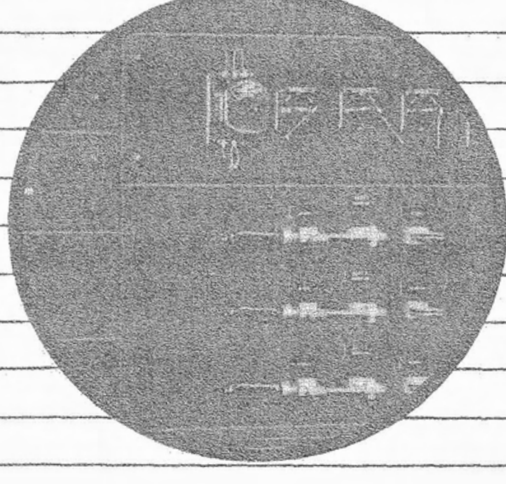
AUTOMATIC ELECTRIC TRAINING SERIES | Bulletin 812

POWER AND SUPERVISORY EQUIPMENT

STROWGER AUTOMATIC TELEPHONE SYSTEMS



AUTOMATIC ELECTRIC
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Power and Supervisory Equipm

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AUTOMATIC ELECTRIC TRAINING SERIES

STROWGER AUTOMATIC TELEPHONE SYSTEMS

May we send you others
pertaining to equipment in your exchange ?

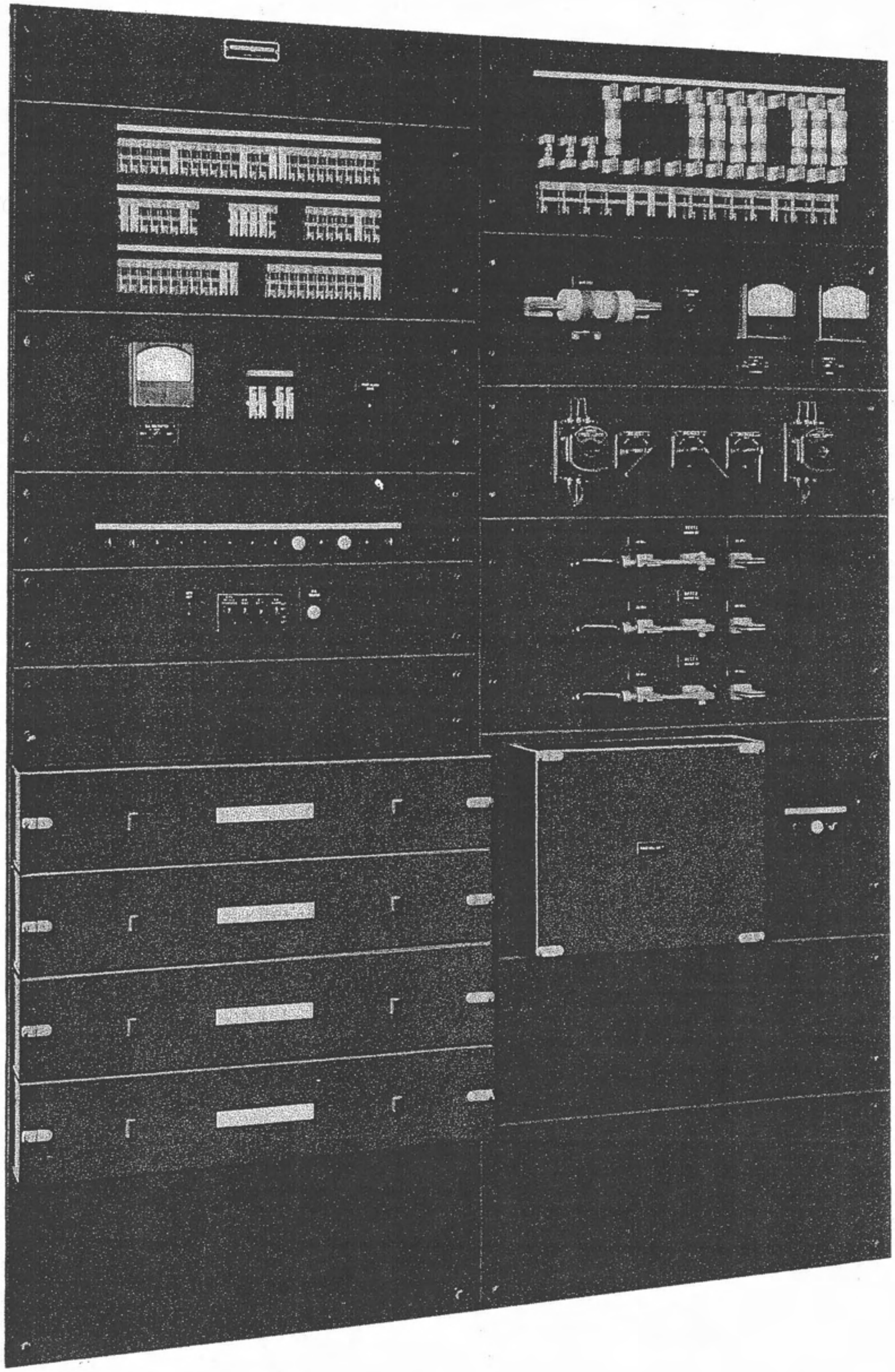


Figure 1. Powerboard for a moderately sized telephone central office.

POWER AND SUPERVISORY EQUIPMENT

1. INTRODUCTION

The purpose of this bulletin is to explain the equipment in a telephone central office used for power supply, ringing supply, and for supervisory purposes. This includes the equipment used for the production, regulation, control, protection, and distribution of electrical power (voltages, frequencies, and tones required for operating a common battery telephone central office). It also includes the equipment and circuitry used to monitor, to control and regulate if possible, and to signal the occurrence of nonstandard or trouble conditions of the switching equipment and power supply equipment and facilities.

The electrical power used in a common battery, automatic, telephone central office includes the following: 50 volts dc (approximately) for voice transmission and for operation of the switching and control equipment; one or more a-c voltages at various frequencies from 16-2/3 cps (cycles per second) to 66-2/3 cps for operating the audible signals at the subscribers' stations; various tones, both interrupted and steady, and pulses (or interrupted voltages) for audible, and sometimes visual, indication of various conditions of the equipment and circuits in the central office. This includes the following equipment: d-c generators, batteries, a-c generators, tone generators, and interrupting equipment; a powerboard with some control, distribution, protection, and alarm-indicating features; and individual fuse, fuse alarm, and equipment-operation and failure-indicating panels and circuitry on each shelf.

1.1 Primary-secondary Equipment

Most telephone exchanges are operated from the commercial a-c power supply in the area. Rectifiers or rotary converters (motor generators) convert this a-c power to 50 volts dc to operate the exchange equipment and keep the battery fully charged.

Each exchange must also have one or more sources – or converters – to supply ringing current, tones, and operate the interrupter; these may be separate units, or, more often, two or three may be combined into a single unit. These units, either singly or collectively, may be operated by a-c power (normally from the commercial a-c source) or by d-c power if preferred or necessary. Each unit (ringing generator, tone generator, interrupter, or combination unit) usually has an alternate or stand-by unit which may be used in its place if it should fail. Depending on the type of equipment (and, in part, on the age of the office), the stand-by equipment may be operated either by the same type of power (ac or dc) or by different power (dc or ac) if desirable for any reason.

Whenever possible more than one d-c charging unit is installed so that some degree of service may be maintained in case of failure of one charger unit. The battery also helps maintain service in case of charger failure or overload. The battery is used to maintain service during transfer operations, to cause the transfer to take place, and, if necessary, to operate the exchange if all other sources of power fail.

