TELEPHONE POWER PLANTS

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PREFACE

This pamphlet has been prepared for the use of the members of the Installation Organization of the Western Electric Company wishing to acquire a general knowledge of Telephone Power Plants and their component elements. The text material has been prepared with the idea of describing the operation of the principal elements of the most commonly used modern plants.

In order to aid the reader in visualizing the field of use of many of the types of equipment, voltage and current values are referred to in the text. These are only examples and might not hold for specific applications.

The contents are of a purely descriptive nature and do not prescribe methods or give engineering information for the installation of central office power plant equipment.

It has been assumed that the reader will have some knowledge of the elementary principles of direct current and alternating current, or the principles of electricity applied to telephone and telegraph work, such as is contained in the educational pamphlets on these subjects.

At the end of each section a number of questions are given reviewing the contents of the section. The answers to some will be found concisely stated, while others may require a digest of several paragraphs.

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1. INTRODUCTION

1.1 General

1.11 The term power plant, or power equipment, when applied to telephone work has reference to that part of the central office which is devoted to furnishing current required to operate the telephone apparatus. The purpose of the telephone power plant is to furnish energy of the required character in proper amount and available 100 per cent of the time. An elaborate telephone system is rendered useless if the supply of power fails. Such a failure could cause the "memory" circuits used in today's larger telephone exchanges to lose their memory and forget everything, to say nothing of cutting off thousands of established telephone conversations. In addition, no conversations could be held and no calls could be made or received, during this interval. In a way, the power plant might be termined the heart of the system since every line and connection depends on the supply of power.

1.12 In order to meet the vital need of ever-ready power, it is necessary to furnish a primary souce of power which is reliable. This is usually available through the commercial power services of the local electric and power company. Wherever possible, two services connected to different generating stations or systems are brought into the telephone building. Storage batteries of sufficient capacity to carry the load of the office during failure of the sources of power supply are used. Common practice and experience have resulted in batteries of certain sizes being provided to carry the load for certain specified intervals.

Carrier power plant ac requirements are such that a continuous supply of power is necessary for the proper functioning of repeater units. This is accomplished by the use of motor alternator sets which are ac driven from commercial power under normal conditions and battery driven during the period of commerical power failure.

To provide reserve power to clocks and other ac operated apparatus during momentary interruptions of commercial power or where the commercial voltage drops below approximately 85% of normal, ac generating units driven from the central office battery for the particular equipment involved are automatically switched-in.

Reserve power supplied by an engine driven alternator on the premises is usually provided under present day practices to supply the essential ac power requirements of the telephone office until the commercial power service is restored.

1.13 The central office equipment requires direct current (dc), usually at 24 and 48 volts, for voice transmission and also for operating switching mechanism, relays and other apparatus. In addition many other forms of current are required such as 20 cycle, 135 cycle or 1000 cycle alternating current (ac) for ringing and signaling subscribers or operators in other central offices. 130 volt (dc) supply, both positive and negative is required for telegraph and teletypewriter operation and for plate battery on electron tubes. Since central office equipment and apparatus is engineered to function within certain specified voltage limits, all battery voltages are closely regulated within these limits.

1.14 Since continuous power must be provided by the telephone power plant, storage batteries are always provided. Motor generator units and rectifier units are used to keep them charged so that they can take over the load temporarily in case of failure of the commercial power supply. There are several arrangements of generators and batteries that have been used in the past to develop central office power. The practice at present is to supply the load current continuously from several charging units operated in parallel with each other and with a single storage battery line-up. In this arrangement, the storage battery is "floated", or connected continuously across the main bus bars. Being always connected to the load, the storage batteries in addition to being immediately available in case of a power failure, have an important filtering effect in reducing noise caused by the charging units. Noiseless direct current (free from ripples or fluctuations) must be furnished for the talking circuits as the telephone receiver is sensitive to noises as well as voice currents. Noise filters, therefore, are provided in the battery feeders for this purpose.

1.15 The nominal voltage of each charging unit used is maintained at a value sufficiently high to take care of the load requirements of the office and to supply a small "trickle" charge to the battery, thus keeping it fully charged. The present practice is to provide automatic voltage regulation to insure that the load on the plant is absorbed by the output of the charging units and to insure that the required number of charging units to absorb the load may be cut-in or cut-out as required.

1.2 The Power Plant

1.21 Telephone power plants vary in size and detail depending upon the size and kind of central office they are used with. Broadly, the principal elements of power plants for medium and large sized central offices are:

1.211 Commercial power supply fusing and protective equipment for safeguarding the supply as it enters the power plant.

1.212 The charging equipment consisting of the motor generator charging machines or rectifiers and their associated equipment, used to convert the commercial power supply to direct current at voltages suitable for central office operation.

1.213 The power board containing the control and distribution equipment which includes switches, meters, safety devices and other equipment, necessary for the operation of the plant.

1.214 The storage batteries for providing a source of emergency power in case of failure of the power source, and to aid in maintaining a uniform voltage for the current supply.

1.215 The ringing and signaling equipment including the ringing machines and ringing power board for supply and control of the ringing current, tone supply, interrupted current, coin control current and other forms of current required for central office operation.

1.216 The reserve power supply consisting of an engine-alternator set is used to furnish ac power when the commercial power service fails. In some older offices engine driven dc generators are used to charge the batteries during this failure. However, present day requirements dictate the use of ac generators (alternators) for supplying reserve power.

QUESTIONS

1. What is meant by the term telephone power plant?
2. What happens if the telephone power plant fails or its output is momentarily interrupted?
3. Why are the power plant output voltages usually regulated within close limits?
4. Why is quiet (noiseless) current required for talking circuits?
5. What are the principal elements of a power plant?

2. PRIMARY POWER SERVICE SUPPLY

2.1 Sources of Power Supply

2.11 The source of primary power for use in telephone power plants must be dependable. Commercial ac power obtainable from the local power companies is as reliable as can be expected. If the power company can furnish power from two generating plants independently or if there is available some other source of suitable power, the most dependable and adaptable source is selected as the regular supply and facilities for switching to the alternative source are provided. However, interruptions in the transmission of the power supply to telephone central offices do occur on occasions and because of this possibility provision must be made to furnish reserve power. By this means the telephone power plant may continue functioning in the normal manner irrespective of the duration of the commercial power failure.

2.12 Reserve power is supplied by Engine Alternator sets which are manually controlled in the larger offices. These units are usually large enough to provide all the ac power required to properly operate the power plant in the regular manner and also that the ac power required for the proper functioning of radio and television channels, automatic message accounting equipment, emergency lights and certain elevator services will be available.

2.121 In the smaller central offices, particularly those that are unattended, the engine alternator sets are automatically controlled and are cut-in as soon as the ac voltage drops below a certain value for a predetermined period of time. In some remote localities such as microwave towers, engine alternator sets furnish the power exclusively. In these instances, 2 sets are provided and each one automatically carries the load 1/2 of the time.

2.2 Power Service Panels

2.21 A power service panel including the necessary switches, wattmeters and protective equipment are provided by the power company for the purpose of terminating the power supply within the central office building. This main power supply panel is used to furnish all the power required for lighting and operating the various electrical equipments within the building, as well as for operating the central office power plant. Additional smaller Power Distributing Service Cabinets fed from the main service panel are located throughout the central office building as required.

2.3 Fusing Protection

2.31 All electrical circuits are protected against abnormal current flow, short circuits or grounds, which might damage the equipment or create a fire hazard, by means of fuses or other protective devices. Fusing protection for power applications includes fuses, saftofuses, fusetrons and circuit breakers.

2.32 Fuses of the cartridge type (N.E.C. or National Electrical Code Standard) are most commonly used for power circuits.

2.33 Saftofuse is the trade name of a safety fuse unit (called dead front) consisting of fuse clips (for holding a cartridge fuse) attached to an insulating holder which may be connected to the current carrying parts of the circuit by inserting the holder into an insulating body which carries the bus-bar and lead connections. See Figure 2-1.

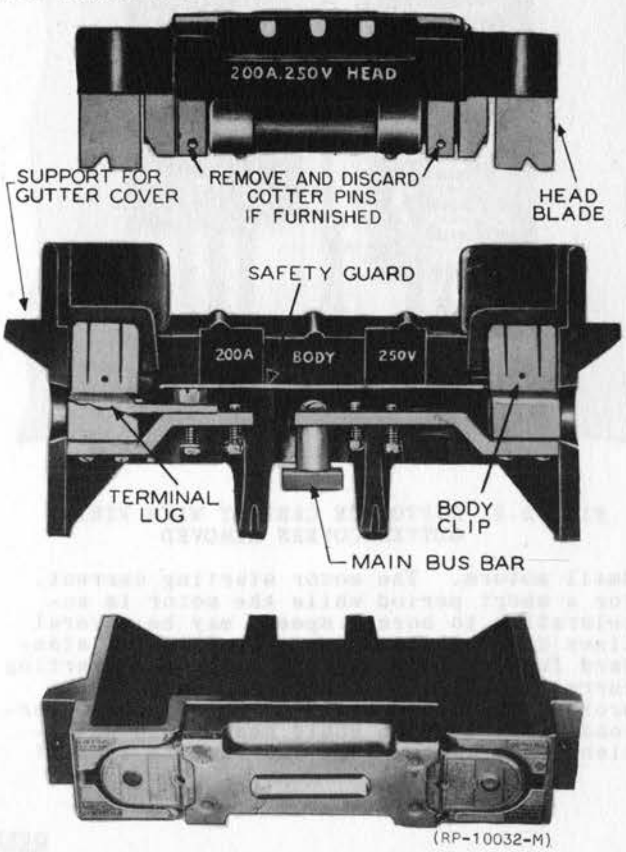


FIG. 2-1 SECTIONAL AND EXTERIOR VIEW OF SAFETY TYPE FUSE UNIT (SAFTOFUSE)

2.34 Saftofuse Cabinets shown in figure 2-2 are sheet metal housings for enclosing the saftofuse units. The larger saftofuse cabinets are provided with covered wiring gutters which are opened only during installation or maintenance work. In a central office power plant the power service leads are run from the power service panel to the saftofuse cabinet (also called "power distributing service cabinet") where the circuits which lead to the charging machines, rectifiers and other electrical equipment requiring primary power voltages are protected.

2.35 Fusetrons (and Fustats) are the trade names of a protective device which is a combination of a fuse and a thermal element. (See Figure 2-3). They are commonly used for the protection of

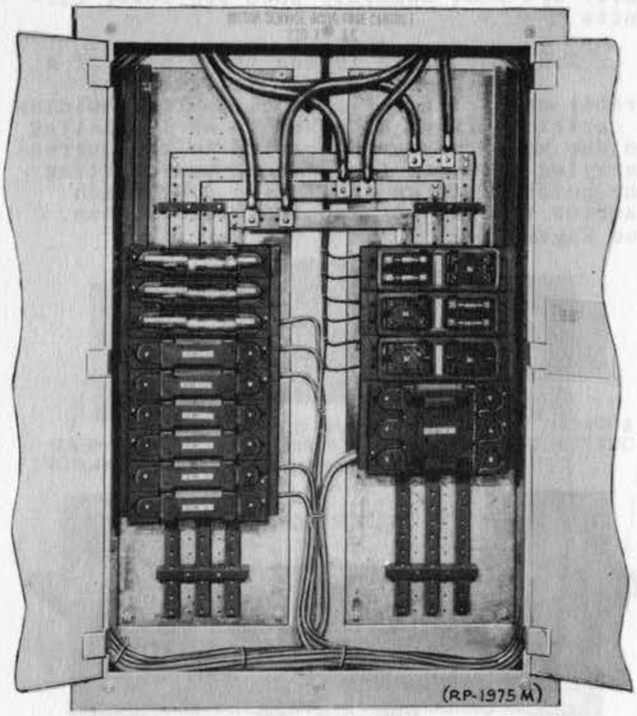


FIG. 2-2 SAFTOFUSE CABINET WITH WIRING GUTTER COVERS REMOVED

small motors. The motor starting current, for a short period while the motor is accelerating to normal speed, may be several times the full load ampere rating. A standard fuse large enough to carry the starting current would not, therefore, adequately protect the motor against a continuous overload which in time would heat it up sufficiently to damage it. The fusible link of

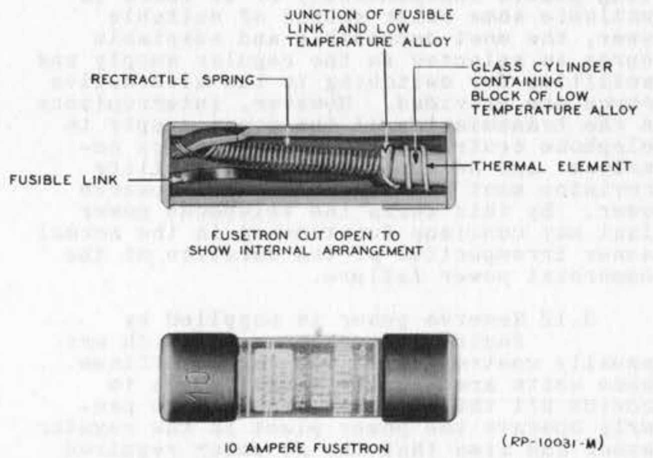


FIG. 2-3 CARTRIDGE TYPE FUSETRON

the fusetron provides the same protection against momentary abnormal currents as an ordinary fuse, while the thermal element heats up and opens the circuit on a continuous current flow only slightly greater than its rated capacity. A fusetron of approximately the same ampere rating as the name plate rating of the motor is usually used. A fusetron will open in about 1 to 3 minutes at 50 per cent above its rating and in a somewhat longer period at 25 per cent above its rating. It would carry 6 or 7 times its rated capacity for only one to two seconds.

QUESTIONS

1. What steps are taken to assure a reliable source of primary power supply?
2. When and how is a reserve power supply provided?
3. What is the purpose of power service panels and power distributing fuse cabinets?
4. Describe a saftofuse unit.
5. What is the purpose of the saftofuse cabinet?
6. Describe the purpose and operation of fusetrons.

3. CHARGING EQUIPMENT

3.1 General

3.11 The term charging equipment applies to motor generator sets or rectifiers used to convert the commercial power service supply into direct current at the proper voltage for operating central office equipment. Motor generators usually consist of an alternating current motor driving a direct current generator. If the motor and generator of such a set are combined in one housing with a single rotor, the machine is referred to as a rotary converter. In either case, however, electrical energy is first converted to mechanical energy and this in turn is converted to a different type of electrical energy. Accordingly, rectifiers may be somewhat more precisely defined as devices for converting ac energy to dc energy directly or without an intervening step. The term "charging" equipment is used because storage batteries are usually connected across the output which serves to keep the batteries charged in addition to supplying the current necessary to carry the central office operating load. The output voltage of the charging unit under normal operation is controlled at a value which will cause a small conditioning charge to flow into the batteries to keep them charged.

3.12 When a motor generator charging unit is started it takes a little time to obtain the proper output voltage before connecting it to the battery. This is due to the fact that if the battery voltage is higher than that of the charging unit, current from the batteries will flow back through the generator and operate the reverse current circuit breaker which opens the circuit to the battery. With automatic charging units this feature is taken care of automatically. When the commercial power supply fails, the charging units are automatically disconnected by the reverse current circuit breakers and the central office load is carried by the storage batteries.

3.13 When the commercial power supply is restored after a failure it is necessary to charge the batteries promptly so they will be ready for the next emergency. During the failure the batteries will become partially discharged reducing their voltage. While the batteries are being charged the charging unit voltage is usually raised to a "charging voltage" value which is somewhat higher than the "floating voltage" used for normal operation.

3.2 Operation

3.21 Manual

3.211 The term manual operation as applied to charging equipment refers to the method of controlling the charging units. With manual operation the charging units are started and their output regulated manually to obtain the proper output voltage.

3.212 All automatically controlled plants are arranged so that they may be operated on a manual basis by the operation of a control key. This arrangement facilitates maintenance, adjustment and testing when required.

3.22 Automatic

3.221 When the charging equipment is being operated on an automatic basis the charging unit is automatically started and its output increased as required until it reaches full load, at which point the succeeding charging unit is automatically started and its output regulated in the same manner. Each charging unit of the motor generator type is controlled by a motor driven rheostat or an electronic regulated exciter. Charging units of the rectifier type utilize either an autotransformer, a relay type regulating circuit or an electronic type regulating circuit to control the output.

3.222 In some cases a common voltage regulation circuit is automatically connected to the unit that is being regulated and as the output of the unit reaches its maximum or minimum, the regulation circuit is automatically connected to the next higher or lower numbered unit for regulation purposes.

3.223 Small rectifier charging units are self regulating as to output voltage. However, they utilize a control circuit for connecting or disconnecting them to the battery when several are required to float the office load.

3.23 Typical Power Plant

3.231 Figure 3-1 is a schematic of a typical power plant showing both a motor generator and a rectifier as a source of supply and having load requirements in the order of 100 to 4000 amperes. The battery in this type plant is continuously floated and the charging unit voltage, therefore, maintained at a constant value. As indicated in Figure 3-1 this is accomplished automatically by means of a motor driven field rheostat associated with a shunt wound generator and by an electronic regulating and control circuit associated with the rectifier.

3.232 A voltage relay designated GEN. REG. Voltage Relay in the drawing, is bridged across the main battery. As long as the battery voltage remains at its proper value, this relay is not operated. If the battery voltage becomes too high or too low, one or the other of the two relay contacts is closed. This causes either relay L or relay R to operate and the operation of either of these relays causes the motor driven field rheostat to move in the direction which will restore the generator voltage to its normal value; or in the case of a rectifier, cause the electronic control circuit to raise or lower the rectifier voltage as required.

3.233 To avoid the possibility of overloading the charging unit, an ammeter relay is inserted in series with the line. When the unit is fully loaded, a contact on this relay closes causing the A relay to operate and open the regulating voltage relay circuit. This prevents any further attempt on the part of the relay to increase the charging unit output.

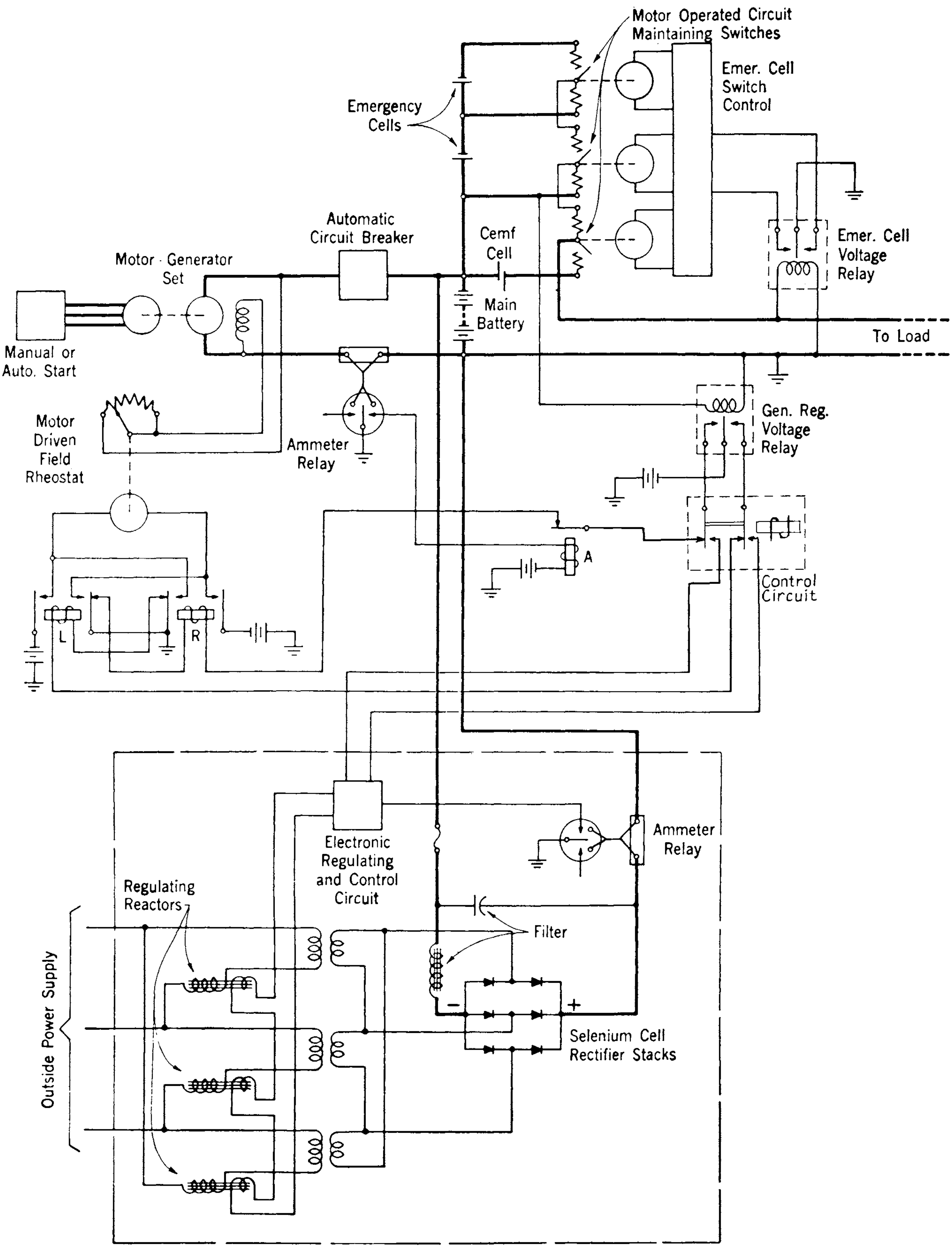


FIG. 3-1 SIMPLIFIED SCHEMATIC OF A FULL AUTOMATIC POWER PLANT

3.234 The circuit shown includes 2 emergency cells which are connected to switches in such a way that one or both may be connected in series with the main battery. These cells are provided to take care of emergency conditions where the outside power supply fails and the charging units are not operating. In such cases the load must be carried by the batteries alone and if the failure continues for an appreciable time, the battery voltage will decrease below the specified minimum value. The emergency cells are then automatically cut into the circuit by means of a voltage relay bridged across the line as shown.

3.235 Switches are provided for charging the emergency cells from the charging units in series with the main battery. However, since the emergency cells are not always in use they are continuously supplied with a small trickle charge furnished by a rectifier which normally maintains them in a fully charged condition. There switches and the emergency cell charging rectifier are not shown in the circuit of Figure 3-1.

3.236 The main battery is, of course, kept in a charged condition as long as the plant is operating normally. When failure of the outside supply requires the battery to carry the load for an appreciable time, however, the battery will become more or less discharged and will therefor require special charging. In order to provide charging current in such a case, it is necessary to increase the output voltage of the charging unit above its normal value. However, since the charging unit is connected directly to the load, an increase in its output voltage would also increase the load voltage.

3.237 To avoid increasing the load voltage, the circuit also includes a counter-emf. (C.E.M.F.) cell which is automatically inserted in series with the load circuit when the output voltage of the charging unit is increased above its specified maximum value. The C.E.M.F. cell has the property, when current flows through it, of setting up a voltage opposing the voltage which is driving the current. The counter cell voltage is approximately 2 volts per cell and is substantially constant under wide variations of current. Physically, the C.E.M.F. cell consists of two plates of pure nickel immersed in a caustic soda solution. The size of the plates is determined by the amount of current which the cell is required to handle. The cells are usually mounted along with the storage battery cells.

3.238 Figure 3-1 shows one generator and one rectifier. However, additional units may be included as required to carry the maximum office load. With a light load the motor generator set is running and the battery voltage is held to close limits by the motor driven field rheostat under control of the voltage relay.

3.239 For the example shown with a rising office load when the first charging unit reaches full load, the ammeter relay makes its "high" contact and causes the voltage relay to be disconnected from control of the first unit thus preventing an overload and at the same time connecting it to the second unit. A further increase in the office load again decreases the battery voltage causing the voltage relay to make on its "low" contact. This causes relays in the control circuit to function and start up the second unit under control of the voltage relay. Any further increase in the load will be handled in the same way and as soon as the second unit reaches its rated full load, the next unit will be started and connected.

3.240 With a falling office load, the battery voltage increases and the output of the charging unit is decreased when the voltage relay makes its low contact. When the output is decreased to no load the unit is shut down and control including the voltage relay is transferred to the next lower numbered charging unit. This process continues until the output of the charging unit or units is sufficient to float the load.

3.3 Alarm Signals

3.31 Visual and audible signals are provided to indicate abnormal conditions such as high or low charging or floating voltages. Alarms are also provided to indicate not only trouble conditions, such as blown fuses and equipment failures, but also to serve as a warning to the attendant when a charging unit is out of service for maintenance purposes.

3.4 Motor Generator Charging Sets

3.41 The motor generator charging sets consist of a direct current generator directly coupled to a 200/230 - volt, 3-phase, 60 cycle alternating current induction motor. Alternating current service is practically universal at the present time. However, in a few older offices, in some larger cities, direct current commercial power is still furnished thus requiring the use of direct current motors.

3.42 Since storage batteries decrease in voltage when discharging and require a voltage somewhat higher than the "normal" or "floating" voltage to bring them up to a fully charged condition, it is necessary that the charging generators have a controllable wide voltage range. The generators for charging 24 volt batteries have a voltage range of about 22 to 33 volts and are generally referred to as "33 volt generators" while those for charging 48 volt batteries have a range of about 44 to 65 volts and are generally referred to as "65 volt generators".

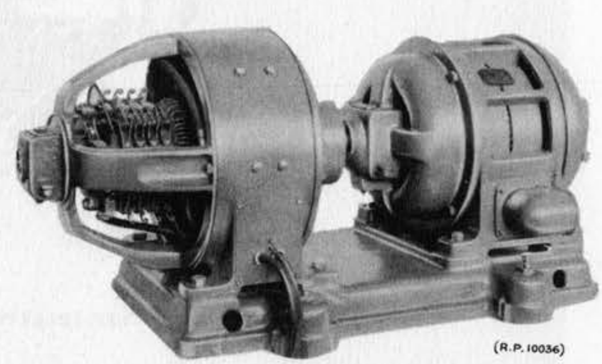


FIG. 3-2 COMMERCIAL MOTOR GENERATOR SET - 200 AMPERE 65 VOLT GENERATOR, 20 HP INDUCTION MOTOR

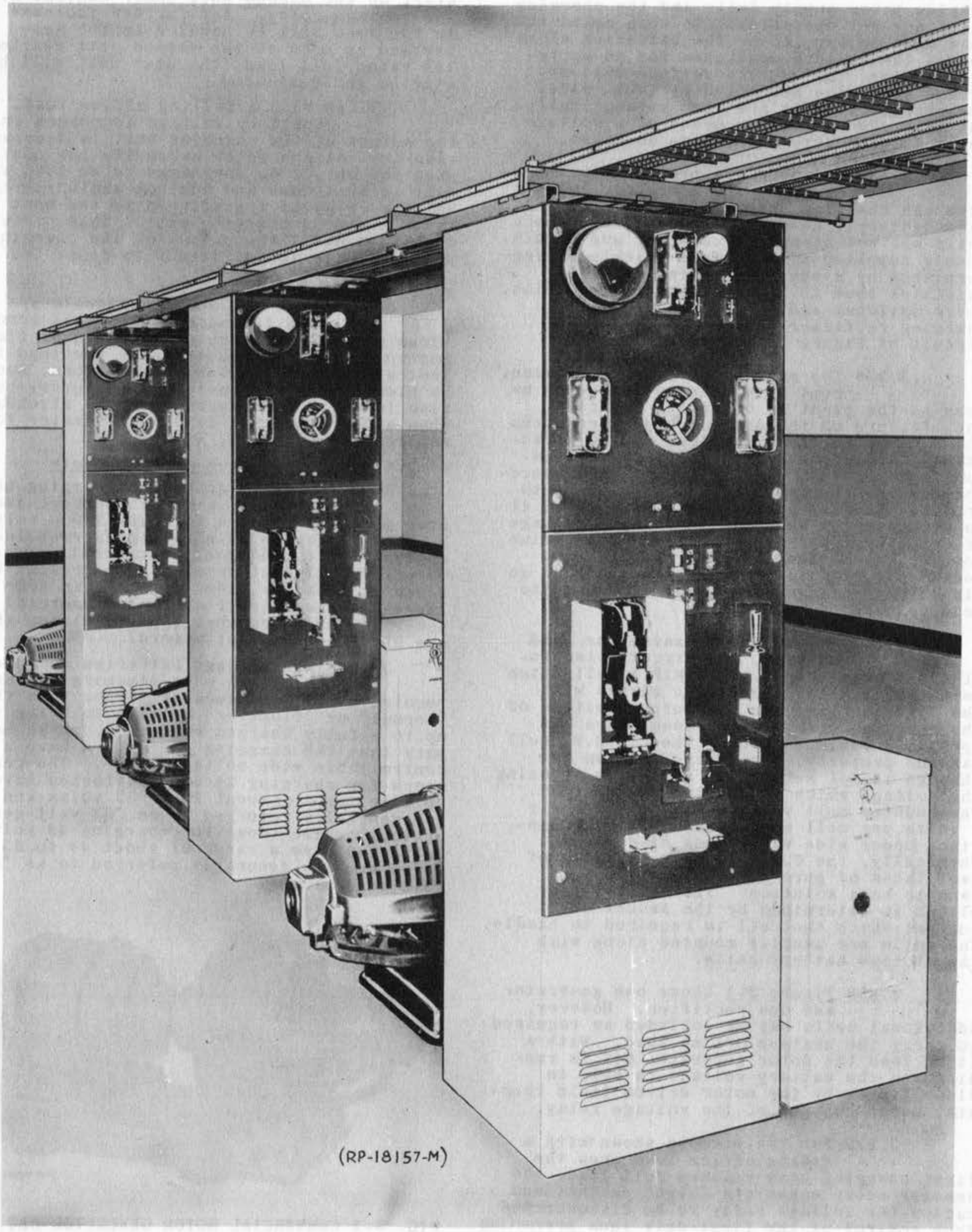


FIG. 3-3 TYPICAL GENERATOR CONTROL CABINETS

3.43 Three types of charging generators have been used in the past, the "M" type, the "Diverter-Pole" type and the "commercial" type. The "commercial" type has replaced both the "M" and "Diverter" types in new plants because of the lesser cost and the standardized features with relation to other commercially available direct current generators. They are usually furnished in sizes ranging from 100 to 750 amperes at 48 volts or 800 amperes at 24 volts. Sizes as large as 1200 amperes at 48 volts or 1500 amperes at 24 volts are used where required.

3.44 Commercial type generators are self-excited (shunt wound) and are provided with a commutating field winding for satisfactory commutation at any load between no load and rated full load. Field rheostats are used to control the output voltage. The characteristics of the armature and commutator are such as to produce noise in the generated current and for this reason interpoles and other design features are utilized to keep the noise level at a minimum. However, a filter, consisting of choke coil and condensers, is required to further reduce the noise to the point where it will not affect the quality of transmission.

3.5 AC Induction Motors

3.51 Since alternating current commercial power is available in practically all localities, the motors for driving the dc generators are usually ac induction motors. However, in the past a few synchronous motors were used because of power factor considerations. Synchronous motors are more expensive than induction motors and require a more costly starting mechanism. In view of the higher initial costs and because power factor correction can be more economically accomplished by means of capacitors, synchronous motors are in general not being specified for motor generator use in telephone power plants.

3.52 The ac induction motors generally used are of the squirrel-cage type and are capable of continuously driving the dc generator at the specified maximum voltage and rated load under any condition of commercial power service within the limits of 190 to 253 volts and 58.8 and 61.2 cycles per second. They are also capable of carrying without injury a 50 per cent momentary current overload on the generator.

3.53 In sizes up to 12 horsepower (with 200 ampere 33 volt or 100 ampere 65 volt generators) the high reactance type of induction motor is furnished which limits the starting current sufficiently to permit the use of across the line starters. Motors larger then 12 horsepower use starting compensators which hold the starting current down.

3.6 Power Factor

3.61 This term is used to indicate a relationship between the ac current wave and voltage wave. If these waves are in phase with each other, this condition is known as "unity power factor". If the current wave lags behind the voltage wave, due to the reaction of inductive loads (such as motors, etc.) this is termed a "lagging power factor", and when the current wave leads the voltage wave it is termed a "leading power factor". Since the technical explanation of power factors is quite complicated it will, therefore, merely be pointed out here that a low power factor results in "wattless" current or current which does no useful work, but heats up the conductors and increases the voltage drop. This condition is observable with a power factor meter, a phase angle meter or a varmeter, which may be mounted on the power board. Some commercial power companies have a form of contract for power service which includes a penalty for power consumed by electrical equipment which operates at a low power factor. One means of power factor correction is by the use of capacitors which in general are associated with the motor starter circuit. They consist of metallic enclosures containing pyranol condensers.

3.7 Motor Starters

3.71 The various types and sizes of motors used in power plants necessarily require different types of starters. For small motors, the starter may consist simply of a tumbler switch associated with thermal cut-outs, or fusetrons, to protect the motor against overloads or abnormal currents. From this simple starter, the types progress to apparatus of a complex nature, such as the automatic starting compensators for polyphase ac motors. Some of those most commonly used in medium and large sized power plants are briefly described.

3.72 Across-the-Line Type

3.721 These starters are usually employed with motors ranging from 1.5 to 15 HP where the starting current is sufficiently low to permit the motors to be started by connecting them directly across the line. They are furnished in either manually operated or automatic types. Both type include a magnetic contactor (electrically operated switch) for closing the circuit to the motor and a temperature overload relay which opens the circuit to the operating coil of the contactor in case of an overload. The contactor and overload relay are mounted on an insulating base and enclosed in a sheet metal housing. A reset button is provided in the cover for manually resetting the temperature overload relay after it has been operated due to an overload.

3.722 The manually operated type employs "start" and "stop" buttons, which may be located on the power board or other location, for controlling the operation of the magnetic contactor.

3.723 The automatic type is equipped with a 24 volt dc relay, (with a resistance for use on 48 volts) for controlling the operation of the magnetic contactor. This relay is operated by the control circuit in an automatic power plant.

3.73 Autotransformer Type AC Starter

3.731 The primary purpose of this type starting compensator is to limit the starting current of the larger ac motors (15 HP up) and to provide automatic starting. Each ac starter consists of a polyphase autotransformer with taps, a multipole starting contactor for connecting the autotransformer to the line and the motor to the autotransformer low-voltage taps, a running contactor for connecting the motor directly to the line, a definite time delay which, after a predetermined time, causes the starting contactor to open and the running contactor to close, and overload relays which open the running contactor in case of overload. As the motor rotates it drives the adjustment dial until a projection on the dial actuates a switchette, thereby operating contacts to control the opening and closing of the start and run contactors. A control relay is mounted within the starter case and connected for operating the starter. The control relay is suitable for use on 20 to 28 volts direct current and a series resistor is furnished for connecting in series with the relay coil for operation on 42 to 52 volts direct current. The complete equipment is mounted with a sheet metal case. A picture and schematic of the 3-phase automatic ac starter is shown in Figures 3-4 and 3-5.

3.732 Where manual start control features are required, manual starters may be used instead of automatic starters. Motor Generator Sets with manual starters are generally used as supplementary units to aid those under automatic control that normally carry the office load. Manual starters for the larger motors (larger than 15 HP) may be identified by the operating handle on the outside of the case with three different positions marked as "OFF", "START" and "RUN".

3.8 Rheostats

3.81 Field rheostats are used to control the current output of generators by regulating the generator field current. There are two kinds, hand operated and motor drive, both are used in series in automatic plants. The hand operated rheostat is preset at the charge voltage for the regular and emergency batteries as required.

3.82 Each rheostat is made up of one or more circular plates on which are contact buttons for terminating the resistance elements. Movable arms with contact shoes are provided for varying the amount of resistance in the circuit. To permit the dissipation of heat generated, the apparatus is not enclosed. See Figure 3-6.

3.83 Hand operated field rheostats are mounted on the rear of the generator control panels associated with the motor generator units. Handwheels on the front of the board are connected to the movable arms for varying the resistance. (See figure 3-3). Interpolating rheostats have two sections; a main section consisting of coarse resistance steps covering the entire operating range of the associated machine and an interpolating section, consisting of fine resistance steps, which has a total resistance approximately equal to the highest resistance step of the Main Section. Dual handwheels are used, one fastened to a hollow shaft and the other fastened to a solid shaft which passes through the hollow shaft. The smallest handwheel fastened to the inner shaft controls the interpolating section.

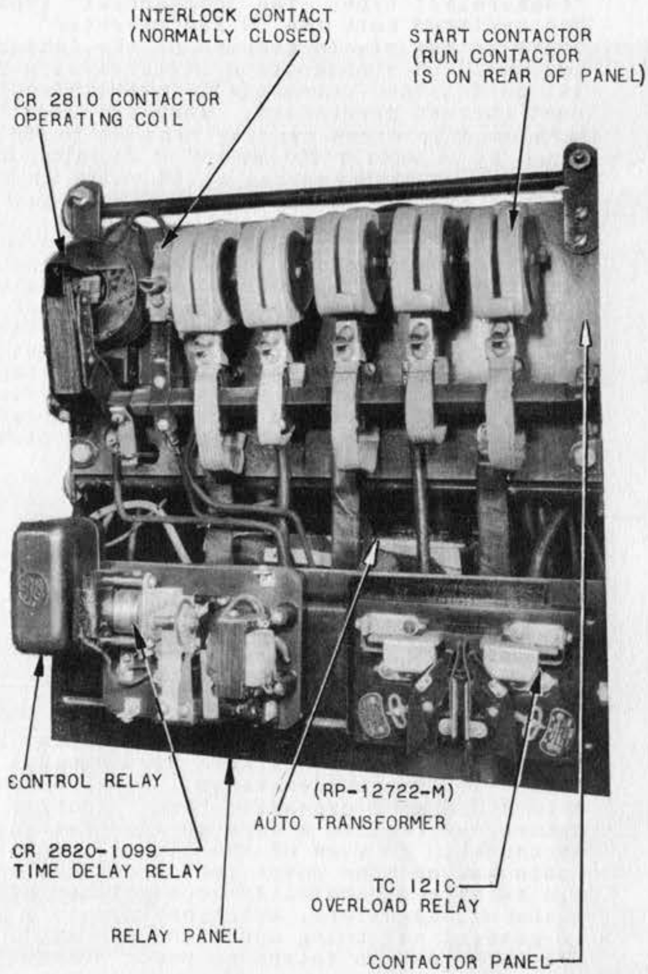


FIG. 3-4 AUTOMATIC STARTING COMPENSATOR AC

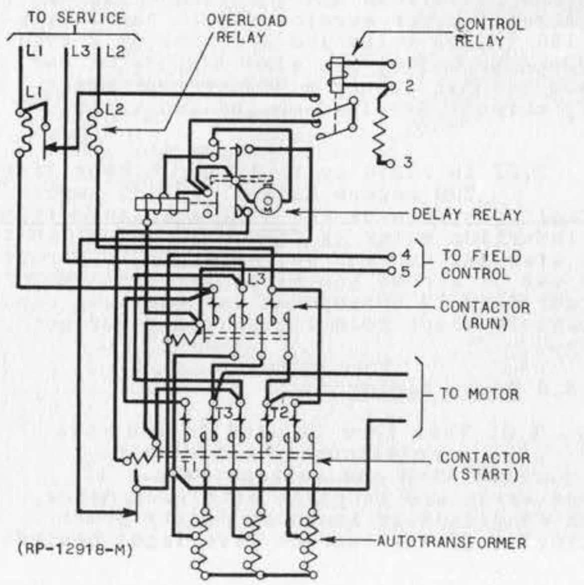


FIG. 3-5 SCHEMATIC OF 3 PHASE AUTOMATIC STARTING COMPENSATOR AS USED FOR 30-75 HP MOTORS

3.84 The motor driven field rheostat used in automatically regulated power plants consists of a circular resistance plate and contact arm operated by a small motor driven through a speed reducing mechanism. This contact arm may be operated in either direction, shunting all or a portion of the total resistance of the plate. Limit switches, which open the motor circuit, are provided to prevent the operation of the contact arm beyond the end contacts. Control circuits actuate the motor drive through relays designated RAISE and LOWER to decrease or increase the output of the charging unit. Arrangements are also available for actuating these relays by means of manually operated keys. The motor driven rheostat is usually mounted on the rear of the charging unit control panel.

