adjustable plate should be cut "V" shape. This is particularly advantageous in testing the 200-ampere dc set which usually requires a full load and light load test. The width of the plate is usually about 1/4 to 1/3 the length, and the thickness is at least 1/8 inch. Since direct current eats the plate, the plate should be at least 1/4 inch thick for full load dc tests to extend more than one working day.

(c) There are two methods of locating the stationary plate. Although it has been placed in the bottom of the barrel in some instances, this has the disadvantage that the electrical connection is below water and the plate is not readily accessible in case trouble develops. Also, it is difficult to insulate this plate from the other plate. Furthermore, the only current adjustment without changing the strength of the solution, is by raising or lowering the other plate. In view of these considerations, the vertical plate method shown in Fig. 21 and 22 is recommended.

(d) The vertical plate method provides a wider range of current control, without

changing the solution, than the plate-in-the-bottom method since at the start both plates can be lowered and also moved close together to give a low resistance path and higher current. They may be moved as close as the wooden separators will permit. As the solution heats the current can be reduced by raising the adjustable plate and also moving the stationary plate to one side of the barrel away from the adjustable plate. The electrical connection is made above water. Also, the plates may be easily insulated from each other by a wooden strip. Where barrels are connected in parallel or in Y, a rigid conductor, such as a bus bar, angle iron or superstructure is usually extended across the tops of the barrels and the plate for each barrel is bolted to it, preferably by two bolts. See Fig. 20, 21 and 22.

(e) The adjustable plate is usually suspended with rope over a pulley. The pulley should be high enough to permit raising the plate entirely out of water when the barrel is full. Where barrels are connected in parallel, the adjustable plates are generally bolted to a rigid metal conductor extending across the tops of the barrels, similar to that used for the stationary plates. The rigid conductor is sometimes supported from one pulley with the rope divided and connected near the ends of the conductor. This gives better control than a single connection but necessitates that the pulley be higher. The rigid conductor may be supported from two pulleys or pulley blocks which gives the better control and permits lower pulleys. This method is sometimes used for two barrels in parallel and is nearly always used with three or more barrels in parallel. The plates in each barrel must be kept apart and the rope should not be depended upon to do this as it may stretch or slip.

(f) While it is not necessary to make as good electrical connections to the rheostat as for permanent installation, all connecting surfaces should be made with fairly flat surfaces. These surfaces should be cleaned and brightened with sandpaper. Before joining, the surfaces should be greased with any grease available such as petrolatum or ball bearing grease. If painted metals (including aluminum painted) are to be joined for electrical connection it is necessary to sandpaper or file off all of the paint on the surfaces to be joined. The leads from the machine to the adjustable plates should be so connected that they will not interfere with raising or lowering the plates.

7.09 Each barrel should be filled initially with water to a little over 3/4 full. In order to draw approximately the same current on each barrel, approximately the same amount of salt should be put into each barrel. Ordinary table salt is preferable to rock salt as it dissolves more rapidly and is readily

