SPECIAL P.A. SYSTEMS

53RH-2

STUDY SCHEDULE NO. 53

For each study step, read the assigned pages first at your usual speed, then reread slowly one or more times. Finish with one quick reading to fix the important facts firmly in your mind. Study each other step in this same way.

SPECIAL P. A. SYSTEMS

THERE are many specialized forms of public address systems that provide opportunities for men engaged in selling and servicing sound equipment. For example, sound systems have become common in industrial plants. Many of the earliest installations were intended only for paging (locating someone in the plant) and for making general announcements (talks, alarms, general messages, etc.). Systems of this sort, intended to reproduce voice only, are deliberately made to have poor low-frequency response. This effect is produced by using loudspeakers having short horns and amplifiers with deficient low-frequency response. As a result, such systems reproduce the human voice clearly but are not suitable for the reproduction of music.

Today, however, more and more industries are using their sound systems to entertain their workers. Sometimes this entertainment is given only at the lunch hour or for gatherings. There is, however, a growing tendency to play music continually throughout the day,

because researches have indicated that, in some kinds of work, doing so will increase the output of the workers. Many plants, hitherto equipped with voice sound systems only, are experimenting with musical programs and consequently need systems having better fidelity. As a p.a. man, you may be called on to modernize and improve the response of an existing system that has proved inadequate for musical reproduction. Thus, the fact that a factory already has a sound system does not mean that it is impossible for you to get business there.

Another large field for sound equipment is in hotels. Here, there are several uses for p.a. systems: paging systems are used to locate guests; installations are used for voice and music in the dining room and in the ball room; and, in an increasing number of hotels, p.a. systems are used to provide radio programs in the guest rooms. In these last installations, master receivers are tuned to the desired stations and their outputs are fed through p.a. amplifiers to the rooms.

to installing individual receivers in the rooms because it is usually simpler than putting up a complex antenna system and eliminating interference. A somewhat similar system is installed in some of the more modern hospitals.

These major installations can be very profitable to a p.a. man, but, of course, they are not everyday occurrences. At the other end of the scale in complexity is the intercommunicator (usually called intercom), which is a low-cost device that is usually very simple to install. Although the profit from the sale and installation of a pair of intercoms is not great, many a p.a. specialist finds these devices are an important source of income because of their wide usefulness and consequent ready sale.

The typical intercom is a unit in which the speaker may be used as a microphone by throwing a switch. This "microphone" is connected to the input of an amplifier of low power, which is used to operate another speaker or several other speakers a fairly short distance away. Most intercom systems are intended for person-to-person communication over distances of not much more than 100 or 200 feet. Some intercoms work only one way—one station, called the master station, can talk to several others, but they cannot talk back. In others, the remote stations can answer; in fact, in the most flexible systems, any station can talk with any other station and sometimes with a group of other stations.

The coin-operated phonographs (juke boxes) that are found in many restaurants and drug stores can also be considered to be specialized forms of p.a. systems. Essentially, these are just record players that operate automatically through a small p.a. system. In localities where the servicing of these units is not handled by the dealer renting or selling them, the p.a. man may get not only service contracts but also installation and remodeling contracts as well.

Band instruments like the electric guitar are specialized p.a. applications that sound specialists are often called on to service. The electric guitar is essentially a stringed instrument with an electrical pickup through which the vibrations of the strings are converted into electrical energy that is fed through a small amplifier to a speaker.

Finally, the home recorder—a device with which anyone can make his own records—can also generally be used as a small p.a. system. This, too, is something a sound expert may be called upon to service.

Now let's take up these specialized applications in more detail.

Industrial Sound Systems

Let's see what problems are involved in furnishing high-power sound to a number of points on a large production line where the noise of machinery, tools, and shouting men must be overcome. We shall assume we are dealing with a conveyor-line factory for heavy units such as automobiles, refrigerators, washing machines, or stoves.

Let's take a moment to consider the problem of noise level. As you know, sound levels are rated in db. The threshold of audibility (0 db) is the level at which no sound can be heard. The soft rustle of leaves on a quiet spring day may be 10 db. Quiet conversation in an average office may be 25 db. Ordinary street traffic may be 75 db, heavy traffic may be 90 db, and
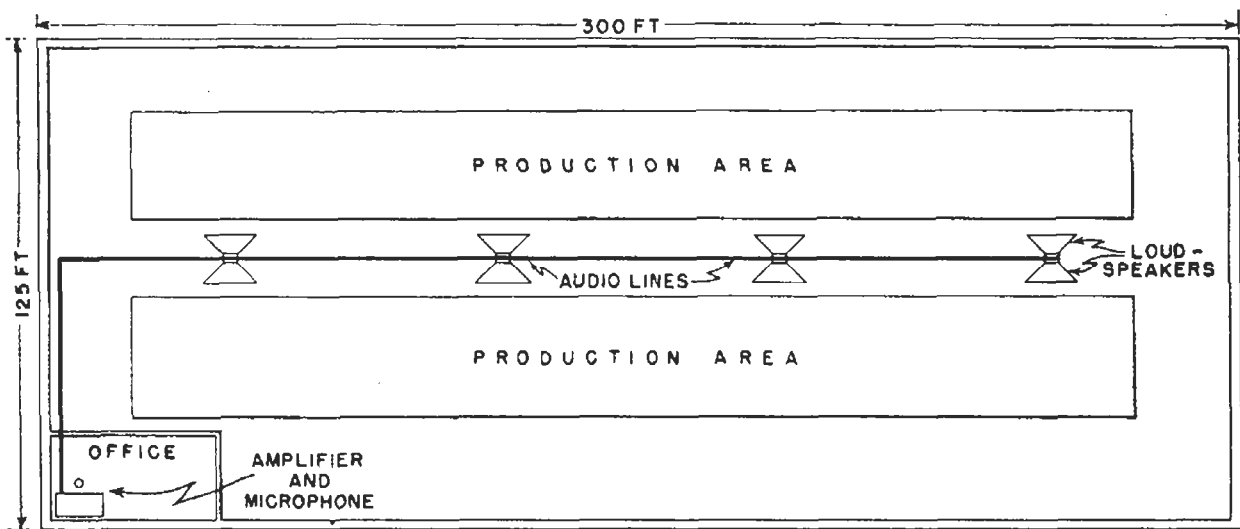

FIG. 1. Sketch showing p.a. installation in a factory.

As you know, the first step is to make an inspection of the plant, draw a sketch of the layout, and make preliminary acoustical and electrical estimates as you learned to do in earlier Lessons. Fig. 1 shows the kind of sketch you would make. Let's suppose that the area is 300 × 125 = 37,500 square feet. We'll assume you have decided that an audio output of 200 watts is necessary for the job. This is, of course, a very high power for the space involved, but it is made necessary by the very high noise level of the plant.

the level of noise in a plant like the one we are considering may range from 70 to 85 db at various points.

This is a very high noise level to overcome with a sound system. As a matter of fact, if the noise level were somewhat higher—say over 100 db—it would be impractical to use a sound system at all, because the sound output would have to be so high that it would be distressing. (Sound actually becomes painful at about the 120-db level.)

You can see, then, that a high-output sound system is needed in a

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plant of the sort we are discussing. 200 watts is not too much, even though the area of the factory is not very great.

A 200-watt amplifier can be secured on special order, but the installation can be made considerably less expensive by using smaller standard units. In this case, you can use two booster amplifiers rated at 125 watts each. The combined power of the amplifiers will then be 250 watts, giving you a margin of 50 watts to take care of line losses and to provide extra power that will be useful if some change in the factory makes it necessary to have more output.

The Bogen HO125 booster amplifier is suitable for use in this system.

The schematic of this amplifier is shown in Fig. 2. Let's discuss its details.

BOGEN HO125

The output stage in this amplifier consists of two 807 tubes connected in push-pull. This stage operates in class B. Driving power for the grids of the 807's is furnished by a pair of 6SN7GT tubes. These latter tubes are normally dual triodes, but in this use, the plates, grids, and cathodes in each tube are connected in parallel so that the tubes act as single triodes. This arrangement permits the tubes to handle twice the power that a single section can. A 6SL7GT, also a dual triode, performs a double function in
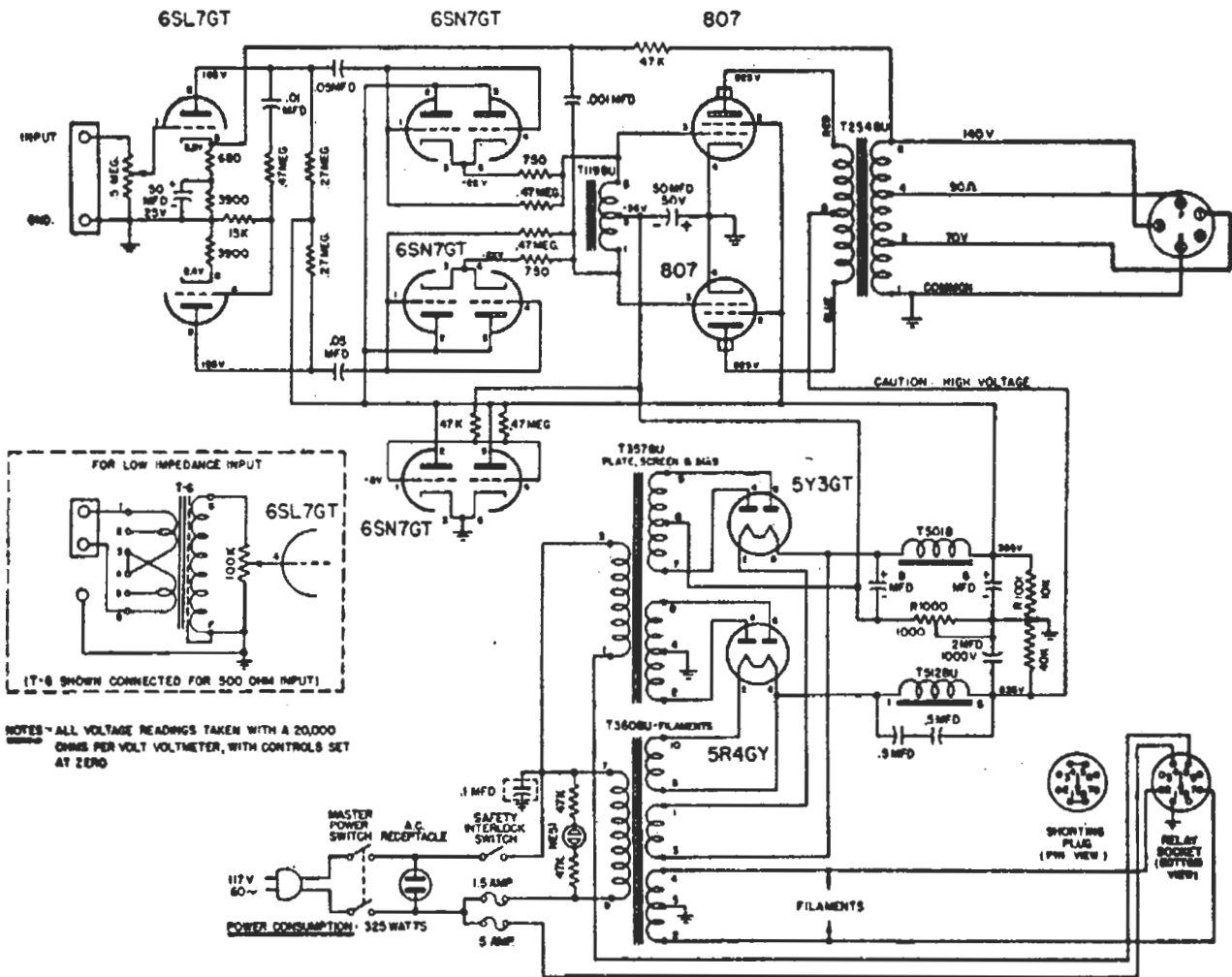
Courtesy David Bogen Co., Inc.