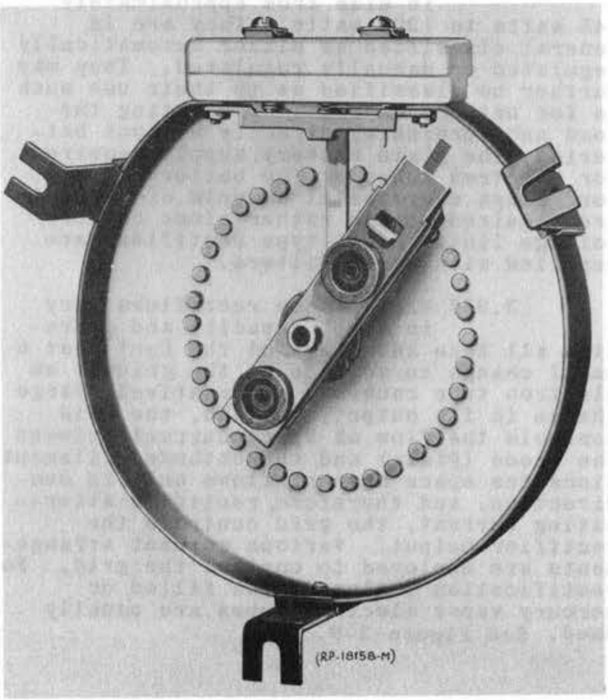


FIG. 3-6 MANUALLY OPERATED RHEOSTAT SINGLE PLATE

3.9 <u>Rectifiers</u>

3.91 A rectifier is commonly defined as a device for converting alternating electric current to direct electric current. All rectifying devices depend for their operation upon the characteristics of permitting electric current to flow through them freely in one direction only. They include a variety of vacuum and gas filled tubes such as the older mercury arc tube, the newer mercury-vapor tube, and the tungar tubes, as well as nearly all other types of electron tubes when properly connected. There are also the metallic or disc types of rectifiers of which the two most commonly used are the selenium (metallic) rectifier and the copper oxide rectifier.

The Tungar and mercury-vapor tube rectifiers depend for their operation upon the emission of electrons from a heated cathode. The basic phenomena involved are

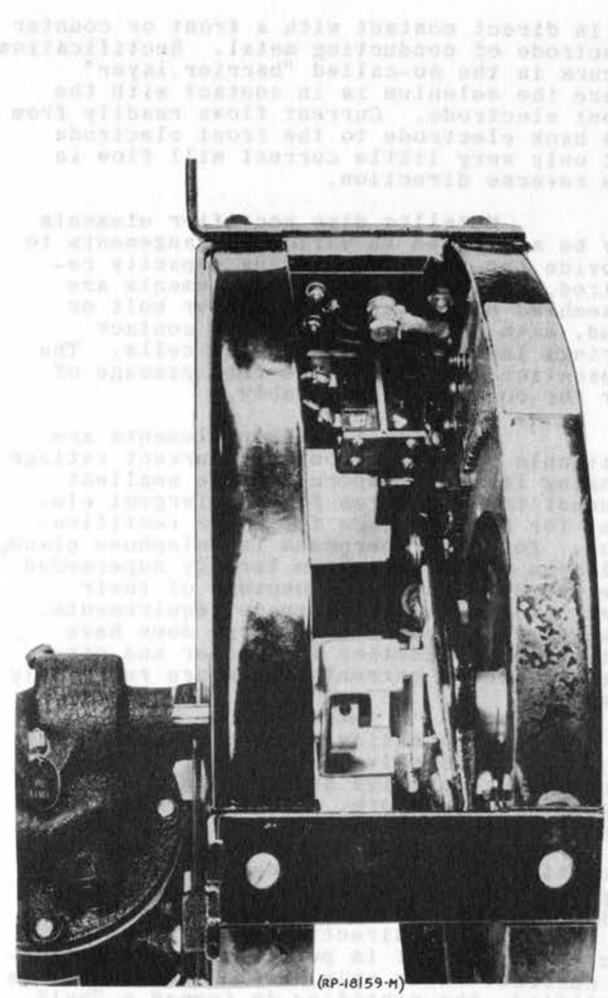


FIG. 3-7 MOTOR DRIVEN RHEOSTAT

the same as characterize all types of electron tubes. Mercury vapor tubes are used in telephone power plants generally for charging small storage batteries and similar purposes.

Metallic disc type rectifiers are widely used for charging small storage batteries and emergency cells, the furnishing of a direct source of power for small repeater installations, etc. In lower voltage plants (12, 24 and 48 volt) they are used in place of motor generator sets in the 100 and 200 ampere and larger sizes.

The copper oxide rectifier element consists of a copper disc upon which has been formed a layer of copper oxide. This combination offers a low resistance to current flowing from the copper oxide to the copper but a high resistance to current flowing from the copper to the copper oxide. Thus it becomes a "valve" to pass current in one direction only. They are generally known as varistors.

Similarly the selenium rectifier or cell consists of a back plate or electrode, usually of steel or aluminum. One side of this plate is coated with a very thin layer of metallic selenium which in turn is in direct contact with a front or counter electrode of conducting metal. Rectification occurs in the so-called "barrier layer" where the selenium is in contact with the front electrode. Current flows readily from the back electrode to the front electrode but only very little current will flow in the reverse direction.

Metallic disc rectifier elements may be assembled in various arrangements to provide the total rectifying capacity required. Selenium rectifier elements are assembled on an insulated center bolt or stud, with spacing washers and contact springs interposed between the cells. The separation allows for the free passage of air for cooling the assembly.

Selenium rectifier elements are available in varying output, current ratings ranging from .01 ampere for the smallest element to 12 amperes for the largest element for single phase full wave rectification. For power purposes in telephone plants, selenium rectifiers have largely superseded the copper oxide types because of their lower cost and smaller space requirements. However, the copper oxide type does have extensive application in carrier and other circuits where current values are relatively low.

3.92 Alternating current is made up of successive waves, half of each cycle being positive and the other half negative. Therefore, when alternating current is impressed on the rectifying element it permits the flow of current in one direction during part of each cycle, but impedes the flow of current during the remainder of the cycle while the potential is in the opposite direction. The resulting rectified current is pulsating unidirectional current. When only half of each cycle is rectified, the rectifier is termed a "half wave" type. When the rectifier is so designed (by the use of two or more rectifying elements) that both halves of the ac cycle are rectified into unidirectional current, the rectifier is termed a "full wave" type. This is shown graphically in Figure 3-8.

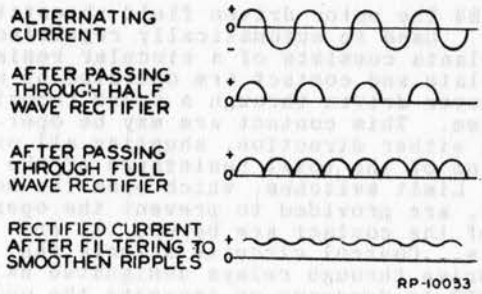


FIG. 3-8 WAVE FORMS OF RECTIFIED CURRENT

3.93 <u>Regulated Tube Rectifiers</u>

3.931 Regulated tube rectifiers vary in size from approximately .45 watts to 1200 watts. They are in general classified as either automatically regulated or manually regulated. They may further be classified as to their use such as for battery charging or floating the load and furnishing directly without batteries, the plate battery supply required for electron tubes or the battery supply for relays where small amounts of current are required within rather close battery voltage limits. All type rectifiers are supplied with noise filters.

3.932 While these rectifiers vary in size, capacity and operation all take advantage of the fact that a small change in voltage on the grid of an electron tube causes a comparatively large change in its output, that is, the grid controls the flow of space current between the anode (Plate) and the cathode (filament). Since the space current flows only in one direction, and therefore, rectifies alternating current, the grid controls the rectifier output. Various current arrangements are employed to control the grid. For rectification 3 element gas filled or mercury vapor electron tubes are usually used. See Figure 3-9.

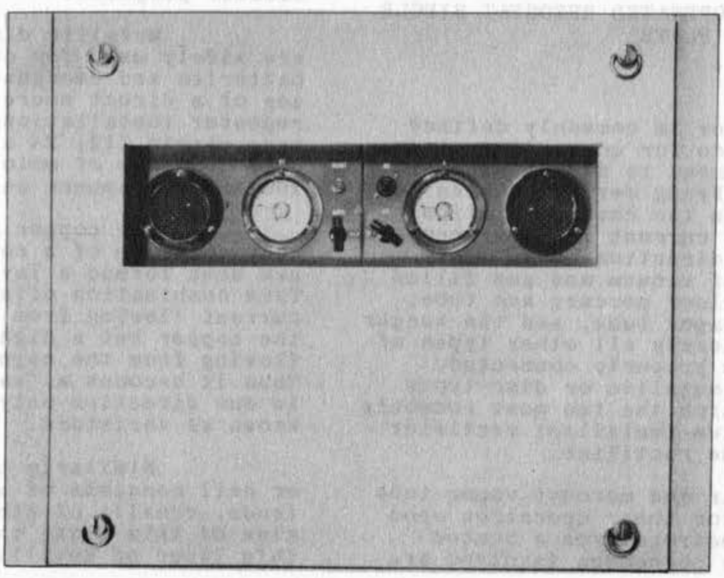


FIG. 3-9 130 VOLT, 8 AMPERE REGULATED TUBE RECTIFIER

3.933 Four types of controls are used for regulating rectifier output. They are Phase Shift, Magnitude, Series and Booster types, any one of which may be operated on a manual or automatic basis. The series type control is limited to the capacity of commercial electron tubes and is not arranged for battery charging. The magnitude type control is simpler in operation and design than the phase shift control but does not lend itself as readily to multiple operation and to higher voltages. The Booster type control is used where the 3 element rectifier tubes of the desired capacity are not available or are uneconomical.

(a) With phase shift control the ac voltage is supplied to the anode of a 3 element gas filled electron tube and a separate ac voltage of the same frequency is supplied to the grid. The grid voltage, however, is out of phase with the anode voltage. This condition is shown in Figure 3-10 which omits the negative loops of the anode voltage because in a rectifier tube no current flows when the anode is negative.

For any point in the positive loop of the anode voltage there is a critical grid bias voltage and whenever the grid voltage curve crosses the critical grid bias curve (shown dotted in Figure 3-10) the tube will fire. Moving the grid voltage curve to the right gives a later firing point and a reduced output and conversely moving the grid voltage to the left gives an earlier firing point and an increased output. Phase shift control is the control of the relative locations of the anode and grid voltage curves.

A full wave, phase shift control rectifier arranged for automatic regulation is shown in Figure 3-11.

(b) With magnitude control (see Figure 3-12), the position of the firing point in the anode positive half cycle is controlled by changes in the grid bias voltage. Under normal conditions the earliest firing point is at A which corresponds to zero grid bias. The latest firing point and minimum output that can be taken from the rectifier occur at C which is midpoint in the anode positive half cycle. By supplying the proper grid bias value between A and C any desired firing point can be selected. The action of the associated filter and control equipment makes any desired output from nearly zero to full rated output available.

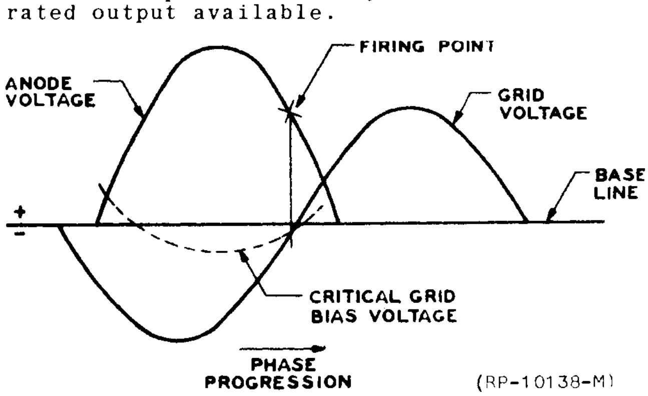


FIG. 3-10 VOLTAGE RELATIONS - PHASE SHIFT CONTROL OF FIRING POINT

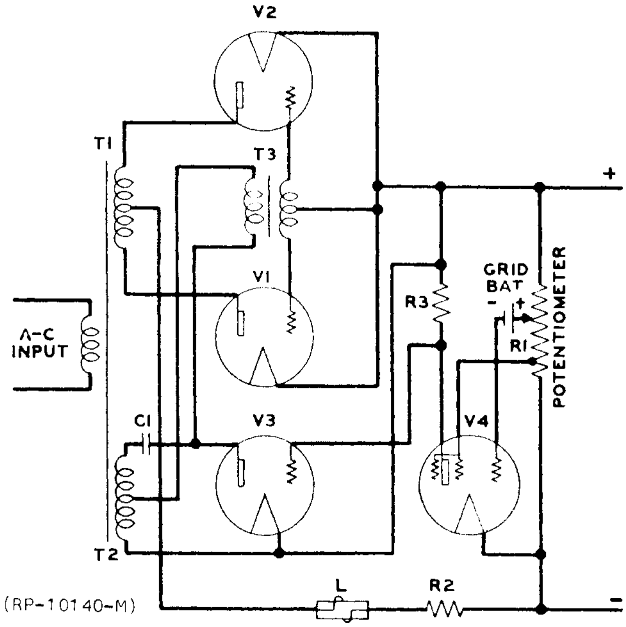


FIG. 3-11 PHASE SHIFT CONTROL FULL WAVE-AUTOMATIC

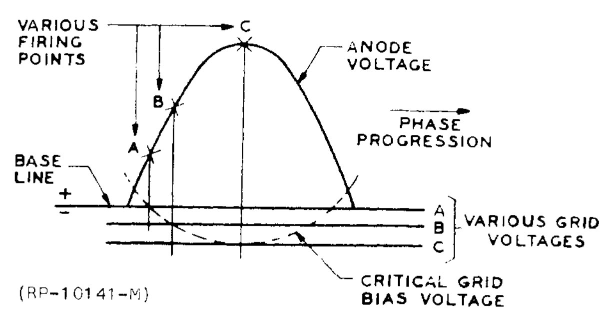


FIG. 3-12 VOLTAGE RELATIONS-MAGNITUDE CONTROL OF FIRING POINT

A full wave magnitude control rectifier circuit together with a series tube control rectifier circuit are shown in Figure 3-13.

(c) The series tube control rectifier (see Figure 3-13) is used primarily for supplying the plate voltage for amplifiers and oscillators. The two anodes of the electron rectifier tube (V1) are connected so that one is positive during one half of the ac supply cycle and the other during the other half which permits full wave operation. No grid is required because the magnitude of the output is controlled by changes in the resistance of the series tube (V2) in the output lead.

This tube (V2) has its cathode and anode connected in series with the positive output lead of the rectifier. The voltage drop over it is controlled by its grid voltage thus controlling the output voltage of the rectifier. To hold the output of the rectifier constant a regulating circuit is provided using electron tube (V3) to amplify the small changes in the regulated output voltage.

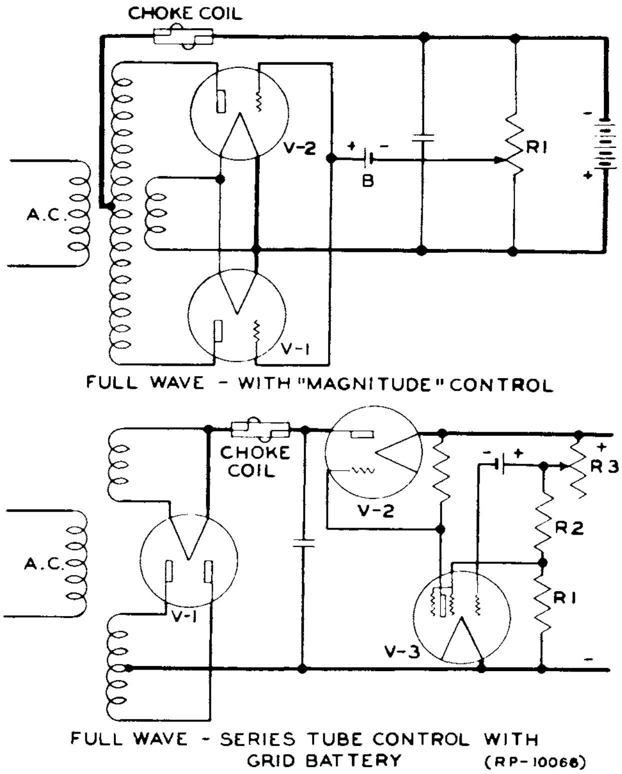


FIG. 3-13 SIMPLIFIED SCHEMATIC OF TWO METHODS OF REGULATED TUBE RECTIFIED CONTROL

(d) With booster control (see Figure 3-14) the ac line voltage is boosted by transformers and an auto-transformer to give the output necessary to maintain the desired battery voltage. The auto-transformer is motor-driven and may be manually or automatically controlled. Unbalance in the resistance of the bridge caused by changes in electron tube (V4) allows current to flow across the diagonal of the bridge through relays (L) and (R) which are in series. These relays are polarized in opposite directions so that unbalance current caused by lowered battery voltage will cause the (R) or raise relay to operate while high battery voltage reflected through the (V3) and (V4) electron tubes will cause unbalance current in the direction to operate the (L) or lower relay. The more turns of auto-transformer (TR) which is connected across the primary of transformer (T2) the more the line voltage is boosted, the higher transformer (T1) secondary voltage becomes and the more output is available from the tube.

3.94 Regulated Metallic Rectifiers

3.941 Regulated metallic rectifiers are in use in sizes from a few watts up to 10K.W. The principal advantage of the metallic type rectifier over the tube type rectifier is that the rectifying element does not require periodic replacement and as a result can be mounted in less accessible locations. Various

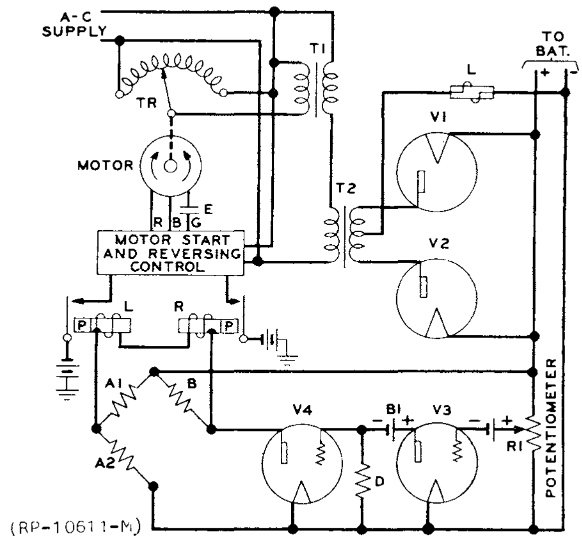


FIG. 3-14 BOOSTER CONTROL REGULATED TUBE RECTIFIER

regulating arrangements are employed but in general they all involve the use of magnetic amplifiers and/or saturable reactors to control the ac voltage applied to the rectifier stacks. All types include a noise filter in the rectifier output.

3.942 Five general regulating arrangements for output control are available. They are:

(1) Saturable Reactor control

(2) Saturable Transformer control

(3) Booster control

(4) Electronic Type control

(5) Relay Type control

3.943 Figure 3-15 shows the rectifying elements for a booster controlled 48 volt unit of 30 ampere output. Figure 3-16 is a picture of the 200 ampere 48 volt saturable reactor control unit.

3.944 The saturable reactor is an electro-magnetic device (usually a coil with a magnetic core) in which the magnetic circuit (core of the coil) may be overloaded before overloading occurs in the electrical circuit (coil windings). An overload (saturation) in the magnetic circuit is reached when an increase of current in the electrical circuit produces no further increase of flux (magnetism) in the magnetic circuit.

When the reactor is placed in an ac circuit with an impressed voltage insufficient to produce overloading in the magnetic circuit of the reactor it would appear as a high impedance due to the high

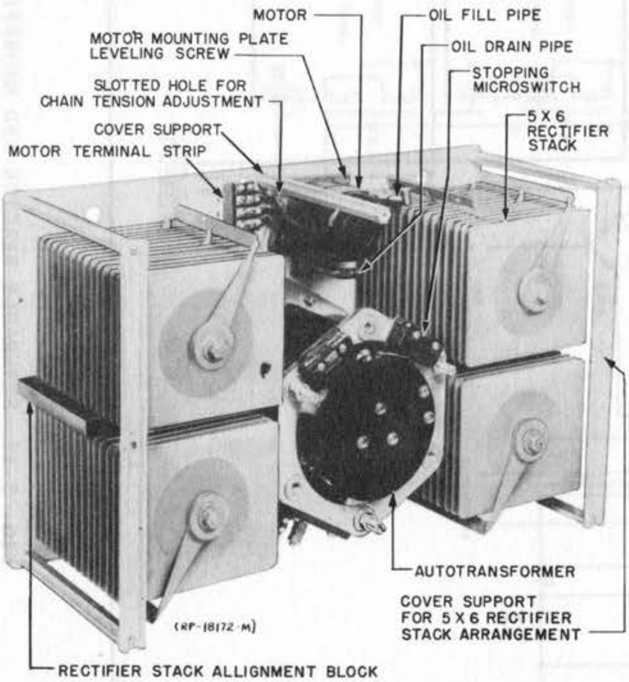


FIG. 3-15 BOOSTER CONTROL METALLIC RECTIFIER

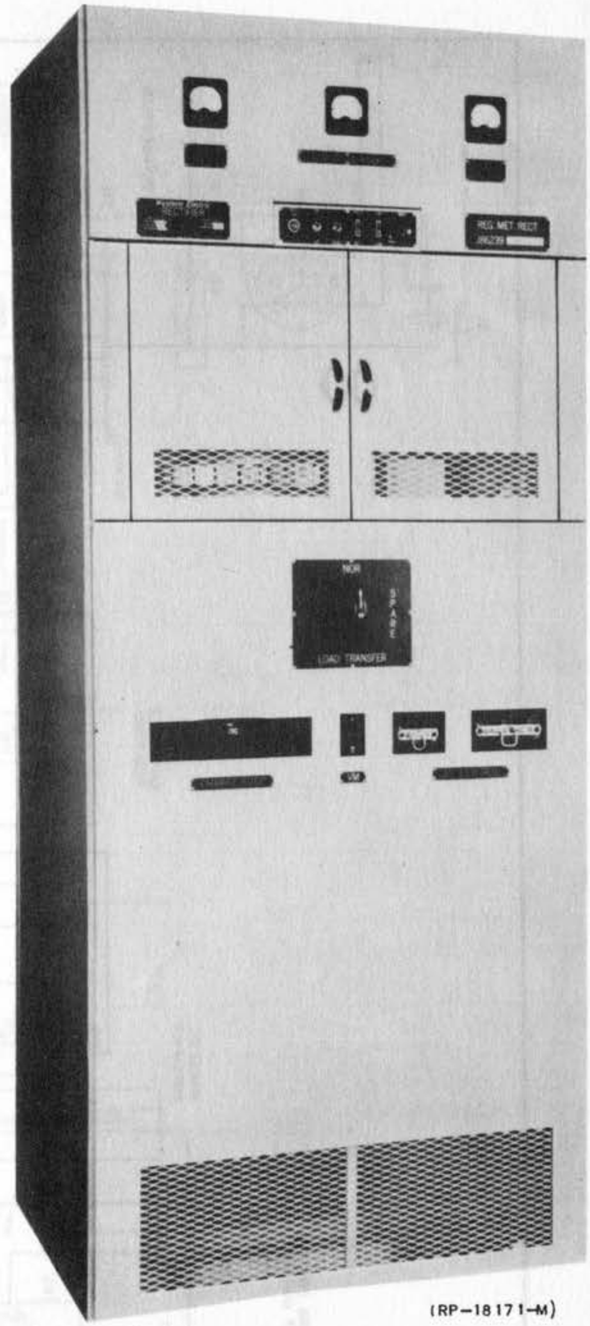


FIG. 3-16 200 AMPERE METALLIC RECTIFIER

inductance from its iron core. This condition gives a high voltage drop across the reactor. If the impressed ac voltage is increased until overloading of the magnetic circuit is reached during a portion of the ac cycle, the reactor then appears as a high impedance only during the portion of the ac cycle when no overloading exists and then appears as a low impedance during the portion of the ac cycle when overloading of the magnetic circuit is encountered. The low impedance during this period results because inductance is directly dependent upon the change in flux in the magnetic circuit there is no appreciable change in the flux. The low impedance is limited only by the dc resistance of the windings. The voltage drop across the reactor is also low during the overloaded portion of the ac cycle. Control of the saturable reactors used in this circuit is obtained by adding a direct current winding to the reactor. Direct current applied to this dc winding may be used to add flux in the magnetic circuit of the reactor. By use of a controlled direct current the saturation point may be set at any desired voltage level of the ac wave, thus controlling the ac voltage drop across the reactor. Figure 3-17 shows the circuit arrangement with a magnetic amplifier.

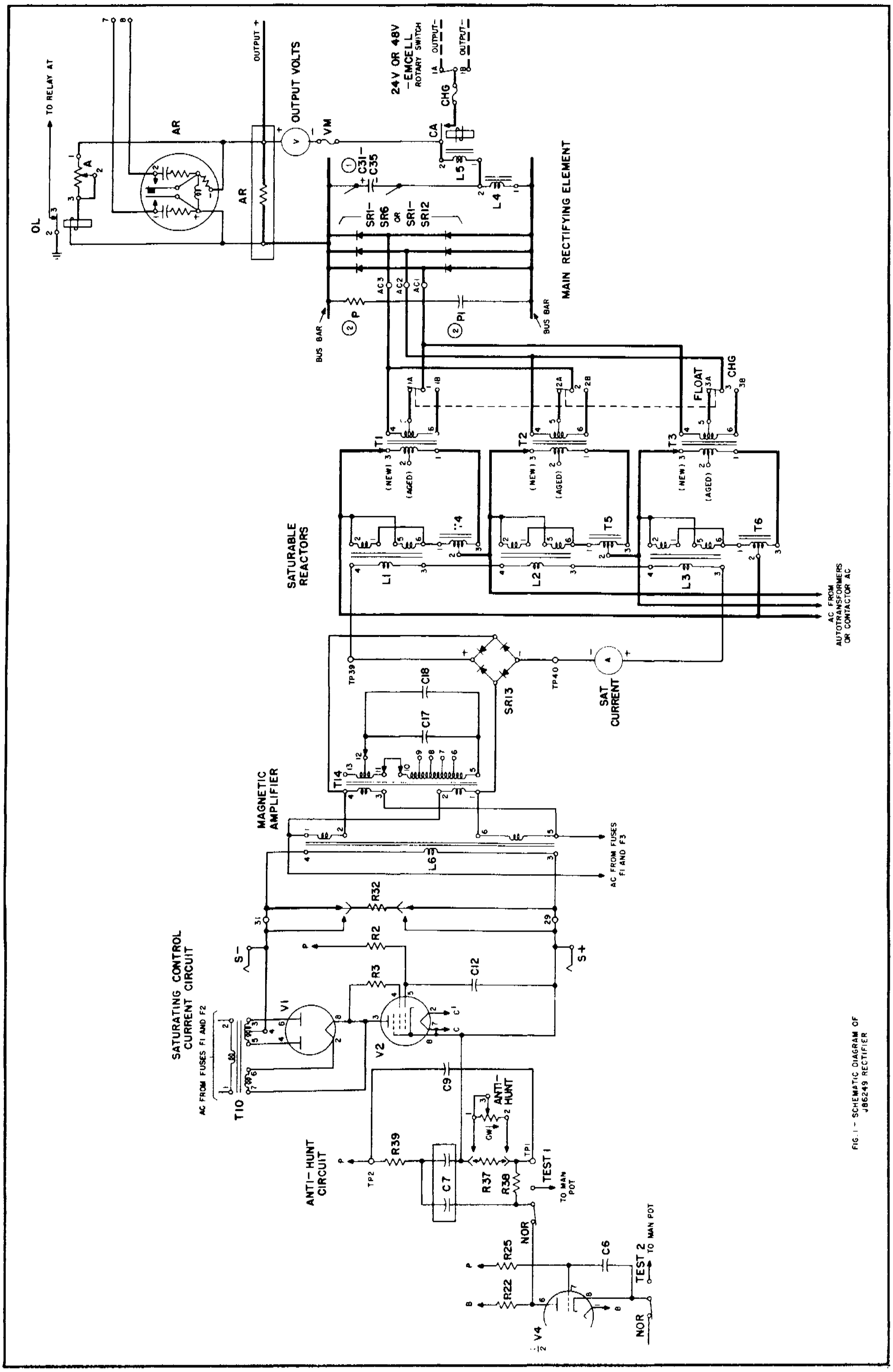


FIG. 3-17 SATURABLE REACTOR AND MAGNETIC AMPLIFIER

3.945 The magnetic amplifier furnishes controlled dc saturating current for the saturable reactor which in turn controls the ac voltage applied to the rectifier units. It is a bridge circuit with two of the legs being windings of the saturable reactor. The balance of the bridge is controlled by the current in the dc windings of the saturable reactor of the magnetic amplifier. An increase in this dc saturating current causes the impedance of the ac windings of the magnetic amplifier saturable reactor to decrease with a resulting increase in the ac output of the bridge circuit. The controlled ac output of the magnetic amplifier is rectified for use in controlling the saturable reactor. A tuned circuit is provided in the magnetic amplifier so that when no saturating current is supplied to the magnetic amplifier from the voltage reference circuit, the output of the magnetic amplifier is at a minimum and consequently the saturating current to the saturable reactor is reduced, thereby reducing the ac voltage applied to the rectifier units. Figure 3-18 shows the schematic for the magnetic amplifier as applied to the control circuit of the 302A power plant.

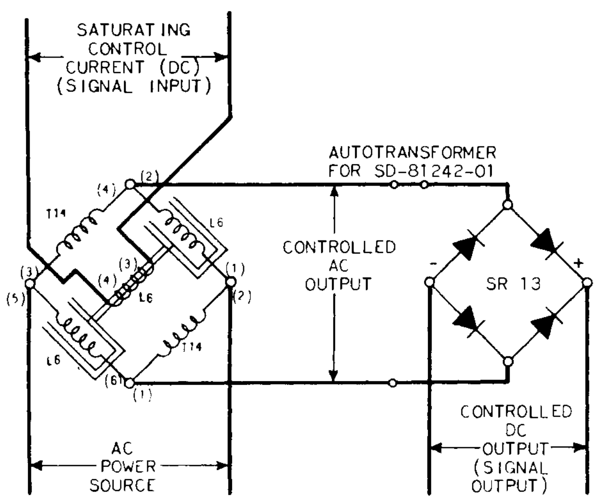


FIG. 3-18 MAGNETIC AMPLIFIER

3.946 The saturable transformer control utilizes a line voltage regulator LR (see Figure 3-19) to minimize line voltage variations so that substantially constant voltage is delivered to retard coil L1 and the primary of the saturable transformer T1. The saturation of transformer T1 is controlled by dc current through the shunt and series coils. The effect of these coils is opposing. The magnetizing force due to the dc shunt coil is practically constant since the coil is connected to the regulated output of the rectifier unit.

At no load the effect of the shunt coil reduces the rectifier output voltage by an amount equal to the drop in voltage due to internal losses at full load. As the output increases the combined effect of the series and shunt coils produces less and less saturation which causes the voltage applied to the rectifying element to be increased. This increase in voltage applied to the rectifying element makes up for the increased internal losses in the rectifier thus giving a constant output voltage.

At full load the series and shunt coils neutralize each other. As the output current increases above rated full load, the series coil overrides the shunt coil and increases saturation which reduces the voltage applied to the rectifying element. The output current is thus limited automatically to prevent overloading.

3.947 Booster control utilizes the same principles as used in the regulated tube booster control circuit except that metallic rectifiers are used in place of the regulated tubes. See Figure 3-14.

3.948 Electronic control is so termed because it controls the ac input to the main rectifying discs through the magnetic amplifier and saturable reactor previously described by means of the electron tube amplification of voltages appearing across an ammeter shunt and the regulating leads. A reference voltage or voltage standard is supplied so that the regulation circuit (error detector portion) may compare this voltage with a voltage which depends on the rectifier output as indicated by the voltage drop across the ammeter shunt. The circuit normally operates with automatic constant voltage regulation. At an output current near full load capacity of the rectifier, automatic constant current regulation begins to take effect. Further load increases put the rectifier completely under constant current regulation at a preset value. If the constant current circuit fails an alarm functions and automatically shuts down the rectifier. A circuit feature is provided to prevent the rectifier from connecting to the load unless it is capable of delivering full rated output. Figure 3-20 shows the control and voltage reference circuits in schematic form.

3.949 Relay output control adjusts the rectifier output in response to "raise" and "lower" signals originating in associated equipment. It uses the same arrangement of series control electron tubes to provide saturating current, a magnetic amplifier and a saturable reactor as the electronic type control. However, it differs from the electronic type previously described in that the output of the series control electron tube, which regulates the saturating current to the magnetic amplifier, is regulated by the charge on a condenser in its grid circuit. The charge on this condenser is changed by two relays, one of which reduces and the other increases the charge. An additional relay provides a slowly increasing raise signal during start conditions to bring the output of the rectifier up to a point at which the rectifier can be connected to the battery. Relay output control rectifiers are normally used as supplementary rectifiers in a multiple unit installation, the first two

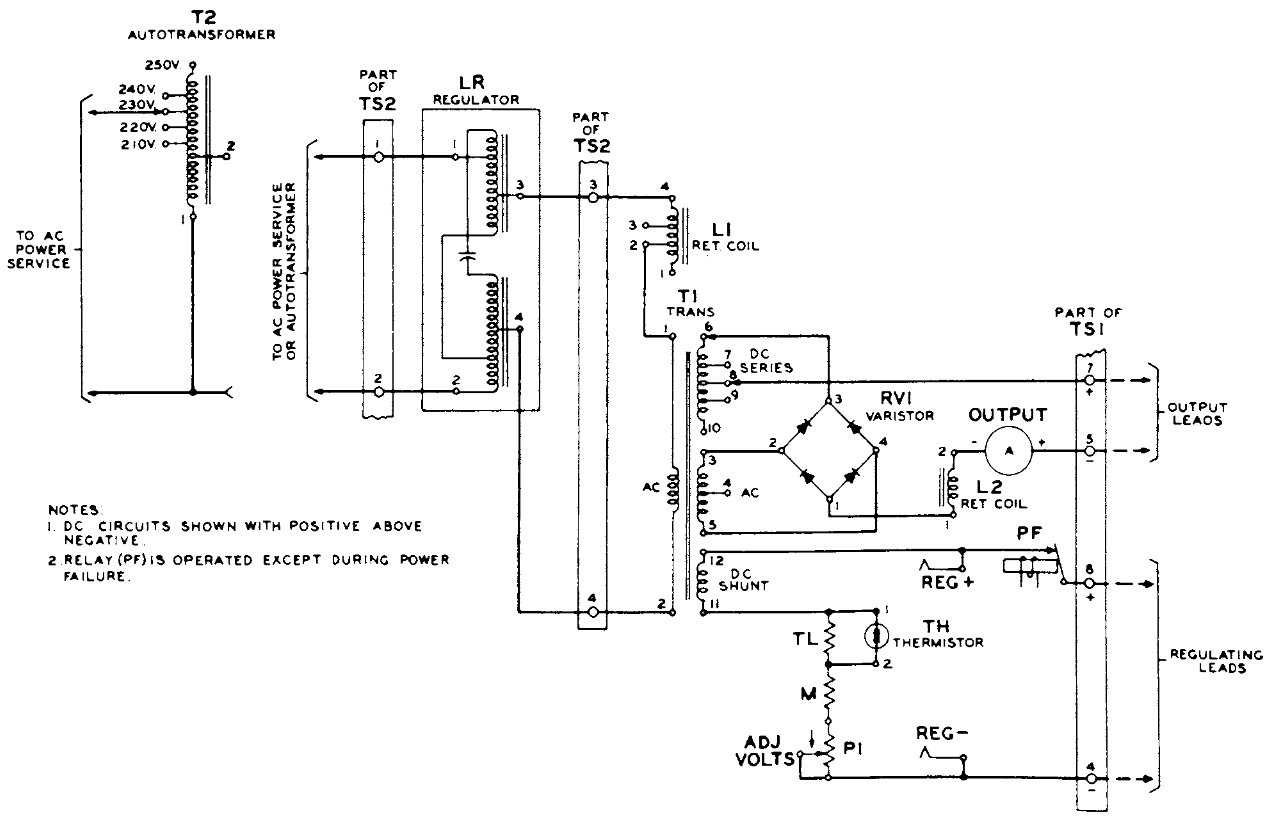


FIG. 3-19 SATURABLE TRANSFORMER CONTROL CIRCUIT

units being of the electronic type. The relay control type unit controls a portion of the load and is under control of signals received from the associated electronic control type of rectifiers. The electronic control units carry the fluctuating portion of the load and provide close regulation of the total output.

3.10 Battery Filters

3.101 The direct current required in a central office in general falls into two classes, "signaling battery" which is used to operate all the various types of electro-mechanical apparatus such as relays etc., and "talking battery" which supplies the medium for voice transmission. Since practically all equipment for generating direct current introduces ripples or noise in their output, it is necessary that battery filters be used to keep such disturbances at a minimum. Figure 3-21 indicates graphically the effect of a filter on an irregular wave form having high frequency ripples or noise.