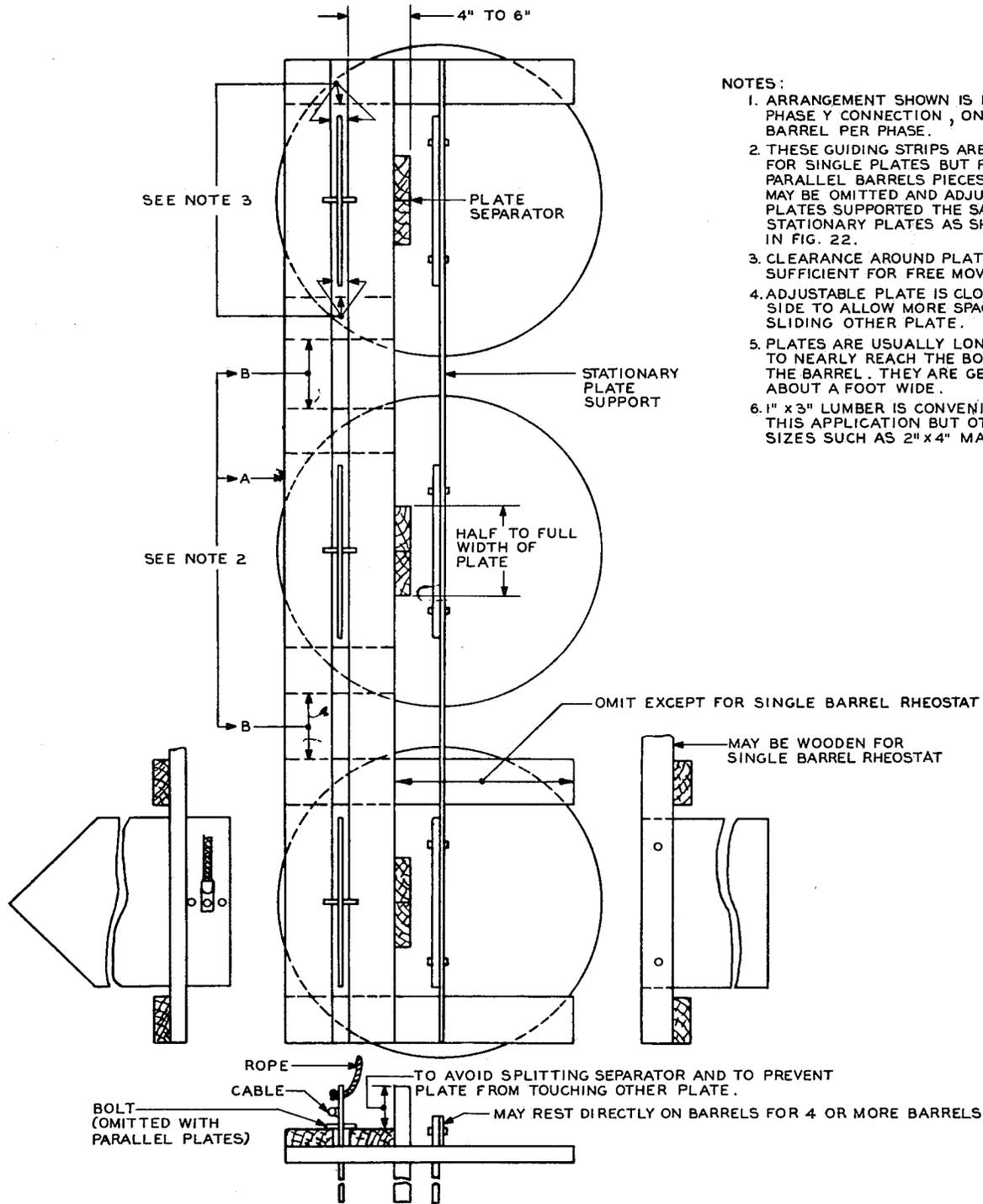
available. The following amounts of salt are recommended initially per 50-gallon barrel.

<u>0-65 Volts</u>	<u>Above 65 Volts</u>
1 pound	1/2 pound

A pint of salt (two ordinary water glasses full) is approximately a pound. It is recommended that the salt for each barrel be dissolved separately. The salt will dissolve much faster when stirred in hot water than in cold water. After the solution is poured into the barrel, the entire solution should be mixed by stirring. This method of adding salt initially is recommended as all of the salt in the barrel will be in solution and hence the current will start immediately when the voltage is connected.

7.10 Prior to connecting the voltage, the plates are usually lowered and moved close together but not touching. When the solution is cold the current will be low, but as it heats the current will increase to several times the starting value. For best results, the load should be allowed to build up gradually as the water heats. Starting with a cold solution, this will be at least two hours, and preferably longer. If after a reasonable time, at least 1 hour, it is desired to hasten the build-up, add 1/8 pound of salt (water glass 1/4 full) in each barrel. This will make an appreciable increase in the load. The salt should be added without dissolving previously. Add additional 1/8 pounds at half hour or longer intervals as required to build-up full load. With some sets, such as the 200 ampere engine-generator set, where full load current is required for a wide range of voltage, best results will be obtained by building up full load on the high voltage and adjusting for full load at low voltage when the solution is hot.

7.11 The ideal condition is for the solution to be just strong enough so that when hot it will draw full load with both plates down. If the current exceeds full load and raising the adjustable plate a few inches does not reduce the current sufficiently, the stationary plate should be moved away from the adjustable plate. The adjustable plate would be used for close adjustment and for light load. The voltage should be removed from the plates while moving the stationary plate. The current in each line wire should be approximately the same value. To obtain light load adjustment on parallel barrels, where the adjustable plates are not cut "V" shaped, the adjustable plates are sometimes raised entirely out of water in some of the barrels. If raising the adjustable plate and separating the plates does not reduce the current sufficiently, add water. However, it is not anticipated that it will be necessary to overflow the barrels unless excessive salt has been added. For ordinary tests the water level will not be lowered more than 3 or 4 inches, in which case it would not be necessary to refill. For extended runs it will be necessary to replace the water which boils away.