FIG. 2. Schematic diagram of Bogen HO125 amplifier.

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this circuit. One half of the tube acts as a voltage amplifier, the other as a phase inverter. Plate power for the 807's is provided by a 5R4GY. A 5Y3GT provides the power needed for the other tubes and for the screen grids of the 807's.

This amplifier has several unusual features. One is the use of a third 6SN7GT as a regulator of the screen-supply voltage. Its regulating action keeps the screen voltage at the proper value to produce correct plate dissipation in the 807 output tubes at all times, whether the signal input is large or small.

As you know, the screen current of any tetrode tube decreases when the signal applied to the control grid decreases. If the voltage applied to the screen grids of the 807 tubes were not regulated, it would increase when the voltage applied to the control grids decreased. This would occur because the regulation of the power supply is not perfect: its output voltage increases when the current drained from it decreases, and vice versa. Therefore, any decrease in the screen grid current would cause an increase in the power supply output voltage. The screen voltage would then increase as the grid voltage decreased, an effect that would tend to maintain the plate current relatively steady in spite of the control grid variations. This, of course, would cause distortion.

The 6SN7GT voltage regulator tube is connected, as Fig. 2 shows, across the screen supply (since it is connected between B+ of the 5Y3GT power supply and ground). The voltage regulator circuit, redrawn for greater clarity, is shown in Fig. 3.

Notice that the grids of the tube are connected to a voltage divider made up of a 47,000-ohm and a 470,000-ohm resistor. One end of this divider is connected to B+, and the other to the negative end of a source of bias voltage V_1. The bias applied to the grids of the voltage regulator tube at any time is equal to V_1 minus the drop V_2
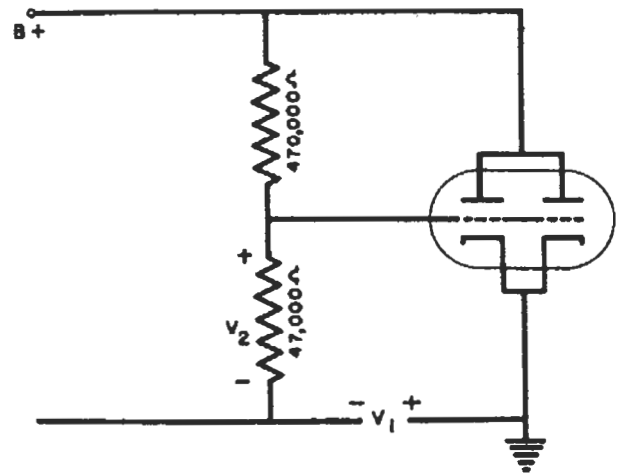
FIG. 3. Voltage regulator section of Bogen HO125.

across the 47,000-ohm resistor. The latter drop is equal to one-eleventh of the total voltage across the voltage divider. If B+ increases, the total voltage across the divider will also increase; consequently, V_2 will also increase. Since the bias applied to the grids of the 6SN7GT is equal to V_1 minus V_2, an increase in V_2 means that the bias will decrease. This will allow the plate current of the tube to rise, creating a greater drain on the power supply and therefore lowering the B+ voltage it can furnish. Thus, the action of the regulator tube is to maintain a fairly constant current drain on the power supply regardless of variations in the signal. The constant current drain keeps the output voltage of the power supply constant, and therefore maintains the screen grid voltage at a fixed value.

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Another unusual feature of this amplifier is the coupling between the driver tubes and the output stage. Notice that the plates of the two 6SN7GT driver tubes are connected directly to the B voltage supply. The loads for these tubes consist in each case of a resistor in the cathode circuit plus one-half of the coil connected to the control grids of the 807 tubes. (To see this, trace the cathode circuits; each is completed to ground for a.c. through the center tap of the coil.). The signal voltage output of each 6SN7GT driver tube is developed across the cathode load, and the part of the signal voltage that is developed across the halves of the coil is applied to the grids of the 807's.

The arrangement just described (called a cathode-follower coupling) is used because it provides direct, low-impedance coupling to the output stage, which, since it operates in class B, has a very low input impedance. Generally a stepdown transformer is used to couple to a class B stage. This method of coupling eliminates the need for such a transformer, which would be very expensive.

Another feature of this amplifier is that the application of high voltage to the plates can be controlled remotely if desired. This is made possible by a relay assembly incorporated in the power supply. When this relay is plugged into the relay socket shown in the schematic diagram, high voltage will not be applied to the tubes until the relay is actuated, which will not occur until a connection is made between two terminals on the relay box. A remote switch can be used to connect these terminals. If this remote switch is left open, the filaments of the tubes in the amplifier will be heated; thus, the amplifier will be ready to go into operation as soon as the switch is closed. This is a completely optional feature; the relay can be disconnected entirely, and a shorting plug can be plugged into the relay socket, in which case high voltage is applied to the amplifier tubes whenever the master power switch is closed.

The output transformer of this amplifier has four connections. One is ground, the other three are marked, respectively, "70V," "90Ω," and "140V." The 70V and 140V taps are called "constant-voltage" taps, so named because when the amplifier is delivering no more than its rated output, voltages between these taps and ground are essentially constant if the proper matching transformers are used to connect the loudspeakers to the taps. The 90Ω tap is used when the amplifier is connected to a high-output, multi-driver loudspeaker. Most such loudspeakers have input impedances of 90 ohms.

Loudspeakers may be connected in parallel to either of the constant voltage taps. With either tap, the correct impedance of the matching transformer is equal to $E^2 \div P$, where E^2 is the square of the tap voltage (which is approximately 20,000 for the 140-volt tap and approximately 5000 for the 70-volt tap), and P is the power to be applied to the loudspeaker. For example, if we want to drive a 25-watt loudspeaker driver from the 140V tap, the matching transformer must have a primary impedance of $E^2 \div P = 20,000 \div 25 = 800$ ohms. In other words, the primary impedance of the matching transformer used to couple

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a 25-watt loudspeaker to the 140V tap must be 800 ohms. If two 25-watt loudspeakers are to be fully excited, and are connected to this output tap, the primary impedance of each matching transformer must be 800 ohms.

If we wish to connect a 25-watt loudspeaker to the 70V tap, the necessary primary impedance of the matching transformer must be $E^2 \div P = 5000 \div 25 = 200$ ohms. Again, transformers having this same primary impedance should be used when several loudspeakers of the same power are to be connected to the 70V tap.

Whether you should choose the 140V tap or the 70V tap depends upon which permits the more readily available matching transformers to be used. In general, you should use the 70V tap when low power is to be taken, and the 140V tap when you are going to draw high power.

Notice that this amplifier is not provided with a tone control. The reason is that it is intended for use only as a booster amplifier driven by another amplifier; control of the tone takes place in the other amplifier.

This amplifier may be secured with either a low- or high-impedance input. Which you use depends on the driver amplifier you are going to use; with the high-impedance model, a driver amplifier having a 100,000-ohm output impedance is required; with the low-impedance model, the driver amplifier should have a 500-ohm output impedance. The schematic diagram in Fig. 2 shows the high-impedance type. The box at the lower left of the diagram shows the input section of the low-impedance model.

Fig. 4 shows the input circuit that should be used to couple a 500-ohm

driver amplifier to this booster amplifier. The 500-ohm resistor shown in this diagram must be able to dissipate the full output of the driver amplifier. Resistors R_a and R_b must have a ratio such that approximately 5 volts will be developed across R_b when the driver amplifier is delivering about two-thirds of its rated output across the 500-ohm load. The combined value of R_a and R_b must be great enough so that no more than $\frac{1}{4}$ watt
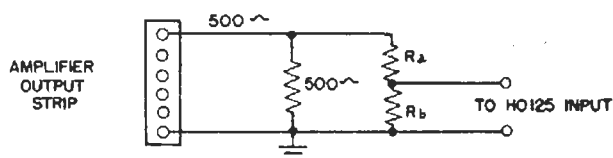
Courtesy David Bogen Co., Inc.

FIG. 4. Coupling between driver and Bogen HO125 booster amplifier.

will be dissipated in either R_a or R_b when the driver amplifier is delivering its full rated output to the load. Under these conditions, $\frac{1}{2}$-watt resistors may be used for R_a and R_b.

Values of 12,000 ohms for R_a and 1000 ohms for R_b are recommended by the manufacturer when a Bogen E10 amplifier is used as a driver. Let's see what this driver amplifier is like.