3.102 Battery filters consist essentially of an indicator (retardation coil or coils) and a pair of (or one) electrolytic capacitors with a 20 ampere self-alarming fuse or with a 15 ampere fuse per capacitor between the filtered side of the inductor and ground. An alarm type fuse is wired in parallel with each 15 ampere fuse. Filters come in

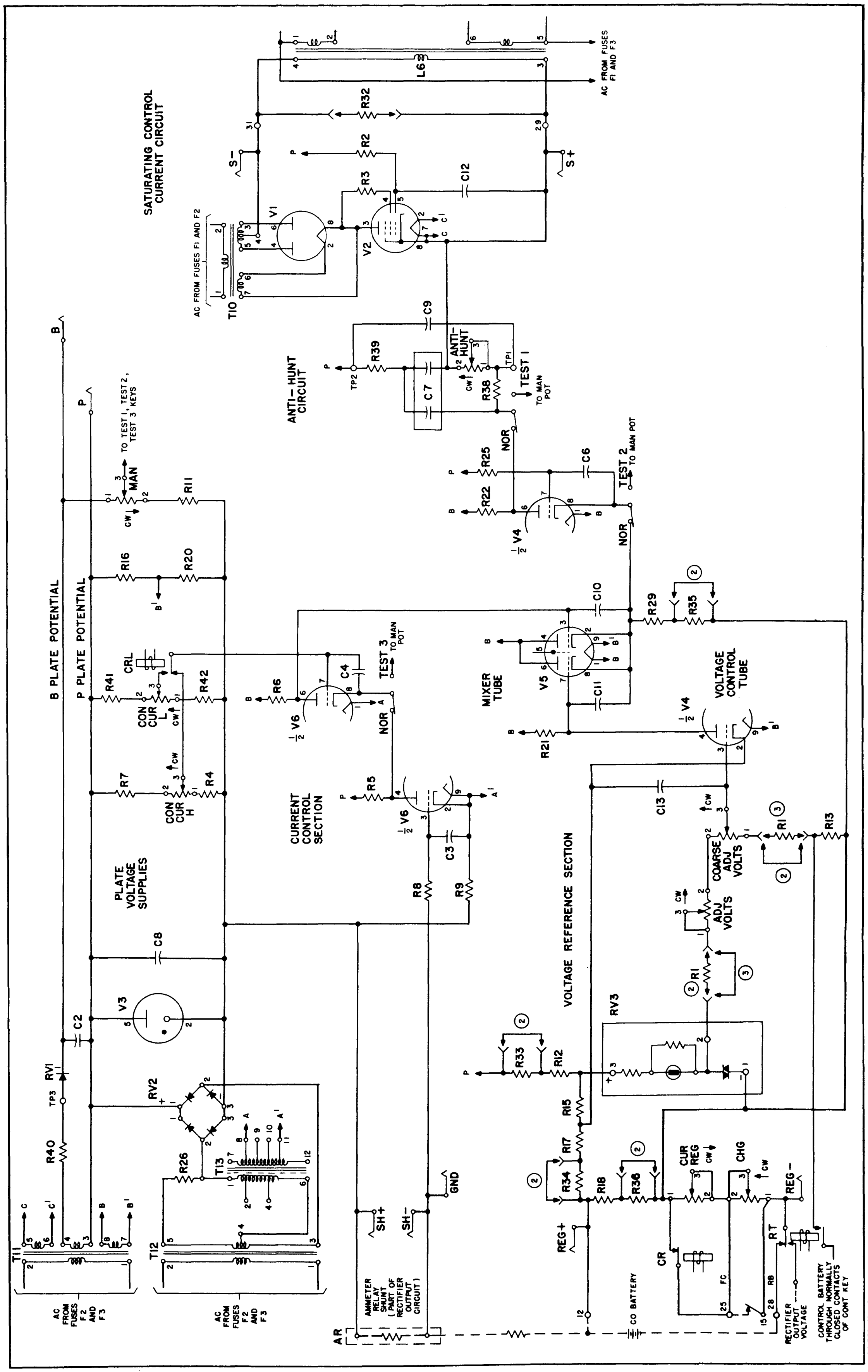


FIG. 3-20 ELECTRONIC CONTROL CIRCUIT

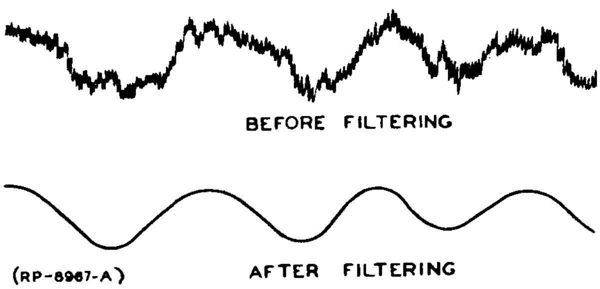


FIG. 3-21 EFFECT OF A FILTER ON AN IRREGULAR WAVE FORM

capacities of 10-200 amperes. Large common filters formerly located in the power room have been replaced by the decentralized type which are mounted on relay rack bays, fuse bays, cable racks, on top of frames, and in switchboard turning sections, as required. The use of decentralized filters makes unnecessary separate power cable runs for signal and talking battery between the power plant and the various frames. This not only results in a saving in power cables but also improves the troublesome noise and crosstalk exposure encountered with former common filter arrangement.

3.103 The inductor of the filter impedes the fluctuations in the talking battery and the capacitor of the filter furnishes a by-pass for the high frequency ripples (ac). A typical filter arrangement is shown in Figure 3-22.

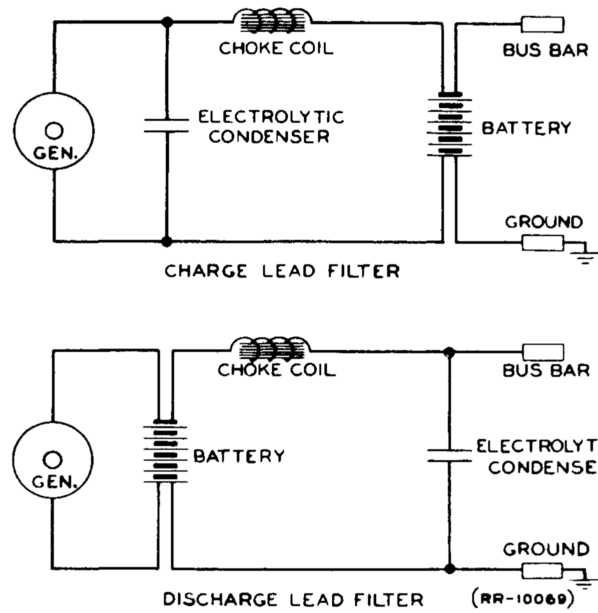


FIG. 3-22 TYPICAL FILTER ARRANGEMENT

In computing the values of the desired inductance and capacity, a combination is obtained which constitutes a "low pass" filter, that is, it will only pass low frequencies that are not considered disturbing. In this connection it should be remembered that storage batteries also offer a low resistance to high frequency ripples and therefore contribute greatly in by-passing noise that might otherwise reach the discharge circuits.

QUESTIONS

1. What is meant by manual operation and automatic operation?
2. What type ac motor is used for motor-generator sets?
3. Describe the difference between across-the-line starters and starting compensators.
4. Why are field rheostats used.
5. What is the principal of operation of a rectifier and what advantages does it have over motor generator sets?
6. What type controls are used for controlling output of Regulated Tube rectifiers?
7. What type controls are used for controlling output of metallic rectifiers?
8. Describe briefly the Saturable Reactor control used in metallic rectifiers?
9. What is the purpose of noise filters in power leads and what do they consist of?

4. CONTROL AND DISTRIBUTION EQUIPMENT

4.1 General

4.11 This section describes the principal items of equipment and apparatus employed to control the operation of the power plant and for controlling the power plant output. Some apparatus that might be considered in this category has been previously described in Section 3 because of its close association with the operation of charging units. Most of the apparatus described in this section is mounted on the power board or charging unit control panel.

4.12 The use of automatic power plants and automatic emergency cell switching, voltage regulation, etc., have led to the use of many new devices and because of the wide variations in size and operating characteristics, the following descriptions are necessarily limited to a brief outline of the purpose and basic operation of each type.

4.2 Power Boards

4.21 The power board serves to centralize the miscellaneous equipment used in the operation and control of the power plant and consists of unit panels of impregnated asbestos composition, each of which either carries the switches and other apparatus required for a certain function or is associated with one or more other panels arranged for accomplishing the desired result. Each bay is assembled on a welded angle iron box type framework arranged for mounting in the power board lineup. After assembly, the structure constitutes a floor supported box type framework which supports not only the front panels but the cable rack and bus bars on top as well. Sheet metal end panels are placed on the framework when specified. The machine control panel frameworks are also floor supported and designed to support the auxiliary framing, bus bars and cable rack on top. It is therefore, possible to support the bus bars and cable racks in the power room without the use of ceiling inserts, threaded rods and ceiling supported auxiliary framing, except in portions of the building where such supporting frameworks are not available.

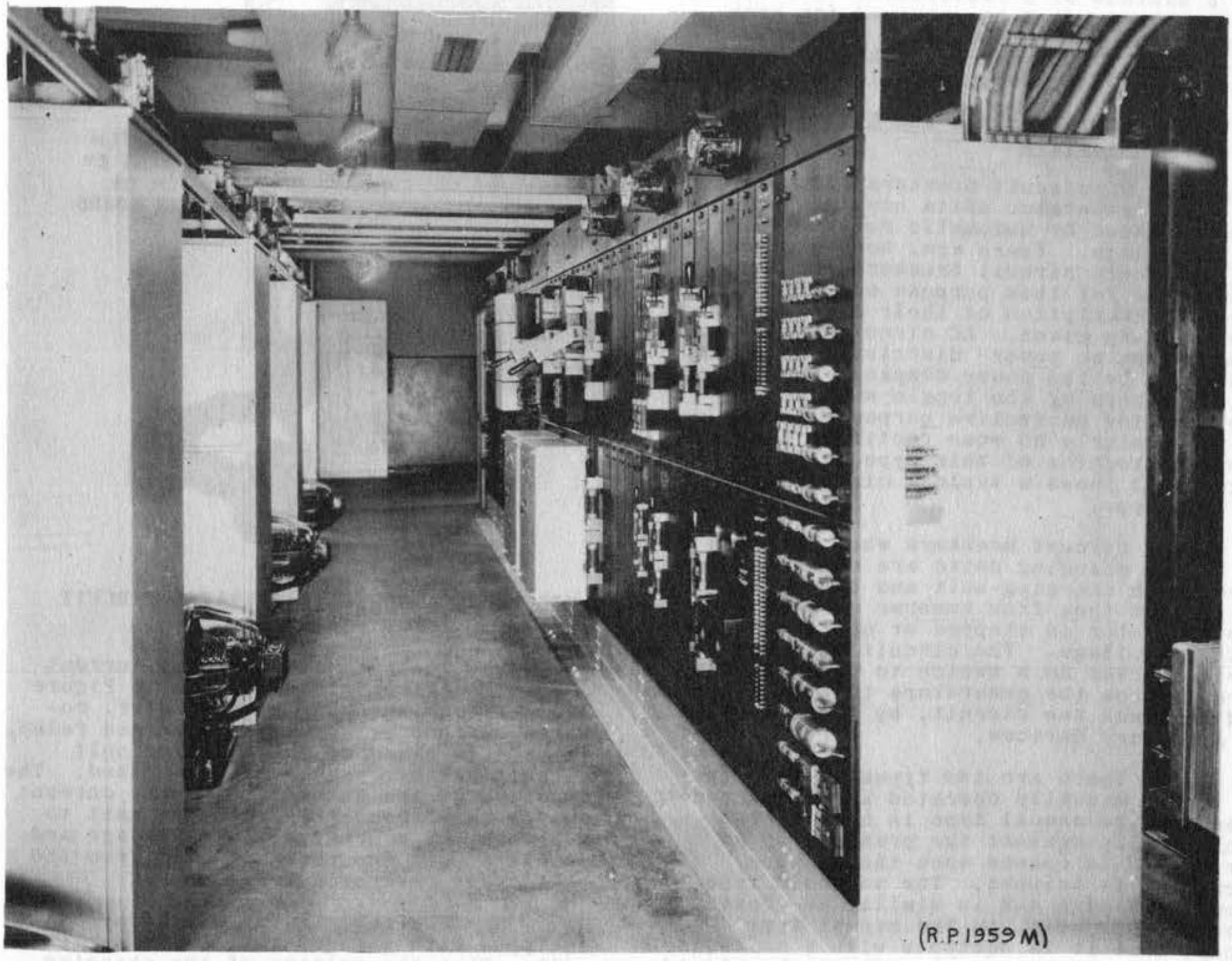


FIG. 4-1 POWER BOARD, ROW OF CHARGING MACHINES AND CONTROL PANELS

4.22 The battery control board is the control and distribution center between the charging generators and batteries, and the fuse panels to which the battery supply is furnished. It consists of two or more bays of panels mounting charge and discharge fuses, switches, etc., associated with the control of the batteries and is usually located in the central portion of the power board line-up. Emergency cell switch and charge fuse units containing the main charge fuses and an automatically operated emergency cell switch panel, mount in this part of the board. A panel mounting miscellaneous fuses and a panel mounting the discharge ammeter and voltmeter are located in this part of the board as well as a voltage relay for controlling the automatic switch. Figure 4-1 shows a power board, a row of charging machines with their associated machine control panels and a saftofuse cabinet at the end of the aisle.

4.23 The main control board mounts the various voltage, control and alarm relays together with the fuses, lamps and keys associated with the control and alarm circuits. Rectifiers used for charging the emergency cells are also on the main control board, space being available for a maximum of 2 rectifiers. One bay of main control board is required for each power plant and is assembled on a welded angle iron box type framework arranged for mounting in the power board line-up.

4.3 Circuit Breakers and Reverse Current Relays

4.31 DC circuit breakers for charging generator units have generally been replaced by automatic reverse current switch relays. There are, however, some offices where circuit breakers are still being used for this purpose and, therefore, a brief description of their operation and use is being given. AC circuit breakers are used on the ac power distribution boards installed by the power company. Small circuit breakers of the toggle switch type are used for protective purposes for ac and dc particularly on some rectifier panels where protection of this type is required. Figure 4-3 shows a typical circuit breaker of this type.

4.32 Circuit breakers when used on charging units are connected between each charging unit and the batteries to protect them from reverse current when the generator is stopped or operating below battery voltage. The circuit breaking device serves as a switch to complete the circuit from the generators to the batteries and to break the circuit, by the operation of auxiliary devices.

4.33 There are two types in use, the manually operated and the solenoid operated. The manual type is held closed mechanically against the pressure of a spring and is opened when the locking mechanism is tripped. The solenoid type shown in Figure 4-2 is similar in construction and operation to the manual type except that it is equipped with a solenoid operated mechanism so that it may be closed or opened by the operation of a remote control switch located on the front of the power board.

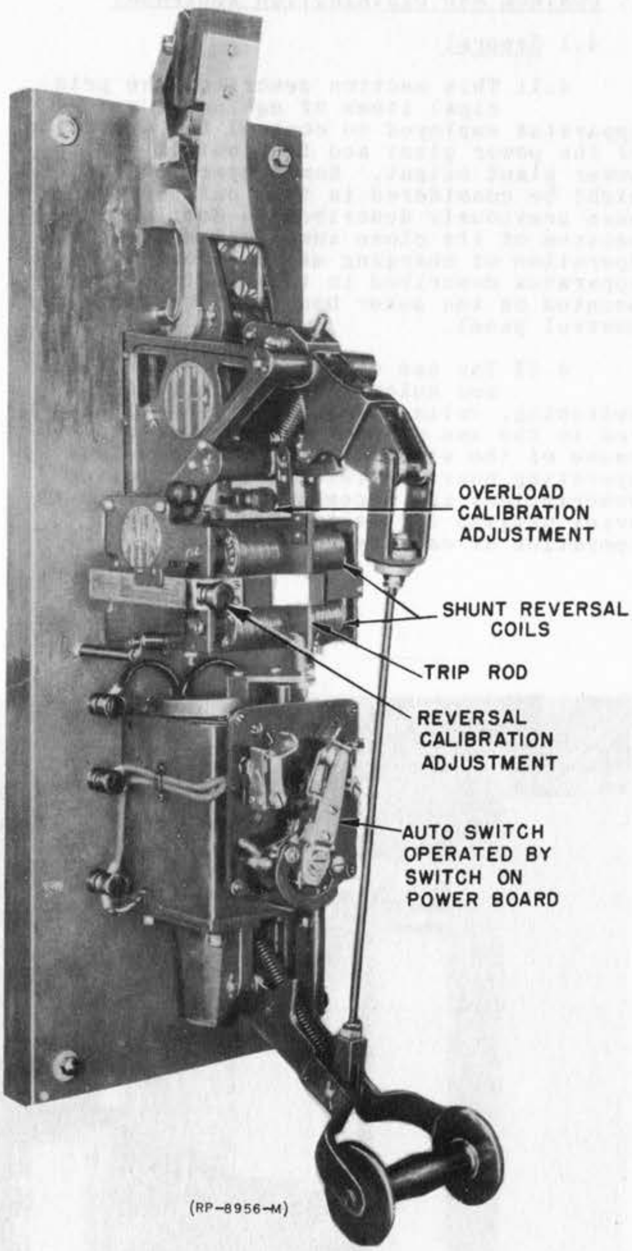


FIG. 4-2 A SOLENOID OPERATED CIRCUIT BREAKER

4.34 The Automatic reverse current switch circuit shown in Figure 4-4 and consisting of a contractor, reverse current relay and a polarized relay, is used in place of the charging unit circuit breaker previously described. The function of the automatic reverse current switch is to connect a charging unit to a battery at a predetermined voltage and to disconnect the charging unit from the battery on reverse current.

The reverse current relay is equipped with a shunt coil and a series coil. When the voltage of the charging unit slightly exceeds the voltage of the battery, a polarized relay external to the switch will operate and cause the reverse

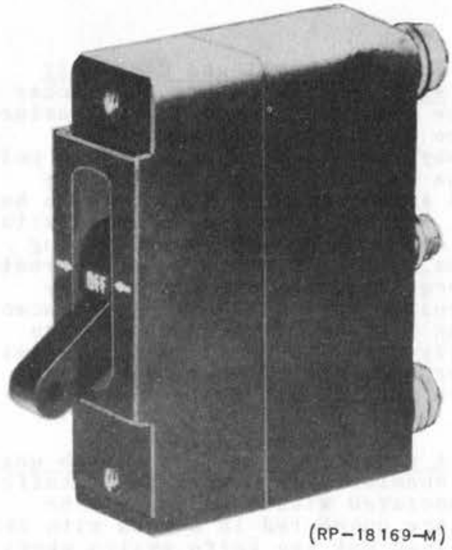


FIG. 4-3 TYPICAL KS-TYPE CIRCUIT BREAKER

current relay to operate through its shunt coil. This relay operates the contactor and current flows from the generator, through the series winding of the relay to the battery, helping to hold the relay operated. When the charging unit voltage drops and current flows from the battery to the charging unit, the series coil of the reverse current relay opposes the shunt coil and allows the relay to release and to release the contactor.

4.4 Fusing Protection For Power Plant Discharge Leads

4.41 All power supply circuits leading from the power plant to other parts of the central office are fused to protect the wiring and the power plant equipment. The carrying capacity of each fuse is limited to a value that will protect the wire connected to it against overheating in case of a short circuit or ground. Where a large lead supplies current to a number of smaller leads, each of the smaller leads is also fused to protect that size wire. In many cases the fuse capacity specified may be lower than would be required to protect the wiring, in order to safeguard the apparatus in the circuit.

4.42 N.E.C. (National Electric Code Standard) cartridge type fuses are used for the supply leads. Western Electric Company manufactured No. 35 and No. 70 alarm type fuses are used for individual central office circuits or small groups of circuits and are furnished in capacities of 5 amperes or less. The 70 type is known as the dead front type. These alarm type fuses are so designed that when the fuse wire melts, a small visual signal is displayed (a flag type signal for the 35 type and a plastic cylinder protruding from the housing of the 70 type) and a spring arrangement makes contact with an alarm bar. This alarm bar is connected through the central office alarm circuit which rings a bell and displays a lamp signal.

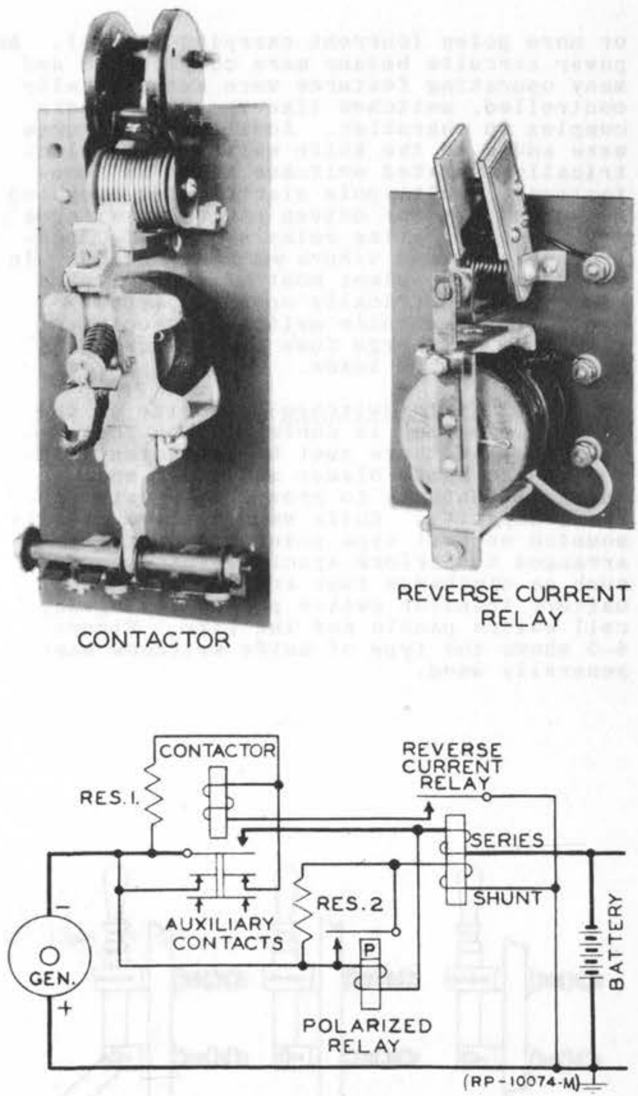


FIG. 4-4 SCHEMATIC AND PICTURE OF AN AUTOMATIC REVERSE CURRENT SWITCH

4.43 Where cartridge type fuses are used on a central office supply lead it is the usual practice to connect an alarm fuse in parallel with it so that when the main fuse blows the alarm fuse also operates, thereby displaying a signal and operating a central office alarm to indicate which circuit has failed. Since some part of the central office is out of service when a fuse fails, the alarm type fuse serves a very important function in sounding an alarm to enable the maintenance people to quickly locate the condition and correct it.

4.5 Switches

4.51 Broadly, the term "switch" applies to any device used for opening and closing a circuit, or for transferring the continuity of a circuit from one path to another. In the past most power switches were of the knife blade type, either single-throw or double-throw and equipped with one or more poles (current carrying blades). As power circuits became more complicated and many operating features were automatically controlled, switches likewise became more complex in character. Additional features were added to the knife switches and electrically operated switches known as "contactors", "multi-pole electrically operated switches", "motor driven end cell switches", "emergency lighting relay switches", "control relays" and others were introduced. In a modern power plant most of the switches are of an electrically operated type, except for the knife switches associated with the "discharge fuse and switch units" in the discharge leads.

4.52 Knife Switches: The size of the switch is controlled by the current flow as there must be sufficient copper in the knife blades and jaws, and suitable contacts to provide adequate carrying capacity. Knife switches are usually mounted on unit type power board panels arranged to perform specific functions, such as discharge fuse and switch panels, battery transfer switch panels, emergency cell switch panels and the like. Figure 4-5 shows the type of knife switches most generally used.

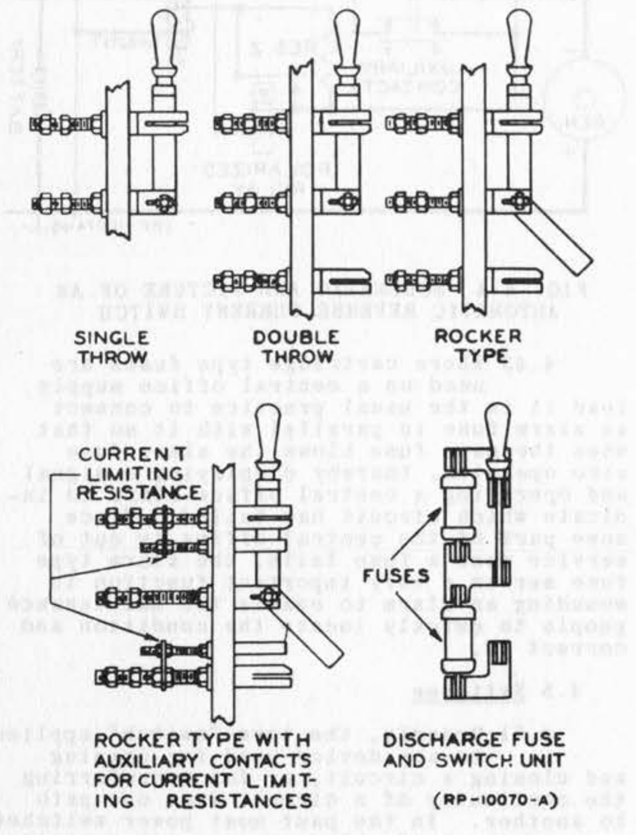


FIG. 4-5 COMMONLY USED TYPES OF KNIFE SWITCHES

4.53 Emergency cell and CEMF cell switches are either the rocker or slider type and include additional features. A unit type panel for emergency cell switches may include 2, 3 or 4 single pole rocker type switches, depending on the number and arrangement of the cells to be switched. The switches are equipped with auxiliary contacts and current limiting resistances, to limit the flow of current, as the emergency cells are momentarily short circuited through these resistances while being switches. The switches are mechanically interlocked so as to prevent an improper sequence of operation which might short circuit the cells and injure them.

4.54 A discharge fuse and switch unit consist of a double-throw knife switch associated with two fuses. The two fuses are connected in series with the discharge lead but the knife switch short circuits one of them. Should the other fuse operate, the switch can be thrown, thereby short circuiting the operated fuse and placing the good fuse in the circuit. After the operated fuse is replaced, the switch blade may be returned to its normal position.

4.55 Safety type switches consist essentially of knife type switches mounted on an insulating panel and enclosed in a metal cabinet. A handle on the outside of the cabinet operates the

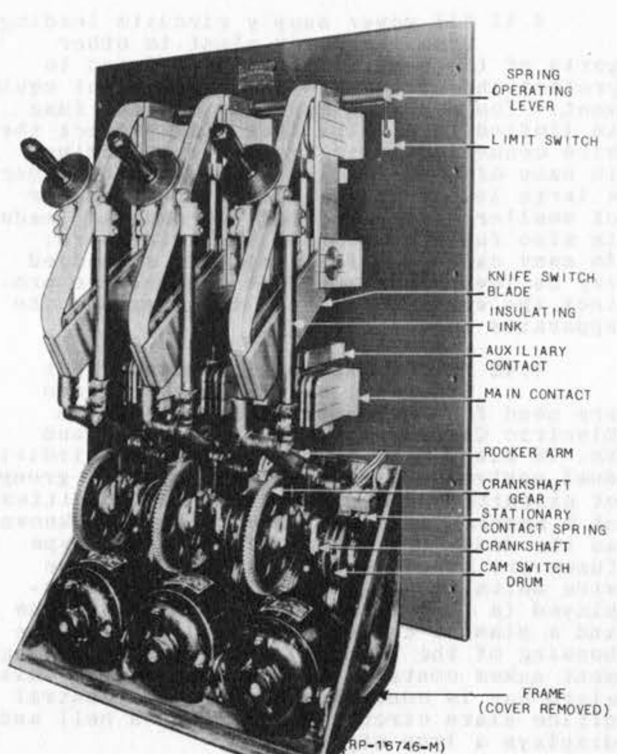
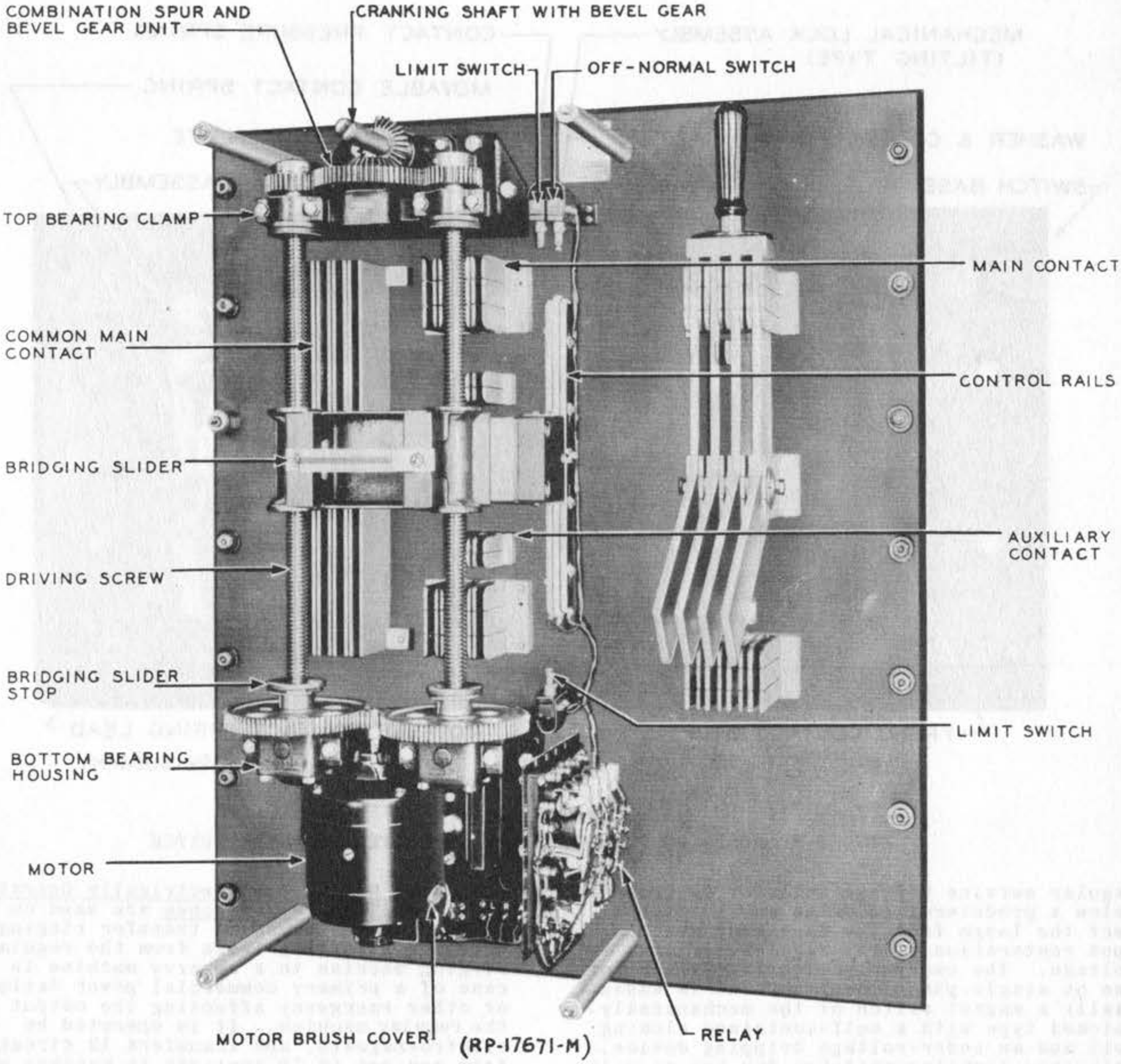


FIG. 4-6 KNIFE BLADE TYPE SWITCH



(RP-17671-M)

FIG. 4-7 SLIDER TYPE SWITCH

switch. They are furnished in single-throw and double-throw types, the single-throw type having fuse clips of the proper capacity mounted on the panel. They range in capacity of 30 to 1200 amperes and are used principally for controlling circuits carrying primary commercial power supply voltages.

4.56 Saftofuse units serve as switches in many applications. The insulated saftofuse unit which carries the fuse may be removed from its holder, thereby opening the circuit. This unit may then be placed in the holder reversed, exposing the fuse to view as an indication that the circuit is open.

4.57 Motor Driven Emergency Cell Switches are used in either manual or automatic power plants where it is desired to have the emergency cell switching performed automatically under control of a voltage relay. The "knife blade type" motor driven emergency cell switches are most generally used, although the "slider type" is also used to some extent. These switches are mounted on the front of the power board. See Figures 4-6 and 4-7.

4.58 Emergency lighting relay switches function to automatically connect a number of lamps to the emergency lighting service (usually battery) in case the

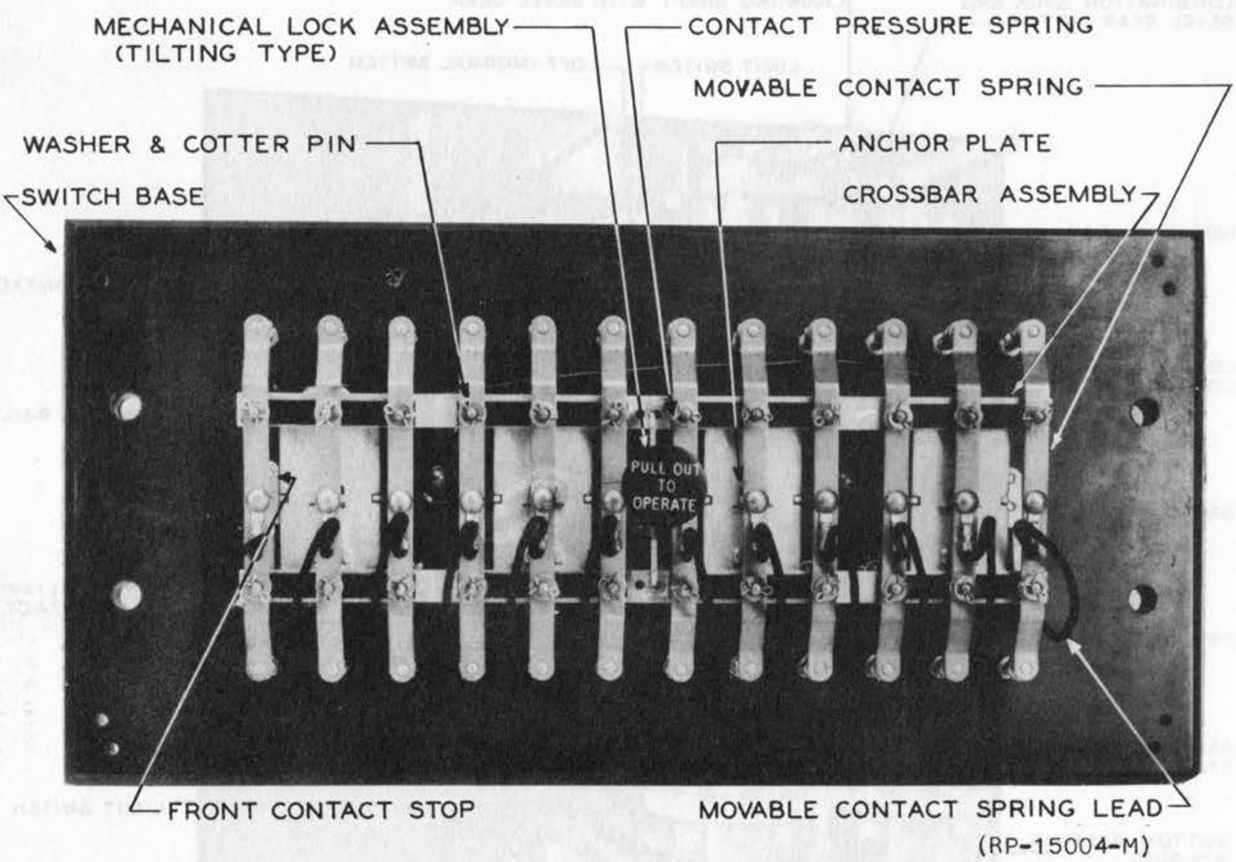


FIG. 4-8 MULTI-POLE ELECTRICALLY OPERATED TRANSFER SWITCH

regular service voltage fails or decreases below a predetermined value and to disconnect the lamps from the emergency service upon restoration of the regular service voltage. The emergency lighting switch for use on single-phase power service is essentially a magnet switch of the mechanically-latched type with a self-contained closing coil and an under-voltage tripping device. Emergency lighting switches for use on poly-phase services are similar to the single-phase switches except that additional under-voltage relays are included. A terminal block is provided for connecting the grounded side of the emergency lighting system. A test switch or switches are provided on the panel for simulating a power failure for testing purposes. Emergency lighting switches are double-pole single-throw, are available in capacities of 30, 60 and 100 amperes per pole and are suitable for use on 115 and 230 volt single phase and 200 volt three phase, 60 cycle regular lighting services and on 24 and 48 volt dc emergency lighting services. They are available in either flush mounted or surface mounted cabinets or on panels without cabinets.

4.59 Multi-Pole Electrically Operated Transfer Switches are used on ringing power boards to transfer ringing, tone and signaling leads from the regular ringing machine to a reserve machine in case of a primary commercial power failure or other emergency affecting the output of the regular machine. It is operated by electro-magnets, and transfers 12 circuits from one set of 12 contacts to another set of 12 contacts. See Figure 4-8. The switch is held closed on one throw when the operating coils of the magnets are energized, and held closed on the opposite throw by springs, when the coils are de-energized.

4.6 Contactors

4.61 Contactors are essentially electrically operated switches. The main contacts (1 or 2) are operated by an electro-magnet, which in turn is controlled by power circuit control apparatus such as control relays. They are arranged for front or rear-of-board connection, that is, the terminals may be on the front or brought

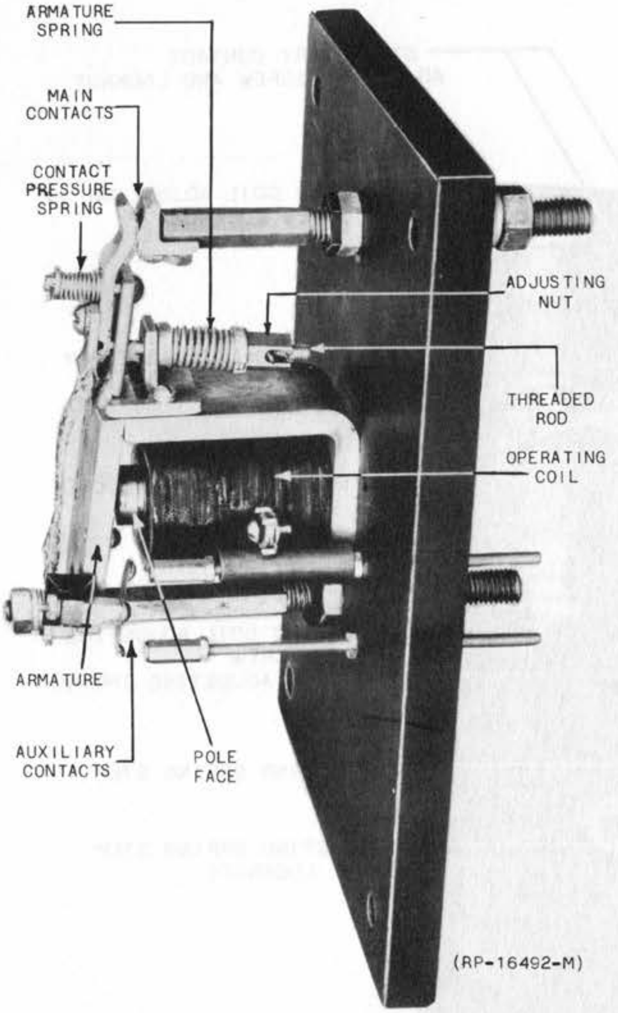


FIG. 4-9 150 AMPERE CONTACTOR

through to the rear of the power panel. The operating parts are on the front. The larger sizes are usually provided with magnetic blowout coils connected in series with the main contacts and are shields which form a chute into which the arc is blown by the magnetic blowout. The contactors in some cases are equipped with one or more sets of independent auxiliary contacts for performing associated circuit functions. They are furnished in various types such as single-pole, double-pole, normally open or normally closed types; and they range in size up to 1500 amperes capacity for the normally-open types and 300 amperes for the normally-closed type. Figure 4-4 shows a contactor of 1500 ampere variety used in connection with automatic reverse current relays. Figure 4-9 shows the 150 ampere size.