- NOTES:
1. ARRANGEMENT SHOWN IS FOR 3 PHASE Y CONNECTION , ONE BARREL PER PHASE.
  2. THESE GUIDING STRIPS ARE DESIRABLE FOR SINGLE PLATES BUT FOR PARALLEL BARRELS PIECES A AND B MAY BE OMITTED AND ADJUSTABLE PLATES SUPPORTED THE SAME AS STATIONARY PLATES AS SHOWN IN FIG. 22.
  3. CLEARANCE AROUND PLATE JUST SUFFICIENT FOR FREE MOVEMENT.
  4. ADJUSTABLE PLATE IS CLOSE TO ONE SIDE TO ALLOW MORE SPACE FOR SLIDING OTHER PLATE.
  5. PLATES ARE USUALLY LONG ENOUGH TO NEARLY REACH THE BOTTOM OF THE BARREL . THEY ARE GENERALLY ABOUT A FOOT WIDE.
  6. 1" x 3" LUMBER IS CONVENIENT FOR THIS APPLICATION BUT OTHER SIZES SUCH AS 2" x 4" MAY BE USED.

Fig. 21 - Typical Job Made Water Barrel Rheostat Details



7.12 The particular setup shown in Fig. 22, was used for testing a 208-volt 2-phase 70-kw alternator. The connection shown between each rope and the ends of the plate supports was made with spare wire. It will be noted that a board is provided to stand on beside the barrels. A board is also suggested on the outside of the framework to stand on as an added protection against shock while adjusting the plates. At the start of the test, the long angle iron, supporting the stationary plates, was moved close to the plate separating boards. While the water was heating, it was moved to the left as far as possible and the adjustable plates were raised (less than the amount shown) to hold the load down to full load of the alternator. After the water reached its maximum temperature, gentle boiling in this case, very little additional adjustment was necessary. Three fourths of a pound of salt was used per barrel but 5/8 of a pound would probably have been adequate.

#### 8. PERMANENT WATER RHEOSTAT (TANK TYPE)

8.01 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 routing 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.

8.02 The permanent water rheostat consists of a glass lined tank, water inlet, water outlet, Nichrome V wire coils, see Fig. 23, and associated wiring which runs to the artificial load switching panel. See 2.16. A typical example of a permanent water rheostat handling a four step noninductive load of 100-kw to 400-kw is explained in the following paragraphs.

8.03 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.

8.04 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 cross-

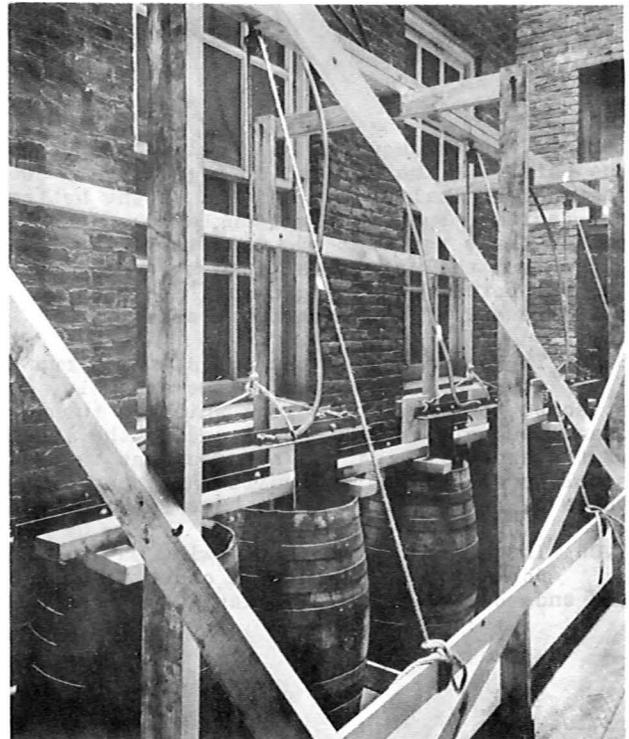
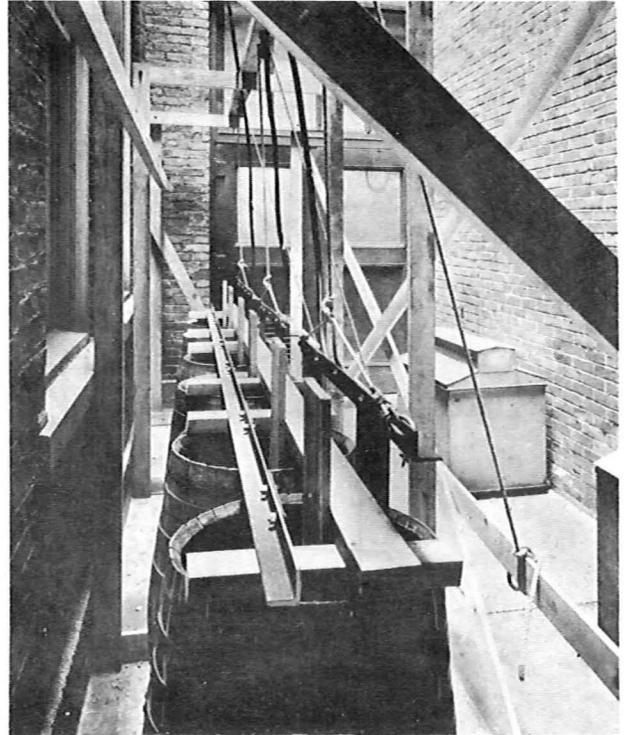