BOGEN E10

A schematic diagram of the Bogen E10 amplifier is shown in Fig. 5. This amplifier has two input channels, one for a high-impedance microphone and the other for a phonograph. The microphone channel feeds into one half of a 6SC7 dual triode. The output signal of this half of the tube is then fed to the other half of the tube. The output of this section is then fed to a combination voltage amplifier and phase inverter stage, also using a 6SC7, the output of which is fed to a pair of 6V6GT output tubes connected in push-pull.

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FIG. 5. Schematic diagram of Bogen E10 amplifier.

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The phono input feeds into the grid of the second section of the first 6SC7, so the two input signals can be mixed in this tube. The volume level of each channel is controlled by a ½-megohm potentiometer. The two input signals can be mixed in any desired proportion by adjusting the potentiometers. When only the microphone is to be used, the volume control in the phono channel should be set at zero; conversely, when only the phono is to be used, the volume control of the microphone channel should be set at zero.

The amplifier has a simple tone control, consisting of a .006-mfd. condenser in series with a ½-megohm variable resistor across the plate load of the amplifier section of the second 6SC7 stage.

The output of this amplifier is developed across two speaker sockets. A 5-hole impedance-selector socket is connected to taps on the output transformer of the amplifier. You can select any one of 4 output impedances—4 ohms, 8 ohms, 15 ohms, and 500 ohms—by inserting a connector in the proper socket. The diagram shows how this should be done.

When you are using the E10 ampli-fier as a driver for the HO125 amplifier, you should plug the connector into socket hole 5, thus connecting the 500-ohm tap across the speaker sockets. Insert pins in the speaker socket to make connections to the HO125 amplifier, using the connecting circuit shown in Fig. 4.

INSTALLATION

It is perfectly possible to connect the inputs and outputs of the two booster amplifiers in parallel, producing, in effect, a 250-watt amplifier. In one important respect, however, it is better to use parallel inputs and separate outputs for this installation. By doing so, you will have two sound systems, each consisting of one booster amplifier and its associated loudspeakers. Then, if either booster amplifier becomes defective, you can find out which one is at fault by determining which group of speakers does not operate.

A block diagram of the installation using this arrangement is shown in Fig. 6.

Eight loudspeakers, each with a 25-watt driver, are shown in this sketch. If desired, one more speaker could be
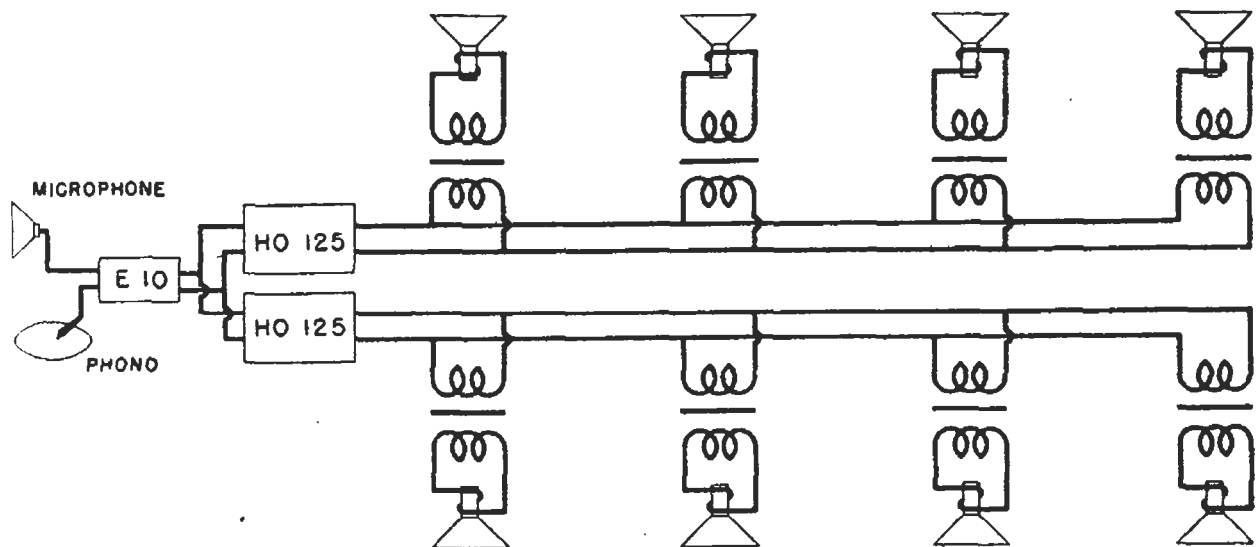

FIG. 6. Block diagram of factory p.a. installation.

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added to each line. Since high efficiency of reproduction is needed to overcome the high noise level in this plant, reflex trumpets should be used for the loudspeakers. You are already familiar with the use and installation of these trumpets from earlier Lessons. In a factory of this sort, it will probably be possible to mount the trumpets on girders used to support the roof.

Because of the relatively long runs, and the high power to be used, heavy wire should be used in the line. No. 14 or even No. 12 wire should be chosen and it should be enclosed in conduit or BX. Most likely, the local safety regulations will make it necessary to have the wiring installed by a licensed electrician, who may be a plant employee.

The Bogen E10 driver amplifier we have described is designed for use with a high-impedance microphone. Either a crystal microphone or a high-impedance dynamic microphone can be used. With either type, the microphone cable should be kept as short as possible and should be well shielded.

Wired Hotel Systems

The ordinary sound systems used in hotel dining rooms and ball rooms are basically the same as those systems that you have already studied. Intercommunicators are covered later in this Lesson. Right now, let's take up sound systems that carry entertainment to the guest rooms.

A block diagram of a typical system of this kind is shown in Fig. 7. Most generally three or four programs are made available to each guest room. A speaker, a volume control, and a selector are located in the guest room, making it possible for the guest to select the desired program and regulate the volume.

Because different programs are available, there must be a separate channel and a separate amplifier for each. These programs are fed into the amplifiers by radio tuners. Each tuner is normally adjusted to receive a local station and then remains fixed in its tuning.

As shown in Fig. 7, it is standard practice to provide an extra tuner and an extra amplifier for emergency use to replace any unit that happens to fail. Sometimes one or two channels are fed from a phonograph instead of a radio tuner. Sometimes, also, provision is made for plugging in a microphone so that announcements can be made over the system.

Let's see what problems we would meet in setting up such a hotel sound system.

The amplifier in each channel must, of course, be capable of supplying the power needed to operate all of the speakers that can be connected to it. In other words, each channel amplifier must have enough power to operate every speaker in the guest rooms, even though it is unlikely that every one will be connected to the same channel at the same time.

To take a typical example, let's suppose that the hotel is a fairly small

one having 90 rooms that are to be supplied with sound. Allowing one watt per room, 90 watts is needed for each channel. This is a minimum; to allow for the usual decrease in output caused by aging of the amplifier components, we should use a 100-watt amplifier for each channel.

Once the problem of how big an amplifier is needed is settled, designing the system becomes quite simple as far as the input and amplification

plifiers and the wires going to the rooms.

So far, as you can see, there is nothing particularly unusual about the installation. We meet a new problem, however, when we come to plan the connections to the loudspeakers in the room. The problem is that we have no way of knowing how many loudspeakers are going to be connected to any channel at any time. This means that we cannot simply
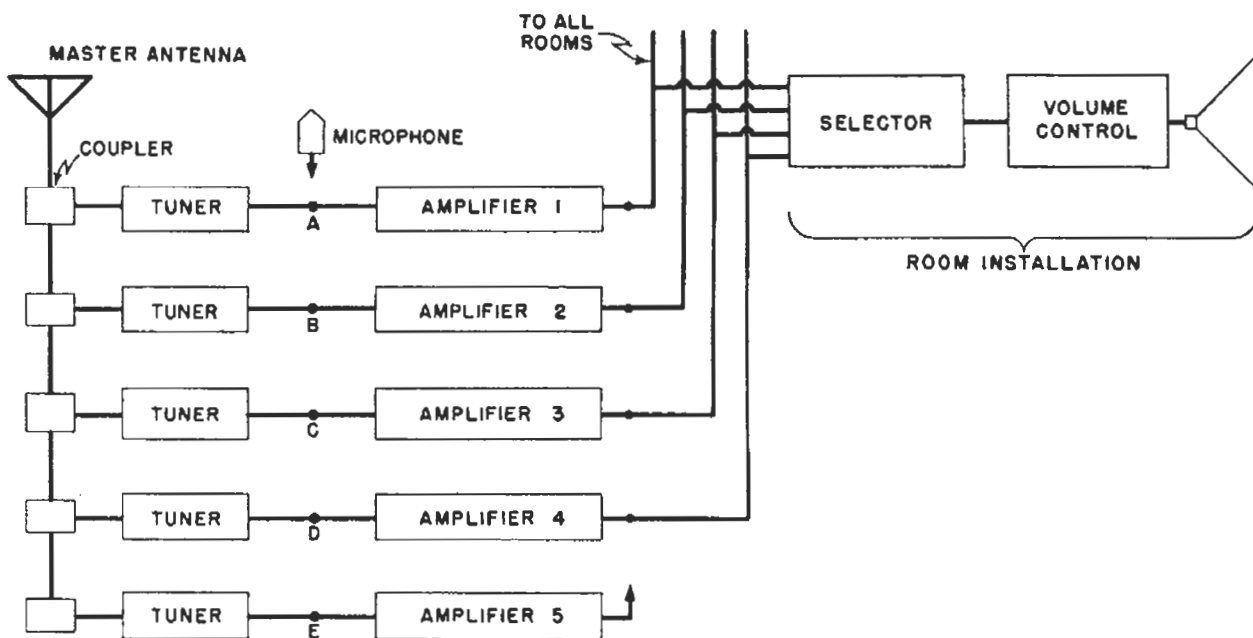
FIG. 7. Block diagram of typical hotel p.a. system.

sections of it are concerned. We select a suitable tuner and amplifier and make provisions for coupling each tuner to a master antenna system and each amplifier to one of the channels going to the rooms. To make the system flexible and to make it possible to substitute the stand-by equipment on any channel, we provide jacks at the outputs of the tuners and at the inputs of the amplifiers so that patch cords may be used to make the connection quickly between any tuner and any desired amplifier. A somewhat similar arrangement may be used between the outputs of the am-

provide a switch for connecting each loudspeaker to a channel. If we did, the impedance of each channel would vary each time a loudspeaker was connected to it or disconnected from it, with the result that the volume would be constantly varying in level and the tone quality would be adversely affected. If it happened that only a few loudspeakers were connected to one channel, they would be heavily overloaded and probably damaged.