4.62 Normally open contactors are those on which the main contacts remain open when the electro-magnet is not

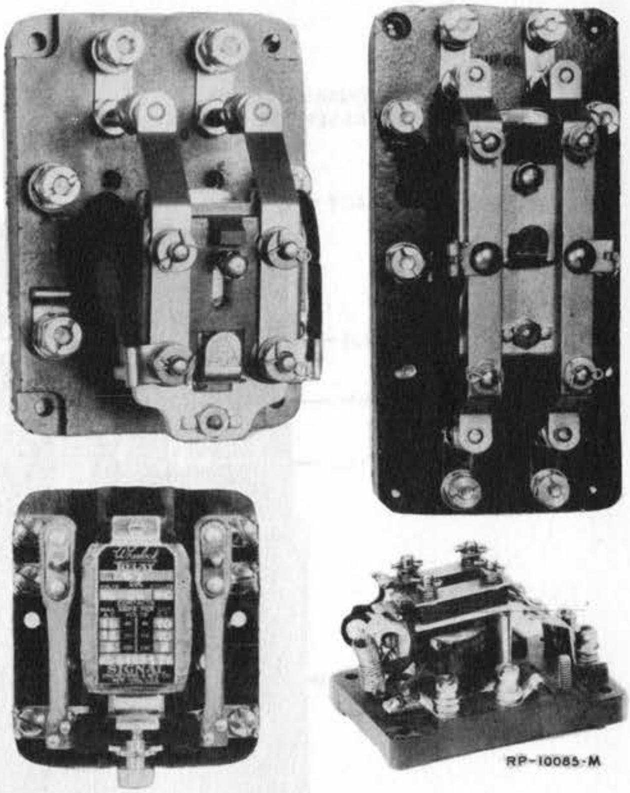


FIG. 4-10 FOUR TYPES OF COMMONLY USED CONTROL RELAYS

energized. Normally closed contactors have the main contacts held closed under spring pressure and are open only while the electromagnet is energized.

4.7 Control Relays

4.71 Many types of electrically operated power apparatus (such as contactors, motor operated emergency cell switches, etc.), require more current to operate them than the originating control device such as a key, telephone relay or voltage relay will carry. It is, therefore, necessary to have the originating control device operate a "control relay" which in turn operates the larger apparatus. Figure 4-10 shows the appearance of a number of typical types. Control relays are furnished in many types and sizes to meet various operating conditions. They may be furnished with 1 to 4 contacts and with front contacts, back contacts, or combinations of both. Some types operate on direct current and some on alternating current. The smaller sizes have contacts intended to carry 1 or 2 amperes and some of the larger sizes may carry up to 30 amperes under certain conditions. The control relays arranged for back of board connections and mounted on power board panels are usually fitted with glass or sheet metal covers. Those arranged for front connections may not have covers, although some are enclosed in sheet metal housings, when they are not located on power board panels.

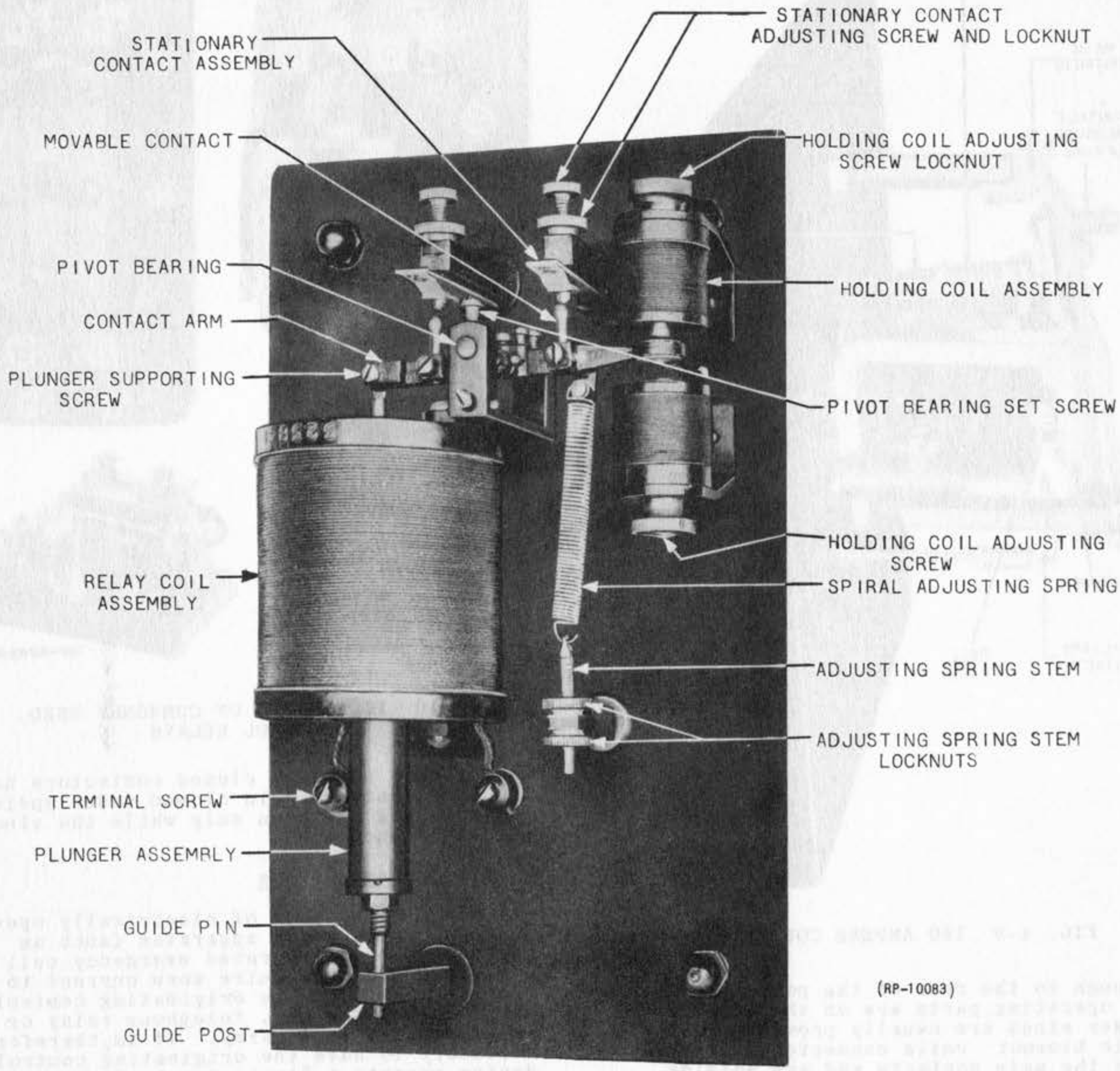


FIG. 4-11 VOLTAGE RELAY ASSEMBLY

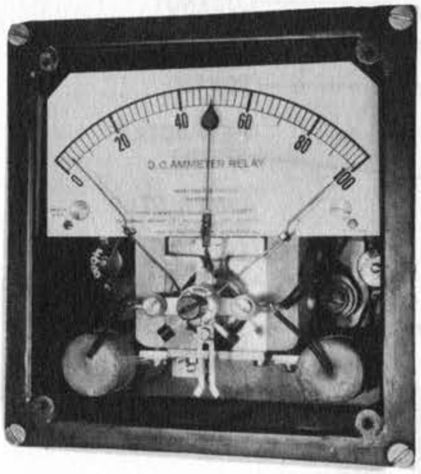
4.72 <u>Voltage Relays</u>

4.721 Voltage relays are used to operate alarm circuits and control emergency cell switching circuits and charging rates for battery charging units when the voltage reaches a predetermined high or low value. Each voltage relay is furnished for a specified voltage range. The relay is so designed and adjusted that the "low" contact will make at its rated low voltage limit and the "high" contact will make at the rated "high" voltage limit.

4.722 The contacts are also adjustable to a limited extent, within the range of the particular relay, the method of adjustment depending on the type of voltage relay used.

4.723 Broadly, voltage relays fall into two general types, the moving coil type and the solenoid type.

4.724 The current carrying capacity of the contacts of both types is limited, so they are arranged in the circuit to operate telephone type relays which in turn operate alarm circuits, control relays or other equipment.



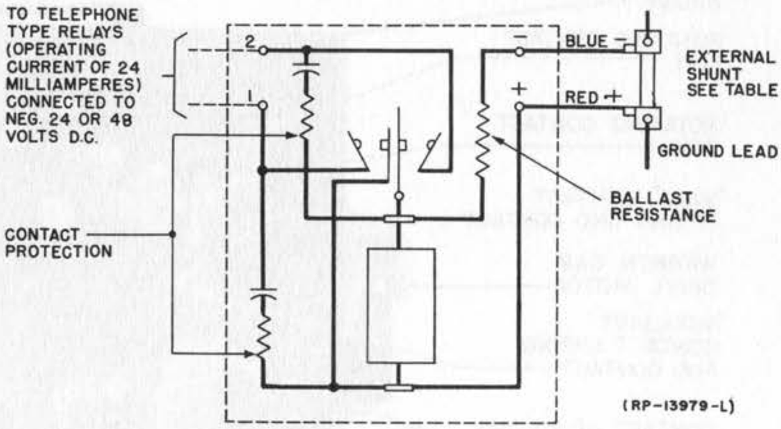


FIG. 4-12 AMMETER RELAY COVER REMOVED

4.725 The moving coil type voltage relay is similar to a standard voltmeter in general construction except that the moving arm is provided with contacts. The cases may be designed for either flush or surface mounting depending on the type used. Shielded type voltage relays are provided for applications where the accuracy of operation might be affected by the field created by the presence of current carrying leads.

4.726 The solenoid type voltage relay as shown in Figure 4-11 employs a solenoid with a floating core linked to a pivoted contact arm. Holding coils are provided, one connected in series with each contact. These coils when the contacts close tend to hold them tighter. The holding effect of the coil is adjustable, and the contacts are adjustable. This type voltage relay is in general used to regulate the discharge voltage of power plants by controlling the automatic switching of EM cells and CEMF cells.

4.73 Ammeter Relays

4.731 In automatic power plants, ammeter relays are connected in the output circuit of the charging machines as part of the control circuit equipment for the starting and stopping of individual charging units as the office load varies. The ammeter relay resembles a conventional ammeter in appearance but the moving pointer is equipped with contacts which make on "high" or "low" stationary contacts. See Figure 4-12.

4.732 Each ammeter relay consists of a millivoltmeter of the D' Arsonval type for use with an external shunt. Suitable shunts connected in series with the charging unit output are available in capacities of from 25 to 1500 amperes inclusive. The moving pointer is provided with a set of insulated contacts which move with the pointer and make contact with corresponding contacts on two stationary pointers (high and low). The ammeter scale is calibrated to correspond to the output of the associated charging unit; such as 0-400 amperes for a 400 ampere unit. Each meter is enclosed in a pressed steel, circular, dust-tight, moisture-proof case with a removable cover.

4.733 The high and low contacts are adjustable and are usually adjusted at the factory. The high contacts are adjustable by means of an adjusting screw outside of the case. The low contacts are adjustable by means of an adjusting screw located under the case.

4.734 In an automatic power plant the low contacts are set at a point which will cause the charging unit to be shut off through the control circuit. The high contacts when operated cause the motor driven field rheostat to stop so that the charging unit will not be overloaded and at the same time, when furnished, starts up the next charging unit, connects it to the battery and increases its output as required to carry the office load.

4.735 The contacts of ammeter relays are limited in their current carrying capacity and, therefore, they are arranged in the circuit to operate telephone type relays which in turn operate control relays or other apparatus required for controlling the output of the charging units.

4.8 Automatic Voltage Regulators

4.81 In general, the purpose of an automatic voltage regulator is to control the output of a charging unit to float the office load and maintain the battery voltage within specified float or charge voltage limits.

4.82 Since the output of a generator depends upon the generator field strength, it is necessary to change the field strength as the load and voltage tend to vary. An automatic voltage regulator which responds to changes in voltage is, therefore, used to control the field strength

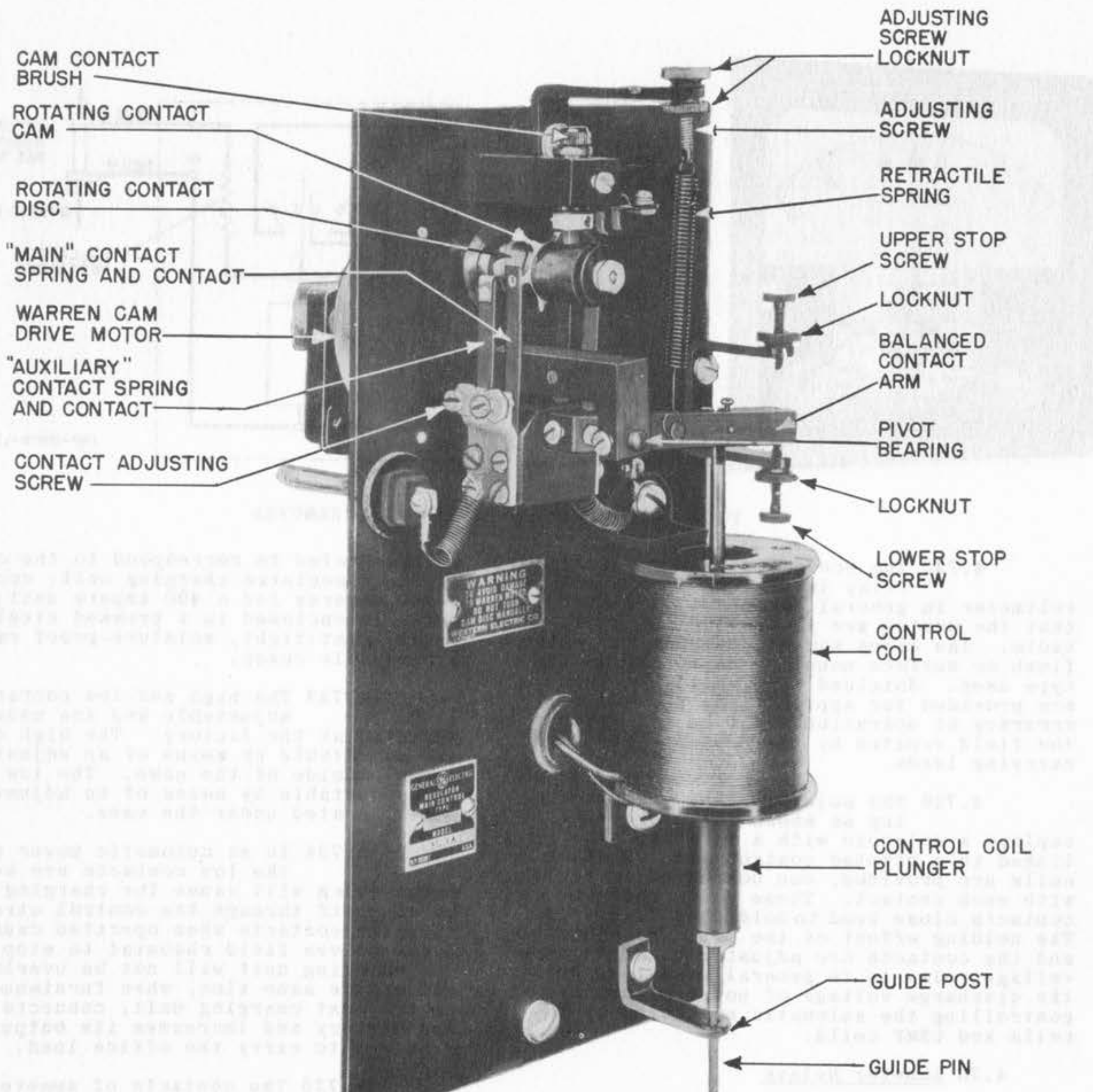


FIG. 4-13 VOLTAGE CONTROLLER

of the generator to accomplish this purpose. Several types of automatic voltage regulators are used depending on the size and characteristics of the generators involved.

4.83 Voltage regulators are also used to control ac line voltages where power service line voltage variations exceed the allowable voltage variation of the equipment. They may be either the magnetic type with no adjustments to control the degree of regulation or a motor operated variable transformer type which controls the voltage applied to an auxiliary transformer to correct for changes in line voltage and load.

4.831 The magnetic type consists of inductors and capacitors arranged in a magnetic regulating circuit. It consists of an input transformer the output of which is applied to a circuit consisting of an unsaturable inductance which is in series with a parallel resonant circuit. This circuit combination compensates for variation in input voltage the output of which is applied to a frequency compensation network and the primary of the output transformer.

4.832 In the motor operated variable transformer type (more completely described in paragraph 4.9), the voltage applied to an auxiliary transformer is controlled to correct for changes in line voltage and load. The motor operated variable transformer is usually controlled by a bridge and thyratron circuit.

4.84 Voltage Controller

4.841 The voltage controller shown in Figure 4-13 is mounted on the battery control board of the power plant involved and consists of a solenoid coil and plunger operating a contact lever which controls two sets of contacts, a main set and an auxiliary set. These contacts operate in conjunction with a cam which is driven by a synchronous type single phase motor. The main contacts make and break with the toothed part of the cam and the auxiliary contacts make and break with the solid disc part.

4.842 The rotating cam and disc permit the "high" or "low" contacts to make every 10 seconds if the movement of the contact arm places them in a position to make. This allows time for the motor driven rheostat, located on the charging unit control panel and operated through control relays, to function and the regulated voltage to stabilize between the contact intervals.

4.85 Motor Driven Centrifugal Type Automatic Voltage Regulator

4.851 These regulators are usually mounted on the power board and may be used for the regulation of small dc generators. When used for ac ringing generators, the ac voltage to be regulated is fed to the regulating motor through an autotransformer and a copper oxide rectifier, both of which are part of the regulating unit.

This type, as shown in Figure 4-14, consists of a permanent magnet excited dc motor which is connected to a centrifugal type regulator enclosed in the same housing. This regulator includes contacts which in normal operation open and close rapidly, in turn opening and closing a shunt circuit across part of the resistance which is in series with the generator field, thereby varying the field excitations of the ringing generator. The dc motor, which is connected to the output circuit of the ringing generator being regulated, increases or decreases in speed as the voltage varies. As the ringing generator voltage drops and the regulator speed slows down, the contacts close short circuiting part of the ringing generator field resistance thus strengthening the field and increasing the voltage. This increase in the voltage causes the regulator motor to speed up, the centrifugal action on the weights causing the contacts to open and again insert the field resistance in the circuit, thus weakening the field and decreasing the ringing generator voltage. This rapid cutting in and out of the resistance in the field circuit provides an effective excitation which gives the desired voltage. An adjusting knob and dial is provided on the end of the frame to increase or decrease the regulated generator voltage.

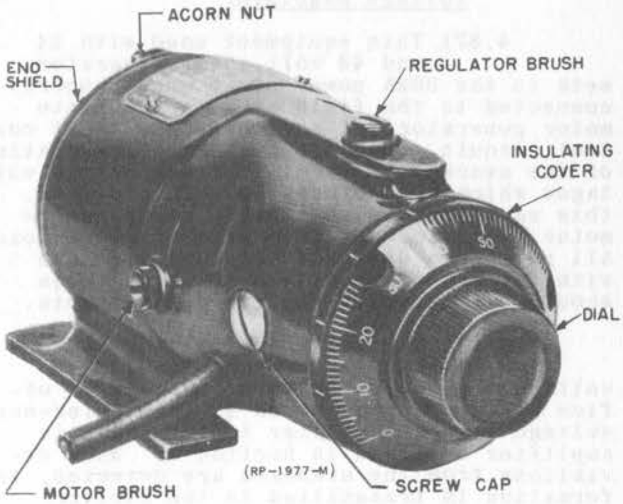


FIG. 4-14 MOTOR DRIVEN CENTRIFUGAL TYPE AUTOMATIC VOLTAGE REGULATOR

4.86 Contact Type Speed Voltage Regulators

4.861 This type regulator is designed to control the speed (frequency) and voltage of battery driven ringing machine (initially used on the 804C Ringing Power Plant), by operating on the respective motor and generator fields. The mechanical contact type regulators used for this purpose control the resistance of these field circuits by sampling the 20 cycle output voltage of the ringing machine and thus maintain the frequency between 18 1/3 - 20 cycles and the voltage between 84-88 volts.

4.862 This type regulator consists of a sensitive solenoid or actuating element which moves an armature which in turn operates a push bar. The movement of the push bar governs the position of the direct acting fingers and determines the amount of resistance in the regulated circuit. In the no voltage position all ten fingers are closed and the regulating resistance is at the minimum value. As the voltage on the solenoid is increased, the pull of the reference springs is overcome and the fingers pushed from the associated contact bar, thereby increasing the resistance in the regulated circuit. An air dashpot with an adjusting screw is provided to obtain optimum speed of response.

4.863 The regulator is arranged for pin jack mounting in a suitable receptacle with soldering type terminals, for connecting the external regulating resistances and the solenoid winding.

4.87 Rectifier Type - Electronic Control Voltage Regulator

4.871 This equipment used with 24 and 48 volt motor generator sets in the 302A power plant when properly connected to the field of an appropriate motor generator set and the power plant control circuit, provides high grade regulation of the average battery float and charge voltages which are adjustable. In addition, this equipment automatically protects the motor generator set from excessive overload. All parts are designed for long life and with the exception of the electron tubes should not normally require replacements.

4.872 The voltage regulator and exciter are combined. The voltage regulator monitors the central office battery and compares it to a reference voltage standard similar to the magnetic amplifier outlined in Section 3. When deviations from the standard are detected, information is transmitted to the exciter which in turn changes the field current of the generator to increase its output and return the battery voltage to the proper value.

4.873 Battery voltage deviations are primarily caused by changes in office load and if these deviations exceed the capacity of the regulated charging generator, the voltage regulator automatically switches from constant voltage to constant current to protect the machine from overload.

4.874 This equipment also regulates for changes in the ac input voltage rendering the output of the regulated machine virtually insensitive to ac input voltage changes. It is mounted on a framework designed to fit into the bottom of the control bay of the regulated motor-generator set. One is used for each regulated machine.

4.9 Autotransformers

4.91 Autotransformers are used as a means of controlling ac output voltage, particularly in L type carrier plants, where constant current high voltages are required at main stations to feed a series circuit consisting of auxiliary repeater stations. The output voltages required must be maintained within rather close limits in certain applications and in these instances two connected in series and referred to as Course and Fine adjustment autotransformers, are used.

4.92 They normally consist of a single-phase reversible motor which is coupled through a gearing arrangement to a brush mechanism which is moved across the commutating surface of the autotransformer.

4.93 The magnitude of the voltage output is controlled by the position of the brush on the autotransformer commutator which changes the winding ratio. With this arrangement an output voltage may be obtained within required limits.

4.94 Limit switches are furnished which function with a motor control circuit to stop the brush travel when predetermined positions are reached on the commutator segment.

4.95 The motor of the unit may be controlled by relays or an electron regulator which in turn in controlled by a voltage sensitive bridge circuit.

4.10 Meters

4.101 To provide a visable means for determining the characteristics and the amount of current flowing in the power circuits, meters are provided for permanent or temporary connection to them. They are usually mounted on the power board or machine control panels.

4.102 Ammeters: Ammeters are used to indicate the current flow in amperes between the batteries and distributing fuse panel, between the generators and battery or at other points where such information is useful in operating the plant. Under certain conditions, an instrument switch may be used to permit one ammeter to be switched from one circuit to another, such as to a charging or discharge circuit. Where the generators vary in size it is the usual practice to provide ammeters of the proper range for each machine. In connecting an ammeter to a circuit, an ammeter shunt (of the proper value for that ammeter) is connected in series with the circuit, and the terminals of the instrument are connected to the terminals of the shunt either directly or through the instrument switch. Most of the current flows through the shunt and only a very small portion is bypassed around the shunt through the meter. When the amount of current to be measured is comparatively small, this shunt is sometimes self-contained in the ammeter case.

4.103 Voltmeters: The voltmeter is used to indicate the voltage (or potential) of a circuit. It is connected directly to the sides of the circuit to be measured by means of fused leads. An instrument switch is sometimes used to connect one meter to more than one circuit, such as to one or more generators or to a battery to which the generators may be connected.

4.104 Wattmeters: Wattmeters are occasionally used at emergency engine driven alternator installations when it is necessary to know the actual kilowatt output of the alternator when carrying the office load.

4.105 Frequency Meters: This type of meter is used to indicate the frequency of alternating current. When furnished with an emergency engine driven alternating current generator (alternator) it serves to indicate the frequency of the alternator output and also as a check on the engine speed which is directly proportional to the frequency.

4.106 Power Factor, Phase Angle and Varmeters: These meters are used on those installations where the commercial power company imposes a penalty for operating at a low power factor, and where either synchronous motors or static condensers are provided for "boosting" the power factor. They are special ac wattmeters arranged to indicate the power available in a circuit but not being used because the voltage and current are out of phase.

QUESTIONS

1. What is the purpose of the power board and how is it constructed?
2. Describe the function and operation of circuit breakers.
3. Why are the power supply leads fused?
4. Why are alarm fuses associated with N.E.C. fuses in dc supply circuits?
5. How is a "discharge fuse and switch unit" used?
6. Describe the operation of a motor driven emergency cell switch.
7. What is the purpose of emergency lighting relay switches?
8. Describe the function of a multi-pole electrically operated transfer switch.
9. What are contactors and how do they operate?
10. How are control relays used?
11. What is the purpose of a voltmeter and ammeter?
12. When is a power factor meter used and what is its purpose?
13. Describe ammeter relays and outline their use.
14. Describe the two principal types of voltage relays.
15. What is the purpose of an automatic voltage regulator?
16. Describe the "voltage controller" and its operation.
17 How does a motor driven centrifugal type automatic voltage regulator function?

5. RINGING, TONE AND SIGNALING EQUIPMENT

5.1 General

5.11 In the operation of a telephone plant, ringing, tone and interrupted currents are of almost equal importance to those obtained from the charging units and their associated batteries. These currents, which are supplied by the "ringing power plant", are used to operate the bells at subscribers' stations, to signal from one office to another for establishing trunk or toll connections and for providing the various kinds of tone and signaling current necessary in the operation of the central office. Continuous service of the ringing power plant output is therefore required. For this reason reserve equipment is furnished for use where failures occur in the regular equipment or where there is an interruption in the commercial power service.

5.12 Ringing current, tones and interrupted signal requirements differ for manual, dial, toll and repeater equipments. The type ringing equipment required to furnish these needs is influenced by the size central office involved. In general, the output of the ringing power equipment usually embraces the following types of current, or combinations thereof.

5.13 Ringing current at a frequency of approximately 20 cycles is furnished for ringing subscribers' bells. For passing ringing signals over toll circuits, 135 cycle or 1000 cycle ringing current is usually employed.

5.14 Tone current is used to audibly transmit circuit conditions such as "busy signals", "dial tone" and the like to subscribers or to the operating forces.

5.15 Interrupted signaling current is employed for the ringing and silent intervals for machine ringing, flashing supervisory signals and for other purposes where periodically interrupted or timed pulses are required in performing central office operating functions. Interruptions of 60 IPM (interruptions per minute) and 120 IPM are commonly used in many types of central offices and in addition, interruptions of one, two, three or four seconds and combinations thereof are used in central offices arranged for machine ringing.

5.16 Coin control current is generated by the larger size ringing machine for controlling the "coin collect" and "coin return" features of pay stations. Positive and negative 120 volt direct current is used for this purpose. In the smaller central offices dry cell batteries are used to provide the coin control current.

5.2 Ringing Systems

5.21 Manual Ringing Systems

5.211 Manual ringing systems are employed in the small manually operated central offices and some P.B.X.'s where the subscribers' bells are rung by operating a key in the operators' keyshelf. The duration of the ringing period and the method of ringing, that is, whether it is a steady long ring or an intermittent series of short rings is entirely under control of the operator. For this service, the ringing equipment provides a steady flow of alternating or superimposed ringing current to the switchboard.

5.212 Alternating ringing current of approximately 20 cycles is employed for single party lines, where the subscribers' ringers are connected across the line, and for two party selective or four party semi-selective (code) ringing, in which case the ringers are connected from each side of the line to ground.

5.213 Superimposed ringing current is supplied for four party selective ringing or eight party semi-selective ringing, the subscribers' ringers being connected from each side of the line to ground. Superimposed ringing current is alternating ringing current superimposed on a direct current by connecting the ringing current supply in series with a battery of about 36-40 volts so that the ringing current becomes in effect pulsating direct current. This is shown graphically in Figure 5-1. The ringing current is superimposed on a positive and a negative battery, to obtain positive and negative pulsating current. The subscribers' ringers are so constructed and adjusted that each will respond to only one polarity of superimposed current. By connecting a ringer responding to negative and another responding to positive ringing current from one side of the line to ground, and two more similar ringers from the other side of the line to ground, four party selective ringing is accomplished. By doubling the number of ringers and employing "one-ring" and "two-rings", eight party semi-selective ringing is obtained.

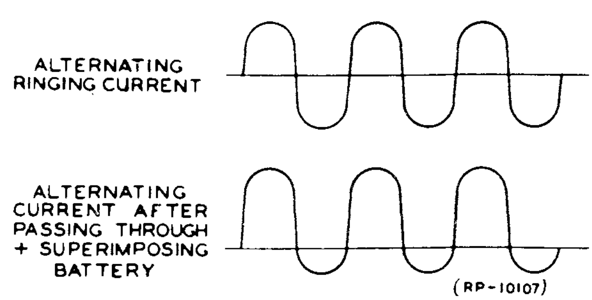


FIG. 5-1 COMPARISON OF AC AND SUPERIMPOSED RINGING WAVE FORMS

5.22 Machine Ringing Systems

5.221 The term "machine ringing" indicates that after ringing is started it continues automatically until the subscriber answers or the call is abandoned. It is employed in dial central offices and in the larger manual and P.B.X. exchanges. In manual central offices the ringing is started by the depression of a key controlled by the operator, or by the operator plugging into a jack. In dial offices the ringing starts as soon as the connection is established to the called subscriber's line. The ringing current flows through a "tripping relay" in the operators cord circuit, or in an equivalent circuit in dial exchanges, and when the subscriber answers the tripping relay operates and discontinues the flow of ringing current to that line.

5.222 The ringing current supplied for machine ringing is broken up into ringing and silent intervals. These intervals vary somewhat in different types of ringing plant equipment, but in the larger plants the ringing interval is two seconds and the silent interval four seconds. For semi-selective ringing where "one-ring" and "two-rings" are employed the two rings are one second ring, one second silent. These interruptions are provided by the slow-speed interrupters which are driven by the gear ringing machine, although in small plants motor driven interrupters are used.

5.223 In order that the tripping relay may function the instant the subscriber answers, tripping battery is furnished (also through the low-speed interrupters) during the silent interval. This silent interval tripping battery may be furnished by the central office battery or by separate cells. The direct current component of the superimposed ringing current, where this type of ringing current is employed, assists in the operation of the tripping relay during the ringing interval.

5.224 "AC-DC ringing" is employed to improve the operation of the tripping relays in machine ringing circuits where straight ac ringing was formerly used. This current is obtained by connecting central office 48 volt battery in series with the ac ringing generator. The dc component of the AC-DC ringing increases the tripping range and assures that positive tripping will occur during the ringing interval as well as during the silent interval.

5.225 The "pick-up" circuit arrangement, where one-ring and two-ring semi-selective machine ringing is used, is devised to avoid the false ringing of the two-ring subscribers. The connecting circuits, include pick-up relays which control the starting of the ringing interval and these relays are in turn controlled by the "pick-up" slow speed interrupter (PKU) on the ringing machine. By means of the pick-up circuit the ringing is always started so that both rings of the two-ring code are sounded initially as well as during the remainder of the ringing period.

5.23 Toll Signaling

5.231 Ringing, supervisory and pulsing signals over toll circuits involve the passing of suitable forms of current over toll trunks directly or by dc composite signaling. AC or DC signals are used at toll switchboards to operate outgoing signaling units which in turn transmit 135 or 1000 cycle ringing currents over toll circuits to the terminating end where the signaling current passes through a tuned circuit and a combination of relays send out the type local signal required. Since 135 and 1000 cycle frequencies are within the voice range, they are generally suitable for toll circuits. However, 135 cycle ringing currents are generally limited to certain repeater arrangements for composited toll circuits. Since 1000 cycle ringing current is in the middle of the voice frequency range, it is known as "voice frequency signaling" and may be used in connection with any type or combination of toll trunk or carrier

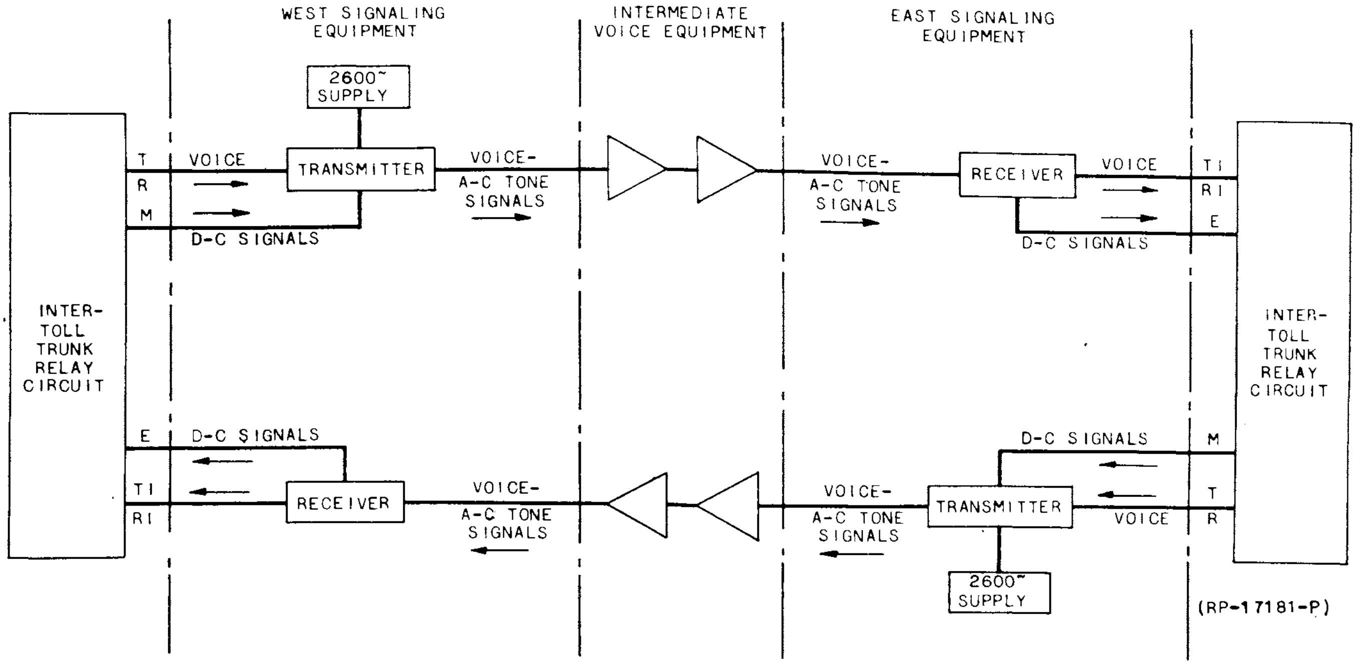


FIG. 5-2 SF SIGNALING 4 WIRE LINE FACILITIES

telephone system. DC composite or simplex signaling may be used for toll trunk signaling, dialing and supervision over limited distances.

5.232 Under the Nationwide Dialing arrangement including "Direct Distant Dialing" it is essential that all intertoll trunks provide for rapid 2-way transmission of the necessary supervisory signals in addition to meeting the requirements of speech transmission and pulsing. For efficient dial operation certain supervisory signals are required. These signals may be transmitted by dc signaling methods, however, composite signaling is not practical or economical on trunks more than 300 miles long.

To meet the requirements imposed by direct distant dialing and the extensive use of carrier facilities a single frequency (SF) signaling system was developed. This SF system transmits supervisory signals and dial pulses over the same channel as voice by using signal tones of one or two distinct frequencies in the voice band (2400 or 2600 cycles). Briefly, the principle used is as follows: At each end of the trunk a single frequency signal tone source is provided. This tone is applied or removed from the trunk under control of the intertoll trunk relay circuit. At the opposite end of the trunk an electron tube responds to the application or removal of the signal tone, and then passes dc signals to its associated trunk relay circuit. All supervisory signals required for dial pulsing and multi-frequency pulsing intertoll trunks can be transmitted by this method. In addition, like composite signaling, the SF system can be used on dial pulsing trunks to transmit the digit pulses which route the call to the called station.

The signaling tones of 2400 or 2600 cycles are supplied by electron tube oscillators which are very stable as to both output and frequency. These oscillators are accurately adjusted to within ± 1/2 cycle of 2400 or 2600 cycles and must stay within ± 3 cycles for proper operation of the system. Figure 5-2 is a schematic view of the application to a 4 wire circuit.

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FIG. 5-3 A 135 OR 1000 CYCLE SIGNALING MOTOR GENERATOR

5.233 The 135 cycle and 1000 cycle motor generator sets are similar in size and appearance and is shown in Figure 5-3. They consist of a dc motor (operated by the central office battery) and an inductor alternator, mounted on the same shaft and enclosed in the same frame. A speed regulator is incorporated in the motor end of the frame for controlling the speed of the motor. The 135 cycle generator delivers this frequency at approximately 20 or 35 volts.

5.234 The 1000 cycle generator has three armature windings; one delivers this frequency continuously at about 6 volts (used principally for testing) while the other two windings deliver 1000 cycle current at about 4.25 volts which is interrupted at the rate of 20 times per second. These windings, therefore, deliver in effect 20 cycle current imposed on a 1000 cycle carrier which is used for the toll signaling. The tuned circuit and combination of relays on the terminating end of the toll circuit are designed to respond to this form of current, but will not respond to a continuous note of 1000 cycle voice current.

5.235 These motor generators are mounted on a panel of the ringing power board and two are usually provided, one which runs continuously and the other serves as a reserve to be switches into service in case of emergency.

5.3 <u>Tones and Interrupted Signaling Current</u>

5.31 Tones are used to audibly transmit circuit conditions to subscribers or operators. These are usually furnished as "high tone" and "low tone".