1.2 Auxiliary Engine-driven Equipment

Some installations also include one or more engine-driven, a-c generators which may be used in case of failure of the commercial a-c power to the exchange. This may be used simply to operate the d-c power equipment (rectifier or d-c generator) with the d-c power in turn used to run alternate (d-c operated) ringing tone-interrupting equipment; or the stand-by a-c power supply may be connected directly to the a-c operated units.

An auxiliary engine-driven generator consists of an a-c generator driven by either a gasoline or Diesel engine. Exchanges usually use engine-driven auxiliary generator equipment when the a-c power is not very reliable and/or they either prefer to or must use a small capacity battery (one which can carry the exchange load for only a relatively short period of time). An exchange which uses engine generators may have one or more units, depending upon the size of the exchange and the load. The number and total capacity of the units used is sufficient, normally, to supply the maximum busy-hour load plus any other emergency equipment required. The fuel tank

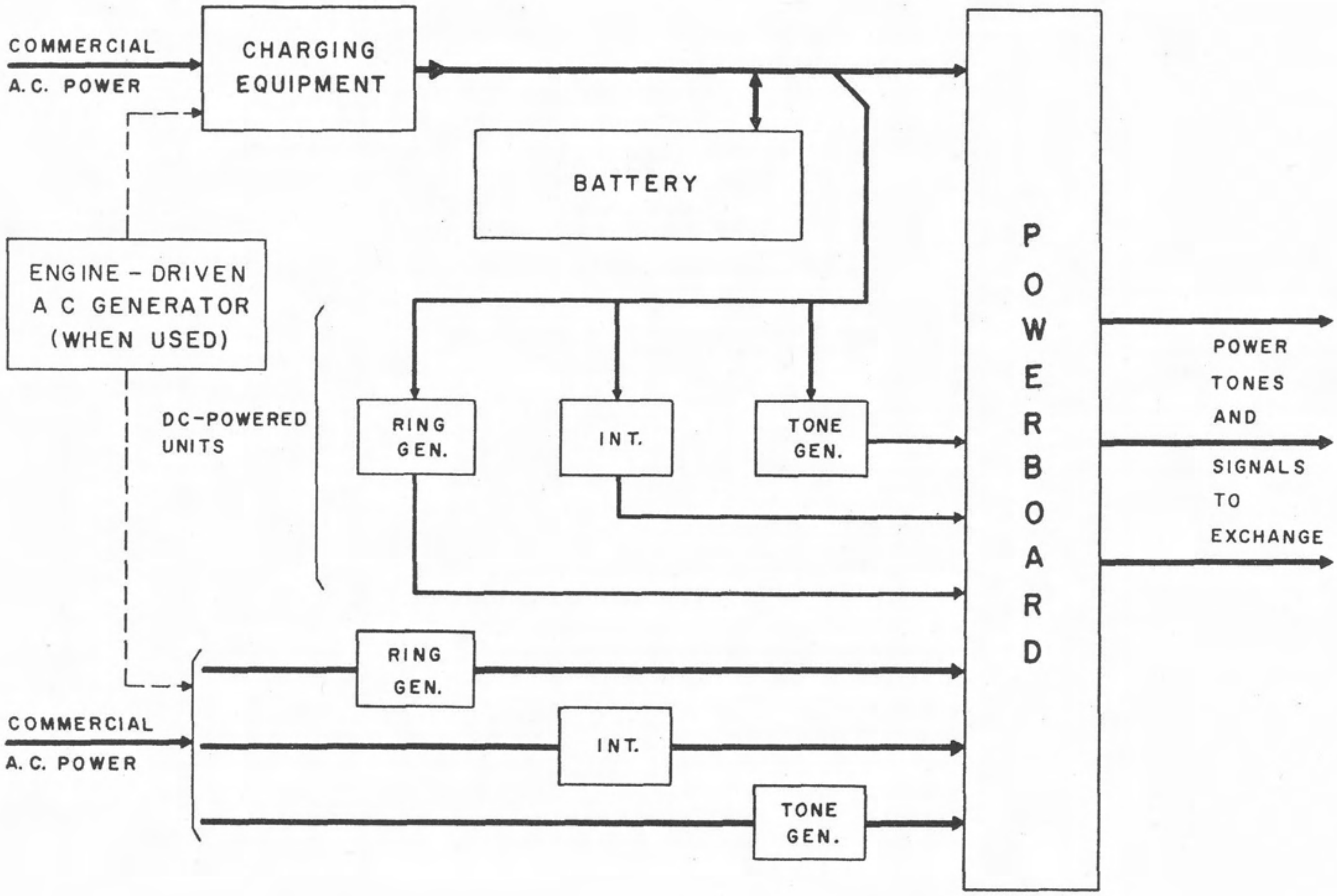


Figure 2. Block diagram of central office power supply equipment showing auxiliary apparatus, and relations and interconnections between units.

may be as large as necessary to operate the engine and exchange for whatever period of time desired.

When an exchange uses engine generators, the battery capacity is usually only great enough to supply the exchange load until the engine units are started. Engine generators are normally furnished with automatic starting; they are available with manual starting only if desired.

2. D-C POWER

Generators and rectifiers provide most of the 50-volt d-c power required by telephone exchange equipment. The operating range of most exchange equipment is about 46 to 52 volts. When the power supply equipment cannot meet the load current demands of the exchange, as during peak loads or commercial power failure, the exchange battery furnishes the required power. The power supply equipment also functions to keep the battery fully charged for emergency use.

The powerboard is the control center of the power supply equipment. This board holds the voltage-control equipment for the charger units and the battery. The board also has fuse panels for distributing the power to the exchange equipment and for protection against short circuits.

2.1 The Exchange Battery

The exchange battery is a group of electric storage cells connected in the proper combination (series or series-parallel) to furnish the voltage and current required by the exchange equipment. The battery serves three main purposes to the exchange: (1) provides the additional power which might be needed for peak loads, (2) supplies stand-by emergency power in case the a-c power fails, and (3) filters any ac which is not completely rectified in the d-c power supply.

If there is a commercial a-c power failure, the battery normally has a sufficient capacity to supply the average busy-hour (maximum normal) load continuously for a period of about 5 hours. The size of the battery and the type of control equipment used is dependent upon the size of the exchange, the reliability of the commercial power, and the presence of engine-driven power supply equipment in the exchange.

2.1.1 The electric cell.

The electric cell is a device which stores electrical energy in the from of potential chemical energy. Each cell has three essential parts: a container, an electrolyte, and electrode plates. The container holds the electrolyte which stores the chemical energy; the electrode plates are immersed in the electrolyte and carry the electrical energy from the electrolyte to the two terminals on top of the container.

When the cell is charged, the stored energy in the electrolyte creates a potential difference (a voltage) between the cell terminals. For example, the potential of a fully charged lead-plate cell is about 2.05 volts; when a conducting path is connected between the terminals, the voltage causes the cell to discharge or deliver an electric current. During discharge the cell loses potential energy, and the voltage gradually decreases. When the voltage falls below a certain value, such as 1.75 volts for a lead-plate cell, the reserve power of the cell is considered exhausted, since any further discharge causes the voltage to rapidly drop to zero. The complete discharge of a cell often causes permanent damage to the electrode plates.

There are two types of cells, the dry cell and the wet cell. The dry cell contains a paste electrolyte, and it cannot be recharged. The wet cell uses a liquid electrolyte; it can be recharged. The magneto telephone, which has a very light demand for power, uses the dry cell. The telephone central office battery, which has a rather heavy demand for power, uses the wet cell.