Instead, we must use a switching arrangement that provides a constant load for each channel. Such a switch-

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ing system must connect a load resistor to the channel whenever the loudspeaker is disconnected from it, thus keeping each channel fully loaded at all times.

The basic principle of the switching system is shown in Fig. 8. When switch S is thrown to position 1, the primary of line-coupling transformer T is connected to the line, and the signal is fed through the transformer and
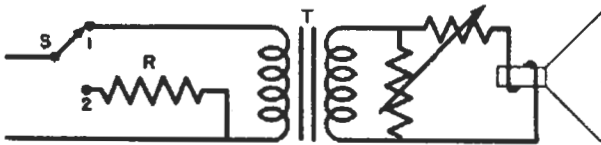

FIG. 8. Basic design of a constant-impedance switching system.

through the volume-control pad to the loudspeaker. The dummy load resistor R is not used when the switch is in this position.

When we wish to disconnect the loudspeaker from this particular line, switch S is thrown to position 2. Resistor R is then connected to the line in place of the transformer primary. Resistor R has a resistance equal to the impedance offered by the primary of transformer T, so the line is not affected by the switch-over and for practical purposes is feeding into a constant impedance.

The transformer impedance, which determines the value of resistor R, is in turn determined by the number of loudspeakers on each line and by the impedance of the line. Usually the wattage rating of resistor R is somewhat above the value calculated for the loudspeaker so that it can safely handle the necessary power.

The switching system shown in Fig. 8 is all right for a single channel, but a more elaborate system is necessary where there are more channels. For example, if there are four channels, it is necessary for the selector to have an off position in which resistances are connected to all four lines and the loudspeaker coupling transformer is disconnected from all of them. Then, at the position for line No. 1, the first resistor must be cut out of the circuit and the transformer put in its place. At position 2, the resistor on line 2 must be removed, the transformer put in its place, and the resistor on line 1 must be reconnected to that line. Similarly, at positions 3 and 4, the transformer must be substituted for the resistances on those lines and the switching system must reconnect the resistors to the other lines.

There are several different switches made specifically for this purpose. The exact manner of operation will depend upon the switch used, so you should get from the manufacturer of the selector you install, a schematic showing the proper connections.

Some of the selectors are 2-pole switches having a very elaborate band-type switch arrangement for the second pole. Others, like the one shown in Fig. 9, have a pole for each line. This switch is a 4-pole, 5-position switch. At position O (the off position) the resistances R_1, R_2, R_3, and R_4 are connected across lines A, B, C, and D respectively. (Notice that the shielding on the line is used as a return circuit for these resistors and for the loudspeaker matching transformer.)

When the switches are moved to position 1, the transformer T is connected by S_1 between line A and the shield, but all other lines are still connected through their matching re-
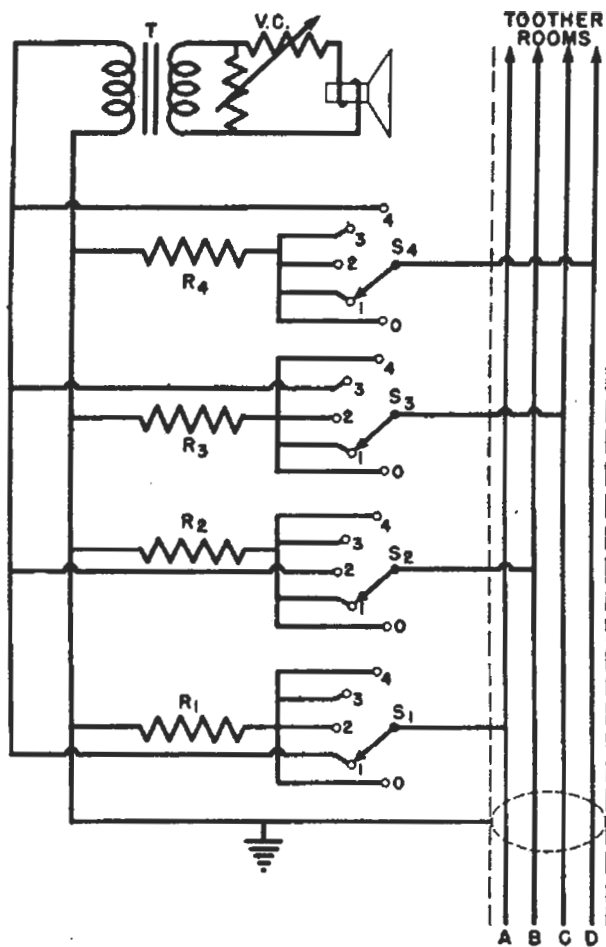
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FIG. 9. Multi-channel constant-impedance switching system.

sistors. Similarly, at positions 2, 3, and 4, the transformer is connected by switches S_2, S_3, and S_4 to B, C, and D in turn.

To keep the line loss at a minimum, and to minimize the possibility of a line defect knocking out of commis-sion too many of the guest-room loud-speakers, it is common practice to split up the distribution systems. In other words, each of the channels A, B, C, and D is broken into sections. For each channel, a small group of the rooms are wired in parallel to one line, which is then run to the amplifier. At the amplifier, this line is paralleled with other similar lines, each of which is connected to a group of rooms. The parallel combination of these lines then constitutes one channel.

In our example, assuming 90 rooms, a logical arrangement would be to split the rooms into 9 or 10 groups, whatever works out more satisfac-torily for impedance-matching pur-poses. The simplest possible manner of dividing the rooms should be fol-lowed. If the hotel has 9 or 10 floors, lines could be run straight down, con-necting to one room on each floor. In some cases, it may be preferable to connect all the rooms on one floor to a single line. The exact arrangement will depend upon the layout of the hotel. You should choose the one that will use the least cable and will in-volve you in the fewest difficulties in installation.

Intercommunicators

All the p.a. systems you have studied so far have been primarily designed to communicate with large groups of people. However, there is a large and rapidly growing field in person-to-person communication sys-tems. Strictly speaking, that is not public address—it is more like an am-plified telephone system. However, the p.a. man logically gets the job of installing and servicing such equip-ment, because, except for size and power, an intercom is basically the same microphone-amplifier-loud-speaker combination found in any p.a. system.

Intercoms sell readily because they are extremely useful in many applica-
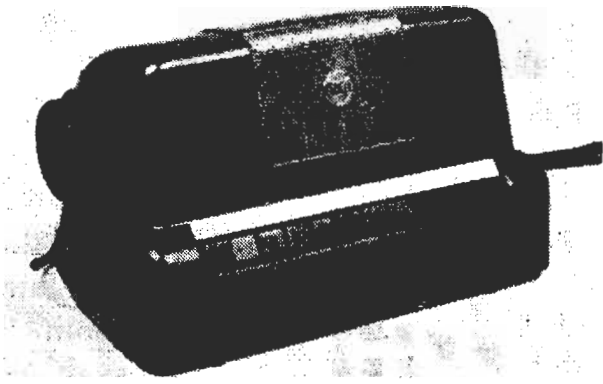
FIG. 10. Typical master intercom unit.

tions and are initially low in cost and relatively easy to install. Fig. 10 shows a typical intercom, and Fig. 11 shows a number of interoffice uses for such equipment. In these, the execu-

tive at the master station can get in touch with any department of his business at the flick of a finger—he doesn't have to wait for telephone connections to be made or undergo the annoyance of tied-up lines.

As shown in Figs. 11B and 11C, it is also possible for other sections of the same office to communicate with each other. Communications between the stock room and the purchasing office or accounting office are frequently of importance. Intercoms here permit a stock clerk to move about among the shelves and search for the required items or call out the inventory,
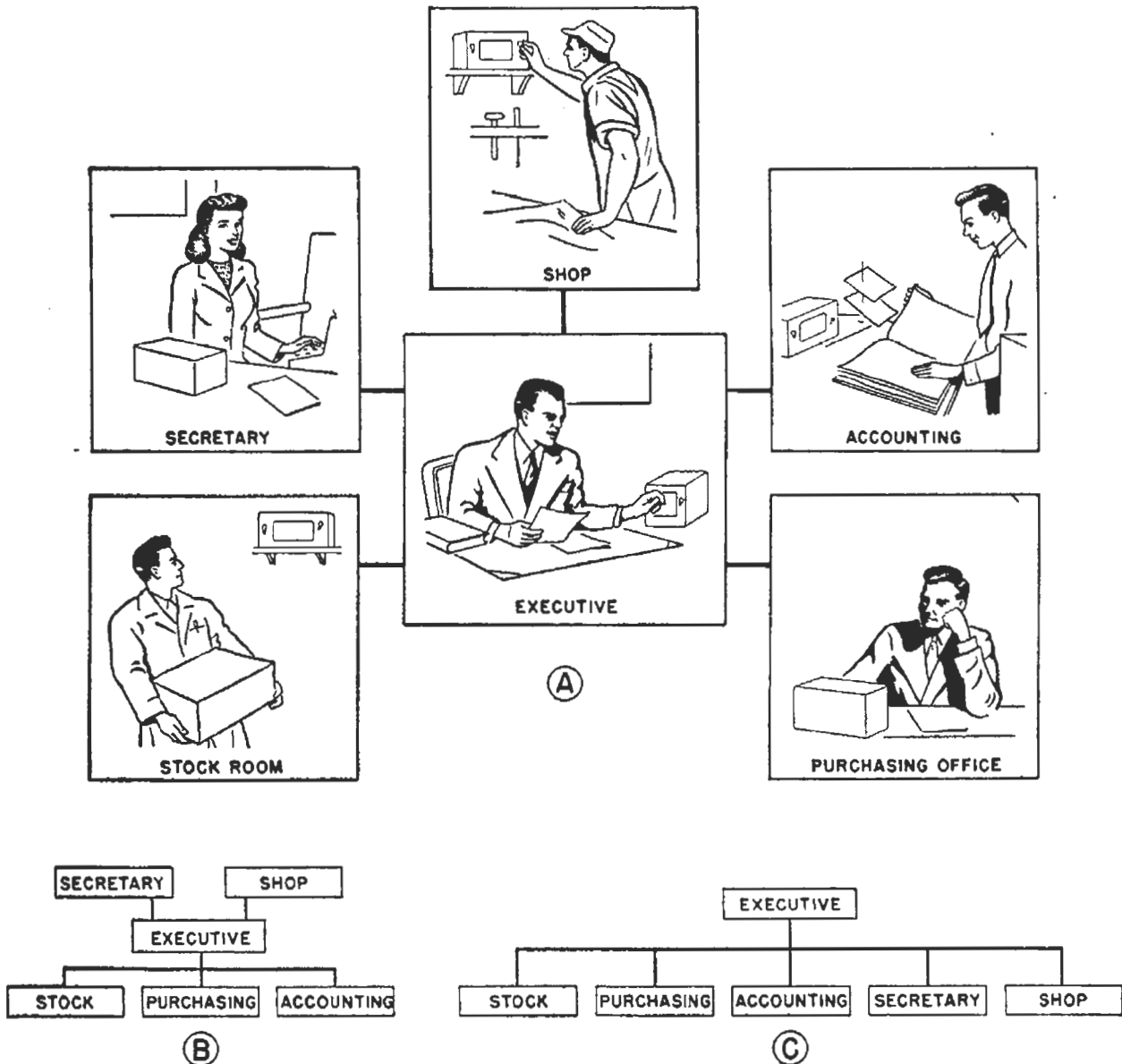