For certain purposes they are furnished as continuous tones such as "dial tone", "audible ringing tone", "number checking tone", etc. For other purposes the tones are uniformly interrupted by means of motor driven interrupters for such as "busy tone", "all trunks busy tone", etc. Howler tone, used for attracting the attention of subscribers where the receiver has been left off the switch hook, is provided by the high tone frequency. In the larger sizes of ringing plants the tones are produced by a tone alternator which is provided as part of the ringing machine. In smaller plants these tones are produced by high speed split ring interrupters normally driven by small ac or dc motors or by static frequency generators. Static frequency generators usually include a varistor, condensers, resistances and transformer units potted in a metal case and are used as a source of high tone, low tone, busy tone, dial tone and audible ringing tone.

5.32 The tone alternator consists of three inductors and is wound for three different tone channels. One tone channel produces low tone, a second channel produces high tone and a third channel produces audible ringing tone. The "low tone" frequency is 660 cycles/second, the "high tone" frequency is 500 cycles/second and the "audible ring" frequency is 420 cycles/second. The audible ringing tone, when used in connection with suitable repeating and retardation coils, impresses upon the ringing circuit a tone which

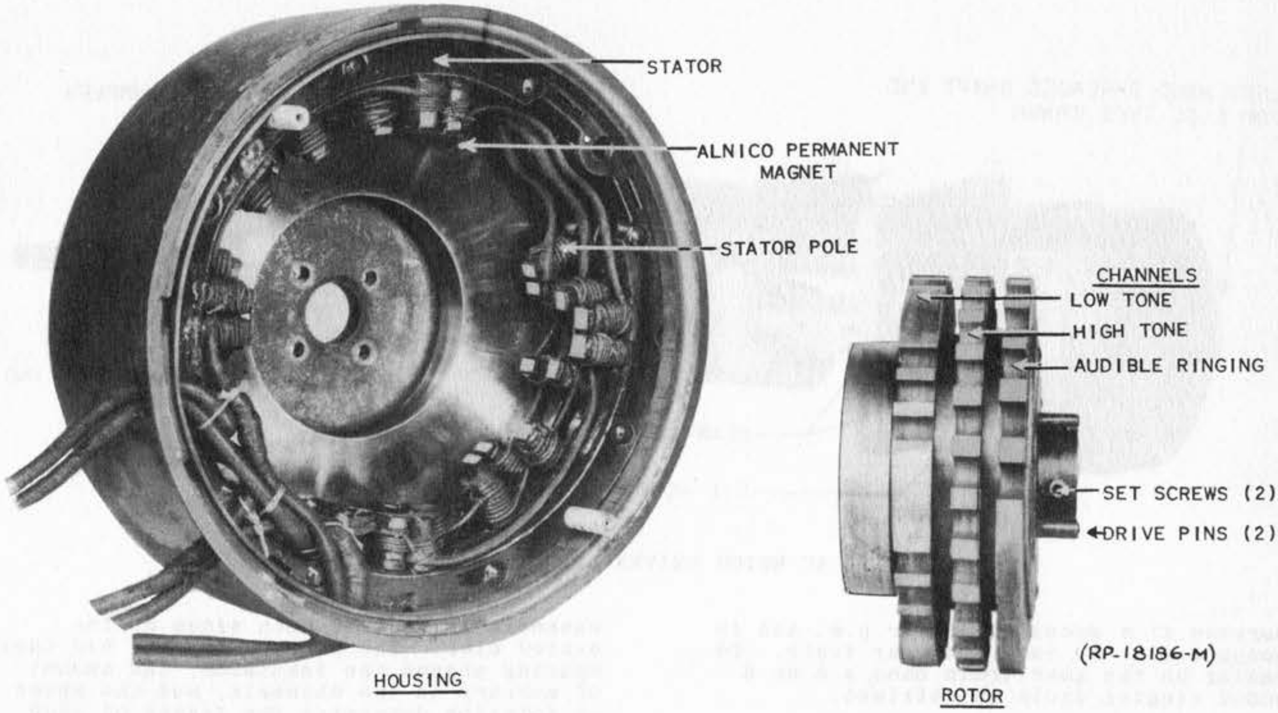

FIG. 5-4 TONE ALTERNATOR ASSEMBLY

is audible to the calling subscriber during ringing. As shown in Figure 5-4 the tone alternator consists of a case in which are mounted a common exciting structure of Alnico (a permanent magnet type), three stators, each with a separate inductor winding for supplying tones and their corresponding rotors. It produces a uniform induced tone which is taken from the stator windings without brushes. The tone alternator case is arranged for bolting to the bearing housing of a ringing machine. The rotor spider is provided with pins for driving a low-speed interrupter.

The flux through the stator poles changes as the teeth of the rotor rotate past the stator poles and thus generates the alternating voltages in the windings on the poles. Figure 5-5 shows the tone alternator mounted between the ringing generator and the low speed interrupters.

5.33 The low-speed interrupter, which serves to control the ringing and silent intervals for machine ringing and for providing variously timed interruptions or signals for many other purposes, consists of a worm driven reduction gear assembly and the necessary interrupting units. In the smaller plants the interrupting units may consist of contact springs operated by cams and the reduction gear may be driven by the ringing machine shaft or by a small motor. Figure 5-6 shows a 25 watt ringing machine with cam-and-spring type low-speed interrupters at one end and the high-speed (tone) interrupters at the other end. Figure 5-7 shows an ac motor driven spring-type interrupter used in 806F type ringing power plants. The single-phase synchronous capacitor-type motor

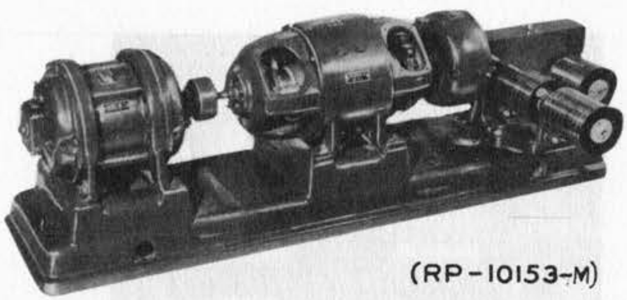

FIG. 5-5 LARGE RINGING MACHINE WITH TONE ALTERNATOR AND MERCURY TYPE INT.

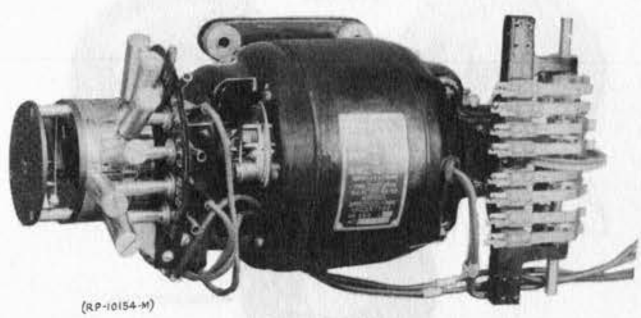

FIG. 5-6 A 25 WATT RINGING MACHINE WITH HIGH-SPEED AND LOW-SPEED INTERRUPTERS

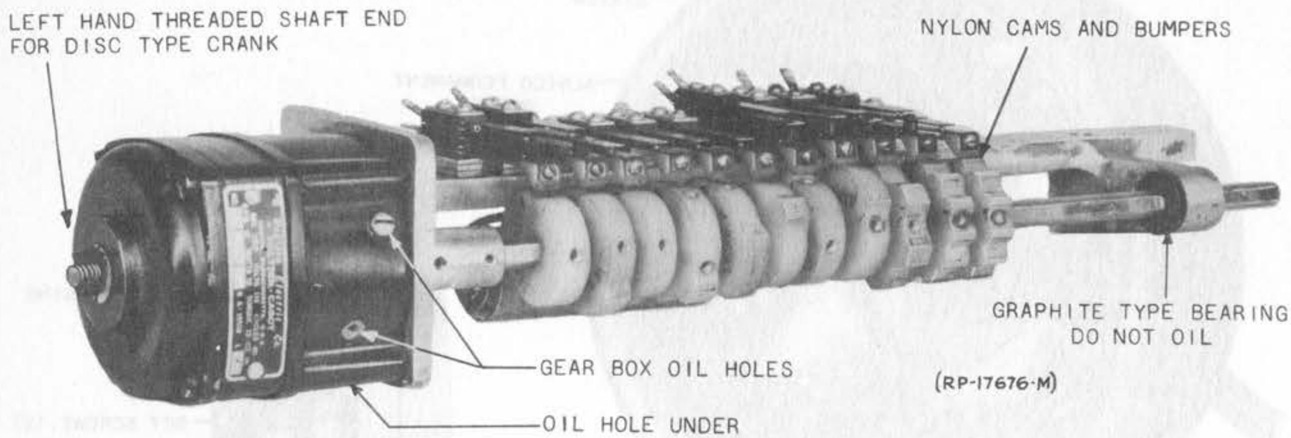

FIG. 5-7 AC MOTOR DRIVEN LOW-SPEED INTERRUPTER

operates at a speed of 1800 r.p.m. and is equipped with an inclosed gear train. Depending on the gear train used, a 6 or 8 second ringing cycle is obtained.

5.34 The rotary mercury type interrupter used on the larger 803C Ringing Power Plant consists of one or more interrupter units mounted on the low-speed shafts of a reduction gear driven by a ringing machine. The rotary mercury-type interrupter units shown in Figure 5-8 consist of either two or three steel discs separated by insulators placed between the discs and the whole clamped tightly together. Annular grooves or channels are cut in one side of the discs and the units are so assembled that the channel of one disc is adjacent to the channel of the next disc with the insulator separating them. The insulators have one or more openings or ports connecting adjacent channels. The grooves are partially filled with mercury and, when the units are rotated, contact is made from one disc to the other by means of the mercury when a port of the insulator dips into the mercury pool. The port openings are provided with Lavite washers to withstand the arcing during operation. On interrupter units having 3 discs, channels are cut on both sides of the center disc. The number of ports and their spacing around the insulator, the amount of mercury in the channels, and the speed of rotation determine the timing of each interrupter unit. The rims of the discs against which the brushes bear, present a continuous surface and, therefore, longer wear with less maintenance is obtained. Figure 5-9 shows a group of rotary mercury-type interrupter units as assembled on the 803C Ringing machines.

5.35 Ringing machines with tone alternators and cam-driven spring-type interrupters shown in Figure 5-10 are used on the 804C Ringing Power Plant. In this plant high and low tones are furnished by a tone alternator which is part of the ringing machine. One channel of high tone and two channels of low tone (one for steady tone and one for interrupted tone) are furnished. Each channel is tapped so that all tone voltages, with the exception of step-by-step dial tone (10V), may be obtained direct from the tone alternator without the necessity of additional coils. Machine and code ringing and various other interruptions are obtained from the new type nylon cam-driven interrupters which can be maintained to a greater degree of accuracy than has been previously possible with the spring-type interrupters.

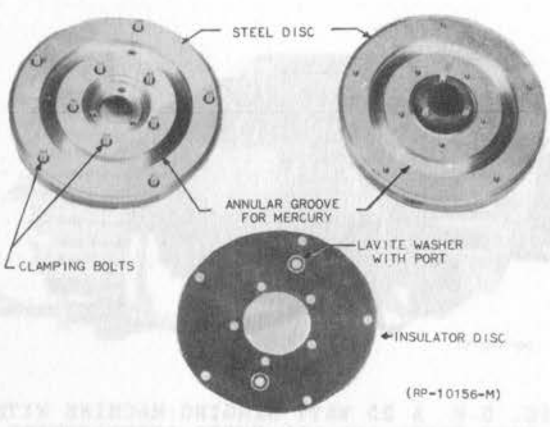

FIG. 5-8 ASSEMBLY OF A ROTARY MERCURY-TYPE INT. UNIT

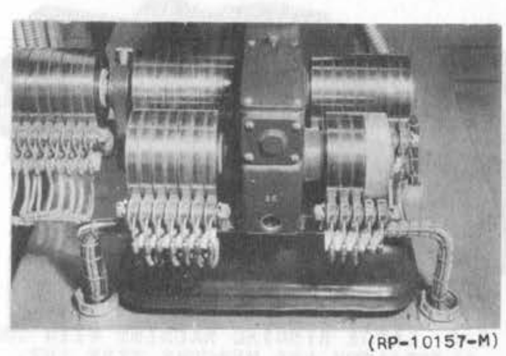

FIG. 5-9 A GROUP OF ROTARY MERCURY-TYPE INT. UNITS

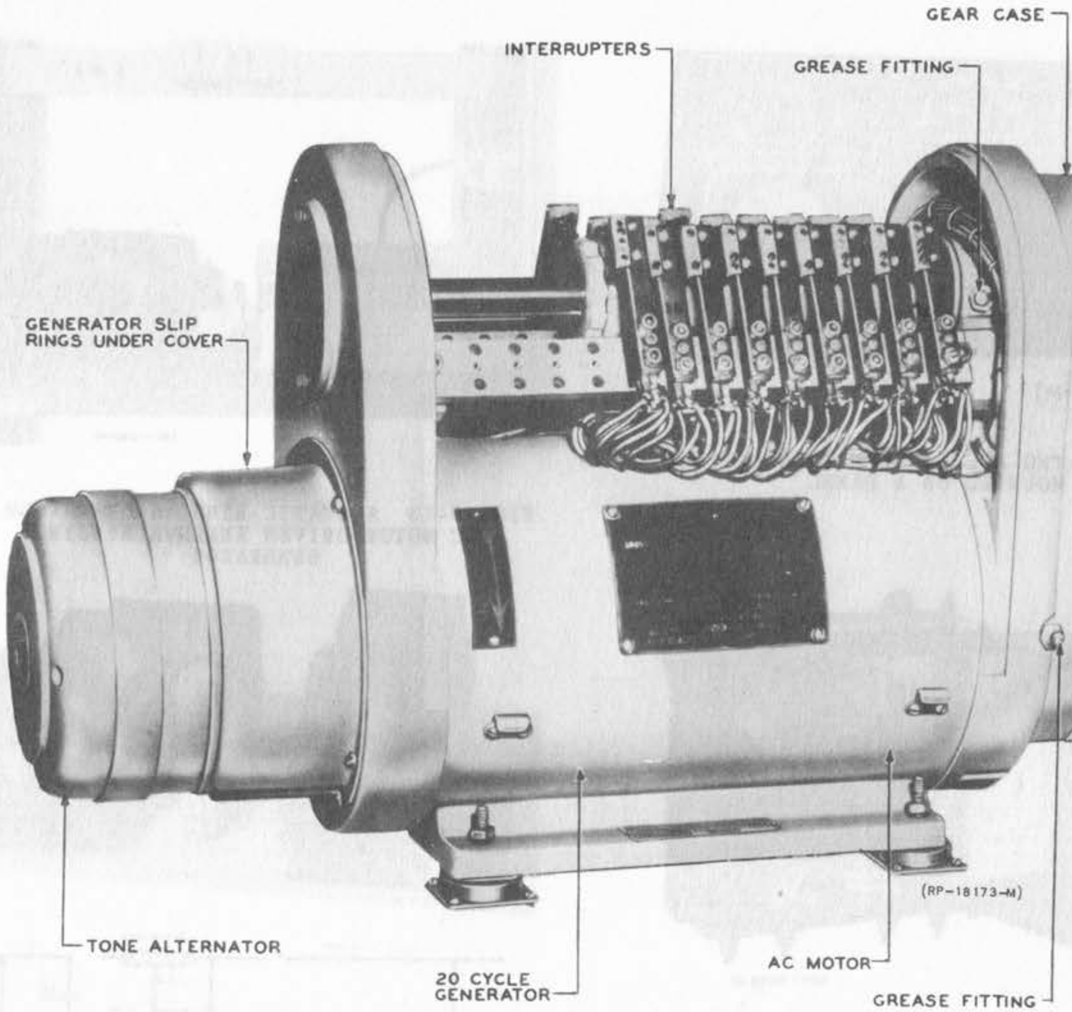

FIG. 5-10 MOTOR DRIVEN 804-C RINGING MACHINE

5.4 Ringing Generators

5.41 The three principal methods of generating ringing current are by means of pole changers, static ringing generators and motor generators. Space does not permit describing all the types of ringing generators in common use but several representative types are outlined in order to illustrate the scope of applications.

5.42 Pole Changers

5.421 In small central offices employing manual ringing a type of pole changer known as the "No. 84 interrupter" may be used, although the static ringing generator is preferred because of its lower maintenance and accurately regulated output. It consists of a vibrating element, operating on the same principle as a common door bell, actuated by the storage battery. The vibrating contacts interrupt the flow of battery current through the primary of a transformer thus inducing alternating current in the secondary at a frequency satisfactory for ringing purposes. The No. 84 interrupter, which produces ringing current, should not be confused with the high-speed and low-speed interrupters previously described which perform entirely different functions. Figure 5-11 shows a standard arrangement of two No. 84 interrupters on a panel, together with a three-pole double-throw switch for connecting either one into service. Figure 5-12 shows a No. 84 interrupter with the cover open.

5.43 Static Ringing Generator

5.431 Static ringing generators are frequency converters and are used to convert 60 cycle commercial power to 20 cycle ringing power. Similar generators are used to convert 50 cycles to 16 2/3 cycles. They have no moving parts, except a starting relay armature which is found in some generators. This armature is in motion only at the time of starting. When a starting relay is not required, a modulating transformer is provided to start the 20 cycle oscillations.

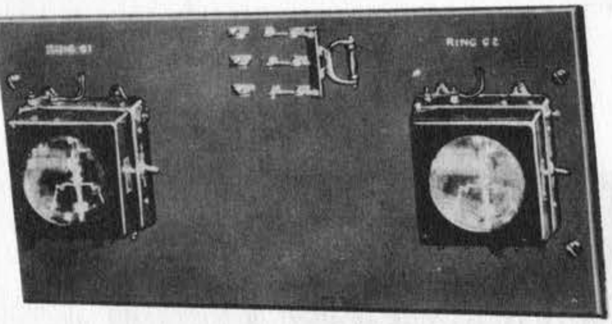

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FIG. 5-11 TWO NO. 84 TYPE INTERRUPTERS MOUNTED ON A PANEL

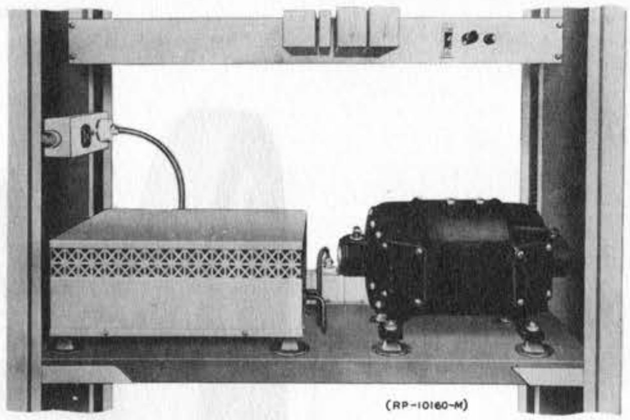


FIG. 5-13 A STATIC RINGING GENERATOR AND DC MOTOR DRIVEN RESERVE RINGING GENERATOR

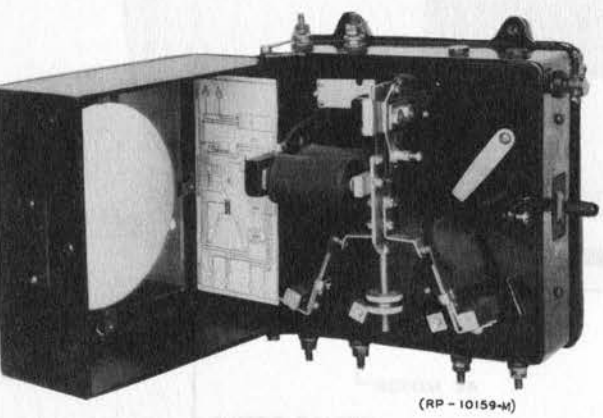


FIG. 5-12 NO. 84 TYPE INTERRUPTER WITH COVER OPEN

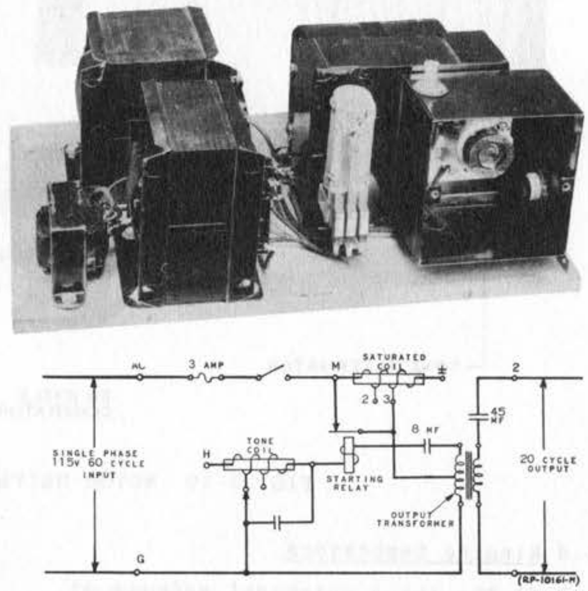


FIG. 5-14 STATIC RINGING GENERATOR WITH COVER REMOVED AND SCHEMATIC

5.432 Figure 5-13 shows an exterior view of a static ringing generator together with a small dc motor driven ringing machine for reserve use. Figure 5-14 shows a view with the covers removed and a schematic of the static ringing generator with a starting relay. When the 60 cycle supply is applied, the starting relay operates, opening its back contact and setting up a condition favorable for the 20 cycle oscillations. If the 20 cycle frequency is sustained, the starting relay will be held operated; but if the 20 cycle frequency is not sustained, the starting relay will release and a second start will be made. In general, not more than 2 or 3 successive starts of the starting relay are required. On those generators where the input is a 50 cycle source, the same operation will give a 16 2/3 cycle output.

5.433 Referring to the schematic diagram, 60 cycle ac is applied to the oscillating circuit consisting of part of the output transformer, the 8 MF condenser, winding of the starting relay, and the tone coil. The circuit, with the saturated coil shorted by the starting relay back contact, has a relatively low impedance to 60 cycle current which operates the starting relay, placing the saturated coil in the circuit and setting up a condition favorable for 20 cycle oscillations. If the 20 cycle frequency, for which the circuit is favorably turned, is sustained the current at this frequency will be great enough to hold the starting relay operated. If the 20 cycle current is not sustained with the initial operation of the relay it releases and reoperates until the 20 cycle frequency is sustained. The frequency of the 60 cycle primary supply, being equal to the third harmonic, serves to keep the train of the 20 cycle wave and its harmonics, in operation. The 20 cycle ringing output is taken from the secondary of the output transformer. By means of the tone coil and its condenser, proper harmonics are made to serve the useful purpose of furnishing audible ringing tone.

The static ringing generators will deliver an output up to approximately 1/2 ampere of 20 cycle ringing current continuously at 75-110 volts and withstand temporary overloads of 100 per cent. In offices where superimposed battery is connected in series with the ringing supply a separate autotransformer is used for this purpose and connected to the output transformer terminals.

5.44 Motor Driven Howler Interrupter

5.441 This apparatus consists of a single-phase, split-phase motor with a tone commutator mounted on the motor shaft extension. The commutator has one solid collector ring and one segmented ring with 16 live segments, each connected to the collector ring, to obtain 480 interruptions per second at a speed of 1800 r.p.m. The collector ring has one common brush to feed current into the interrupter, and the segmented ring has three brushes furnishing three interrupted circuits.

5.45 Small Motor Driven Ringing Machine

5.451 In some smaller central offices which require a continuous ringing current supply, dc motor driven ringing generators are used either as the reserve source or for both the regular and the reserve sources. They may be arranged to operate continuously or to operate under control of the telephone switching equipment. Figure 5-6 shows the type machine used in these plants. They are of the inverted rotary converter type and are used in small offices and large P.B.X.'s. Two of these machines are usually mounted on a power board panel and covered with a common sheet steel cover with circuit provisions for automatically switching from the regular machine to the reserve machine in case of failure.

5.452 As shown in Figure 5-13 a dc motor driven ringing generator may be used as a reserve for the static ringing generator during a commercial power failure. However, the more recently developed plants, such as the 806 E and 806 F types, use static ringing generators, frequency generators and ac motor driven cam and spring interrupters on a regular unit and a reserve unit basis. In these plants a rotary inverter is provided to furnish ac during power service failures. If the ac line voltage falls below 85 per cent of normal, the plant transfers automatically to the inverter. About 15 seconds later the plant transfers back if the line has recovered to at least 90 per cent of normal voltage, or if not, remains on the reserve until the line voltage does recover, Figure 5-15 shows a typical disassembled inverter.

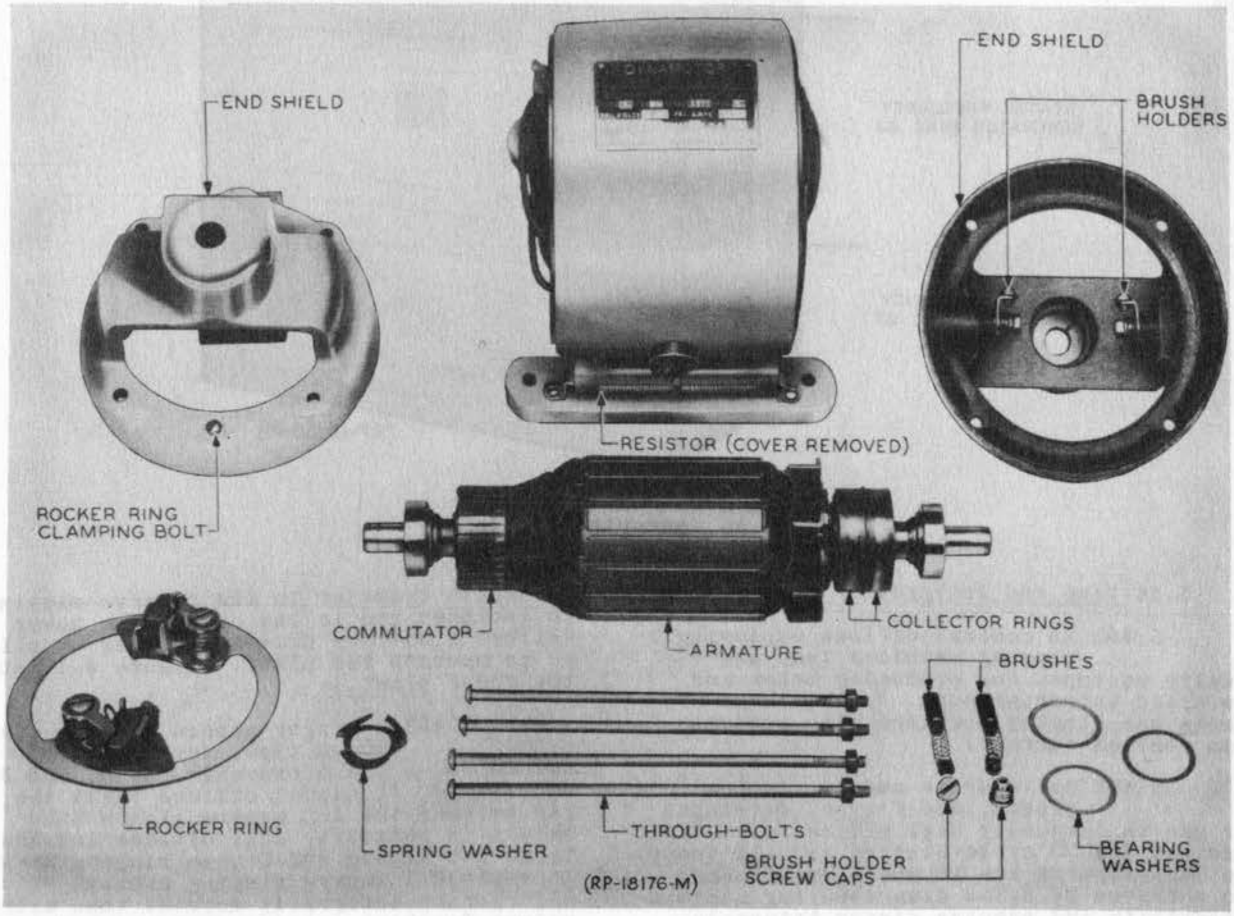


FIG. 5-15 TYPICAL ROTARY INVERTER

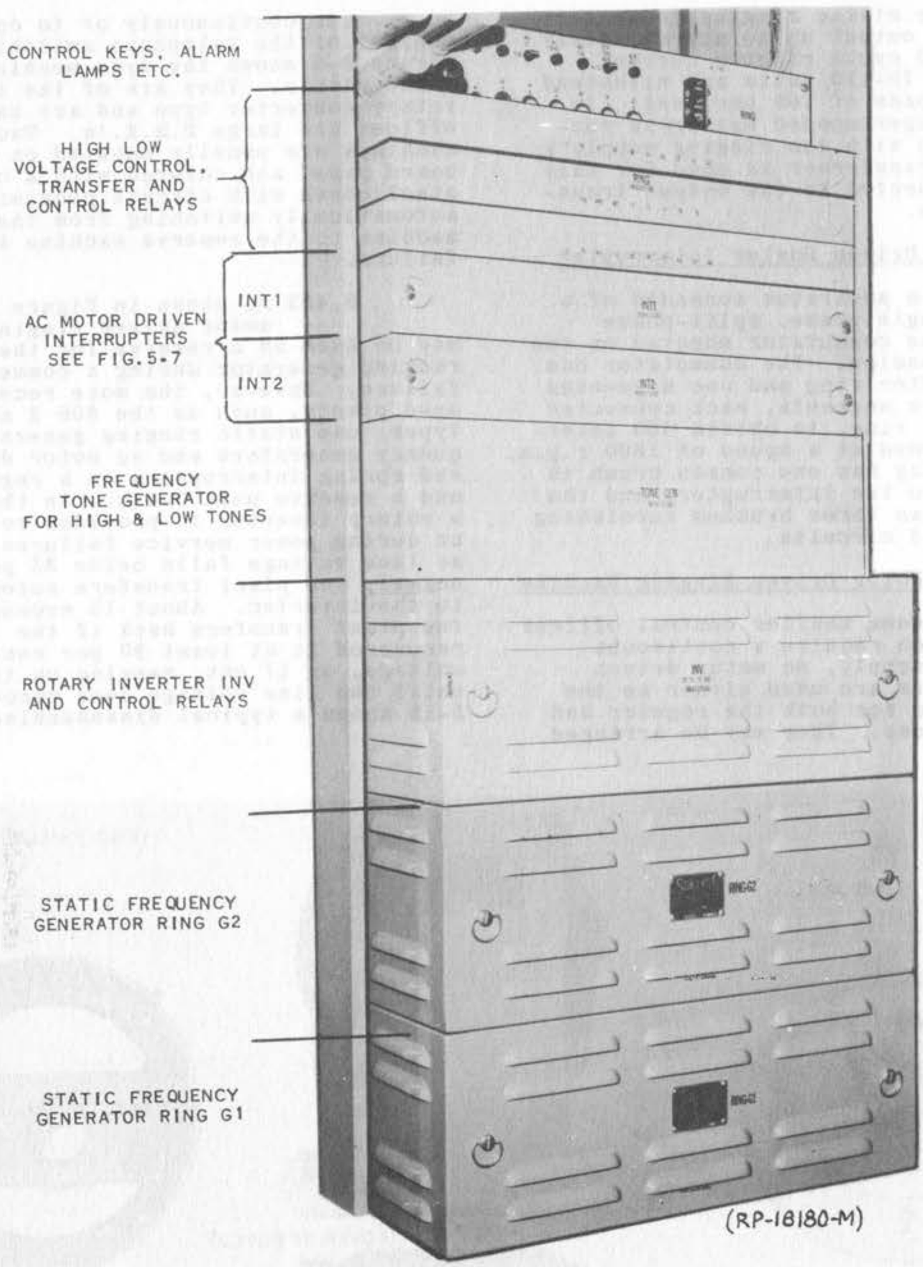


FIG. 5-16 806-F RINGING PLANT

5.46 Tone and Interrupter Features

5.461 In central offices employing ringing machines they are usually equipped for producing tones and low speed interruptions. In the large plants the ringing machines also produce coin control current.

5.462 One quarter ampere ringing plants, 806-F type, developed for use in community dial offices use static machines for 20 cycle ringing and all tones. The interrupters are ac motor driven and are operated by nylon cams assuring maximum reliability and precise timing intervals. Automatic transfer to the reserve machine is included and in the event of a power failure a battery driven inverter supplies ac to operate the plant. Figure 5-16 shows the 806-F plant.

5.463 A larger ampere ringing plant, 804-C type, developed for use in No. 1 and 5 crossbar, No. 1 and 350 SXS and No. 11 manual offices fills the gap between the 1/2 ampere plants used mainly in community dial offices and the large 2-6 ampere 803-C type ringing machine. It employs 1 ampere ringing machine which incorporate integrally mounted tone alternators for high quality dial and busy tones

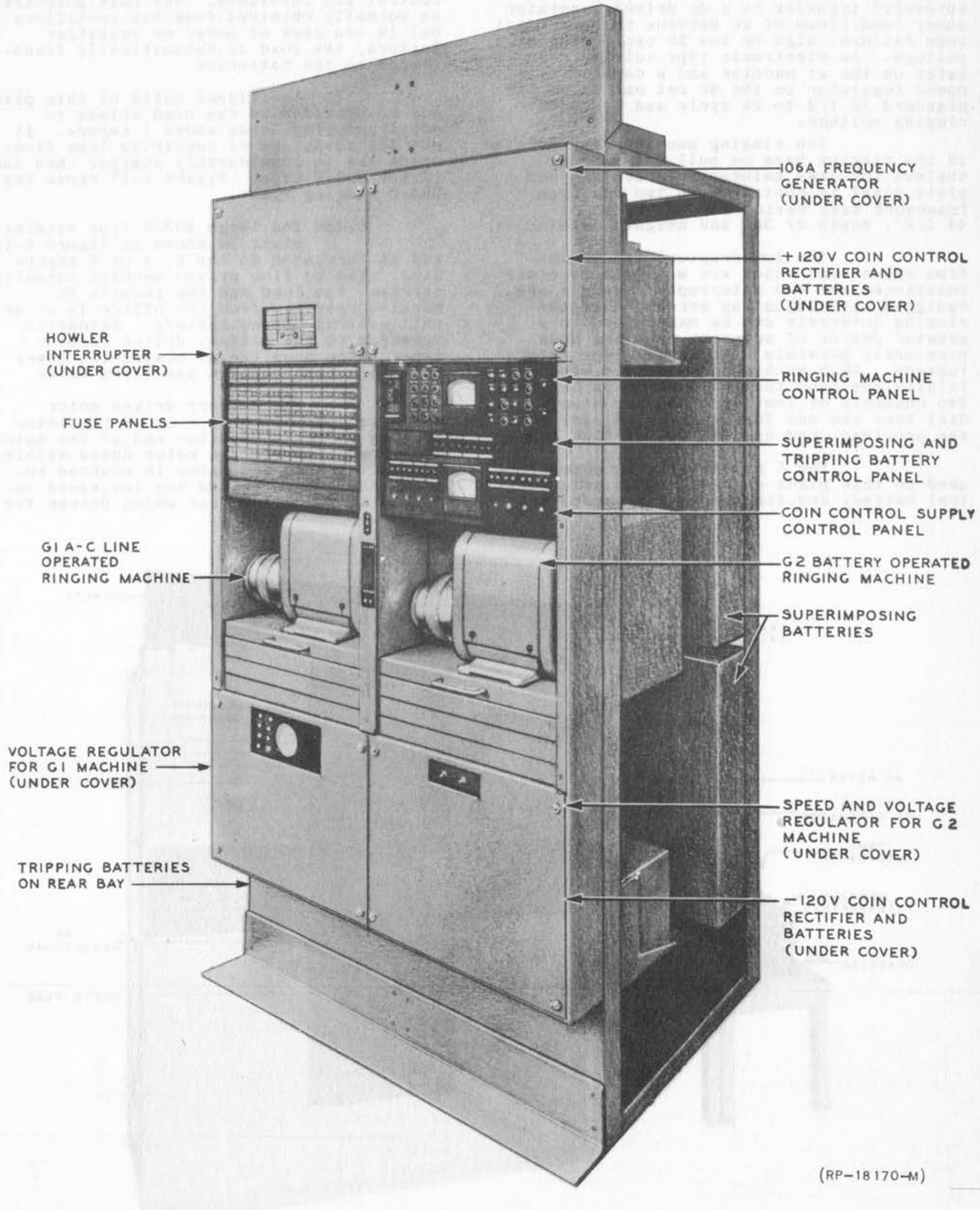


FIG. 5-17 804C RINGING PLANT

and adjustable type interrupters capable of a high degree of accuracy of interrupter timing intervals. There is an ac line driven ringing generator for normal supply with automatic transfer to a dc driven generator under conditions of ac service failure, dial tone failure, high or low 20 cycle ringing voltage. An electronic type voltage regulator on the ac machine and a contact type speed regulator on the dc set maintains the standard 18 1/2 to 20 cycle and 84 to 88 ringing voltage.

The ringing machines are mounted in the ringing bays on pull out sliding shelves for easy maintenance, and the complete plant is contained in two box type framework bays having a total width of 49 1/8", depth of 36" and heighth of 8'.

The interrupters are driven from nylon cams which are machined to close tolerances and the interrupter springs are equipped with adjusting screws, thus the ringing intervals can be maintained to a greater degree of accuracy than has been previously possible with spring type interrupters. Each machine is equipped with a totally enclosed tone alternator on one end. Two channels of low tone, one for steady dial tone and one for interrupted busy tones are provided, and one channel of high tone.

The 1 ampere ringing generators used in this plant do not furnish coin control battery and, therefore, a separate unit consisting of two 120 volt, 0.8 ampere rectifiers and two strings of 6 dry cells, one for positive and one for negative coin control are furnished. The coin potential is normally obtained from the rectifiers, but in the case of power or rectifier failure, the load is automatically transferred to the batteries.

Additional units of this plant may be provided as the need arises to supply ringing loads above 1 ampere. It has the advantage of requiring less floor space and is considerably cheaper than the larger 803-C type. Figure 5-17 shows the 804-C Ringing Plant.

5.464 The large 803-C type ringing plant is shown in Figure 5-18 and is furnished in the 2, 4 or 6 ampere size. The ac line driven machine normally carries the load and the reserve dc machine operates from the office 24 or 48 volt central office battery. Automatic transfer to the battery driven machine takes place when the ac commercial power fails or drops below a specified value.