Fig. 22 - Typical Job-Made Water Barrel Rheostat Setup

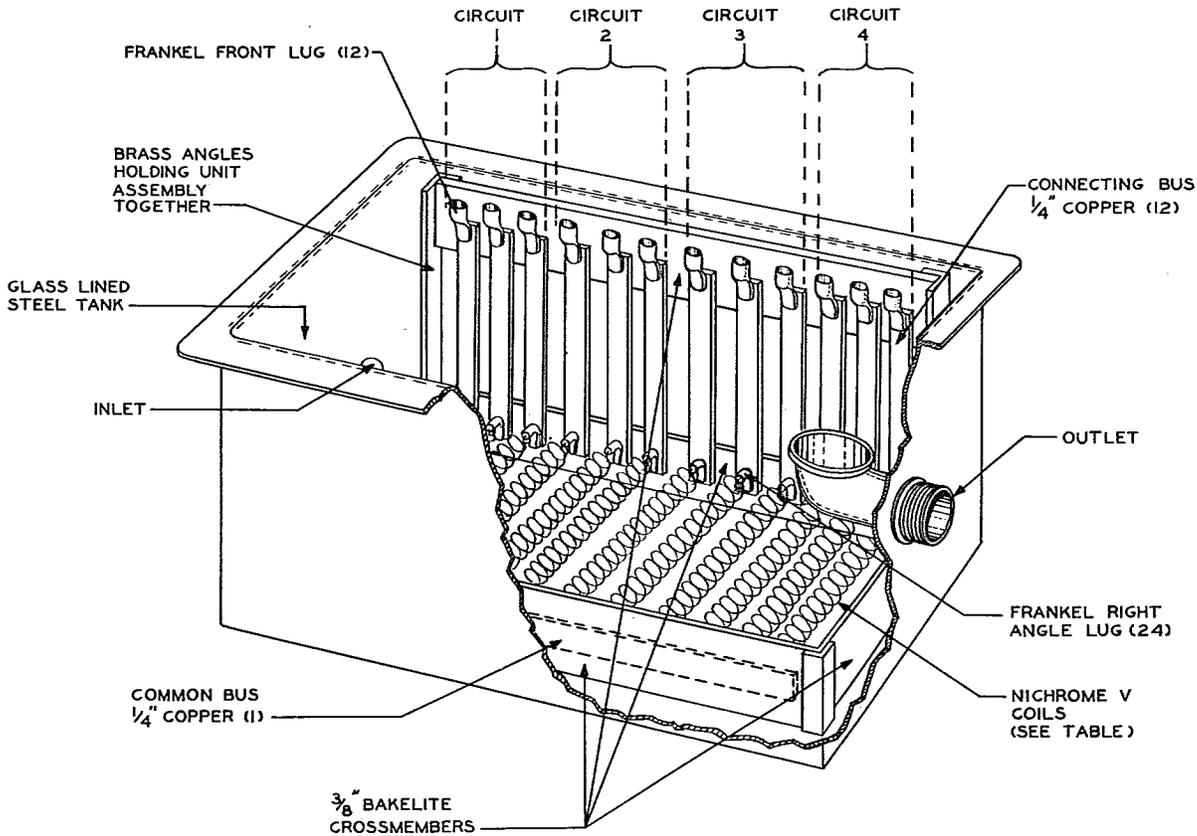


Fig. 23 - Typical Permanent Water Rheostat (Tank Type) With Section Removed to Show Nichrome V Wire Coils

members, are 12 equally spaced 1/4-inch copper bus bars. At the top end of the bus bars are fastened Frankel front lugs and at the bottom are fastened Frankel right-angle lugs. Each set of three top lugs are 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.

8.05 The other end of the coils, which run along at the bottom of the assembly, are 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. 23.

8.06 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.

8.07 Listed below are some of the gauges of Nichrome V wire used for various artificial loads.

B & S Gauge No.	Turns on 1-1/2" Dia. Form	Developed Length	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.