2.1.2 The 23-cell battery.

A 23-cell battery consists of 23 wet electric-storage cells connected in series. Each cell has a 2.05-volt fully charged potential, giving the battery a total potential of about 47.2 volts. This battery is both sufficient and economical for up to approximately a 1000-line exchange where the commercial a-c power supply is reliable, or where all operations cease if the commercial power fails. A minimum of control equipment is required for the 23-cell battery, since all 23 cells are always used together.

2.1.3 The 23-cell battery with three end cells:

In exchanges of approximately 1,200 lines and larger, a 23-cell battery having three additional wet electric-storage cells, called "end cells", is generally used. Figure 3 illustrates the connection of the end cells in the battery circuit.

If there is a commercial power failure, the 23 regular cells will supply the exchange power immediately; when the potential of the 23 cells drops from the fully charged value of 47.2 volts to some preset value between 46 and 47 volts, the three end cells are automatically connected in series with the 23 cells. The result is a 26-cell battery with a potential of about 52 volts.

2.1.4 Counter-electromotive force (CEMF) cells.

The CEMF cell is a special type of cell used to regulate battery potential. The function of the CEMF cell differs from that of the regular battery cells; instead of contributing to the battery potential, the CEMF cell lowers it by developing a potential equal to and opposing that of one regular cell. The CEMF cell creates this counter-potential only while current flows through it.

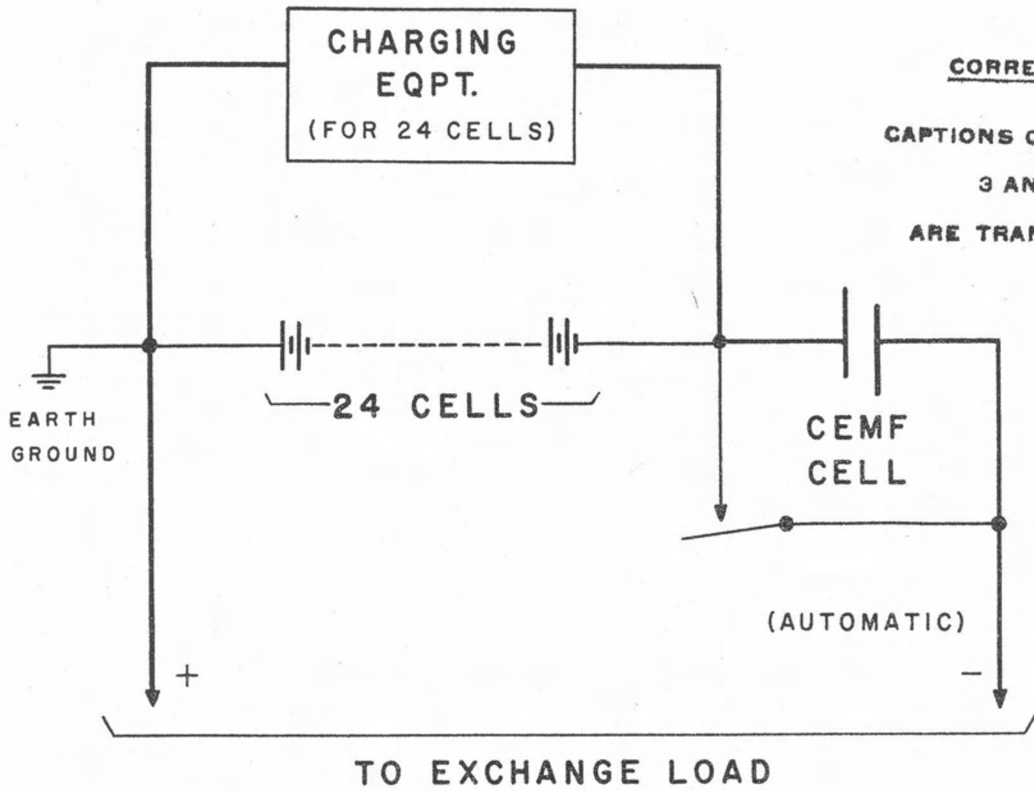
The most widely used wet CEMF cell is the alkaline CEMF cell, which has a sodium hydroxide electrolyte and pure nickel or stainless steel electrodes. The counter-potential developed by this cell varies from 1.70 to 2.25 volts, depending upon the amount of exchange load current it carries; the greater the current, the higher the counter-potential. Another type of wet CEMF cell is the lead-plate CEMF cell; the use of this cell is not as extensive as that of the alkaline CEMF cell.

The dry CEMF cell, made of special plates which maintain a fairly constant counter-potential within a given range of current, is a more recent development. This type of CEMF cell comes in current capacities ranging from less than one ampere to over several thousand amperes. Section 2.1.5 describes the specific use of the CEMF cell in an exchange battery.

2.1.5 The 24-cell battery with one CEMF cell.

Except for the simple 23-cell battery which uses little control equipment, a 24-cell battery in series with one CEMF cell is the next most economical type of stand-by power source to use in exchanges of approximately 1,200 lines or less. Figure 4 illustrates the connection of a CEMF cell in the battery circuit.

If there is a commercial power failure, the 24 cells in series with the CEMF cell will supply the exchange power immediately. When the resultant potential of the 24 cells and the CEMF cell drops from the fully charged value of 47.2 volts to some preset value between 46 and 47 volts, the CEMF cell is automatically shorted out of the battery circuit. This removal of the CEMF cell increases the resultant potential to about 49 volts.



CORRECTION

CAPTIONS OF FIGURES

3 AND 4

ARE TRANSPOSED

Figure 3. Schematic diagram of 23-cell exchange battery with three end cells, and including charging apparatus and switching connections.