The battery driven motor speed is controlled by a speed regulator mounted on the commutator end of the motor and serves to keep the motor speed within limits. A tone generator is mounted between the generator and the low-speed interrupter reduction gear which drives the

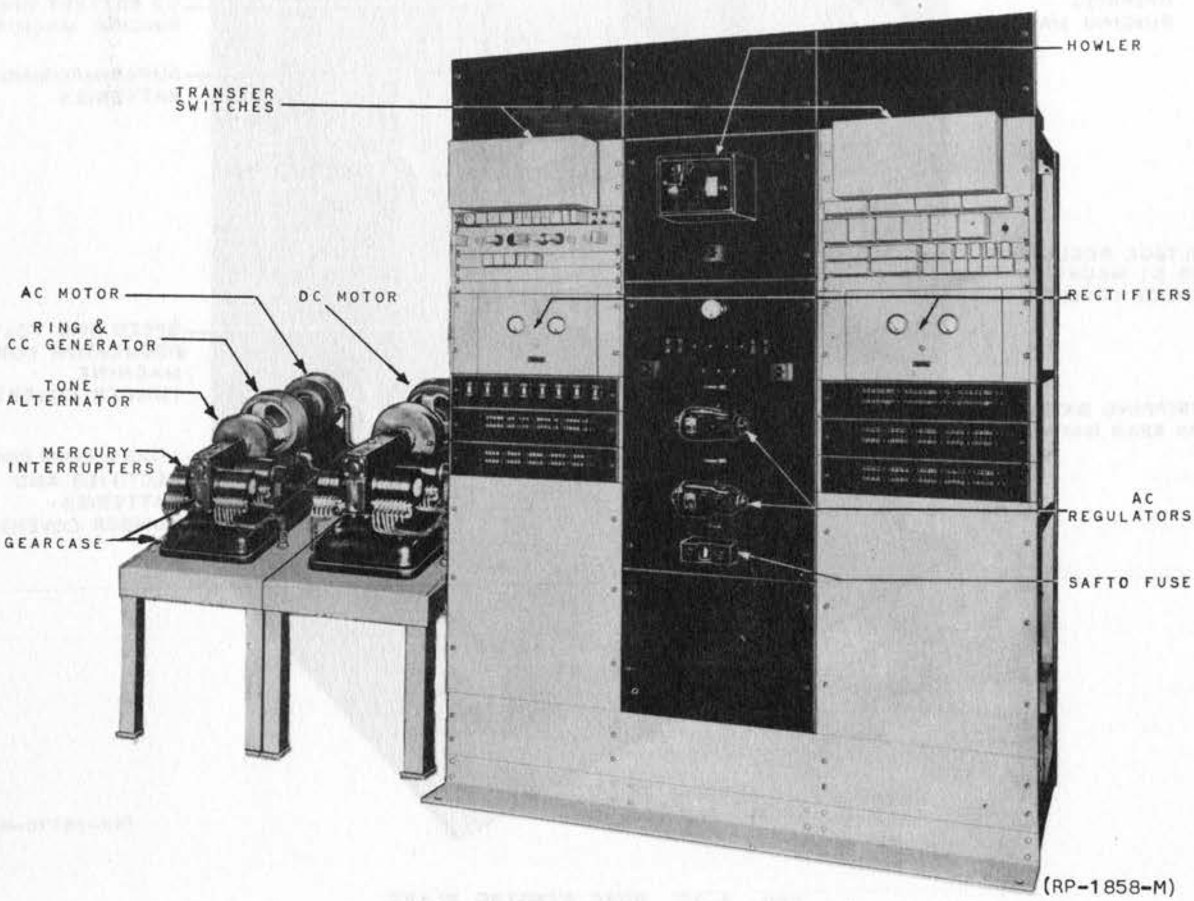


FIG. 5-18 803-C RINGING PLANT

rotary mercury-type interrupters. The generator furnishes ac ringing current and positive and negative direct current at approximately 120 volts for coin control. This direct current is also used to excite the field coils of the generator and for this purpose is connected through a generator field rheostat and an ac motor driven centrifugal voltage regulator for controlling the ringing current voltage.

In order to provide the various ringing voltages necessary for the continuous supply to PBX's as well as for the AC-DC or superimposed machine ringing service, an output transformer having several output voltage taps is supplied with each machine.

5.5 Ringing Plant Operating Features

5.51 The foregoing descriptions did not outline certain features, frequently incorporated in ringing power plants, which are described broadly in the following paragraphs.

5.52 The division of the ringing load in machine ringing offices is accomplished by means of the slow-speed interrupters. Since the ringing interval is usually only one half as long as the silent interval (2 seconds and 4 seconds) it is possible to utilize three slow-speed interrupter units in an arrangement whereby one-third of the office is supplied ringing current during a two-second ringing period, another third of the office during the next two-seconds and a third during the following two-seconds. Thus the ringing generator can carry three times the load it could handle if the whole office were supplied during the same two-second ringing period.

5.53 Automatic switching from the regular to reserve ringing supply is employed in most of the larger plants. While the detailed circuit arrangement may differ with various sizes and types of plants this feature provides for starting the reserve battery driven machine when the voltage of the regular ac driven machine falls below predetermined value, caused by a primary power supply failure or other trouble. The ringing supply, tone and interrrupted signal circuits are transferred from the regular machine to the reserve machine by means of a multipole electrically operated transfer switch. When ringing current of the proper voltage from the regular machine becomes available, the supply circuits are automatically transferred back to it and the reserve machine stopped.

5.54 The charging of the ringing batteries is treated as a function of the ringing power plant. It was previously mentioned that batteries are employed in connection with silent interval tripping, ringing interval tripping and for superimposed ringing. In certain systems the central office battery is used for some of these functions and separate storage batteries for others. Where separate storage batteries are used as part of the ringing facilities the ringing power plant is provided with suitable types of rectifiers and auxiliary equipment to maintain these batteries in a properly charged condition.

QUESTIONS

1. What are the principal types of current furnished by a ringing power plant?
2. How is superimposed ringing current produced and what is it used for?
3. What is meant by "machine ringing"?
4. How is semi-selective machine ringing accomplished?
5. What is the purpose of AC-DC ringing?
6. Why is the "pick-up" circuit arrangement used and how does it function?
7. Briefly describe how 135 or 1000 cycle signaling functions.
8. Describe the 135 and 1000 cycle motor generator sets.
9. How are tones used and what are the two principal types?
10. Describe a tone alternator.
11. What is the purpose of low-speed interrupters?
12. How does the rotary mercury-type interrupter function?
13. Briefly describe a No. 84 Interrupter and its function.
14. Describe a motor driven howler interrupter.
15. What is the purpose and operation of a static ringing generator?
16. Why are dc operated ringing machines provided with speed regulators?
17. Describe the 804-C type ringing plant.
18. Why are output transformers usually used with ringing machines?
19. How is the division of ringing load accomplished in machine ringing plants.
20. Briefly describe "automatic switching from regular to reserve ringing supply."

6. BATTERIES

6.1 General

6.11 There are three general types of battery cells used in telephone plants. They are storage batteries, C.E.M.F. cells and dry cells. The most important of these is the storage battery or accumulator in which chemical changes are brought about by passing direct current through them, called charging, thereby rendering them capable of delivering electrical energy, called discharging. The plates of some storage battery cells contain lead-calcium and others lead-antimony. Nickel-cadmium (nicad) batteries are being used for engine starting batteries in reserve power plants with excellent results. However, the voltage per cell is less than lead-type cells so that more nicad cells are required for any required voltage.

6.12 Associated with the storage battery in certain instances are counter electromotive force (CEMF) cells which do not accumulate or store energy but develop potential or voltage when current is passed through them. Therefore, they are not charged and discharged as are storage batteries but are connected in series with them in units of one or more. They are used for regulating the voltage supplied to the telephone plant by the storage batteries in combination with the charging equipment.

6.13 In some instances, small amperages at voltages different from those required for the operation of the bulk of the circuits and apparatus in a telephone plant, are obtained from primary batteries of the dry cell type.

6.2 Storage Batteries

6.21 Storage batteries are of great importance in telephone plants. They act as reservoirs of electricity and are, therefore, capable of supplying energy for limited periods, irrespective of interruptions in commercial power service. They are of low impedance and absorb much of the electrical noise which charging machines generate by reason of undulations in the voltage of their output.

6.22 A storage cell can be made by immersing lead plates in dilute sulphuric acid and passing direct current through the combination thus electrically "forming" the plates. This is an expensive method of accomplishing the results, and the storage capacity of a battery so made would be relatively small. Commercially it is more economical to form the plates chemically.

In a commercial lead-acid storage battery the plates consist essentially of lead with which a small amount of antimony or calcium is alloyed to increase its mechanical strength and stiffness. The plates are cast in the form of grids and are so formed to become containers for lead compounds known as active materials. There are many different designs of storage battery grids, however, the result obtained by all of them is essentially the same.

6.23 A storage battery cell is an electrolyte cell for supplying electric energy. It consists of several positive and negative plates with separators in between in a suitable container filled with an electrolyte which is dilute sulphuric acid. All positive plates of a cell are connected together and all negative plates are connected together and terminated at suitable positive and negative terminals used to connect the cell into the circuit. The number of plates in a cell will always be odd since an extra negative plate is required in each cell in order that each positive plate may have a negative plate on each side, this being necessary to prevent buckling of the end positive plates, which are more likely to become distorted in operation, than are the negative plates.

6.24 <u>During charge</u> a chemical action takes place within the cell between the plates and electrolyte whereby the lead sulphate on the positive plates is changed to lead peroxide and on the negative plates it is changed to sponge lead.

<u>During discharge</u> a similar but opposite chemical action takes place whereby lead sulphate is formed on both sets of plates. This form of lead sulphate is in a finely divided state, and is essential to the operation of the cell. The loss of sulphuric acid from the electrolyte in the formation of the lead sulphate causes the lowering of the specific gravity during discharge while the chemical reaction producing water further dilutes the electrolyte. The relative density of electrolyte is an indication of the state of charge of a cell which may, therefore, be determined with a hydrometer.

6.25 <u>The voltage</u> of a storage cell varies between 1.75 volts when discharged, to approximately 2.55 volts at full charge. The normal voltage under correct operating conditions may be computed at approximately 2.17 volts. Therefore, the number of cells to be connected in series to obtain a desired circuit voltage requirement is in general obtained by dividing the desired voltage by 2.17.

6.26 The capacity of a storage cell is determined by the surface area of the positive plates of the cell, that is, the ampere capacity of the cell increases in direct proportion to the increase in the area of these plates. Rated capacity, or ampere-hour capacity, is the number of ampere-hours which can be delivered under specific conditions as to rate of discharge, final voltage and temperature. For example, the rated capacity in ampere-hours of batteries classified under the 8 hour rate is 8 times the 8 hour discharge rate in amperes at a temperature of 77 degrees fahrenheit when discharged to 1.75 volts per cell. If the discharge rate is 12.5 amperes, the rating is 8 hours x 12.5 amperes or 100 ampere-hours.

6.27 <u>Sediment</u> accumulates in the normal use of a cell which is regularly discharged and charged. The active material, mostly from the positive plates, is gradually worked loose from the plates and settles to the bottom of the cell in the form of sediment. Unnecessary overcharging, resulting in excessive gassing accelerates the wear on the plates and consequently the accumulation of sediment. If sediment piles up either on the bottom of the container or on the plate supports, so that it comes into contact with the bottom of the plates, it will produce a partial short-circuit which will shunt part of the current during charging and will also cause the affected cell to discharge continuously when not being charged. With present operating methods, particularly continuous float, there is very little sediment deposited.

6.28 Sulphation in a storage cell is due to the lead sulphate on the positive plates reaching an abnormal condition where it tends to fill the pores of the plates and make the active material hard and dense. During the normal discharge of a cell lead sulphate is being formed on the plates. If a cell is permitted to stand completely discharged, is habitually undercharged, or is otherwise neglected, the sulphate reaches the condition called sulphation. This form of sulphate makes the portions of the plates on which it is deposited inactive, thus reducing the capacity to that which is given by the remaining good material. The harmful sulphate formed in this manner when not in too large masses, can usually be converted into lead peroxide and lead in the same manner as the finely divided useful substance by considerable extra charging.

6.3 Pilot Cell

6.31 A readily accessible and well lighted cell of the battery which is selected and used as a guide for voltage and temperature readings in the initial and other charges necessary to meet requirements before turn over to the telephone company. In general, it is the new cell which arrived on the job with the lowest electrolyte level except, that it shall not be a cell next to a window or hot radiator or a cell at the end of a row. This precaution is necessary since heat from the direct sunlight or nearby radiators will increase the local action in any type cell.

6.4 Battery Plates

6.41 A positive plate consists of a grid and positive active material. A charged positive plate is usually dark brown in color. The terminal to which positive plates are attached is usually designated (+) or (POS) or is referred to as the plus terminal.

6.42 A negative plate consists of a grid and negative active material. A charged negative plate is light gray in color. The terminal to which negative plates are attached is usually designated (-) or (NEG) or is referred to as the minus terminal.

6.43 Positive and negative plates of any cell are separated mechanically to prevent metallic contact or short circuit. The material used must be porous to allow circulation of electrolyte and provide low resistance to current flow.

6.5 Separators

6.51 It is essential that the positive and negative plates of any cell should be mechanically separated from each other in a way to prevent metallic contact or short circuit. The material used is porous and allows circulation of the electrolyte and low resistance to current flow.

6.52 Wood or microporous hard rubber separators and fine spun glass-fiber mats or perforated hard rubber retainers in various combinations are used to separate the plates. See Figure 6-1.

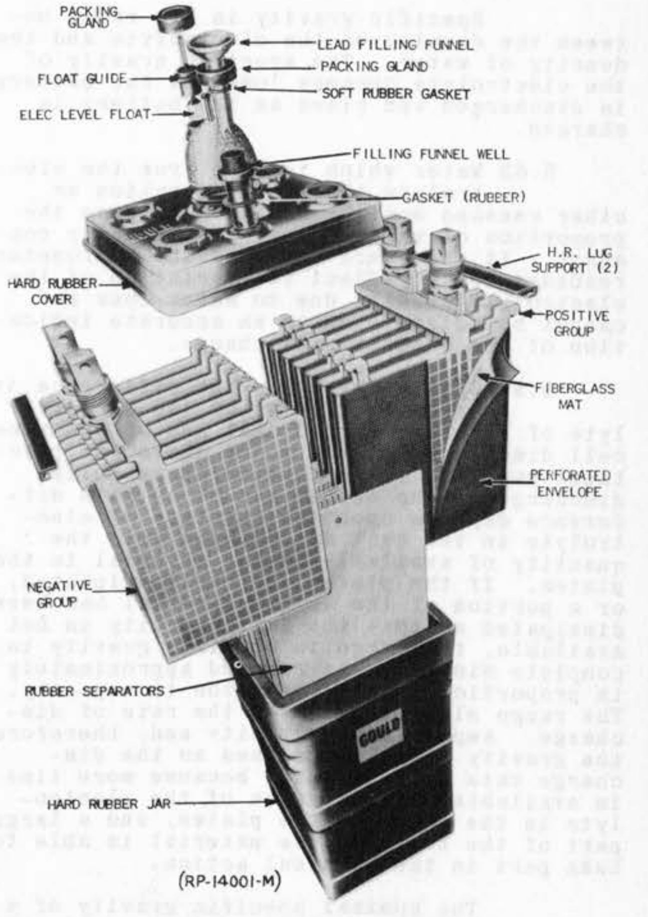


FIG. 6-1 CELL ASSEMBLY

6.53 The separators deteriorate with age becoming mechanically weak or brittle or both so that if work is done on an aged cell, it is quite likely that the separators will be damaged. However, if the cell is not disturbed, the separators are likely to provide the required separation and last as long as the plates.

6.6 Electrolyte

6.61 The electrolyte is the solution in which the plates of a storage cell are immersed and which in combination with the active material of the plates, determines the electromotive force or voltage of the cell. This solution consists of purified sulphuric acid and approved water.

6.62 The specific gravity of the solution at any time is dependent upon the type of cell, the electrolyte temperature and the amount of charge in it. Since specific gravity varies with changes in temperature, readings must be corrected to an established base temperature of 70 or 77 degrees Fahrenheit for reference purposes.

Specific gravity is the ratio between the density of the electrolyte and the density of water. The specific gravity of the electrolyte becomes lower as the battery is discharged and rises as the battery is charged.

6.63 Water which is lost from the electrolyte through evaporation or other reasons must be replaced to keep the proportion of water to acid practically constant. If this were not done the hydrometer readings would reflect the variation of the electrolyte density due to water loss and cannot be relied upon as an accurate indication of the condition of charge.

6.64 Gravity range is the difference in specific gravity of the electrolyte of a fully charged cell and of the same cell discharged to the point where for practical purposes it is considered as fully discharged. The actual amount of this difference depends upon the quantity of electrolyte in the cell as compared with the quantity of available active material in the plates. If the plates are badly sulphated, or a portion of the active material has been dissipated so that the full capacity is not available, the range in specific gravity to complete discharge is reduced approximately in proportion to the reduction in capacity. The range also varies with the rate of discharge. Ampere-hour capacity and, therefore the gravity range, increases as the discharge rate is decreased, because more time is available for diffusion of the electrolyte in the pores of the plates, and a large part of the total active material is able to take part in the chemical action.

The nominal specific gravity of a cell is an assumed value which the cell will approximate when new, fully charged, with the electrolyte near the maximum level and temperature at 77 F. The majority of the batteries now used in telephone power plants have a nominal specific gravity of 1.210 (1.201 to 1.225)

6.7 Charge and Discharge Rates

6.71 The nominal charging rate is a current value recommended by the manufacturer as a current which can be absorbed by the cell throughout the charge without overheating or harmful gassing. There is no harmful effect in charging at a rate less than the nominal and usually a reduced rate is more economical and tends toward greater battery life. In order to conserve time, a relatively high starting rate with a low finishing rate is sometimes specified.

6.72 Because the large surface of active material and the low internal resistance, a battery can usually be discharged at any rate without injury. In general, the greatest output in both ampere-hours and watt-hours is obtained when the battery is discharged over a considerable time such as several days, since the diffusion of acid through the active material is more complete and a greater percentage of the active material is available to sustain the charge. Telephone batteries are usually rated to discharge to 1.75 volts per cell in 8 hours.

6.8 Accessories

6.81 A number of accessories are required for the maintenance and operation of the various type batteries some of which are shown in Figures 6-2, 6-3 and 6-4.

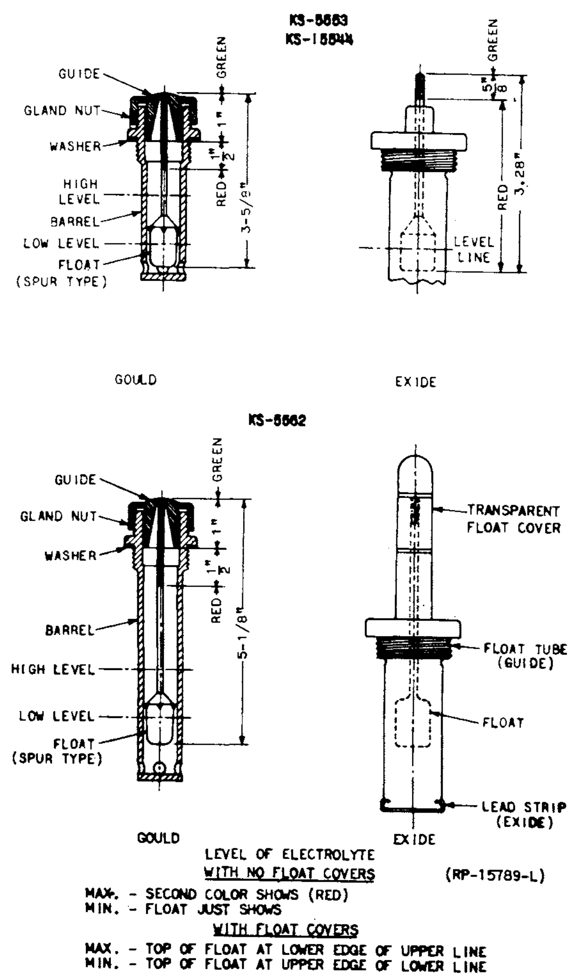


FIG. 6-2 ELECTROLYTE LEVEL INDICATORS

FIG. 6-3 EXPLOSION PROOF VENT AND FILLING FUNNEL BAYONET TYPE

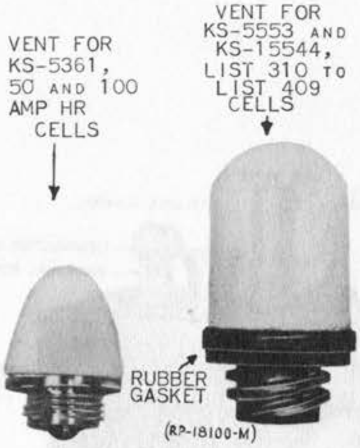


FIG. 6-4 EXPLOSION PROOF VENT

6.82 Level indicators are provided for cells when the level cannot be observed through non-transparent containers such as rubber jars. The indicator floats through a hole in the cover of the cell. The stem of the indicator without a dome cover is colored part way so that a change in color indicates the electrolyte at the maximum level as soon as it appears.

6.83 Containers are made of hard rubber and transparent molded plastic.

6.84 The term "case" is applied to the wooden case or box in which small cells are packed and left during life.

6.85 A tray is a rubber or lead pan for one or more cells set under a battery, particularly in rented quarters, to catch electrolyte in case a cell should break or leak.

6.86 Thermometers to measure electrolyte temperature are graduated in degrees Fahrenheit and also have a scale indicating the correction to be made on the observed hydrometer reading to correct it to the established base or reference temperature.

6.87 A hydrometer is an instrument for measuring the specific gravity of the electrolyte. The syringe type consists of a sealed glass tube properly weighted and provided with an inner scale graduated in terms of specific gravity. This is enclosed in a syringe, consisting of a glass cylinder with rubber bulb at one end and a tip at the other, arranged so that electrolyte can be drawn out of the cell to float the hydrometer.

6.88 Battery cells always give off a certain amount of hydrogen and oxygen in explosive mixtures. When a static charge or spark is released (discharged) by a person or tool in the presence of this gas, or mixture, near a cell, and the gas is of sufficient concentration it will ignite. If it occurs in a confined space this will cause an explosion. These hazards are controlled by releasing static accumulation to ground and by dissipating the gas. Static hazards are most severe in dry cold weather rather than in humid warm weather.

The design of battery cells fitted with explosion control devices reduces to a minimum the possibility of an explosion that would injure personnel, or cause damage to the cell cover or equipment or create a hazard to other equipment. With these features a spark, flame or arc can ignite only a small amount of gas unless it accumulates near the cell in large quantities.

6.9 Types of Cells

6.91 There are two general types of enclosed or sealed type storage batteries in use in the telephone power plant. They are known as the rubber tank type and the jar type. The jar type may be of plastic or rubber. The rubber tank type is enclosed in a hard rubber cover. Figures 6.5 and 6.6 show the two types.

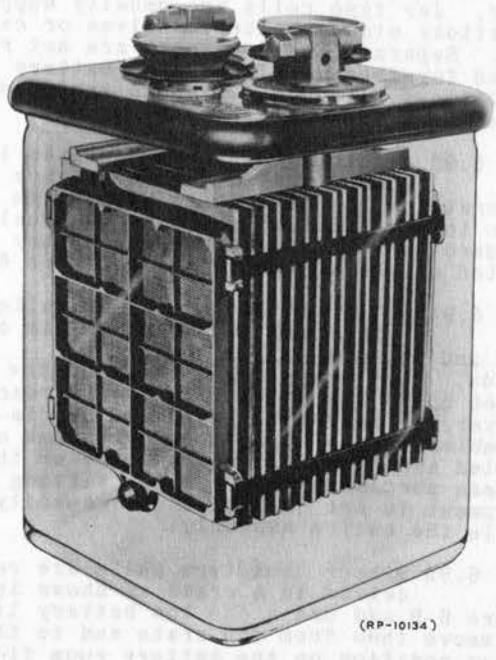
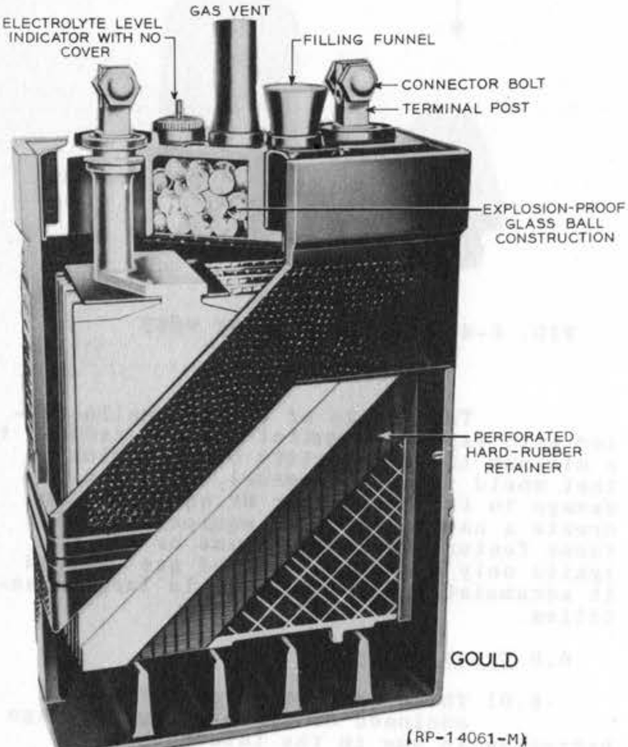


FIG. 6-5 ENCLOSED PLASTIC JAR BATTERY



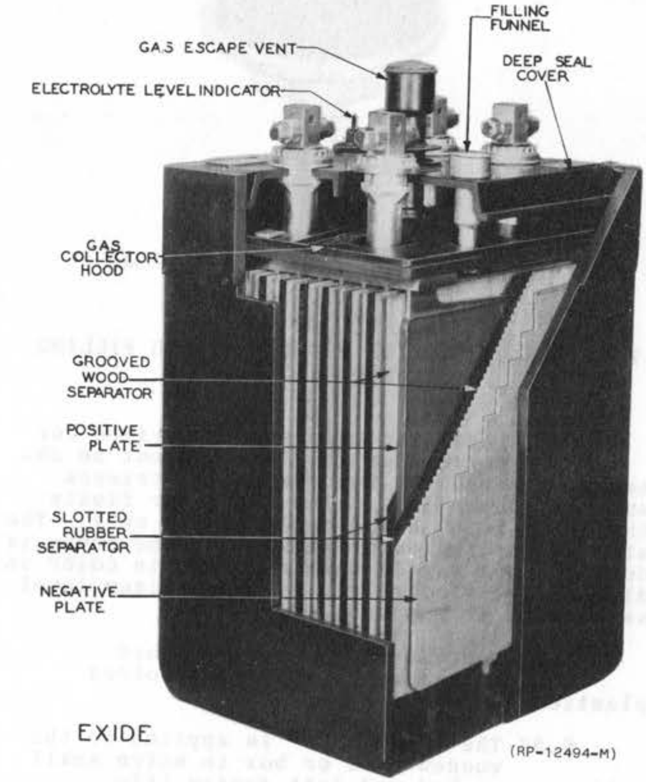


FIG. 6-6 ENCLOSED RUBBER JAR BATTERY

6.92 The rubber tank type cells are designed to rest directly on the floor. Jar type cells are usually supported by battery stands, battery shelves or cabinets. Separate battery rooms are not required for these enclosed type battery installations. Figure 6-7 shows enclosed rubber tank type batteries.

6.93 Jar type cells are received in a wooden shipping crate or box. Any crate or box containing a cell can be taken into a building through the usual standard door or window opening. They are mounted on shelves as shown in Figure 6-8.

6.94 Cells may be shipped on pallets (platform) in groups of six or less and may weigh as much as 2000 pounds. They are normally left on the pallet until the final location is reached. However, the palletized unit may be disassembled in the freight car or truck and handled as individual units whenever this becomes necessary or where the lifting equipment is not of sufficient capacity to handle the entire assembly.

6.95 Rubber tank type cells are received in a crate as shown in Figure 6-9 and use a one ton battery lift to remove them from the crate and to their proper position on the battery room floor.

6.10 <u>Counter Cells (C.E.M.F.)</u>

6.101 After batteries have been partially discharged, it is necessary to charge them promptly, so they will be in condition for further use. During the charging, however, the voltage across the battery must be somewhat higher than when floating. To prevent this higher voltage from reaching the central office discharge circuits, it is necessary to employ counter electromotive force (CEMF) cells, between the battery and the load, to reduce the potential to the desired value.

6.102 Alkaline type counter-emf cells normally function to oppose, and thereby cause a voltage drop in the main discharge battery supply, the voltage being lowered by an amount depending on the number of cells in the circuit. This drop occurs as current is passed through the cells when they are connected in series with the battery discharge supply.

The advantage of counter-emf cells as compared to a series resistance, which may be used, is that the voltage drop through the counter cells does not depend entirely on the amperage flowing through the circuit, whereas the voltage drop due to a series resistance (IR drop)

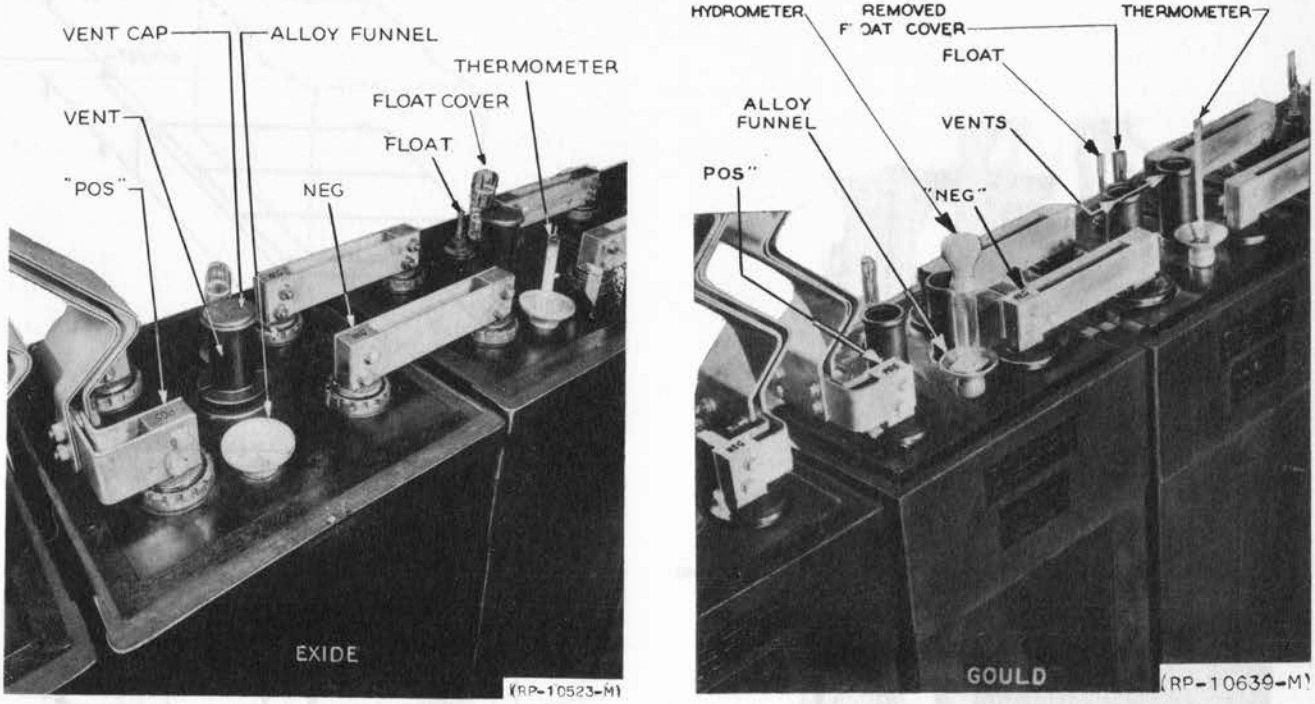


FIG. 6-7 ENCLOSED RUBBER TANK BATTERY CELLS

is directly proportional to the current flow. The counter-emf developed is dependent to some extent on the amount of current passing through it but the range of the counter voltage is fairly narrow, varying from 1.85 volts per cell at 10% rated load to approximately 2.15 volts per cell at full load when the alkaline solution is new, at the correct level and at a temperature of 100 F. The values change with age and temperature.

Primarily counter-emf cells are introduced in the discharge circuit, when the battery is being charged, in order to hold the office voltage within the upper allowable voltage limits at the distribution point, and in other cases to provide a reduced voltage supply constantly. Briefly, their function is that of voltage regulation and, therefore, may operate in the circuit continuously or intermittently.

6.103 The cell shown in Figure 6-10 consists of glass jars in which are contained identical positive and negative plates of approved metal or alloy suspended in an alkaline solution. Since the cell has no polarity, it can be connected for either direction of current flow. The alkaline solution which is of high conductivity, serves as a conductor for the current from one group of plates to another. Each plate is provided with glass bead separators to separate and insulate the plates of opposite polarity. The water content of the solution is decomposed by electrolysis.

After the plates are immersed in the solution, the surface of the solution is covered with a layer of chemically inert mineral oil which serves to prevent excessive spraying and evaporation when the cell is in operation.

These cells have no storage capacity, that is, when it is short circuited after having been in circuit there is no appreciable short circuit current. No initial charge is required, nor adjustment of the solution.

6.104 A cell container or jar is filled with alkaline solution over which there is a layer of mineral oil. Plates are suspended from the cell cover in this solution. One or more of the identical plates are connected to each of the terminal posts on the cover for connection in the circuit. The voltage drop in the cell is the voltage expended in forcing the current from one plate or group of plates through the solution of the other plate or group of plates.

6.105 Cell containers or jars are usually of boro-silicate glass such as pyrex but may be of a plastic such as polystyrene. Glass, when used, must be of this type to resist attack by the caustic solution and to reduce breakage by avoiding the strain usually present in ordinary glass. They must be carefully handled at all times to prevent internal or external scratches.

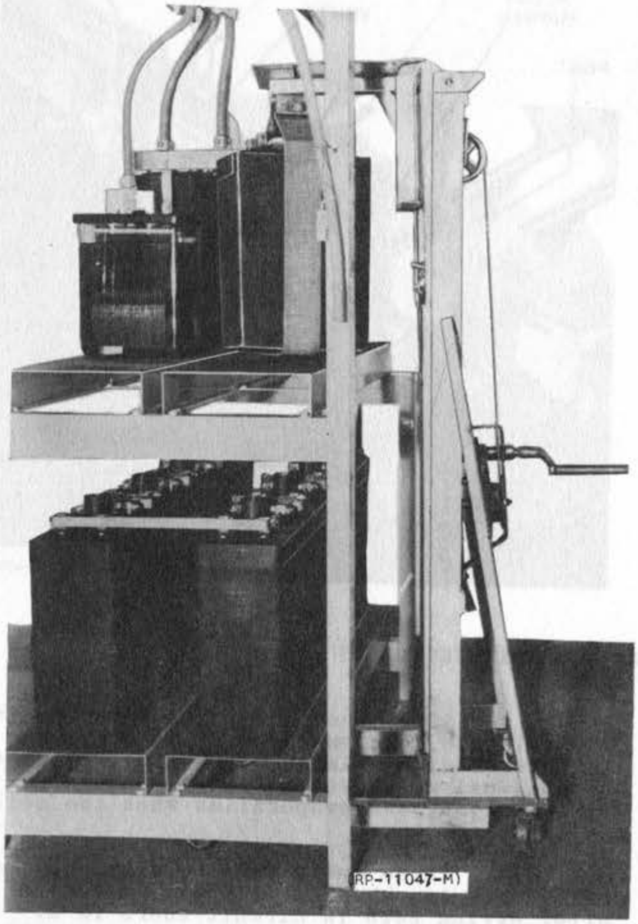


FIG. 6-8 BATTERY HOIST LIFTING RUBBER JAR CELL

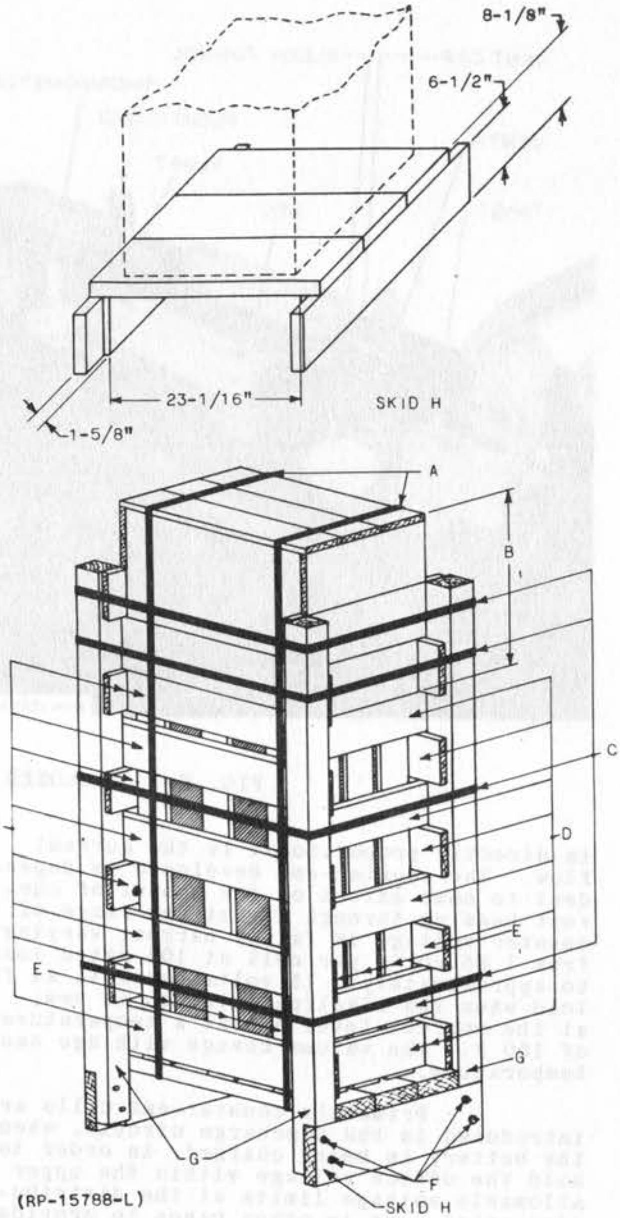


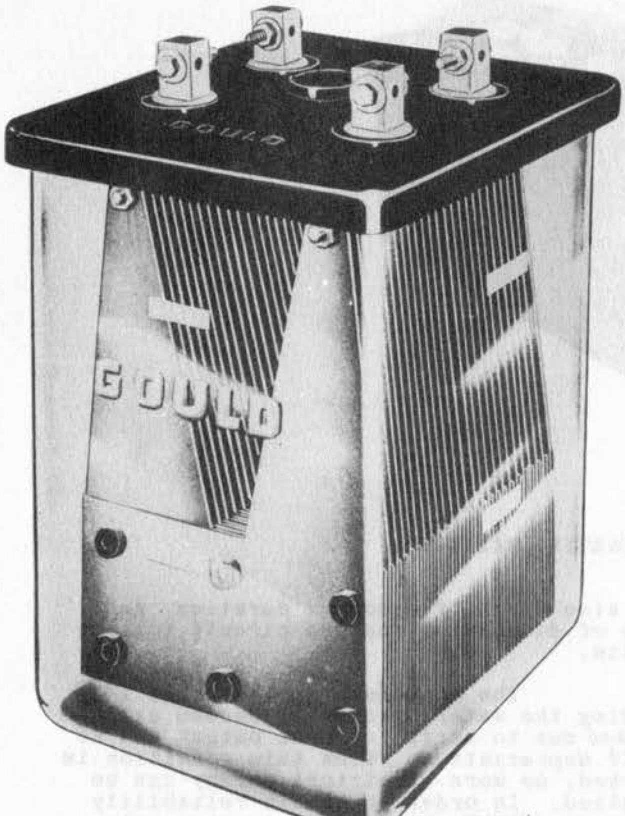
FIG. 6-9 CRATED RUBBER TANK CELL

6.106 The alkaline solution is approximately 9 per cent caustic soda (sodium hydroxide) in distilled water or water approved for storage battery use. It also includes a depolarizer when nickel plates are used. Stainless steel plates are now being used. The solution is corrosive to many materials including aluminum, zinc, clothing, paint, and the skin but it does not attack iron or steel. It may be neutralized with boric acid or vinegar.