FIG. 11. Typical arrangements of intercom systems.

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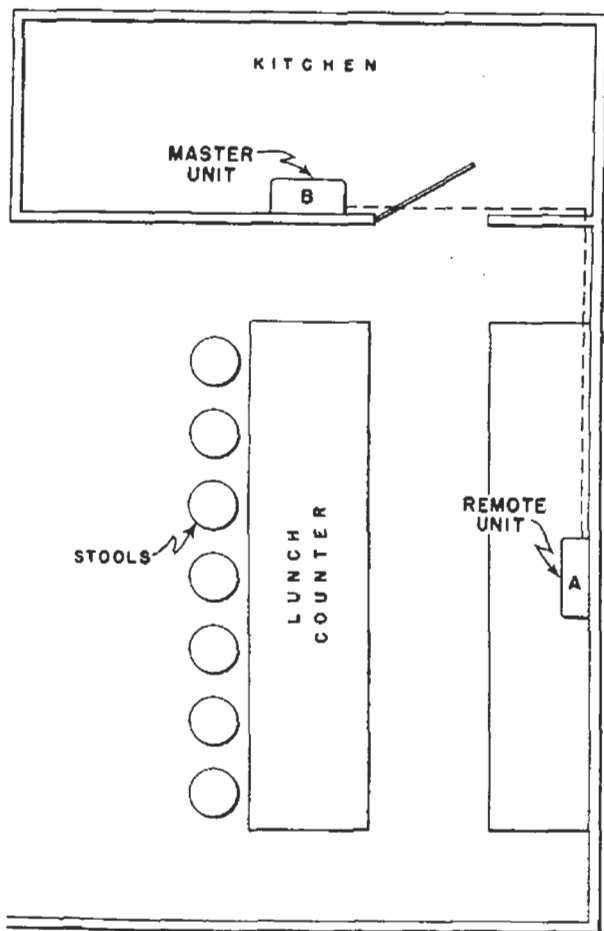
FIG. 12. Intercom arrangement in a restaurant.

without having to go back to a fixed position, as he would if a telephone were used instead. The ability of intercoms to pick up sounds over distances of 10 or 20 feet is very helpful in applications of this sort.

Other typical uses are shown in Figs. 12 and 13. In a small lunchroom, an intercom enables the counter man to give orders to the cook without having to yell, and the cook can hear instructions anywhere in the kitchen. The installation shown in Fig. 13 lets a repair man at a remote location communicate easily with the store counter.

These are only a few basic uses—many more similar applications can be found. The literature of the manufacturers is full of suggestions.

Intercom systems can be divided into two basic kinds—the direct-wire type and the wireless type. The direct-wire type utilizes audio lines between the units, and is completely an audio system. In the wireless kind, the sound modulates a local oscillator. The signal then goes out as an r.f. wave over the power lines to the receiving unit, where it is detected and amplified to operate a loudspeaker.

In either system, sound is picked up and must be reproduced through a loudspeaker. Intercoms are inexpensive devices because it was discovered that small p.m. loudspeakers will also serve as satisfactory microphones. You will recall that the dynamic microphone contains a diaphragm that, when subjected to sound pressure, drives a voice coil that is in a magnetic field. A loudspeaker contains the same items, except that the diaphragm is in the form of a cone. Therefore, a small p.m. loudspeaker that is used for voice reproduction can be used as a microphone if a switching system is provided to connect the loudspeaker to the input of

FIG. 13. Intercom arrangement in a service shop.

the amplifier for use as a microphone, and to the output for listening.

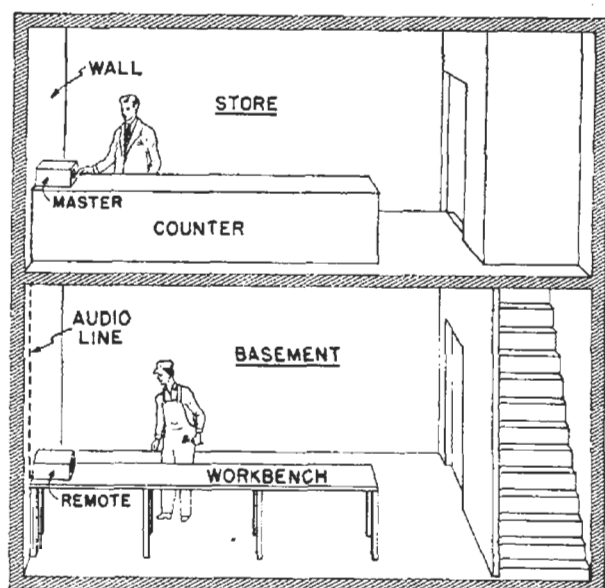This change-over is accomplished by means of a "talk-listen" switch. On most intercoms, this switch is held in the "listen" position by a spring so that the station can hear any other station that may be calling it. When the operator at a station wishes to talk, he presses and holds down the talk-listen switch, thus connecting his loudspeaker for use as a microphone.

To learn more about this switching
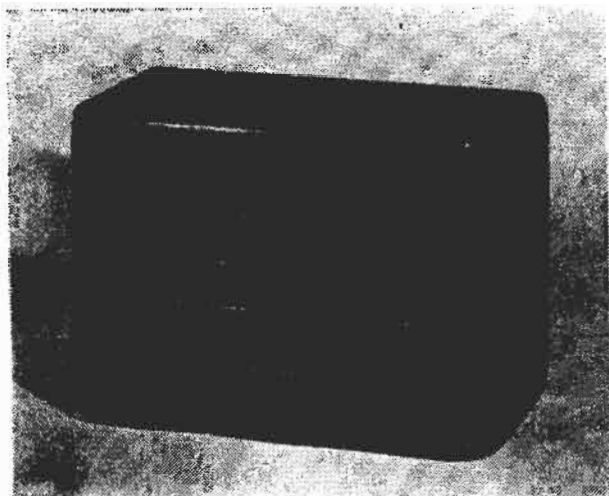
FIG. 14. Typical wireless intercom.

system, let's now study the basic intercoms.

WIRELESS TYPES

Fig. 14 shows a typical wireless intercom. This is a simple type used for communication with one or more remote stations that operate on the proper frequency. The controls on the front panel are a volume control and a talk-listen switch. As we said, the talk-listen switch remains in the listen position until the operator desires to speak. In this particular instrument, this switch is a 5-pole, 2-position switch.

The schematic diagram of this instrument is shown in Fig. 15. A

standard a.c.-d.c. power supply is used.

As you learned earlier, the signal for such instruments travels over the power line. The intercom can pick up a signal on the same frequency that is used for transmitting. Let us suppose that the carrier frequency is 100 kc. If any such signal comes over the power line, it will pass through coupling condenser C_{11} and through the volume control R_9 to one section of the r.f. transformer T_1. From here, the signal is fed to the oscillator-detector tube. When the switches are in the listen position, this circuit will not oscillate, because the plate voltage is cut off—instead the control grid and cathode of the tube act as a diode rectifier. The resulting audio signal developed across detector load resistor R_8 is then passed through from point 2 to point 3 on the talk-listen switch· assembly, and sent through coupling condenser C_1 to the grid of the first audio stage, which uses a 75 tube. This stage is resistance-coupled to a 43 power output tube, from which the signal goes to the loudspeaker.

If the operator desires to talk, he depresses the operating switch to the talk position. This disconnects the loudspeaker from transformer T_2 and connects it to the primary of transformer T_3. This transformer is now connected to the grid of the 75 tube through condenser C_1, because the talk-listen switch now connects terminals 3 and 4 together. The sounds are amplified by the 75 and passed on to the 43 tube, which now acts as a modulator on the oscillator. The other 43 tube now oscillates because it has plate voltage, and because clos-

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ing positions 1 and 2 of the talk-listen switch has changed the grid resistance and thus produced a bias that will permit oscillation.

Plate voltage is applied to the oscillator through L_1 and through the primary of transformer T_2. Any audio voltage appearing across the primary of transformer T_2 as a result of some-one's speaking into the microphone is in series with the plate supply voltage, and hence modulates the oscillator. The signal is transferred through transformer T_1 from the oscillator to the power line. It can now be picked up by any similar receiving unit that is tuned to the same frequency and has its switch at this moment in the listening position.

These instruments are quite easy to install—all you need to do is to plug them into a power outlet that is on the same power line as the receiving unit. There are no wires to run around in the building, and, if you should want to move the unit, all you have to do is to pick it up, move it, and plug it again into a power outlet.

These units would appear to be the ideal type, but they do have their limitations. To begin with, trouble is sometimes experienced if the transmitting and receiving unit are not on the same power-line branch. Sometimes it is not possible to get sufficient signal through the electrical wiring of the building. In addition, defects in the electrical wiring may cause excessive noise or cross modulation. This latter effect will produce mixing of signals having different carrier frequencies.