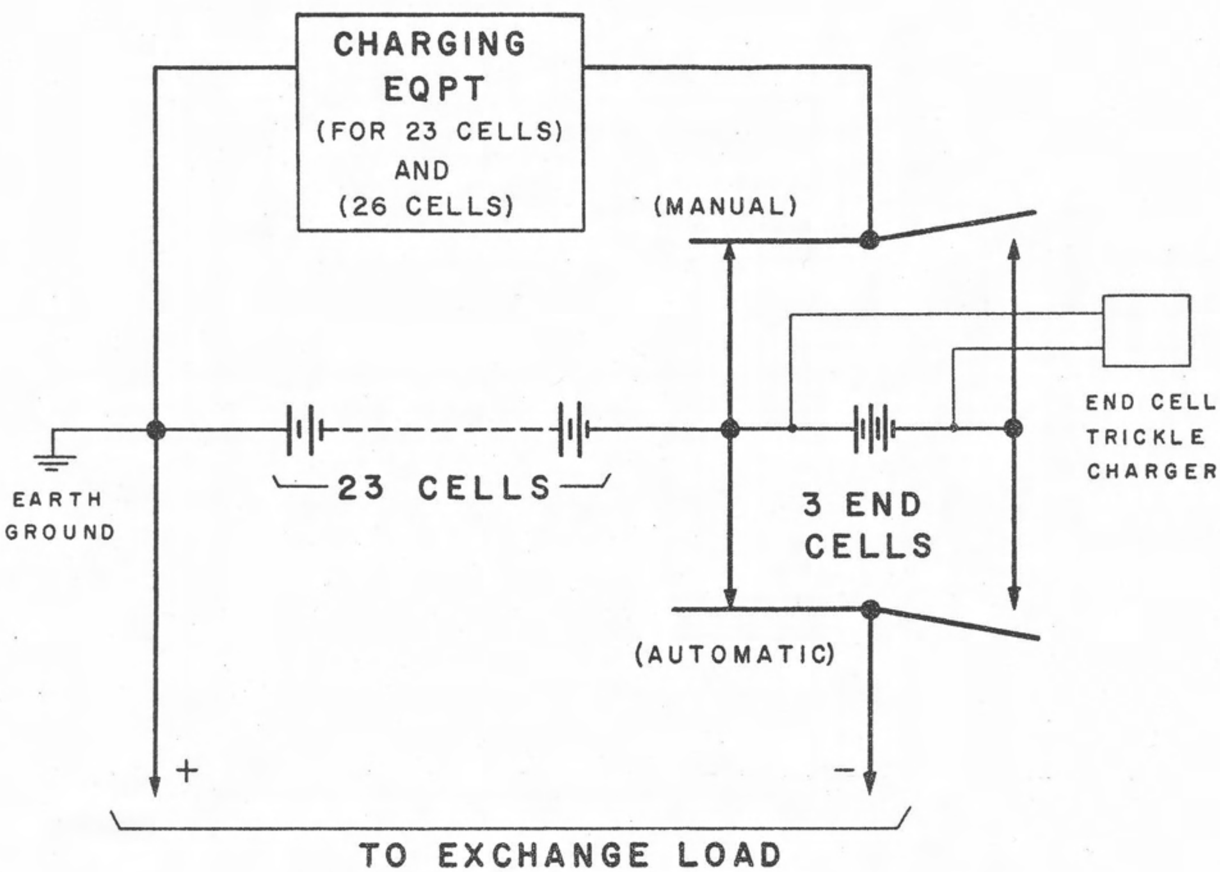


Figure 4. Schematic diagram of 24-cell exchange battery with one CEMF (Counter-electro-motive force) cell, and including charging apparatus and automatic switch.

2.1.6 Exchange battery capacity.

"Capacity" is the term used to denote the power storage or reserve of a fully charged battery. Battery capacity is defined as the amount of current in amperes which a battery will continuously deliver for a given number of hours. The unit of capacity is the ampere-hour.

Many exchanges use a battery of sufficient capacity to provide five continuous hours of the average busy-hour current. If the commercial a-c power is not too reliable, a battery with the capacity to deliver the average busy-hour load for eight continuous hours might be used. If engine-driven charger units are available, a battery with the capacity to deliver the average busy-hour load for only three continuous hours might be used.

There are several factors which affect battery cell capacity. An increase in the area, thickness or number of the electrode plates, or a rise in the temperature of the electrolyte, all increase the cell capacity. However, if this temperature gets too high, reactions may occur within the cell causing it to discharge, even though the battery is not delivering any power. The most efficient temperature for the lead-plate cell is about 70°F.

As the battery discharges, the concentration (specific gravity) of the electrolyte decreases. The concentration of a fully charged lead-plate cell is about 1.215; it is considered discharged when the concentration drops to about 1.150. The charge or available capacity of a battery cell is determined by taking hydrometer readings of the electrolyte concentration.

2.1.7 The battery eliminator.

In areas where the commercial power is very reliable, an exchange which is too small to warrant the cost of a battery installation may use a rectifier power supply unit called a "battery eliminator". This unit has very limited use since it has no provision for stand-by power in case the commercial power fails.

2.2 Charging Equipment and Methods

Charging equipment converts a-c power into d-c power to serve the telephone exchange in the following ways: (1) provides the normal exchange power requirements, (2) charges the battery when the battery potential is low, (3) keeps the battery fully charged for emergency use, and (4) extends battery life by eliminating ontinual "cycling" (discharging and recharging) of the battery. Some of the types of charging equipment are motor generators, and dry-disc rectifiers.

The charging equipment is connected in parallel with the battery to operate the exchange equipment and to charge the battery (if the exchange has one). The equipment normally maintains a constant potential that is slightly greater than the battery potential. The potential difference between the charger and the battery causes a slight current to flow through the battery in a direction opposite to the current flow during discharge; this "float-charging" current maintains the battery charge at maximum value at all times to be ready for maximum emergency use.

The amount of charging current and thus the rate of charge are limited by the capacity of the charging equipment, which is selected in relationship to the capacity of the battery. The capacity of the charging equipment is normally chosen so that it will deliver to a fully discharged battery, in an 8-hour period, enough charging current to recharge it to about 85% of its fully charged condition. When the battery finally reaches a fully charged potential, the charger supplies just enough current to the battery to keep it fully charged. This function of maintaining a full charge, is termed "float-charging". Since the capacity of the charging equipment is lower than the maximum allowable battery charging current, a safe charging rate is assured at all times.

Cost of the charger units, type and size of the exchange and its battery, and the reliability of the commercial power, are some of the factors considered when charging equipment is to be installed. Normally, an exchange uses at least two (or more) charger units to assure that the power supply is sufficient for any period of the day and yet is still economical to use. If one unit cannot supply the entire load, a second unit can be operated to share the load; the charger units usually have equal capacities so that one can replace another in case of a breakdown.

2.2.1 Motor generator charging unit.

A motor generator charging unit consists of a d-c generator driven by an a-c motor; it is usually found in older exchanges. The type of generator most often used is the compound-wound, diverter-pole type, which generates a constant voltage from no-load up to about 110% of the rated capacity of the unit. If the load current from such a generator exceeds this value, the diverter pole and diverter-pole windings will cause the output voltage to decrease in order to prevent overloading of the charging unit.

If the voltage level of the generator falls below that of the battery (due to excessive load), the battery will begin to deliver current to the load in parallel with the generator. If the generator voltage should fall below that of the battery due to some fault or failure condition, and a reverse current begins to flow from the battery back into the generator, a reverse current relay in a generator output circuit (but located on the powerboard) will release and restore, opening the generator circuit and preventing any further back flow of current which might cause the generator to operate as a motor (with considerable harmful effects to the whole exchange power plant).

2.2.2 Rectifier charger units.

The main type of rectifier charger used in telephone exchanges is the dry-disc rectifier. Through recent developments, the dry-disc rectifier has been made more efficient and economical than the vacuum tube type. The dry-disc type has a capacity ranging from a few amperes to 400 amperes. Rectifier charger units use commercial a-c input power, usually 3-phase for larger units and single-phase for smaller units. The d-c output passes through a filter before going to battery and exchange. This filtering helps to smooth out voltage fluctuations and current surges which might cause noise in talking circuits.

These rectifiers put out a constant voltage from no-load up to a maximum which is between 110 and 120% of its rated capacity. If the load on a rectifier exceeds this maximum, an overload protection circuit usually will cause the rectifier voltage to decrease, limiting its maximum load to a safe value. If the rectifier voltage starts to drop, the exchange battery will provide the additional current necessary to operate the exchange.

The inherent high resistance of rectifying devices to reverse potentials or reverse flows of current, prevents any back flow of current from the battery through a rectifier. Reverse-current relays are not required. However, when there is an a-c power failure, or a rectifier is otherwise de-energized, a relay or a hand switch usually disconnects the rectifier from the battery circuit; this action removes an undesirable reverse potential from across the rectifier.

Rectifier units may supplement motor generator charging equipment when the latter is not adequate to provide the increased load requirements of an exchange; however, adapting a rectifier to function properly with motor generator charging equipment requires special control apparatus.

2.2.3 End-cell trickle-charger.

An end-cell trickle-charger unit is a small rectifier which maintains a potential of about 6.45 volts to "float-charge" three end cells of a 23/26-cell battery. Figure 3 shows a trickle-charger unit connected to three end cells.

The usual trickle-charger unit has a capacity of only a few amperes and is not used for charging the end cells; if the end cells become discharged, as after a power failure, they are recharged by the main charging equipment in series with the 23 regular cells.