6.107 The solution may be shipped ready mixed, but considerable saving in shipping charges is possible when the sodium hydroxide (plus depolarizer, if any) is shipped dry for mixing with water on the job. The dry caustic in unopened containers may stand for a year or two without contamination or loss of strength. In solution form, however, the caustic attacks the ordinary glass used in shipping bottles, causing contamination of the solution by sodium silicate. This shortens the useful life of the solution.

6.11 Engine Starting Batteries

6.111 Batteries of the lead-sulphuric acid type, and the more recent nickel-cadmium alkaline type, are designed for engine starting where the normal routine is three starts per week, with voltages maintained between starts at 2.16 volts per cell for the lead acid type and 1.4 volts per cell for the nickel-cadmium type. All batteries are shipped filled with electrolyte and charged. They are composed of a number of cells in trays (nickel-cadmium) or cases (lead-acid) depending on the voltage required to start the engine as shown in Figure 6-11 and 6-12.



(RP-16373-M)

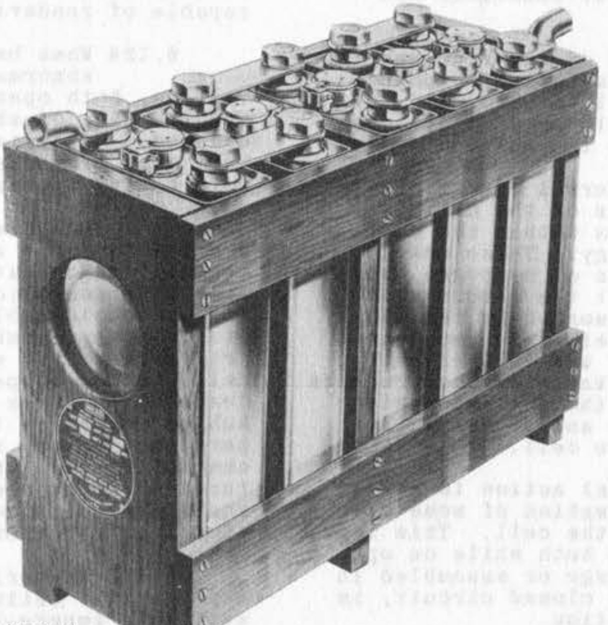
FIG. 6-10 GOULD CEMF CELL

6.112 Nickel-cadmium batteries have been on trial in telephone plants for some time with excellent results and minimum maintenance. These batteries will gas only on charge and then only at potentials over 1.33 volts per cell. At potentials up to 1.47 volts per cell the gassing is negligible. The gas given off is the same as given off by lead-acid cells, namely, a mixture of hydrogen and oxygen. Since this is explosive, the same anti-explosion precautions apply to these cells as to lead-acid cells. However, very little explosive gas is given off at voltages of 1.47 volts and below. Bell System operating routines call for no operation at voltages above this value. For this reason, explosions are less likely than on lead-acid cells, and anti-explosion design features have not been provided for these cells.

The alkaline electrolyte is corrosive and attacks most animal and vegetable products including clothing, the skin, and paint, as well as some metals including aluminum and zinc but excluding iron, steel, and nickel. It attacks glass very slowly (Pyrex-type glass almost negligibly), so exposure of glass other than the Pyrex type or of porcelain should be for as short duration as practicable, and glass or porcelain objects should be washed in water after any exposure to electrolyte.

6.12 Dry Cells

6.121 A dry cell is a primary cell. It produces electrical energy through an electrochemical reaction which is not efficiently reversible except in the earlier stages of discharge. Hence, the cell when fully discharged cannot be economically recharged. The electrolyte is completely enclosed in the absorbent materials within the cell.



(RP-16894)

FIG. 6-11 TRAY OF NI-CAD BATTERY CELLS

FIG. 6-12 EXIDE ENGINE STARTING BATTERY

A dry battery is a combination of two or more dry cells electrically connected together to produce electrical energy.

Ordinarily, the cell is enclosed in a zinc can which serves as the negative electrode and which is usually lined with a layer of paste and absorbent paper. The positive electrode consists of a central carbon rod surrounded by a layer of material known as the depolarizer or "mix." The "mix" consists of a mixture of ground carbon or graphite and manganese dioxide. Both the "mix" and the lining are moistened with electrolyte consisting of a water solution of ammonium chloride (sal ammoniac) and zinc chloride.

The open end of the zinc can is closed by a layer of insulating compound, or by an insulated metal top, to hold the materials in place and to prevent evaporation of the moisture in the cell.

6.122 When the external circuit between the terminals of the cell is closed, chemical changes within the cell produce electrical energy. These changes result in the liberation of hydrogen, which would tend to collect at the carbon electrode if it were not absorbed by the manganese dioxide in the "mix." In use, the various constituents of the cell either become exhausted or coated with the products of chemical reactions, thereby increasing the internal resistance and lowering the operating voltage of the cell.

Local internal action is responsible for the consumption of some of the chemical energy in the cell. This loss of energy, which occurs both while on open circuit (either in storage or assembled in equipment) and while on closed circuit, is known as shelf depreciation.

6.123 The life of a cell depends upon many variables such as its size, ingredients, processes of manufacture, age, and also on the frequency, duration, and rate of discharges and the circuit voltage limits.

The chemicals in the cell, including the water, gradually become exhausted due to useful current output and to shelf depreciation. When this condition is reached, no more electrical energy can be supplied. In order to obtain reliability of service it is economical in most telephone application to discard cells before their capacity is completely exhausted. However, if the cell has become exhausted due to a high rate or extended period of discharge, it may recover to some extent if allowed to stand idle and will then be capable of rendering further service.

6.124 When batteries are exposed to abnormally high temperatures, the voltage, both open-circuit and operating, and the rate of shelf depreciation are increased. Batteries should,therefore,be kept away from abnormally high temperatures both during storage and in use.

Low temperatures decrease shelf depreciation but also reduce the open-circuit and operating voltages. Under most operating conditions the life of a battery may be considerably decreased if its temperature is appreciably below 70F. Except for grid service, it may be considered that a cell becomes inoperative when its internal temperature falls below 0°F. Batteries subjected to low temperatures incur no permanent injury and regain their normal characteristics when their internal temperatures are restored to normal. To minimize shelf depreciation, batteries should be stored at a temperature of about 34F to 40F.

6.125 Batteries in low-current-drain service will deliver almost all of the available ampere-hour output at a relatively high operating voltage, after which the voltage drop will be comparatively rapid. Hence, in this service a high cutoff point is desirable in order to insure reliability.

For batteries in high-current-drain service, the higher current will produce a greater internal resistance drop and a lower operating voltage. A lower cutoff point is, therefore, necessary in order to obtain efficient use of the available energy contained in the cells. When it is necessary to maintain the battery voltage within close limits under high current drains, it is frequently desirable to add one or more cells in series when the cutoff point is first reached, in order to take advantage of the increased output thereby obtainable from the whole battery.

6.126 Dry cell batteries are used in the telephone office for a variety of purposes. In the power plant their most common use is for tripping battery reserve, where a rectifier normally furnishes the supply, and for message register battery supply either as a reserve for use where a rectifier is furnished or as the main source of message register battery supply.

QUESTIONS

1. What types of cells are used in the telephone plant?
2. Describe a storage battery cell and what action takes place during charge and discharge.
3. What determines the capacity of a storage cell and what two methods are employed to increase battery capacities?
4. What is sediment and how does if affect the cell?
5. What is sulphation? What causes it? How is it removed?
6. Name the accessories required for storage batteries.
7. Describe briefly the types of storage battery cells used.
8. Describe the alkaline CEMF cell.
9. Describe a Ni-Cad Battery.
10. Describe a dry cell.

7. RESERVE POWER EQUIPMENT

7.1 General

7.11 Reserve power equipment for telephone central offices consists of alternators driven by internal combustion engines and associated speed and voltage control and either manual or automatic start control equipment.

7.12 It is essential in the design of telephone power plants that provisions be made to assure an uninterrupted source of power. The batteries provide reserve for a short period, but reserve power plants are generally provided. Experience has shown that even in communities where there are two independent sources of commercial power a reserve plant is desirable to insure uninterrupted power service. The size reserve plant and its control features are determined by the telephone company. These units, either gasoline or deisel driven, may be arranged to develop single or polyphase alternating current as required by the needs of the central office or station.

7.2 Types of Engine - Alternators

7.21 There are two general types in use in the telephone power plant; manually controlled and automatically controlled. They are mounted to a floor base and are known as stationary units. The manually controlled sets are used in attended stations where maintenance forces can start them and throw the load on or off. Automatically controlled sets are used in unattended stations and power rooms that are partially attended. They are arranged to start automatically on power failure and assume the load when ready, as well as shut down when power is restored.

7.22 Engines may be either the gasoline or diesel type. Both are available for manual or automatic operation. However, the diesel type is preferred in all available sizes because the exhaust fumes are not poisonous and the fuel does not create a serious fire hazard. The gasoline type is presently only used in the 2 and 4 KW sizes.

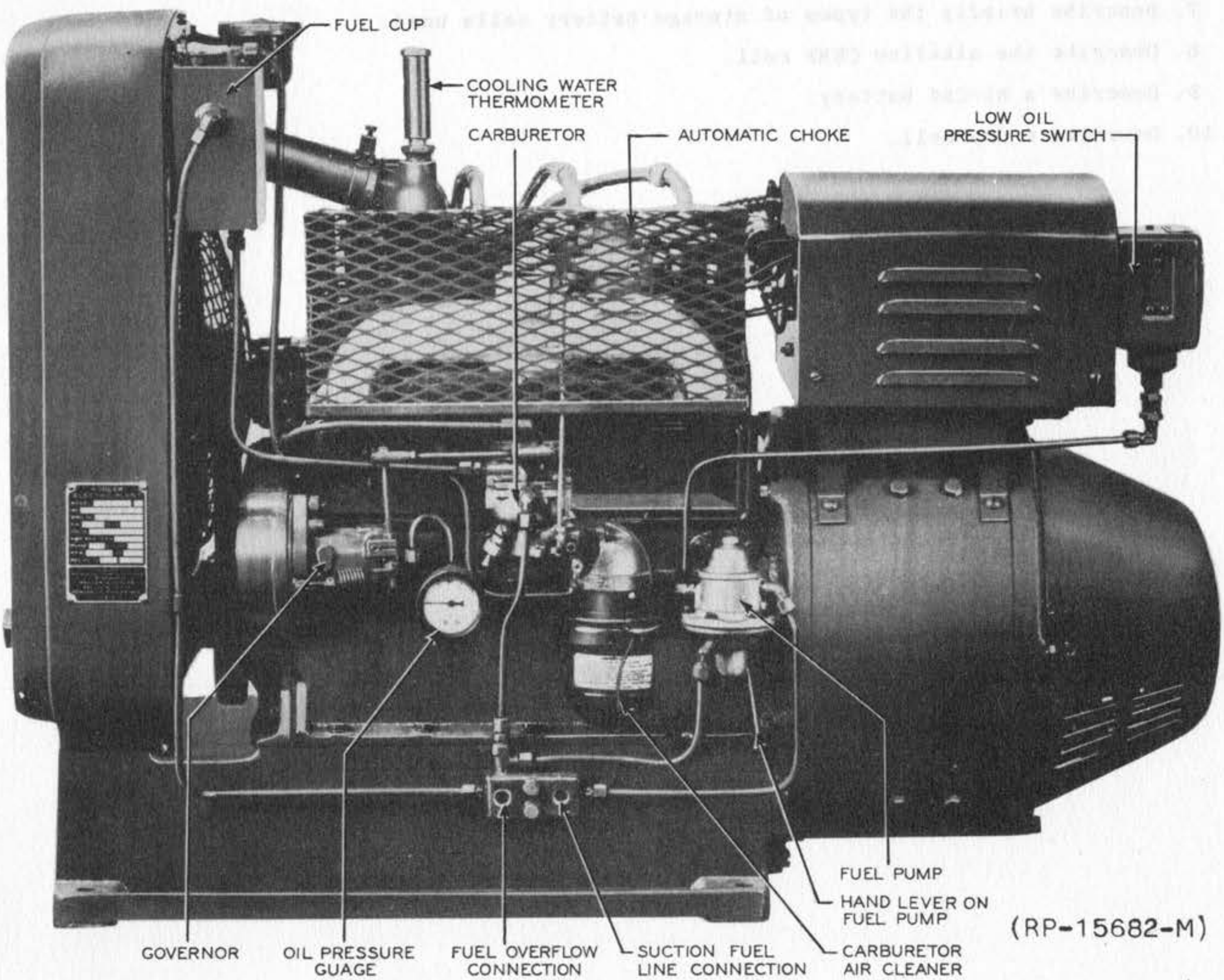


FIG. 7-1 2.8 TO 4KW ENGINE ALTERNATOR

7.23 <u>The fuel supply</u> is usually stored in buried tanks and is pumped from the tanks by fuel pumps on the engine. Over flow pipes are provided to return the excess fuel. Suitable gauges are provided for reading the level of the fuel in the tank.

7.24 <u>The exhaust equipment</u> includes a flexible metallic exhaust hose connection and a silencer located over or close to the engine. An Exhaust pipe is provided from the silencer to the roof or into a building flue known to be tight and adequately strong.

7.25 The alternators used in the reserve power plants are usually furnished for an output of nominally 220 volts, 60 cycle, 3-phase current to correspond with the local normal commercial power supply. The frequency is controlled by the speed of the engine which can be regulated by adjusting the governor when required. Each alternator has a rotating field excited by a direct connected direct current generator called an exciter. Each alternator control panel includes an automatic voltage regulator and necessary controls to insure the desired voltage by manual or automatic control as desired. When more than one alternator is required to carry the emergency load they can be operated in parallel.

7.3 <u>Features</u>

7.31 Gasoline and diesel driven alternator units consisting of the engine, alternator, exciter and starting controls are mounted on a common subbase. The engine is directly connected by means of a flexible coupling to its associated alternator and exciter.

7.32 The engines are cooled by radiators and fans or by city running water in which case heat exchangers are provided. The gasoline engine is of the 4 cycle type while the diesel engine may be either 2 cycle or 4 cycle. They are usually designed to run at speeds of 1200 or 1800 r.p.m. Figure 7-1 shows the gasoline driven type currently in use and Figures 7-2 and 7-3 two diesel driven types.

7.33 In general, the units are started by means of either a 12 or 32 volt starting motor, the control of which is arranged with a manually or automatically controlled starting contactor. Some gasoline driven units utilize the exciter as a starting motor otherwise a separate starting motor is provided.

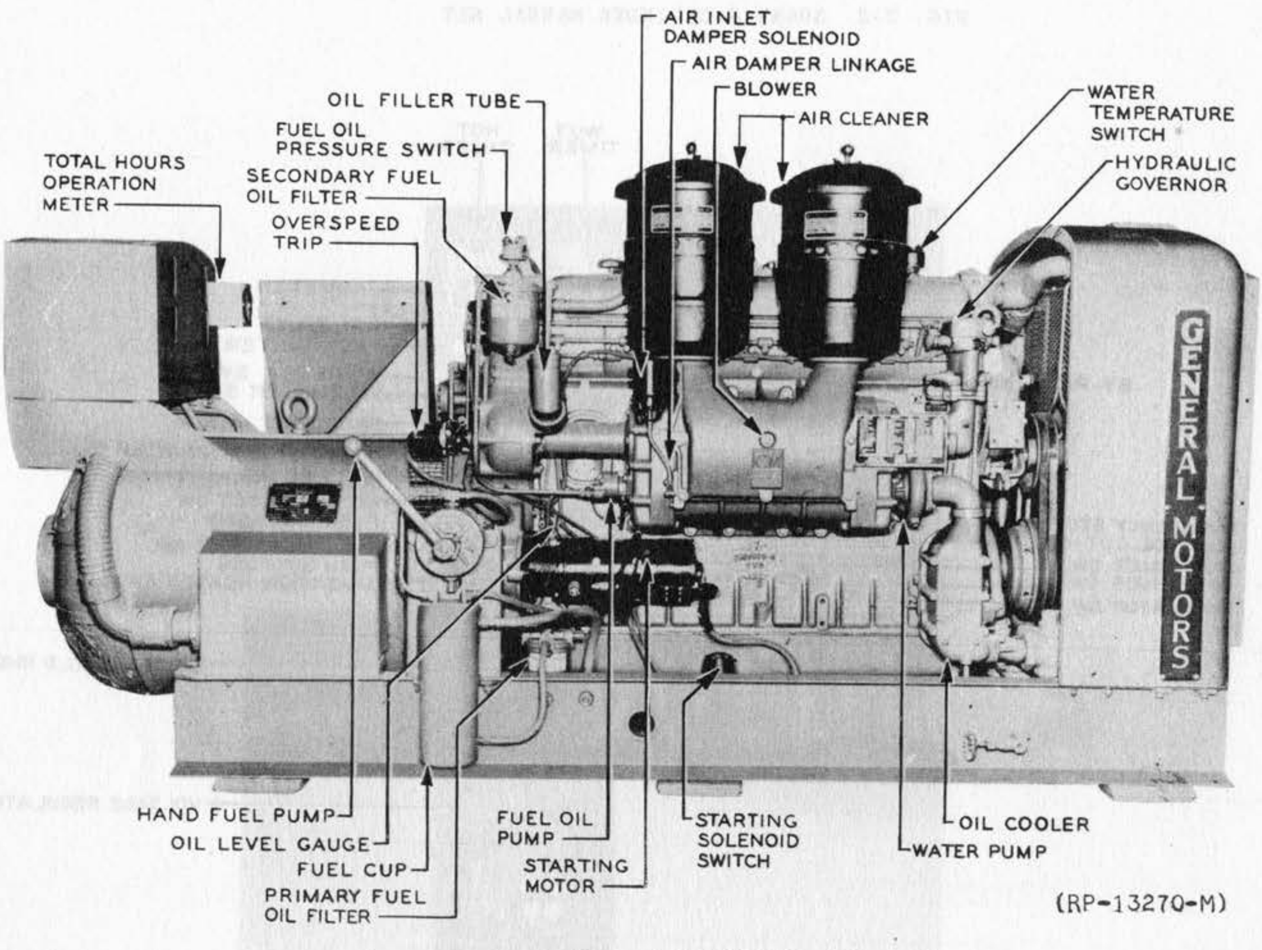


FIG. 7-2 60KW MANUAL SET

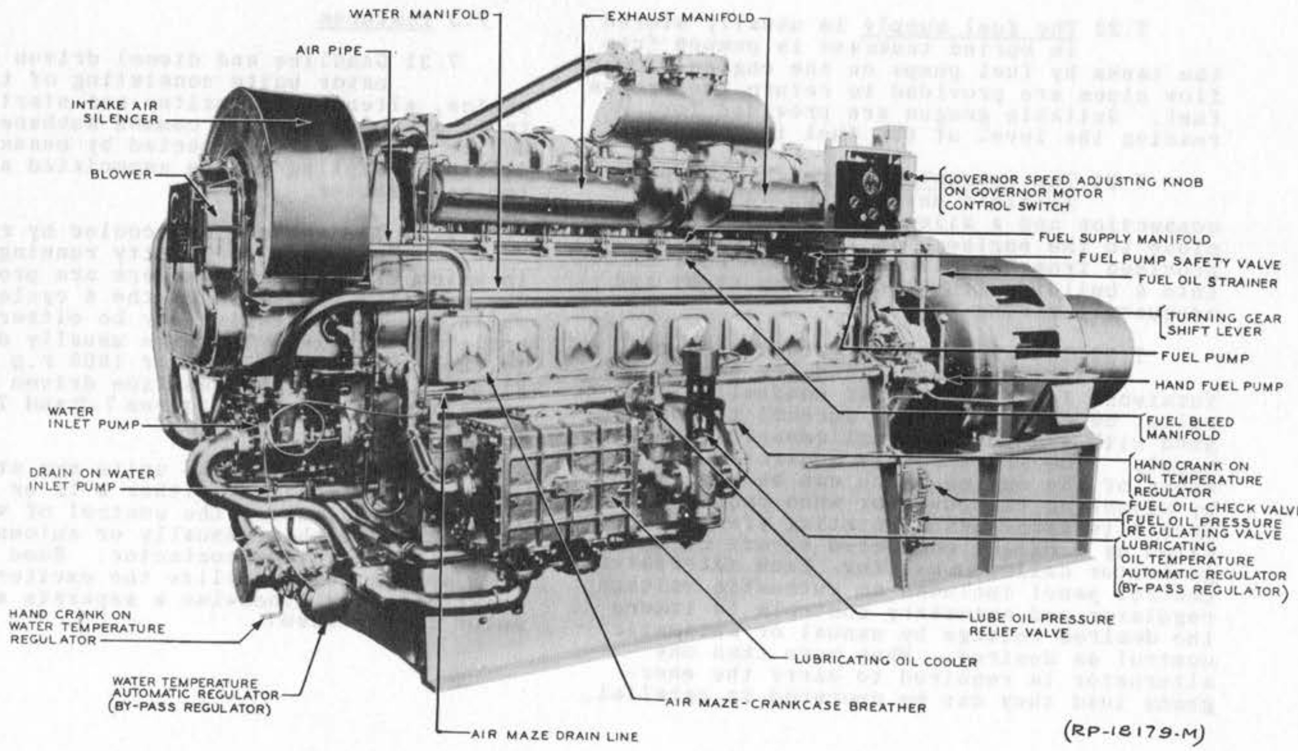


FIG. 7-3 300KW 8 CYLINDER MANUAL SET

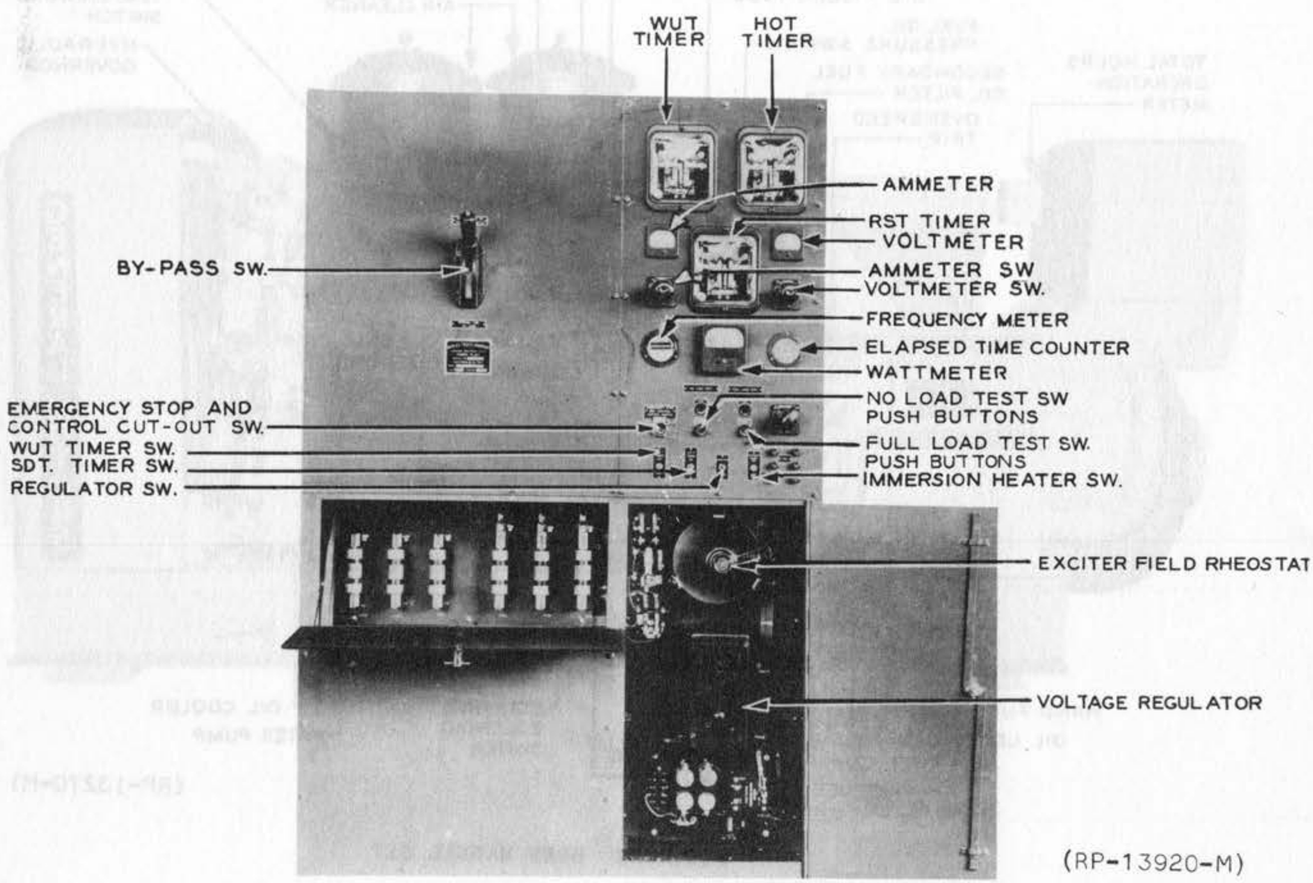


FIG. 7-4 MAIN CONTROL PANEL - FRONT

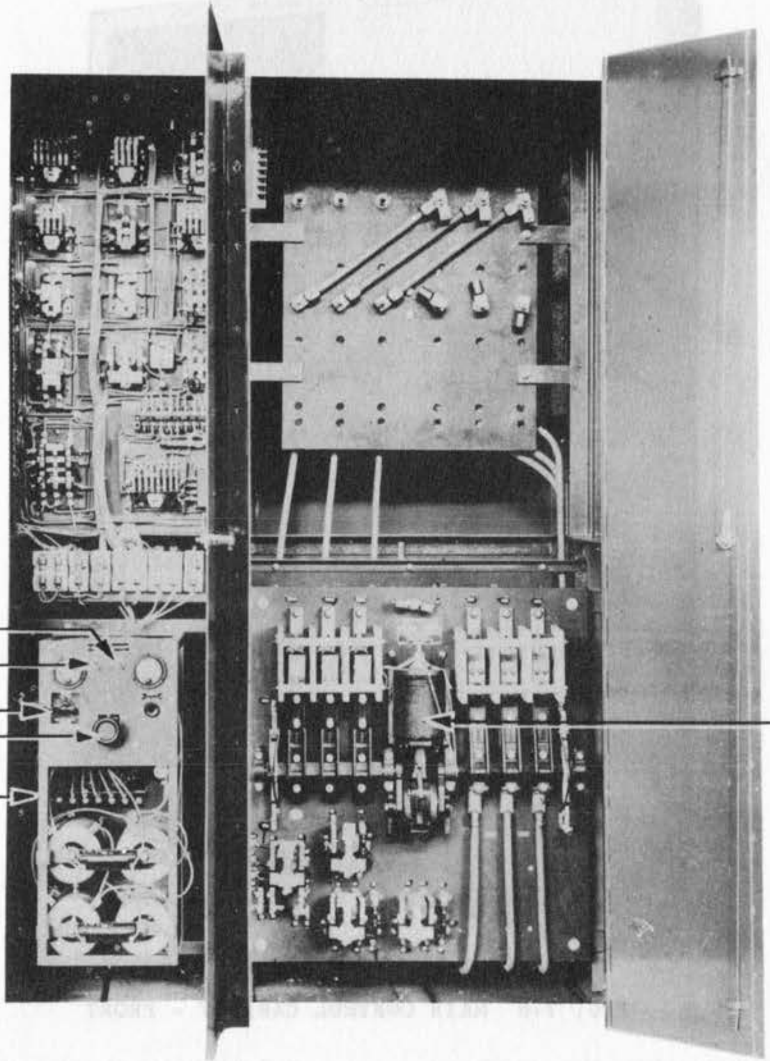


FIG. 7-5 MAIN CONTROL PANEL - REAR

7.4 Start Control

7.41 Engine alternator sets may be manually controlled or automatically controlled. The automatically controlled types are in general the same in appearance as the manually controlled types. Since the automatic types are in most instances used in unattended or semi-attended offices, they are in general smaller in size because of the smaller requirements for emergency power. However, there are some instances where the larger units may be operated automatically.

7.42 All controls for the manually operated type sets are generally available on the control mounted on the set. The controls for automatically operated sets are mounted in a separate main control cabinet. These controls start the set, warm it up, transfer the load to it, and run and stop it on an entirely automatic unattended basis. Additional controls operate to shut the set down when engine troubles occur. When they do occur, still other controls operate to set up connections to the alarm circuits which are transmitted to the attended office for alarm purposes. Figure 7-4, 7-5 and 7-6 illustrate the control panels and cabinets used for both gasoline and diesel automatically controlled sets.

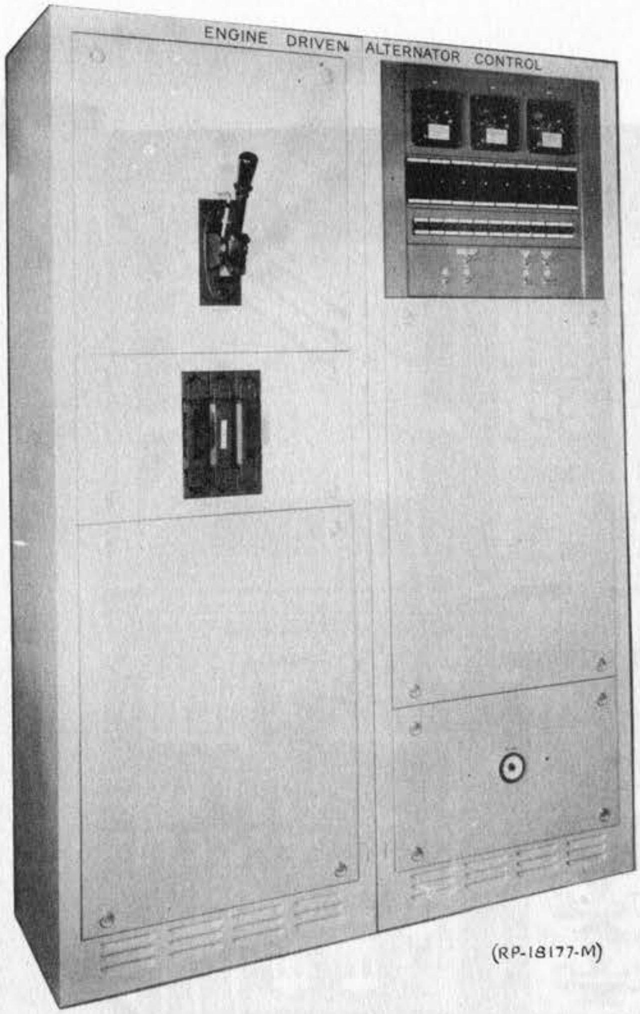


FIG. 7-6 MAIN CONTROL CABINET - FRONT

7.43 The automatic types are operated on a fully automatic basis with their starting, running and stopping entirely under control of preset automatic devices. When the commercial power fails or any one-phase drops to approximately 88 per cent of normal voltage, or lower, the engine starts after a short delay and operates at no load for 4 to 5 minutes before assuming the load. When the commercial power is again available at approximately 94 per cent of normal voltage, or higher, after a slight delay the engine is stopped.

Automatic arrangements for routining the engine alternator may be provided in the main control cabinet or panel for routining the engine alternator set without visiting the station. Arrangements provide for starting the set from a remote location, operating it at no load and at the station load for certain prescribed intervals after which it is automatically shut down.

7.44 The alarm system features on the control cabinets or panels transmit signals to the attended main station where alarms function to indicate a commercial power failure, proper operation of the set, fuse failure and engine failure.

7.5 <u>Alternately Operated Engine Alternators</u>

7.51 Diesel operated automatic sets are available to furnish continuous power at points on transcontinental radio and carrier routes where outside commercial power can not be made available. They are furnished in pairs and arranged so that each set operates for 12 hours.

7.52 Either engine starts automatically at the expiration of a 12 hour run of the other engine, the load being transferred automatically from one set to the other just before the set which has been carrying the load shuts down. Sets are equipped with 32 volt starting motors and a 32 volt starting battery which is common to both sets. The starting battery is charged by means of a regulated rectifier operated from the output of either set.

7.53 Complete automatic operation of the two sets is controlled by means of a main control cabinet which is floor mounted separate from the two engine alternator sets. An engine alternator of this type is shown in Figure 7-7 and the control cabinet with covers removed is shown in Figure 7-8.

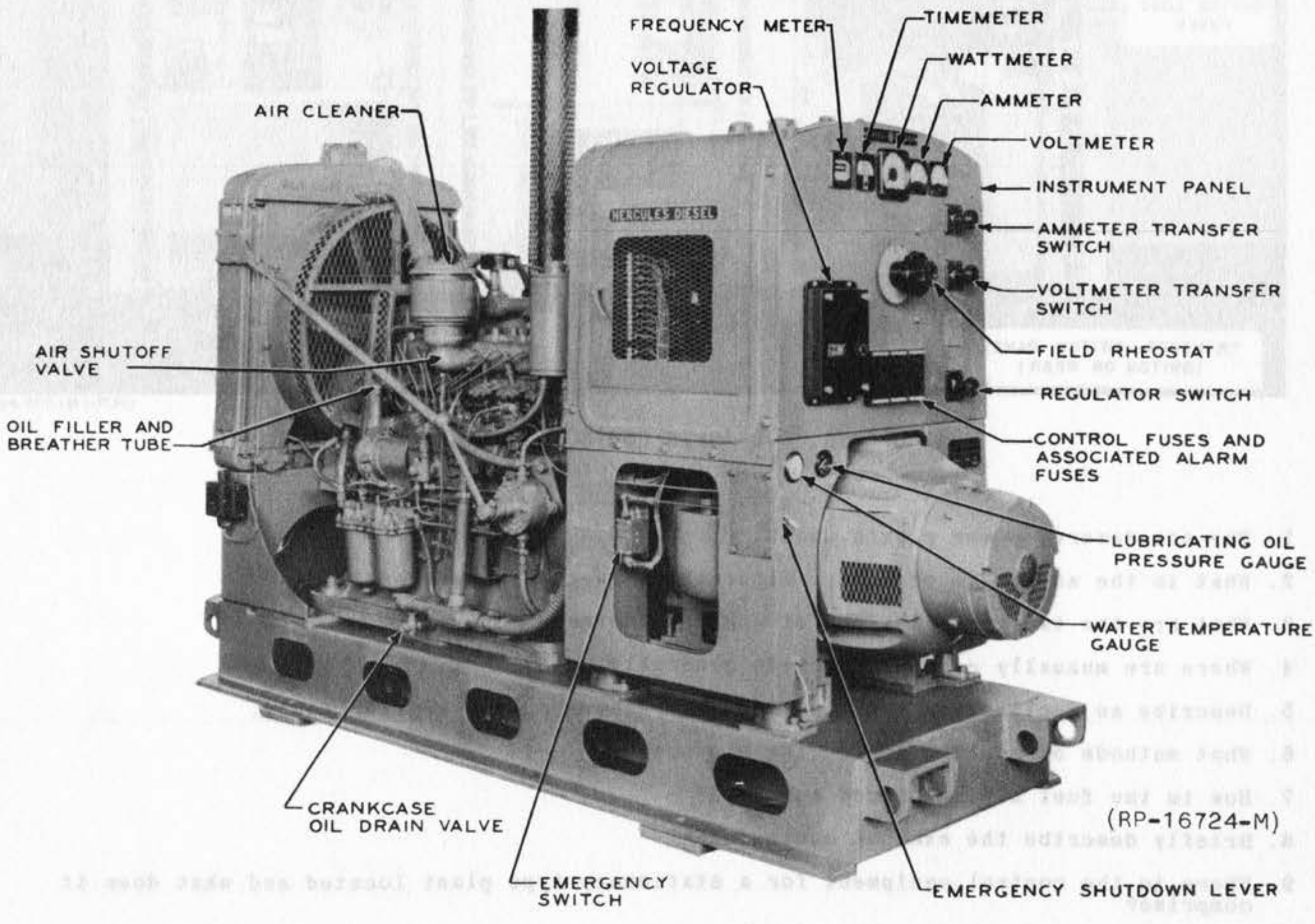


FIG. 7-7 20KW ENGINE ALTERNATOR SET

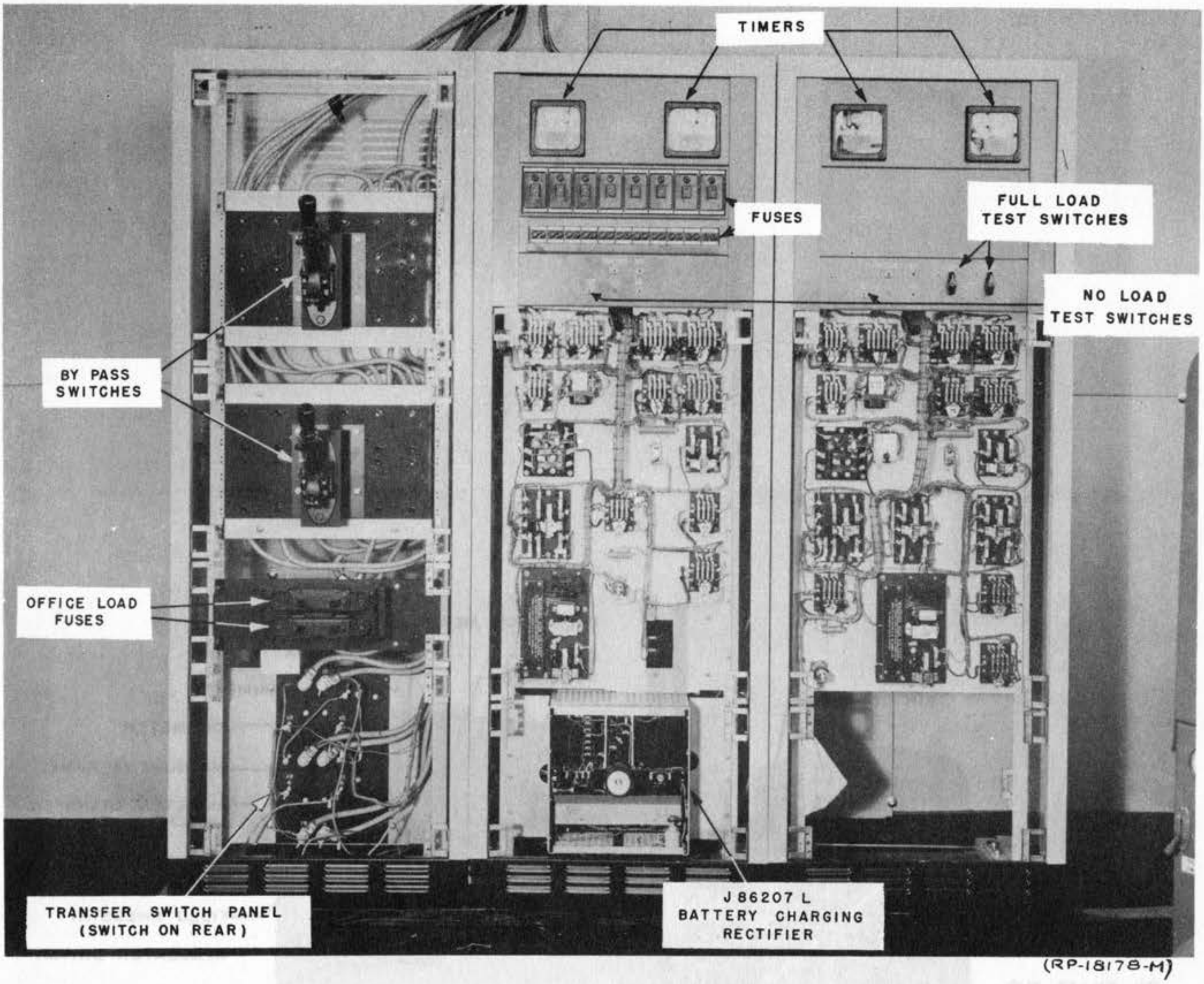


FIG. 7-8 MAIN CONTROL CABINET

QUESTIONS

1. Why are reserve power plants used?
2. What is the advantage of engine alternators over dc generators?
3. What are the two general types of engine alternators?
4. Where are manually controlled units generally used?
5. Describe an application where engine alternators supply regular power.
6. What methods of cooling the engine are used?
7. How is the fuel supply stored and used?
8. Briefly describe the exhaust equipment.
9. Where is the control equipment for a stationary type plant located and what does it comprise?
10. What is the principal difference between a portable and a stationary set?