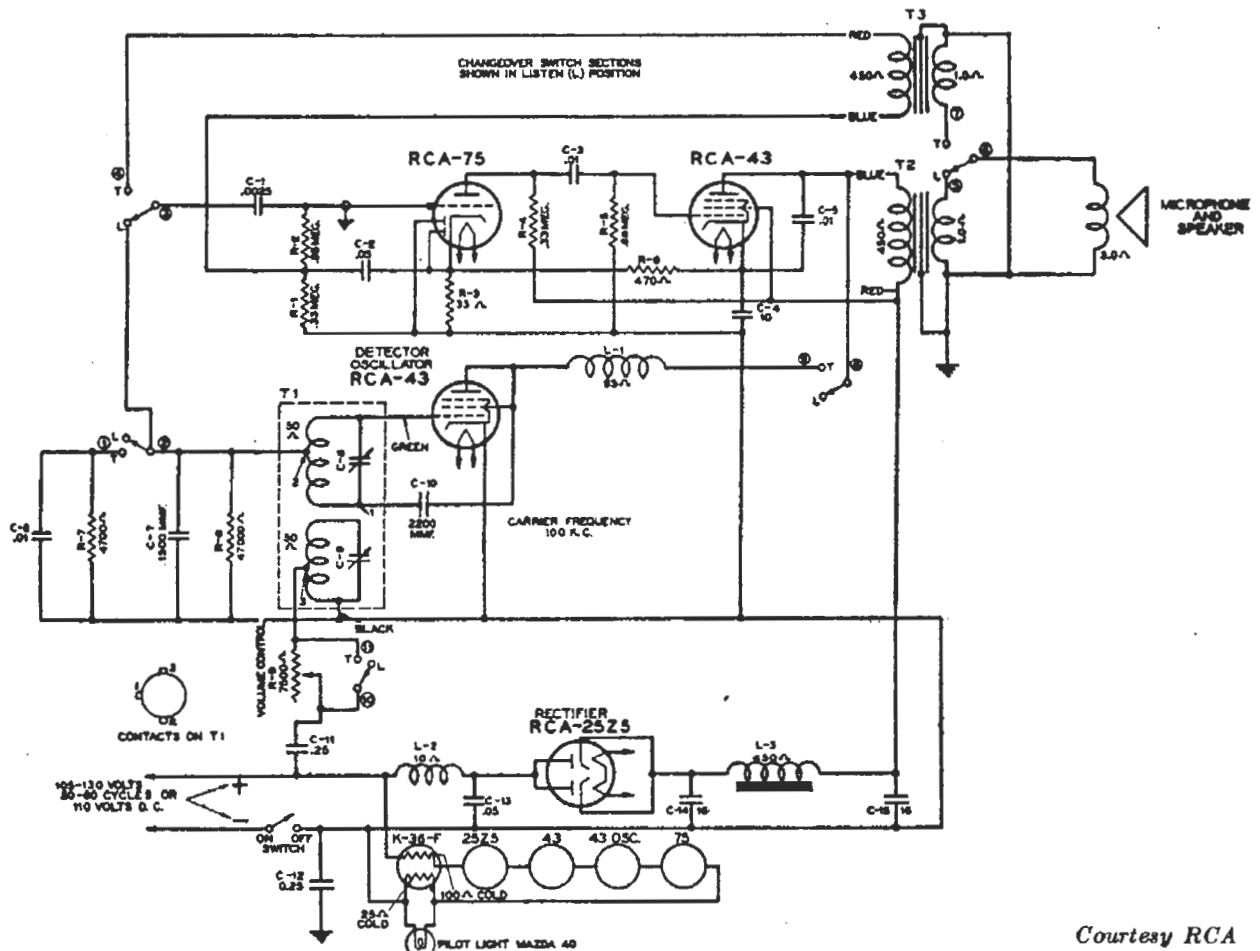A further limitation is that a transmitter can be heard by all receivers

Courtesy RCA

FIG. 15. Schematic diagram of wireless intercom.

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tuned to its frequency. If there is only one receiver, everything is all right. If there are several, however, all the receivers hear all messages, even those not intended for them.

The only way out of this is to use different carrier frequencies. Doing so permits a setup like that shown in Fig. 16, in which three different systems are used in one office without excessive interference among them. However, this system is limited in its usefulness; the executive cannot call the bookkeeper, for example, unless some means is provided for changing the frequency of his unit. If the system must be flexible enough to permit the master station to call just one station if desired and also to call all or several stations, a wireless intercom cannot usually be used. Instead, a wired system must be set up.

We'll discuss wired intercoms in just a moment. First, however, there is another type of wireless intercom that should be mentioned. This intercom uses separate transmitters and receivers. These are single purpose units: the transmitter can be used only for transmission, and the receiver only for reception. Obviously, such an intercom can be used only in applications in which one-way conversation is all that is needed. The schematic diagrams of a typical transmitter and a typical receiver are shown in Fig. 17.

WIRED SYSTEMS

In wired systems, audio lines are used between the intercom stations. Each station consists of an audio amplifier with its accompanying power supply and a loudspeaker that can be connected by a talk-listen switch
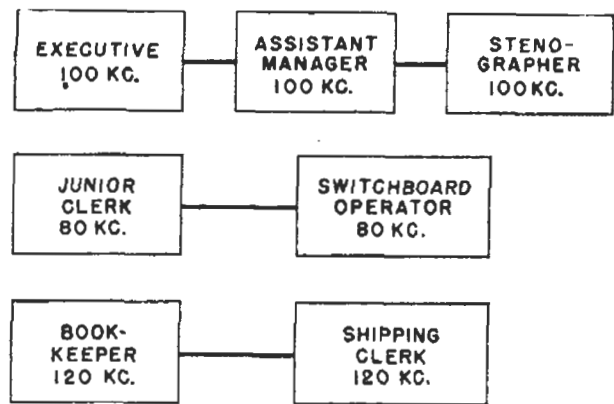
FIG. 16. How three wireless intercom systems can be used at one location.

either to the output of the amplifier for use as a loudspeaker or to the input of the amplifier through an appropriate coupling transformer for use as a microphone.

A unit of this kind that has a selector system for picking out the station to which one wishes to talk is known as a "master" unit. If it does not have a selector, it is known as a "remote" or "slave" unit. A remote unit need not have an amplifier if it is at a reasonable distance from the master unit and is to communicate only with the master. In other words, if a remote unit is to communicate with the master station but not with any other remote unit, it can be just a loudspeaker feeding through a low-impedance cable to the master unit.

An example of a wiring of a system of this kind is shown in Fig. 18. Here, the talk-listen switch on the master and on each of the remotes is normally held in the listen position. The wiring arrangement is such that the master station can at all times hear any or all of the remote stations that may call it. The selector switch of the master station can be set to let the master talk to one particular remote or to all of them.

You can call the master station

from any of the remotes by holding the talk-listen switch to the talk position. You cannot, however, call any of the other remotes. When the talk-listen switch from a remote is in the

normal listen position, it can receive a call from the master when the selector switch at the master is turned to the proper position.