2.2.4 Constant-voltage battery "float-charging".

The battery is normally kept fully charged. The charging units maintain the potential of the battery at about 0.10 volts per cell above the fully charged value of 2.05 volts per cell. This potential, about 2.15 volts per cell, charges the cells when they are below full charge, and keeps them fully charged once they have reached that state. This float-charge potential is about 49.5 volts for a 23-cell battery, 51.6 volts for a 24-cell battery, and 6.45 volts for the three end cells.

2.2.5 Maximum current self-limiting feature.

Most rectifiers and d-c generators are constructed to limit the maximum current they will produce. If the load exceeds the maximum safe value which a charger unit is designed to carry, the unit output voltage is controlled and decreased to prevent the current from exceeding the maximum safe value. This current limiting feature protects rectifiers and d-c generators against overloads without unnecessary interruptions of service. In general, the maximum safe load ranges from about 115 to 135% above the rated capacity of the units, depending upon their type, size and make.

2.2.6 Equalizing charge.

At regular intervals and/or whenever one or more individual cells of a "fully charged" battery has, for any reason, a lower potential than the other cells, the battery is given an "equalizing" charge. This is done by raising the rectifier or d-c generator output voltage level about 7% or 0.15 volts per cell (to approximately 2.30 volts per cell). The exact value of the equalizing charge voltage depends upon the type of cells and the local exchange practice. The change in output voltage level of the d-c generator unit (or units) is accomplished by increasing the shunt field current. Usually the variable resistance rheostat, located on the powerboard and connected in series with the shunt field windings, is adjusted to do this. In rectifiers, the change in the output voltage level is accomplished by changing the reference-voltage or control voltage to a higher voltage tap (usually by operating a small toggle switch on the rectifier control panel).

2.2.7 26-cell charge.

Since the end-cell trickle-charger normally used does not have sufficient capacity to recharge the three end cells when they become discharged, they are recharged by the main charging equipment in series with the 23 regular cells. To do this the main charger potential is raised to 55.9 volts so that it can charge the full 26 cells; this is accomplished by manually operating a switch on the rectifier or by adjusting the d-c generator field-rheostat on the powerboard. When all cells are fully charged, the main charger is returned to its normal 23-cell float-charge potential of 49.5 volts; the end-cell trickle-charger then maintains the float-charge of the three end cells.

2.3 Control Equipment

The efficient operation of the exchange under all conditions is dependent upon the proper functioning of its control equipment. This control equipment may include voltage-sensitive relays, knife switches, multi-position selector switches, metering devices, and fuses. This equipment will be located as is most suitable for the size and type of exchange, power equipment, and facilities.

2.3.1 Charger control switch.

For each d-c generator and rectifier unit in an exchange, there is one charger control switch on the powerboard. This is a three-position switch with HAND, AUTOMATIC, and OFF positions. Normally at least one charger unit will have its control switch in the HAND position; this unit is maintained energized, supplying power to the exchange equipment and the battery. Usually at least one, or more, of the remaining units will have its control switch in the AUTOMATIC position. With its switch in the AUTOMATIC position, a charger unit will start and operate in parallel with the unit already in operation, if the load exceeds 100% of the rated capacity of the unit already in operation. With its switch in the OFF position, a charger unit is disconnected from the power supply circuit and cannot operate.

2.3.2 Automatic parallel charger operation.

When a rectifier or d-c generator unit has its control switch in the AUTOMATIC position, its start control circuit is connected to an automatic current monitoring circuit, which is essentially a current-sensitive relay, very much like an ammeter with an external shunt and with contacts instead of a calibrated scale. When the load on the first unit (the one already energized with its switch in the HAND position) increases above 95-100% of its rated capacity, the first AUTOMATIC unit will start and operate in parallel with the already energized HAND selected unit.

If there are any additional chargers available and set for AUTOMATIC operation, they will be started and operated in parallel in a predetermined sequence as the load current exceeds 95-100% of the rated capacity of the operating units. This will continue until all available units are started.

If the maximum rated capacity and maximum safe overload capacity of the combined chargers is exceeded, each individual rectifier or d-c generator will, in turn, begin to decrease its output voltage level in order to limit its current output to a safe value. The exchange battery will furnish any additional current required as outlined in previous sections.

As the load current decreases and drops below 90% of the combined rated capacity of all operating units except the one started last, the current monitoring and start control circuits will function to de-energize the last unit. As the load continues to drop, any other automatically started units will be disconnected as the load becomes small enough to be handled by other units alone; this will continue until all automatically started units have been de-energized (in reverse of the sequence in which they were started), and only HAND started units will remain energized.

2.3.3 CEMF cell cut-out control.

When a 24-cell battery in series with a CEMF cell is supplying exchange power, and the exchange voltage level drops to some preset value between 46 and 47 volts, a voltage-sensitive relay functions to operate a contactor which shorts out the CEMF cell, increasing the exchange voltage to about 49 volts. When the low voltage condition is corrected, and the battery power is no longer required, the contactor is released, automatically reconnecting the CEMF cell in series with the 24-cell battery and reducing the voltage to its correct, normal value.

2.3.4 End cell cut-in control.

Whenever a 23-cell battery, with three additional end cells, is furnishing exchange power, and the 23-cell voltage drops to some preset value between 46 and 47 volts, a voltage-sensitive relay operates a double-throw switch which connects the three end cells in series with the 23 regular cells, increasing the exchange voltage to about 52 volts. When the low voltage condition is corrected, and the battery power is no longer required, the double-throw switch restores, disconnecting the three end cells from the 23-cell battery and exchange load.

2.3.5 End cell recharge control.

If the three end cells of a 23/26-cell battery are discharged for any reason, they are recharged by the main charging equipment in series with the 23 regular cells. This connection is changed manually by moving the charging control switch from the 23 CELLS position to the 26 CELLS position. It is also necessary to increase the charger potential from 49.5 volts to 55.9 volts. This is done in a manner similar to that for obtaining the higher potential for equalizing charges (see section 2.2.6). On most rectifiers a separate 23 CELL - 26 CELL switch is provided for changing the reference voltage; on motor generator (dc), the same rheostat is used to increase the voltage to the required value. When all the cells are fully charged, the charging control switches are manually restored to the 23 CELL positions to float-charge the 23 cells, and the end cell trickle-charger is energized to float-charge the three end cells.

2.3.6 D-c ammeter and d-c voltmeter.

The d-c ammeter (when provided) is used to measure the exchange load current and the current from the charging equipment. The desired reading is selected by means of a multi-position selector switch or lever key which is mounted below the ammeter. By using external shunts which are permanently connected in the power supply circuits and special calibrated leads to connect the ammeter movement to the meter terminal posts on the shunts, the current readings of several different capacity circuits can be made rapidly and with ease, and without interrupting any power circuit. Each shunt is designed to have the same potential drop for the maximum current of the circuit in which it is used; thus, only one ammeter movement is needed for several circuits.

The d-c voltmeter (when provided) is used to measure the potential of the battery (23, 24, or 26 cells), and the potential across the main distribution panel. The desired reading is selected by means of a multi-position selector switch or lever key.

2.4 Distribution and Protection Equipment

Fuses are used in the exchange mainly to protect the equipment and leads against damage due to short circuits. The fuses used are the main fuse, the distribution fuse, and the alarm fuse. The rating of each fuse depends on the size of the leads which it protects. As the load is divided and distributed, from the main power supply leads through to the switching equipment shelves, both the size of the leads and the rating of the fuses decrease.

Fuses with ratings as high as 400-600 amperes may be used for the main fuse. This fuse protects the main power supply leads connecting the charging equipment and the battery to the power distribution panels. These main leads may be either rubber-insulated copper cable or rigid copper bus bars.