8. AC POWER SUPPLY FOR L CARRIER

8.1 General

8.11 Continuous 230 volt, 60 cycle alternating current power is supplied to L carrier equipment from motor alternator sets. They consist of single-phase, self-excited alternators operated normally from commercial ac service by 3-phase induction motors and during emergencies from the 130 volt central office battery by dc motors all connected on the same shaft.

Three capacities of alternator sets are presently available, namely, 10, 16 and 21-KVA. The 10-KVA set is usually used in stations sending power in one direction for each pair of coaxials or in both directions when the number of auxiliary stations limits the power required within its capacity. The 16-KVA set is usually specified in stations sending power in two directions where the capacity of the 10-KVA set is insufficient. The 21-KVA set has application only for long spans in both directions.

8.12 By supplying the power from the alternator instead of direct from the ac commercial service, the effect of instantaneous changes in the coaxial current due to ac commercial service fluctuations will be reduced and will insulate the coaxials from surges and transients from the ac service due to lighting, power line crosses, etc. On ac commercial power failure or low voltage, a control circuit automatically transfers the drive from the ac motor to the dc motor. The sets are especially designed to include large amounts of inertia in their rotating elements to maintain nearly constant alternator output during the motor transfer and to prevent too rapid changes in the output during motor surges.

8.13 The output from the motor alternator sets is connected to one or more power control bays which supply a substantially constant current to a power section. Means are provided for manual regulation with safeguards to remove personal hazards as well as high voltages due to improper operation.

8.2 Two Motor Alternators

8.21 A two motor alternator set consists of a single-phase, rotating armature-type alternator with exciter, direct-connected to either a 3-phase or a single-phase ac squirrel cage induction motor and a dc shunt motor. They are mounted on a common subbase having resilient mountings and normally operate continuously from ac line motors which have a suitable output to drive the alternator at full load and the dc motor at no load. All sets are started from the central office 130 volt battery under manual control until up to normal speed and voltage limits. Figure 8-1 shows the 2 motor alternator set used on L3 carrier.

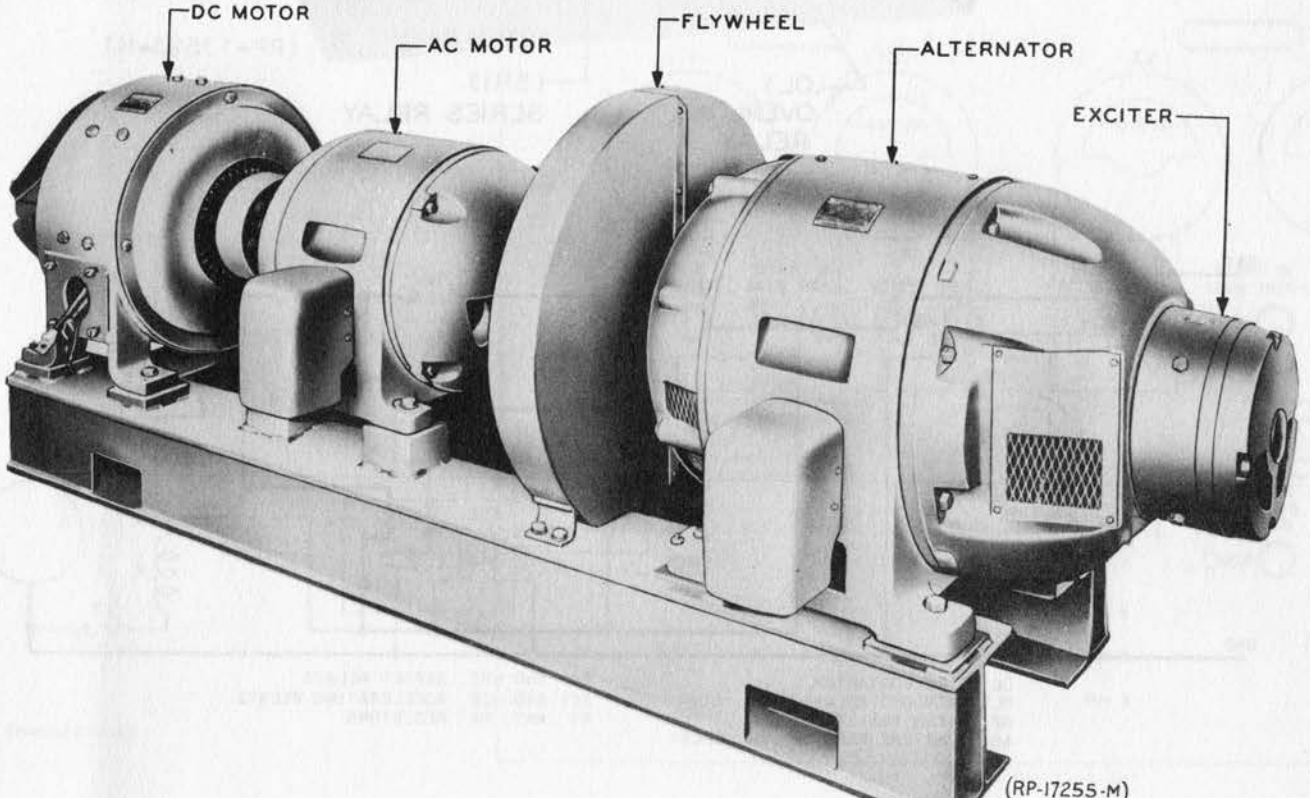
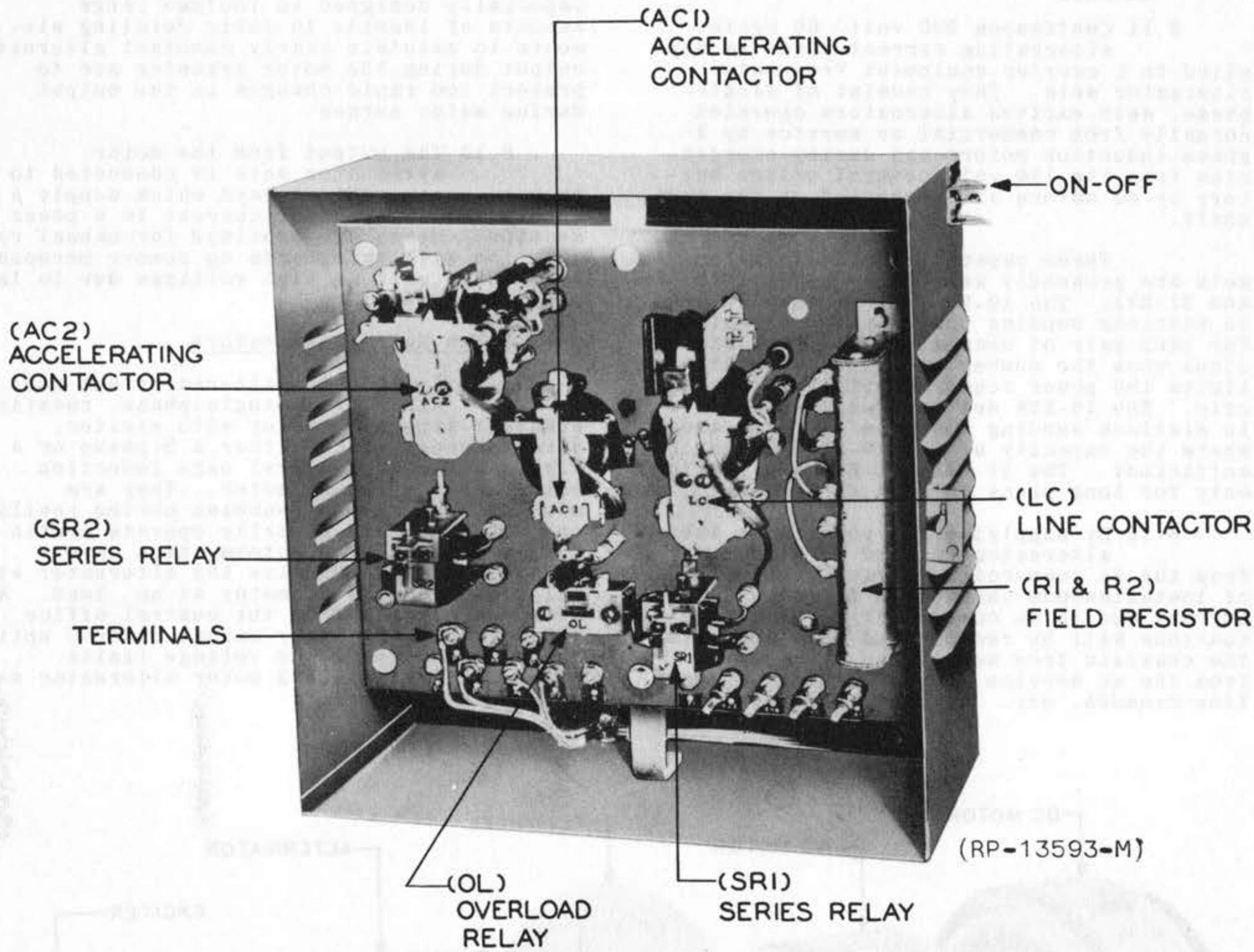
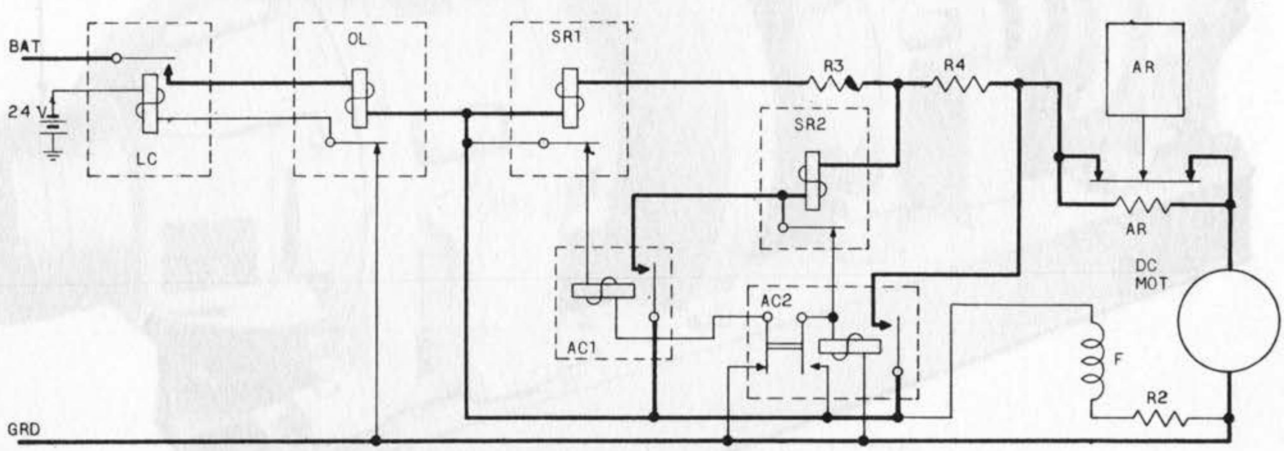


FIG. 8-1 TWO-MOTOR ALTERNATOR SET





LC LINE CONTACTOR
OL OVERLOAD RELAY
R2 FIELD RESISTOR
AR ARMATURE RESISTOR AND RELAY

SR1 AND SR2 SERIES RELAYS
AC1 AND AC2 ACCELERATING RELAYS
R3 AND R4 RESISTORS

(RP-13560-M)

FIG. 8-2 MOTOR CONTROLLER PANEL AND SCHEMATIC

8.22 The output of the alternators of these sets is fed to a power control bay where the 230 volt, 60 cycle supply voltage is stepped up to the required voltage and automatically regulated to maintain a constant current to the power packs of office repeaters and over the coaxials to the power packs of auxiliary repeaters. The alternator, associated with each power section has a designation such as ALT 2 L201-202, etc.

8.23 An emergency alternator set is run continuously at no load, driven by its ac motor normally. This set is a common emergency for a maximum of 4 regular sets for supplying an 8 coaxial system. The emergency set is arranged through a common control unit to replace automatically any regular set that fails or goes low in voltage or that is removed from service for maintenance.

8.24 Alarms are provided for fuse failure, alternator failure, power failure, alternator high low voltage, or failure of the ac motor to hold the alternator voltage above 90 per cent of normal voltage.

8.25 A motor controller panel which contains the contactors and resistors for controlling the starting and running of the dc motor, is mounted on a start control panel directly associated with each motor alternator set. A typical controller panel of this type and a schematic arrangement are shown in Figure 8-2.

8.26 Keys mounted on a transfer control bay provide means for starting and stopping, transferring the load to and from the emergency alternator, transferring the drive from one motor to the other, cutting off alarms, and testing automatic throwover due to power failure. A typical motor alternator control panel is shown in Figure 8-3.

8.27 On ac power failure or low voltage, a marginal control circuit automatically transfers the drive of the set by opening the input to the ac motor and shorting a current-limiting resistance in the battery supply circuit of the dc motor to allow the dc motor to pick up the drive quickly. On resumption of commercial power, after a short delay, to allow the ac service to become stable, automatic transfer returns the drive to the ac motor, reinserts the resistance between the dc motor and the battery, and shorts out a portion of the field resistance to keep the dc motor field at the proper value. During dc motor operation, the speed of the set will be determined by the battery voltage. A fixed field resistance setting on the field resistance mounted on the dc motor controller unit is required to match the ac motor speed at the mean battery discharge voltage.

8.28 Auxiliary charging equipment is required for use in recharging the 130 volt battery of the power plant where the rectifier equipment furnished to float the light normal battery load is inadequate for the heavy emergency load imposed by the

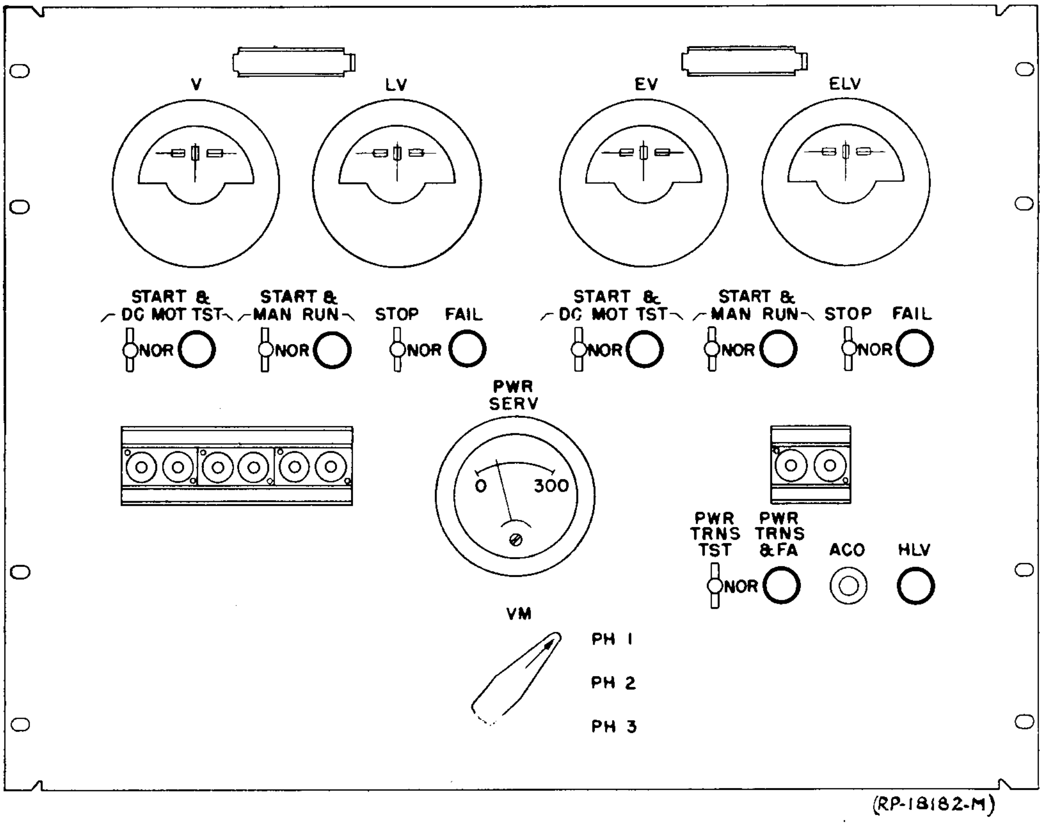


FIG. 8-3 MOTOR ALTERNATOR CONTROL PANEL

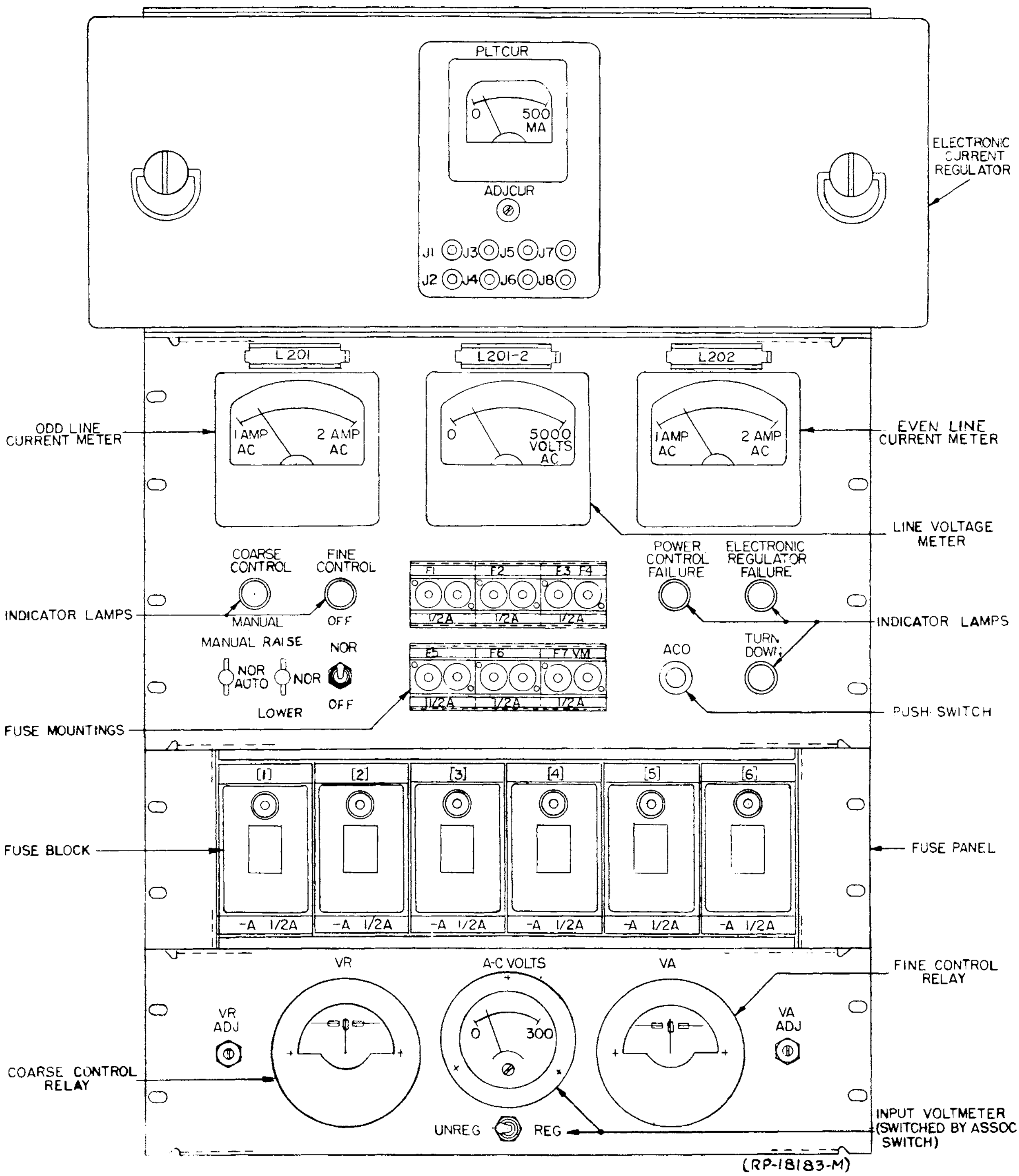


FIG. 8-4 POWER CONTROL PANEL

motor alternators. This control brings in an automatically controlled charging generator operated from the ac service whenever the battery stays at low voltage for a period of approximately 6 minutes. Once connected to the battery, this generator is controlled to charge the battery to its maximum voltage and the control functions to hold this charge for a predetermined time up to 6 hours, after which the battery is returned to its normal float condition.

8.3 <u>Power Control Bay</u>

8.31 The power control bay receives the 230 volt ac output from the motor alternator sets and regulates it for one power section and the associated office repeaters.

A power section is a series loop through the central conductors of two coaxials with the primary windings of the auxiliary repeater transformers in series at each repeater point. The power control circuit output voltage is applied to the input of a power section, the voltage depending on the length of the power section.

8.32 Power for the L3 carrier system involves supplying regulated and unregulated 230 volts to office repeater equipment and regulated current over the coaxials to power sections of auxiliary repeaters. Step-up transformers with secondaries tapped at suitable increments provide power for auxiliary repeaters at 1.5 amperes at any voltage up to 4400 volts depending on the length of the power section. Protective switches are furnished on each power control bay which open the power circuit to the high voltage transformer when the covers to the high voltage panels are removed.

8.33 The particular current for each of the two lines of each power section is usually specified on a card holder mounted just above each of the two ammeters on the power control bay shown in Figure 8-4. The power control bay is shown in Figure 8-5.

8.34 A resistance in series with the coaxial current circuit provides a drop for controlling motor driven variable transformers to raise and lower the supply voltage to the step-up transformer as required to maintain constant coaxial current. Two types of control are furnished; a fine ± 1 per cent control using an electronic regulator to control the motor which drives a fast acting small variable transformer which has a buck-boost range of 10 per cent of the total, and a coarse control using relay control of a motor driving a large variable transformer. This large variable transformer mounted in the base of the control bay is slower acting and normally serves to hold the fine control within ± 3 per cent of a center position so that the fine control will be ready at all times to correct for anticipated changes.

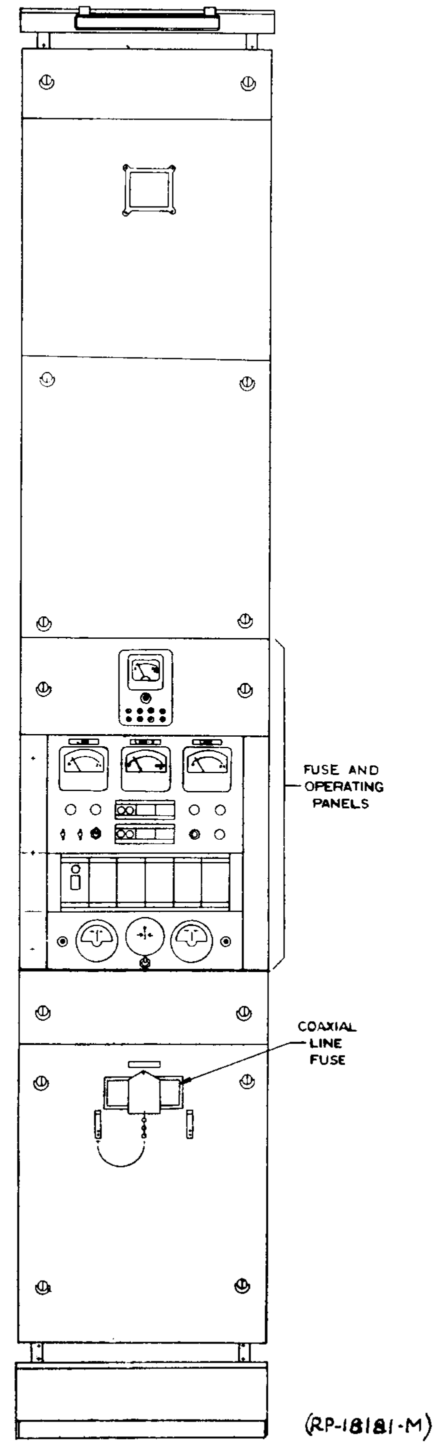


FIG. 8-5 POWER CONTROL BAY

8.35 The course control arrangement also provides emergency regulation within ± 3 per cent in the event of fine control failure and a means for manually turning power up or down on the cables as well as turndown protection in case of trouble such as an open cable.

8.36 Suitable alarms are furnished to indicate fuse failures, high or low line current if it persists more than 1/2 second, or line current failure in either of the two coaxials. Manual controls are included with each power control panel to raise or lower the line current.

QUESTIONS

1. Why are motor alternators used to supply ac power?
2. Describe how a motor alternator functions regularly and during commercial power failures.
3. What is a power control bay and what is it used for?
4. What safety precautions are furnished?
5. What means are provided for regulating the constant current output of the power control bay?
6. What is a power section?

9. POWER CABLING AND WIRING

9.1 General

9.11 Conductors in cables or in conduit are used to extend the commercial power supply to charging, ringing and other motor driven equipment including rectifiers and to lighting and plug fixtures. They are also used to distribute converted ac or dc power to the equipment in the telephone central office. Conductors may be insulated, solid or stranded wires or they may be bus bars which depend upon spacing and non-conducting supports, for their insulation.

9.12 The size conductor required for each particular application will depend on the following factors:

(a) The safe carrying capacity. This is the amount of current a conductor will carry without becoming overheated. An open bus bar of a given sectional area will safely carry more current than an equivalent insulated wire or cable because the bus bar, being directly exposed to the air, radiates heat more readily than does an insulated wire or cable. In general, this factor is controlling for ac circuits since in dc circuits the voltage drop considerations usually dictate the size conductor thus insuring more than an adequate safe carrying capacity.

(b) The permissible voltage drop. This is the amount that may be lost in a pair of conductors, and still supply sufficient potential at the end of the loop to insure that the apparatus served will not fail to operate. It is computed at the maximum current which the conductors are expected to carry. In some instances the allowable drop is in the order of one-tenth of a volt while in others, it may be one-fourth or one half volt.

(c) The limitation of noise. This is accomplished by making the conductors, which are a common source of supply to a number of circuits including telephone transmitters and receivers, sufficiently low in reactance or effective resistance so that the inductive effect is at a minimum.

NOTE: Other precautions which are necessary to limit cross-talk and noise, are covered later in this section.

(d) The size fuse to which the conductor is connected. Main discharge fuses are frequently selected which will carry indefinitely somewhat more current than the expected peak load. This is done as an extra precaution against service interruptions in case some unusual conditions arise. The conductors connected to those fuses must then be made sufficiently large to be protected by the fuses. This means that they must be larger than would be required on account of carrying capacity determined by the maximum load, and in the case of very short discharge leads, larger than needed to meet the voltage drop and noise requirement.

9.13 The various terms used in connection with conductors, cables, etc. are as follows:

(a) "Armored Cable" is usually a multiconductor flexible cable consisting of flame retarding, moisture - resistance wires helically wound with paper, or other fiberous covering, and a flexible metallic armor. The wire is 600 volt type "RH" braided rubber covered as defined by the National Electrical Code. Armored cable may be used in telephone power plants for power service to motors, rectifiers, for ringing and tone circuits and for frame and aisle lighting circuits. Sizes are from No. 14 A.W.G. to 500000 cm.

(b) "Braided Rubber Covered" (BRC) cable and wire is usually 600 volt, type "RH." This wire is made in sizes No. 14 A.W.G. to 800000 and is used in power plant conduit or on racks where required.

(c) "Cable" is an assembly of two or more conductors. Single conductors, whether solid or stranded, are called wire.

(d) "Charge Conductors" are those between charging units and the battery or the point at which discharge conductors connect.

(e) "Discharge Conductors" are those that carry discharge current from the battery. Counter Electro-Motive Force Cell (CEMF), electrolytic condenser and choke coil conductors are classified as discharge conductors.

(f) "Filament Conductors" are those carrying direct current to filanent circuits.

(g) "Paired Conductors" are conductors of opposite polarity of a given circuit run close together (but not necessarily twisted) so that the interlinking magnetic fluxes from currents in opposite directions neutralize each other. Three conductors (ground, 24 volts and 48 volts) are considered paired if run close together. Bus bars are considered paired if run on 3" centers, or as close as the plant equipment arrangements permit.

(h) "Plate Conductors" are those carrying current to plate circuits.

(i) "Service Circuits" are used to designate bus bars or wires connected to commercial power service or to a local reserve engine alternator set during power failure.

(j) "Signaling Conductors" are those classified generally as telegraph, signal, ringing and tone.

(k) "Singly Run Conductors" are those not paired with a conductor carrying current in the opposite direction.

(l) "Sleeves" are conduit nipples or short length of conduit or smooth iron pipe or fiber duct. They are frequently used to protect cables or wires passing through walls or floors.

(m) "Telegraph Conductors" are those carrying current to telegraph or teletypewriter equipment.

9.14 For convenience in handling, and in stocking the conductors, as well as, the terminals and bus bar clamps used with them, power cables are limited to 800,000 circular mils in area, and bus bars 12 inches wide x 1/2 inch thick. Where more conductivity than would be provided by using these maximum sizes is required, parallel cables or laminated bus bars are used. In many instances, space considerations require the use of laminated bus bars less than 12 inches in width.

9.2 Commercial Power Service Leads

9.21 Commercial power service supply leads are brought into the building and terminated on a service panel which is equipped with fuses or circuit breakers or other protective devices as required. From the service panel, circuits are extended to various parts of the building for lighting and other power services not directly associated with the telephone equipment and to a second service panel for telephone equipment known as the power service cabinet. All of this work is customarily arranged for by the telephone company prior to the start of the telephone installation work.

9.22 The power service supply for the telephone power plant is picked-up at the power service cabinet by the installer, and extended, through suitable fusing to the various machines, etc., with their control apparatus. Electric power service for frame and aisle lighting and for convenience outlets at frames and switchboards is usually picked up by the installer at the lighting panel boxes previously provided by the telephone company. All wiring which is either normally or intermittently connected to the commercial power supply sources or to equivalent sources such as reserve engine alternator plants located in the telephone buildings, is either run in conduit or with armored cable.

9.3 Inductive Interference In Power Wiring

9.31 Precautions are necessary in power plant wiring, to insure that the currents flowing in or the voltages maintained on certain wires do not cause objectionable reactions on other circuits through inductive and capacity effects.

9.32 To reduce these effects to a minimum, conductors are paired to neutralize their inductive effect; talking (quiet) battery leads and signaling battery leads are run separately at specified distances apart; and conductors carrying ringing, tone and other high and low frequency ac currents having high voltage peaks including service circuits, are run in armored cable or conduit. In addition, leads which feed amplifiers are shielded since any inductive effect would be amplified along with the voice current.

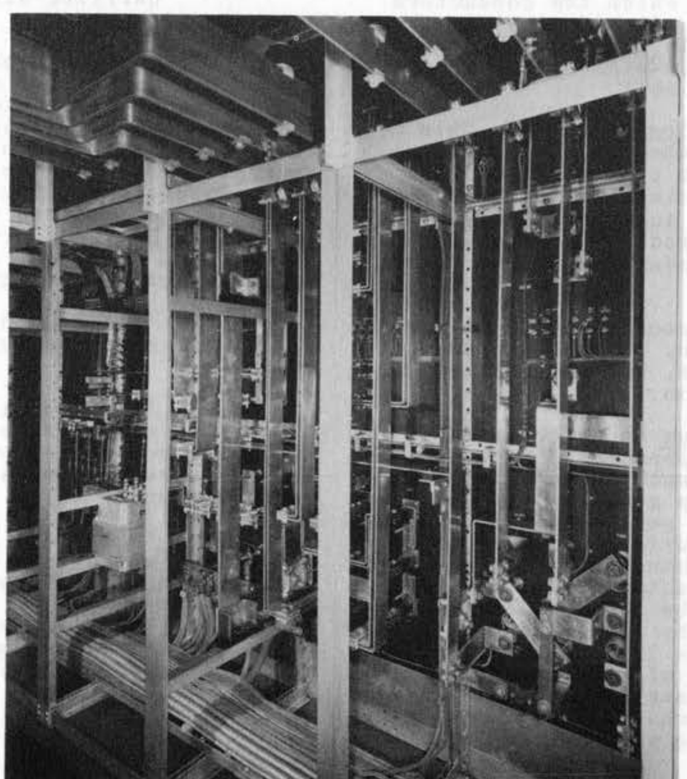


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FIG. 9-1 REAR VIEW OF BATTERY CONTROL BOARD

9.4 Bus Bars

9.41 Where the available space permits, as in runs between charging machines, power boards and batteries, aluminum bus bars are usually used. For any given current carrying requirement, an aluminum bus bar is approximately one and one-half times as large as a copper bar. Owing to the relatively lighter weight of the aluminum, its weight is about one-half of that of the equivalent copper bar. Figure 9-1 shows a typical arrangement of bus bars on the rear of a power board.

9.42 In addition to the weight advantage which makes aluminum bus bars easier to handle than copper, it requires no protective finish even when located in rooms with open type storage batteries, and presents a very good appearance in a telephone office where most of the ironwork and apparatus is finished with aluminum colored paints and enamels.

9.43 To insure satisfactory contacts when aluminum bars are joined together, or to other metals, it is customary to apply petrolatum to the aluminum surface which is to form the connection before cleaning the surface by means of an abrasive. The reason for this is that this metal oxidizes rapidly on exposure to the air, and if not coated with some material which will exclude the air, satisfactory connections would not be obtained. Figure 9-2 shows an arrangement of bus bars joining two battery line-ups. The batteries are sealed rubber tank type and are rated at 5000 ampere-hours.

9.5 Central Office Grounds

9.51 Earth connections or central office grounds, perform several important functions. One of these is the provision of a low resistance path to earth, for dissipating lighting and other strong currents intercepted by lightning arrestors and protectors. Another function is to ground one terminal of the central office common battery to minimize the trouble encountered in case of a cross with a high potential line. Usually this is the positive (+) end of the batteries. If this were not done, that is, if a common battery telephone exchange were insulated from the earth, and some portion of the wiring became crossed with the wiring of an electric light, power or railway distribution system, the potential of the telephone system would be raised to that of the other system and subject the telephone apparatus to voltages which may be higher than they were designed to withstand and subject personnel to unnecessary unusual voltages. Similarly all frames, racks, etc., which support equipment are grounded so they will not be sources of danger to people working in telephone central offices nor to telephone apparatus and equipment.

9.52 Some circuits used in the telephone plant utilize the earth as part of their operating paths. This is particularly true of ringing circuits where selective and semi-selective party ringing is used on subscriber sets and for dc telegraph and simplex or composited dc signaling.

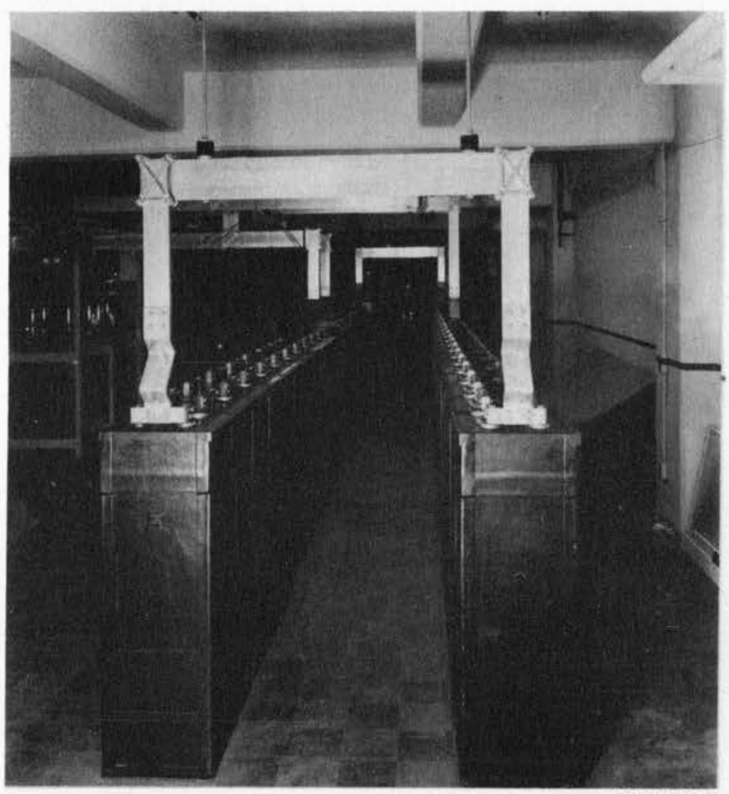

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FIG. 9-2 BUS BARS CONNECTED TO SEALED BATTERIES

9.52 Because of the importance of these grounds, it is customary to make use of the piping of water supply or gas distribution systems which can usually be depended upon to be adequate as to low resistance and carrying capacity. In some instances, such as at repeater stations and small manual and dial offices, where water or gas system piping is not available, what are known as made grounds must be uitilized. Several methods of producing these have been used. The present standard method is to drive several pipes or rods into the ground, preferably in the basement of the building housing the telephone plant. The pipes or rods are spaced six to ten feet apart, and are bonded together so as to form a unit.

QUESTIONS

1. What types of conductors are used in the telephone plant?
2. What four main considerations determine the size of conductors to be used?
3. Why will an open bus bar safely carry more current than an equivalent insulated wire or cable?
4. What is meant by the term safe carrying capacity?
5. Describe what is meant by "permissible voltage drop".
6. What three main precautions are taken to prevent inductive interference in power wiring?
7. Outline the advantages of aluminum bus bars.
8. What are two reasons for a Central Office Ground?
9. What is the usual method of obtaining a ground?