If it is desired to have the remote

Mike →

300 K.C. TRANSMITTER

300 K.C. RECEIVER
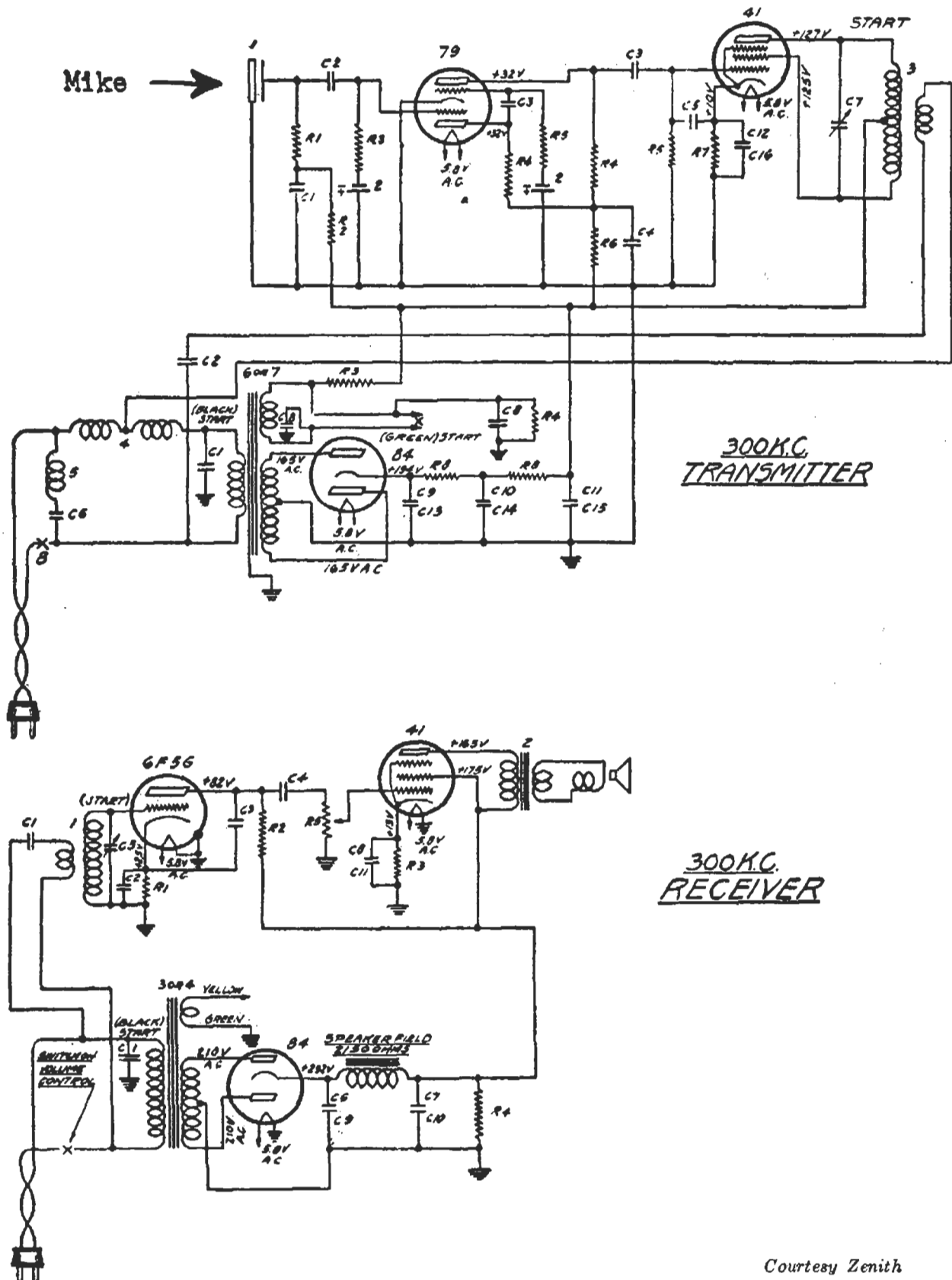
FIG. 17. Schematic diagrams of wireless intercom receiver and transmitter units.
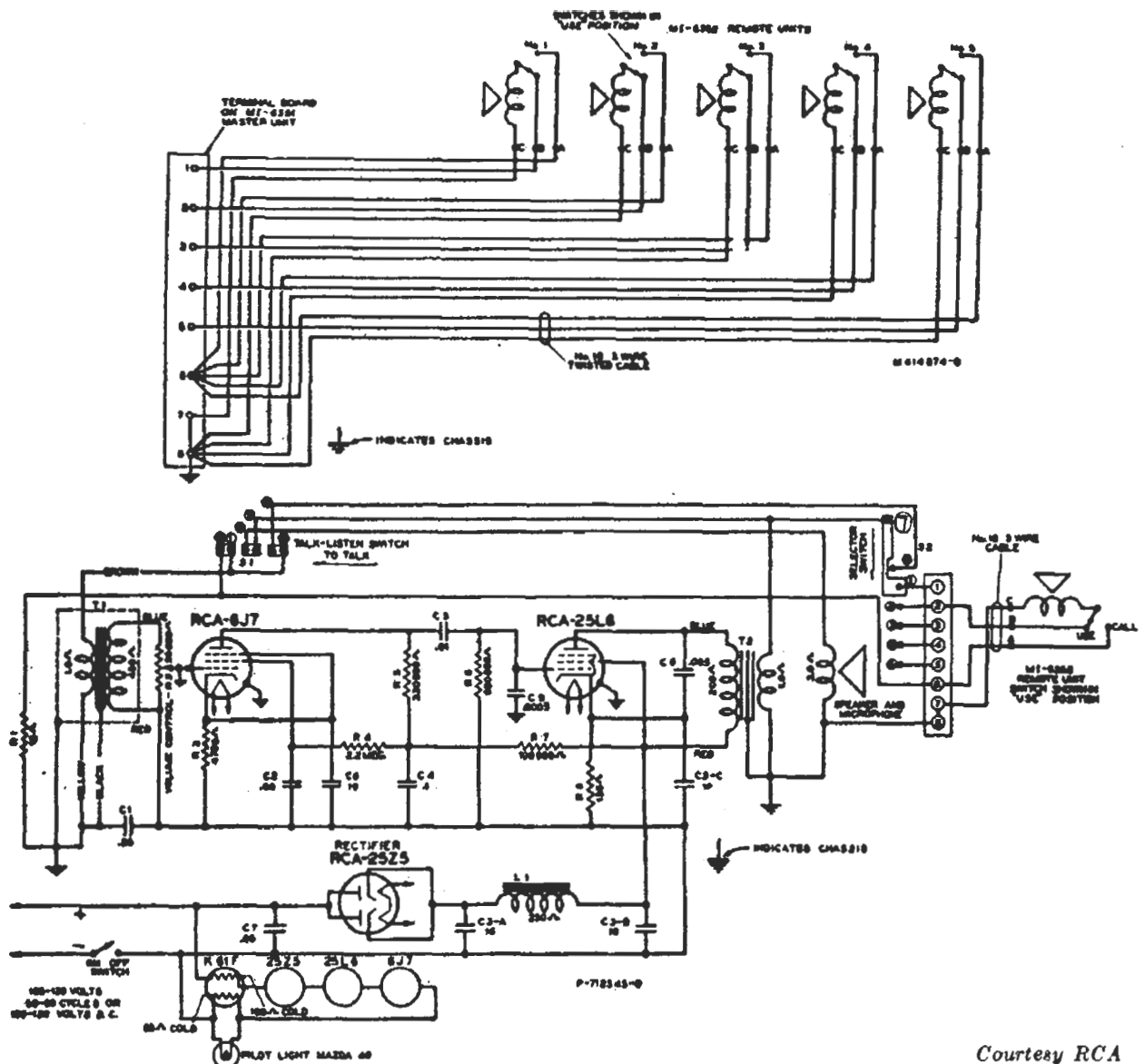
FIG. 18. Schematic diagram of typical master wired intercom.

stations be able to communicate with each other without having to call the master, each must have its own amplifier and its own selector switch. In other words, a system in which each station can call any other station must be essentially a collection of independent master units.

An all-master system must also be used if the stations are at very considerable distances from one another. In this case, it is necessary to use master units to have enough amplification to get the signals through.

A third possibility in an intercom system is a combination of master and remote units. In an arrangement of this sort, each master can call each other master, but each remote can call only the master to which it is connected.

You can see that the wired units offer more flexible arrangements than the wireless type—of course, at the additional expense of installing audio lines. In addition, the wired types are more free from power line noises and hum troubles, which are frequently encountered with the wireless type.

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Specialized Sound Systems

There are three specialized uses for p.a. equipment that do not fall into any of the categories you have studied so far. One of these is in the amplification of individual solo instruments in bands; another is in the familiar coin-operated phonographs or juke boxes; and the third is in the home recorder.

The electric guitar is an example of the first of these specialized p.a. systems. The original model of this instrument consisted of a standard guitar with a microphone attached to the sounding board. More recently, two electronic types have been developed; these are without sounding boxes and depend entirely on electrical pickup for sound output. Let's study both.

ELECTRIC GUITAR

There are several different makes of electric guitar amplifiers on the market. Each of them uses a circuit resembling the one shown in Fig. 19, which is a schematic diagram of the Gibson EH-150 guitar amplifier. The differences between this and other amplifiers are principally in the arrangement of parts in the chassis, cabinet construction, and other minor details.

This amplifier has two input channels, one marked "Instruments" and the other marked "Microphone" on the diagram. The Instruments input channel, into the jacks of which either one or two electric guitar pickups can be plugged, goes to the grid of a 6SQ7 voltage amplifier. The output signal of this stage is fed to a 6N7 voltage
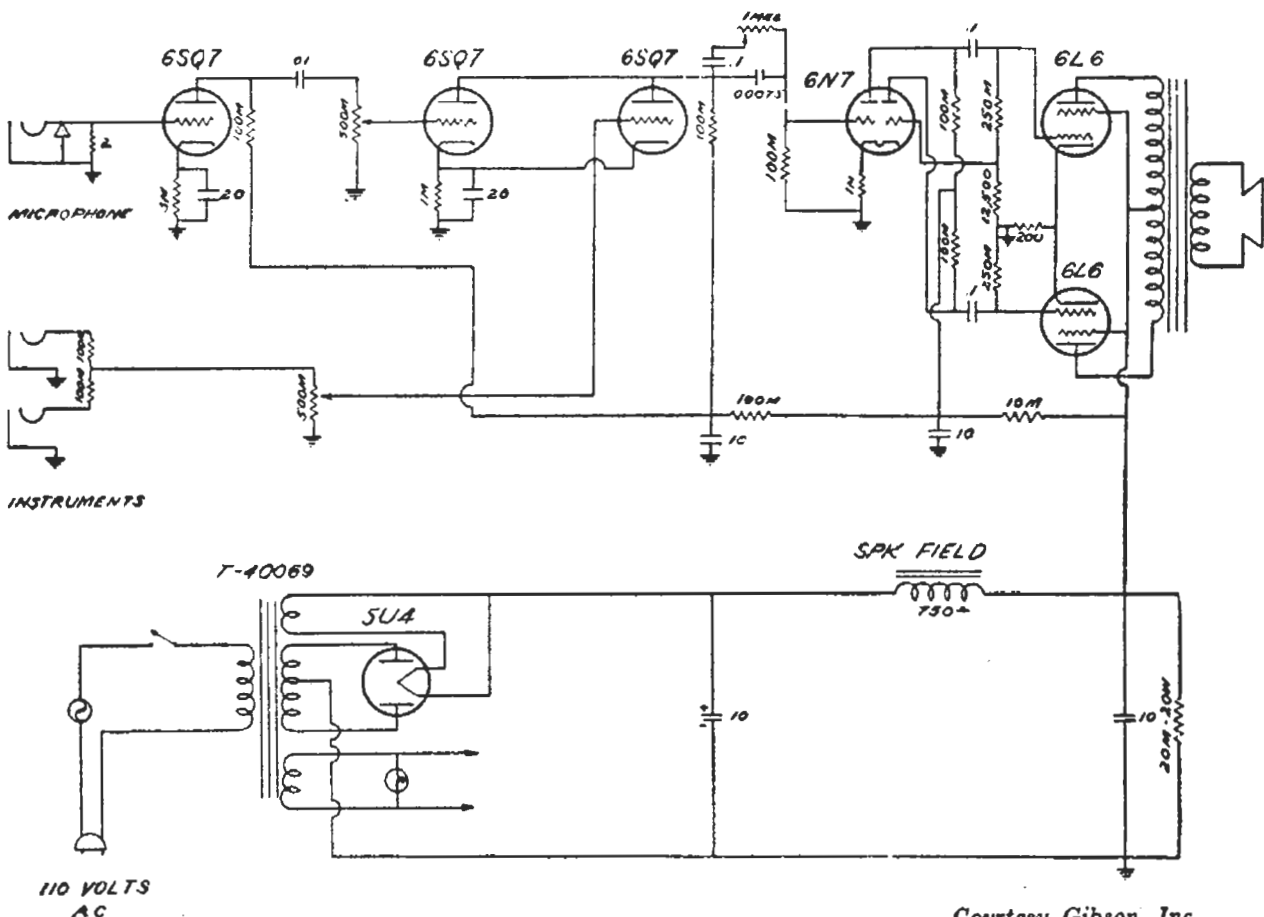
FIG. 19. Schematic diagram of Gibson EH-150 guitar amplifier.