In smaller exchanges usually only one fuse is used for a main fuse; if this fuse blows, the circuit through the main fuse holder is opened. After the blown fuse has been removed from the holder, a new fuse can be inserted.

In larger exchanges, sometimes two or more fuses in parallel are required for the main fuse function. When this is the case, a double-throw switch and two sets of paralleled fuses are usually used, as shown in figure 5. If one set of fuses blows, the second set can be placed in service immediately by operating the switch from one position to the other. The blown fuses may then be removed and replaced by new ones, while the second set carries the load.

In very large exchanges, two or more double-throw switches and sets of paralleled fuses are sometimes needed, each feeding power to a large part of the exchange. No single main fuse for the whole load is practical (due to the size of the exchange load); the power supply units are normally all individually fused. In this case there will be a set of main leads for each switch, and each set will extend to a different distribution panel.

Fuses with a 30 or 60 ampere rating are usually used for distribution. These protect the distribution leads, extending from the distribution panel to individual fuse panels on the equipment shelves. Each distribution fuse connects one distribution lead to the main negative bus bar of the distribution panel. The

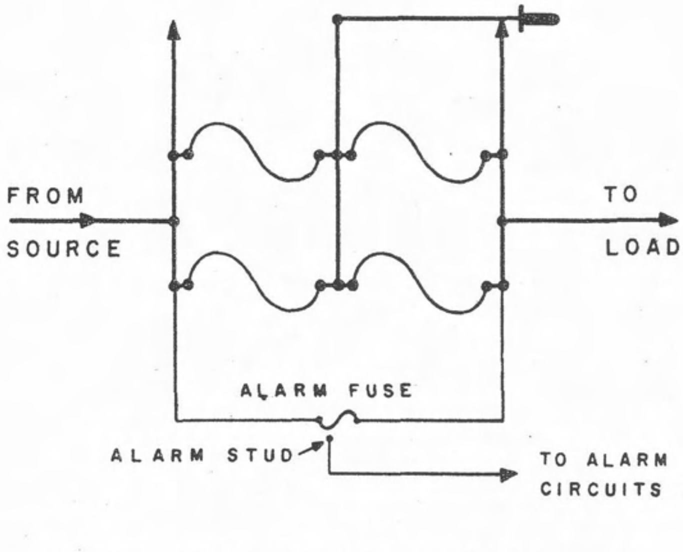


Figure 5. Multi-position fuse and switch arrangement, showing alarm fuse connections.

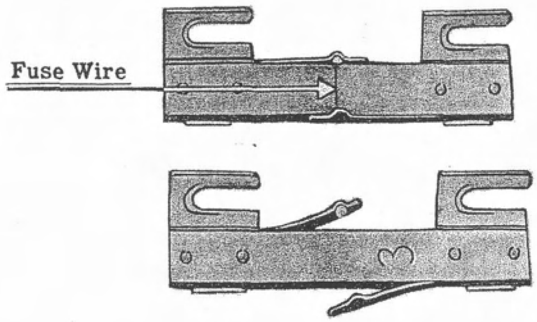


Figure 6. Alarm fuse shown in operating condition (A), and when "blown" (B).

positive (ground potential) distribution leads are not fused; these are connected directly to the positive-ground bus bar of the powerboard. An additional lead is used to connect the positive-ground bus to a grounding bar on the Main Distributing Frame (MDF); this MDF grounding bar, in turn, is connected to earth by a heavy cable and several buried copper plates which establish a stable reference level for the exchange voltage.

Alarm fuses, having ratings of one to five amperes, are used on the shelf fuse panels and in parallel with all main and distribution cartridge-type fuses. When used alone, alarm fuses protect the shelf power wiring and equipment. When used either alone or in parallel with a larger fuse, they also provide a means for signaling the failure (or blowing) of any fuse. When used in parallel with a larger non-indicating fuse, if the larger fuse blows, the full current in the circuit tends to flow through the alarm fuse, causing it to blow at once.

Whenever an alarm fuse blows, two pretensioned springs on the alarm fuse, which are normally held in place by the fuse element, are freed and allowed to bend outward from the fuse body. The back spring of this pair touches an alarm bar or stud, completing a circuit to a signal lamp and audible alarm. A red lamp on the fuse panel is usually used to indicate the panel on which the blown fuse is located; normally a 500 ohm resistor is connected in parallel with each such lamp to provide a circuit path for the audible signal (connected in series with the lamp) even if the lamp should burn out. The front spring of the alarm fuse, bending forward, gives a visual indication, within a group, of the particular fuse that has blown.

3. A-C RINGING POWER

Alternating current of a specific frequency, or of five different frequencies, is generated in the exchange for the purpose of operating audible signals, usually ringers, at each telephone station. The generators used for this purpose deliver continuous power of the required frequencies; this must be fused and then broken into ringing and silent periods by an interrupter mechanism. The interrupter distributes the ringing power to ringing group leads. From the powerboard each lead extends to a group of connectors to provide them with ringing power.

3.1 Requirements and Applications

The frequency, or frequencies, of the ringing power required by an exchange is determined by the ringing scheme used in the exchange. Single-frequency ringing power is used for straight-line, coded, and superimposed ringing, and combinations of these. Multi-frequency ringing power is used for selective (frequency) ringing on party lines.

3.1.1 Ringing frequencies.

Single-party lines usually use 20 or 25 cps ringing power for straight line ringing; also, coded and superimposed ringing on multi-party lines usually use 20 or 25 cps. Multi-party lines using frequency selective ringing require one of the three sets or groups of five ringing frequencies; the three usual sets or groups of frequencies used for selective ringing are:

a. Multiple (also known as harmonic), using the following frequencies: 16-2/3, 25, 33-1/3, 50, and 66-2/3 cps.

b. Non-multiple (also known as synchromonic), using 20, 30, 42, 54, and 66 cps.

c. Decimonic, using 20, 30, 40, 50, and 60 cps.

3.1.2 Ringing frequency voltages.

The voltages at which ringing power is generated varies from 75 volts at the lower frequencies to about 150 volts at the higher frequencies. The higher voltages are used with the higher frequencies in order to overcome increased line and apparatus impedances encountered at higher frequencies and maintain sufficient power to the ringers.

3.2 Ringing-frequency Generating Equipment

The principle types of frequency generating units used to supply exchange ringing power are the vibrating reed converter, rotary generator, magnetic (static) generator, and electronic (vacuum-tube or transistor) generator. The method of operation, power output, shape of the output wave, initial cost, efficiency, amount of adjustment required, size, and power supply required are the principle factors involved in determining which type of unit to use in a particular exchange.

In most exchanges the ringing equipment is usually located at or near the powerboard. Frequency generating equipment normally operates continuously, except in some small exchanges where the ringing generators operate only when a call is made.

3.2.1 Vibrating reed frequency generator unit.

The vibrator unit consists primarily of two magnet coil assemblies, an armature, a reed assembly, and a frame upon which all of these are mounted. This device converts 48v dc to square-wave ac of the correct voltage for the output frequency. This is then modified to sinusoidal current by a filter circuit.

The output frequency of the vibrator unit depends on the reed thickness, and the size and position of the reed weight. For example, as the size of the weight is increased and/or it is moved away from the reed-mounting point, the time period for one complete reed oscillation increases, and the resulting output frequency decreases. In contrast, as the size of the weight is decreased and/or it is moved toward the reed mounting point, the period of reed oscillation decreases, and the resulting output frequency increases. Vibrator units are normally mounted on a panel, usually in groups of five for multi-frequency application.

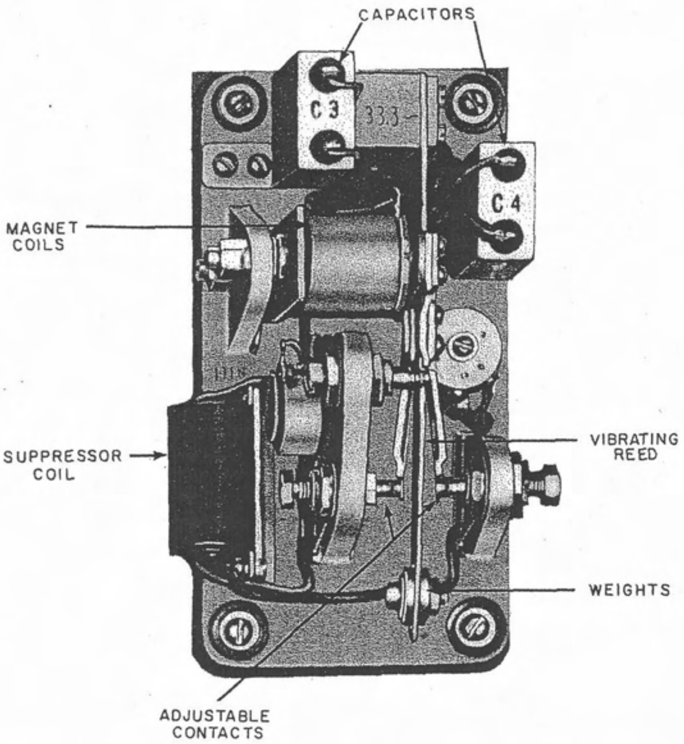


Figure 7. Automatic Electric Company type vibrating reed converter or harmonic-ringing frequency generator.

3.2.2 Rotary ringing generators.

A rotary ringing a-c generator set consists of a single speed motor, either ac or dc, connected either directly (shaft-to-shaft) or by pulleys and belts to one or more a-c generating units which produce the frequency or frequencies required.

Some generating units are arranged to produce several frequencies from a single rotary mechanism. Other generators produce only one frequency, and the output frequency is determined by the speed at which the shaft is turned. A number of such units, with suitable speed-changing belts and pulleys, may be driven from a single motor shaft to obtain a set of frequencies. Figure 8 shows one of the latter combinations; a stand-by set, operated by a d-c motor, is shown mounted beside the primary (a-c operated) unit for emergency use.

3.2.3 Magnetic and electronic generators.

The magnetic, vacuum tube, and transistor ringing generator units all use the principle of the tuned circuit for generating the required ringing frequencies. These units have no moving parts. Each may be used for both single-frequency and multi-frequency applications.

A magnetic generator consists of a number of transformers, filter chokes, capacitors and resistors, and is powered by alternating current. By subdividing and combining frequencies, it produces an a-c output of one or five frequencies, as required.

The vacuum tube and transistor generators use an a-c powered oscillator and tuned circuit components to produce one or five frequencies. Some units produce five frequencies continuously; others produce only one frequency at a time, in sequence. Most of these units are adjustable and may be readily tuned to produce different frequencies.

3.3 Ringing Power Connection and Control

3.3.1 Battery- and ground-connected generator.

Though not required for operation of the ringers, the ringing frequency generating equipment and/or its output is usually connected either to negative exchange battery (-48v dc) or to positive exchange battery (ground potential) to facilitate proper operation of ringing power control circuits. These connections are known as battery-connected generator and ground-connected generator, respectively. The generating units themselves need not have the d-c connection and current flowing through them; the d-c connection may be made at the

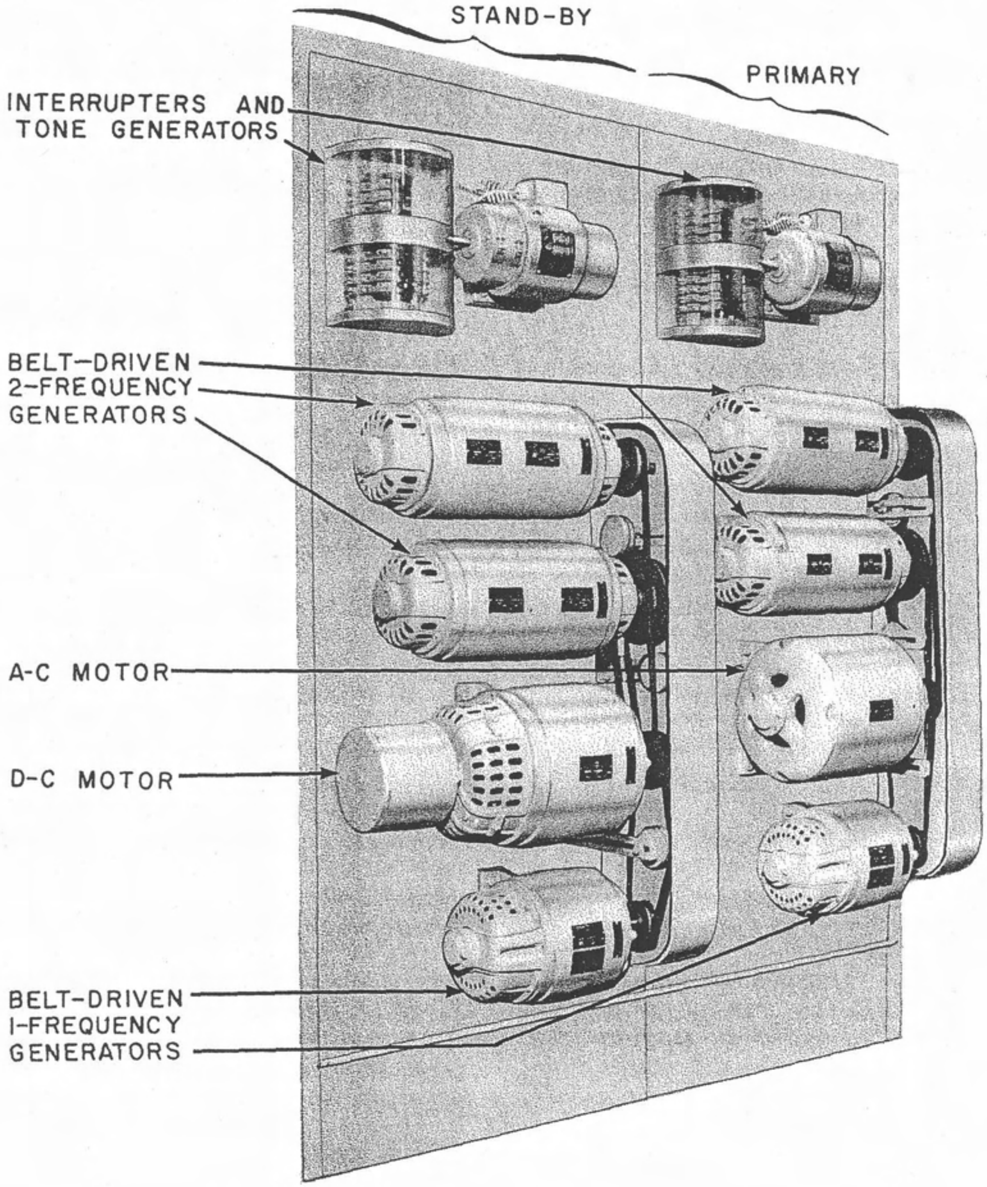


Figure 8. Rotary interrupter, ringing-frequency and tone generating equipment, showing primary (a-c operated) apparatus and stand-by (d-c operated) apparatus.

secondary of an isolating transformer. The choice between these two types of connections has no special significance to the generating equipment, although some exchange apparatus will vary with the type of connection used.

3.3.2 Monitor and transfer provisions.

Provision is usually made, in the power control circuitry, for a-c monitor relays to be connected to the output of each frequency generator. These relays are not frequency-sensitive and do not in any way check the accuracy of the frequency. These relays are voltage-sensitive, and if the a-c voltage of any frequency falls below a predetermined value, the relay will release and complete a circuit to start a stand-by generator or set of generators and transfer the exchange from the faulty unit(s) to the just-started stand-by units. An audible alarm is often sounded and/or a visual signal given if this occurs.

3.3.3 Ringing interrupter.

A mechanical interrupter is used to break the ringing generator(s) output into periods of ringing and silence. The interrupter consists of a motor with a drive shaft and a number of cams. A number of contact spring pile-ups (one for each cam) are operated by the lobes of the associated cam as the drive shaft rotates. These contact springs control the operation of interrupter relays which, in turn, interrupt the ringing power to the exchange equipment, giving the necessary pauses in the ringing cycle (see figure 8).

A stand-by interrupter is normally provided for use in case of any failure. The stand-by equipment may be arranged for manual starting or for automatic start (using relays, figure 8).

3.4 Distribution, Protection, and Isolation Equipment

A-c ringing power is distributed to the connector shelves by means of ringing group leads. These receive ringing current from the ringing generators via the ringing control relays. These relays connect ringing power to the various ringing group leads in a cycle that prevents two different frequencies from being connected to a single lead at the same time, and insofar as possible, prevents connection during any single ringing period of ringing power to two leads which appear, anywhere in the exchange, on adjacent terminals. This is done to minimize the possibility of flashover between closely spaced terminals at the peak a-c voltage necessary. The number of ringing groups used in an exchange is primarily dependent upon the size of the exchange.

Each ringing frequency lead coming from the ringing generator(s) is accompanied by a generator ground lead, the two running as a twisted pair from the ringing equipment to a distribution fuse panel on the powerboard. This panel uses alarm fuses to protect the ringing equipment against short circuits.

Whenever "dry ringing" (absence of dc) is desired, as on toll trunks, a separate 20 cycle ringing power source that is isolated from any battery or ground circuit is often used. If the exchange has a 20 cycle ringing power available, an isolation coil (transformer) may be used to isolate the dc for "dry ringing" power.

4. TONES AND PULSES

Special generating equipment is generally used to produce the tones (audio frequencies) required for busy, dial, and ringback purposes. The interrupter provides the pulse-interruptions necessary for busy tone and ringback tone. If the main tone equipment fails, stand-by equipment is usually provided for continued tone generation.

4.1 Tone Generators

Tone generators are of the same general type as the ringing generators: vibrator, rotary, magnetic, vacuum tube, and transistor. However, the generating equipment designed to produce the tones uses a lower frequency to modulate a higher frequency. The dial and busy tones are 600 cycles, modulated by 120 cycles; ringback tone is 420 cycles modulated by 40 cycles.

The tone generating equipment may be separate from the interrupter and ringing equipment, although magnetic and transistorized ringing equipment can be provided with a ringback tone output.

4.2 Tone Interrupter

Three of the rotary interrupter cams are used to create the busy and ringback tone pulses. These cams interrupt the continuous busy tone source at the following rates:

a. 30 impulses per minute(ipm) for intertoll-trunks-busy.

b. 60 ipm for called-line-busy.

c. 120 ipm for selector (intra-office) all-trunks-busy.

4.3 Tone Equipment Connection and Tone Distribution

Each dial tone output lead and all-trunks-busy tone output lead from the tone equipment is connected to the primary of one or more induction coils (transformers) which have their secondaries grounded in order to provide a d-c path for operating or holding a relay. Each ringback tone output lead and line busy tone output lead from the tone equipment is connected to one side of a capacitor; the other side of the capacitor is connected to the shelf or distribution circuit in which it is to be used. The capacitor prevents d-c feedback between different circuits, and helps minimize any crosstalk between different circuits over the tone leads. In smaller exchanges, these transformers and capacitors are located on the powerboard, whereas in the larger exchanges they are located on the equipment shelves. In general, there is a set of tone-carrying transformers and capacitors for each equipment shelf, or bay.

5. FUSE AND EQUIPMENT ALARMS

There are two main classes of alarms: powerboard and switchboard. These may both be divided into major and minor alarms. Major alarms, in general, require immediate attention; minor alarms, however, usually indicate some nonstandard condition that does not require immediate attention.

The major and minor alarms can be further divided into immediate and delayed types The immediate type of alarm is given at the moment the alarm condition occurs, while the delayed type of alarm is not given until a predetermined period of time has passed after the alarm condition first occurs.

In an attended exchange, a red lamp and a bell are generally used to indicate a major alarm condition; a green lamp and a buzzer indicate a minor alarm condition. White lamps are usually used to indicate nontrouble (no alarm) operating conditions. These lamps are usually located at or near the point of trouble and where they can be readily seen, as at the end of a switch shelf or on top of a frame. With these visual and audible indications, an attendant should be able to find any trouble quickly.

Unattended exchanges are usually arranged to send their alarm condition signals to a nearby attended office. In special cases alarm signals from an unattended office may operate a signal in the residence of a local exchange repairman or supervisor. It is also possible to arrange for authorized persons (those knowing the proper code) to be able to dial into an unattended office and listen to various audible signals which will indicate the condition of the office and if there are any major or minor, delayed or nondelayed, alarm conditions in effect.

5.1 Power Equipment Alarms

All power equipment alarms are of the immediate type; this includes the charging equipment, battery, ringing generators, interrupters, and tone generators. Each piece of charging equipment is usually equipped with a charge-failure relay which releases if there is a power failure. Most exchanges are equipped with high-voltage and low-voltage sensitive relays which function to signal an alarm condition if the battery voltage exceeds the operating voltage limits of the exchange.

The commercial a-c power supply and each ringing generator, tone generator, and interrupter are equipped with an alarm-transfer relay, which operates to signal an alarm condition, and start and transfer to any alternate or stand-by equipment if the primary unit or supply fails in any way. The successful operation of the stand-by equipment removes the immediate major alarm, but establishes a minor alarm to indicate that some trouble does exist. If the stand-by equipment also fails, the original immediate major alarm and the alternate equipment alarm both operate.

5.2 Main Power Fuse Alarms

The blowing of a main power fuse is considered a major alarm of the immediate type. If a main fuse blows, its associated alarm fuse will also blow, in turn, causing its red lamp to glow and the audible alarm signal to sound.

5.3 Powerboard Distribution Fuse Alarms

The blowing of a powerboard distribution fuse is also considered a major alarm of the immediate type. If a distribution fuse blows, its associated alarm fuse will also blow, causing the red lamp on the distribution panel to glow. At the same time the audible alarm signal is sounded.

5.4 Shelf Fuse Alarms

The blowing of a shelf fuse is a major switchboard alarm of the immediate type. If a shelf alarm fuse blows, a red lamp, which is generally on the shelf fuse panel, glows. Depending upon the particular exchange, an audible signal is sometimes sounded in addition to the lamp being lighted.

5.5 Switching Equipment Alarms

There are major and minor switchboard alarms of both the immediate and the delayed types. One of the most common types of switch alarms is the delayed minor alarm given when a linefinder, selector or connector fails to release after its release magnet is energized. After a given number of seconds, a time delay relay operates, lighting a lamp and sounding a buzzer to indicate that the alarm condition exists. Other switchboard alarms are arranged according to the number of subscribers affected and severity of equipment out of use or service.

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