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amplifier and phase inverter stage, which drives the grids of the power output stage. This latter stage contains a pair of 6L6's in push-pull.

The Microphone channel is provided for use in making announcements and so forth. A signal fed into the microphone through this channel is applied to a 6SQ7 pre-amplifier stage that is used to bring the microphone output up to the same level as the signal from the guitar pickup. It is fed from this stage to another 6SQ7 voltage ampli-
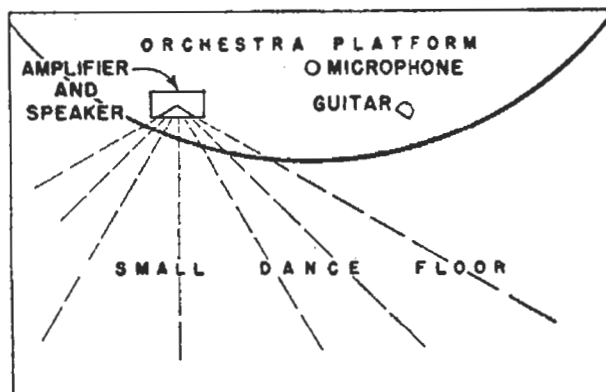
FIG. 20. Typical setup using one amplifier for both guitar and microphone.

fier stage that is in parallel with the similar 6SQ7 stage used in the Instruments channel. The outputs of these two parallel 6SQ7 tubes are mixed by being applied to a common load.

The tone control of the amplifier is located in the grid circuit of the 6N7 stage. It consists of a .0075-mfd. condenser shunting a series combination of a .1-mfd. condenser and a 1-megohm resistor. When the 1-megohm resistor is set at its maximum resistance, most of the signal current is passed through the .0075-mfd. condenser; as a result, the response is high-pitched. Reducing the resistance of the variable resistor allows more signal current to pass through the .1-mfd. condenser, with the re-

sult that the tone of the amplifier deepens.

Each channel has a volume control consisting of a 500,000-ohm potentiometer, the variable arm of which is connected to the grid of one of the two paralleled 6SQ7 stages.

Since a microphone channel is provided in this equipment, it may be used as a small public address amplifier in small dance halls, night clubs, and similar places where great volume is not necessary. A typical set-up is shown in Fig. 20. To reduce acoustical feedback and prevent howling, the cardioid microphone is placed somewhat behind the front edge of the speaker.

The sketch in Fig. 20 shows the amplifier and loudspeaker in one unit. For ease in transportation, they are usually built into one luggage-style case. However, usually the case can be split into two parts when the equipment is set up for use, one part then housing the amplifier and power supply and the other part housing the loudspeaker. This is a desirable arrangement; if the amplifier and loudspeaker are in one case, the sound waves caused by the vibration of the speaker cone may cause physical vibration of the tubes of the amplifier, producing howling, noise, or distortion.

Usually the loudspeaker used in this equipment is placed nearer one side or the other of the stage, not in the exact center. This is done to allow room in the center of the stage, which is usually the place occupied by the vocalist or other entertainer. If the room is reasonably small, the amplifier will drive the loudspeaker with sufficient power to produce adequate

distribution of the sound waves all over the room. It is usually necessary to experiment somewhat with the position of the speaker to determine the direction in which it should be aimed to give the best results in tone quality and intelligibility of the sound output of the equipment.

THE JUKE BOX

Juke boxes (coin-operated phonographs) are a familiar sight all over the country. Like all electronic devices, they require servicing at least occasionally, so it is worth our while to spend a few minutes now to learn something about what is inside them. We shall confine our attention to the juke box amplifiers, which are usually simple and straight-forward in design and construction. The mechanical systems of these record players are too varied and intricate to permit our studying them here. Fortunately, the mechanical systems do not often get out of order. If one does, you may find the information you need to fix it in the special service manual put out by the company that made the juke box. If you are working for a company that owns a string of boxes, it will undoubtedly have such manuals for all the types it owns. If you are an independent serviceman, you may be able to secure these manuals from the manufacturers—or the person owning the box may have one.

In a typical juke box, a coin deposited in an electro-mechanical pushbutton selector system permits selection of one or more records. The pushbuttons may be on the front of the juke box or on remote control boxes distributed through a room, at each table along a wall, or in each booth in a restaurant. The mechanical system causes the proper record to be selected and the pickup to swing in place, and turns on the amplifier. In some types, the amplifier warm-up period is eliminated by running the filaments of the tubes continually and merely switching on the plate supply. In others, the warm-up is shortened by momentarily applying a higher-than-normal filament voltage, then switching over to normal working filament voltage.

There are a number of different types of amplifiers available. In Fig. 21, a simple class B amplifier is shown. The signal voltage provided by a crystal pickup is applied directly to the grid of the 6J5. This tube functions as a standard class A voltage amplifier and is coupled through a step-down transformer to the grid circuits of a 6N7 duplex triode connected for push-pull operation. This tube is designed to work with zero grid bias for no signal input conditions. When grid excitation is furnished, the grids go positive on alternate half-cycles. The power sensitivity and power output are good, but the distortion is higher than for class A operation.

The circuit of a class A amplifier is shown in Fig. 22. A crystal pickup supplies signal voltage to the grid of a 6C5 through a tone-compensating network and a volume control.

The 6C5 supplies signal voltage to the tapped choke through a .02-mfd. condenser. The choke permits push-pull operation of the output stage without the necessity of using a phase inverter. Direct-coupled 6B5 output tubes are used. The tubes operate without external bias, but the grid of the input triode does not draw cur-
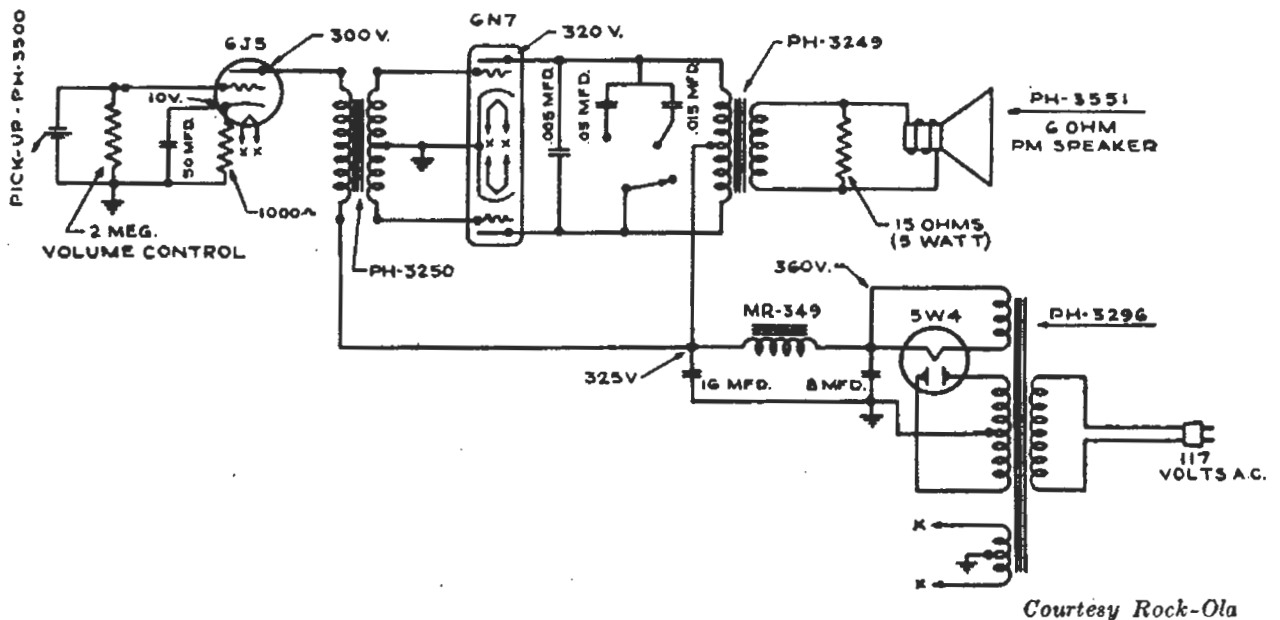
FIG. 21. Schematic diagram of typical class B juke-box amplifier.

rent because a bias voltage for this grid is set up within the tube.

In Fig. 23, a more modern juke box amplifier is shown. The crystal pickup works into a 6J5G voltage amplifier through a special constant-impedance volume control. A tone control of the series type is part of the plate circuit of this stage. Choke-impedance coupling is used to permit push-pull operation of the 6L6G tubes in class A.

As you can see from the diagrams, both this and the preceding amplifier have provision for plugging in an auxiliary p.m. loudspeaker. These are sometimes used when the juke box is installed in a very large room.

The equipment we have described so far uses crystal pickups. In many juke boxes, such as the Wurlitzer 750 shown in Fig. 24, magnetic pickups are used. The magnetic pickup is

FIG. 22. Schematic diagram of typical class A juke-box amplifier.

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coupled through a tone-compensating network to the two-section volume control, which feeds into a 6J5 voltage amplifier. This tube works into a tone-control system, from which the signal goes to a 6SC7 functioning as a low-resistance triode, both triode sections of the tube working together in parallel. The 6SC7 supplies signal power through a choke-impedance coupling to the power output stage,

voltage of 9.8 volts is applied to the amplifier filaments at first. With this above-normal voltage applied, the tubes warm up rapidly. When the filament current rises to the normal working level, a relay is energized and operates; its armature then acts as a transfer switch, disconnecting the 9.8-volt winding from the filament supply circuit and connecting the normal 6.3-volt winding in its place.

Courtesy Rock-Ola

FIG. 23. Schematic diagram of Rock-Ola Model H juke-box amplifier.

which contains two 6L6G's connected in push-pull. This power output stage is considered to operate in class AB; actually the operation is class A at low and moderate volume levels, approaching class B only at high volume levels.

This amplifier contains an arrangement that cuts the warm-up time appreciably. With the amplifier off and the primary circuit of the power transformer opened by a power switch, the 9.8-volt winding on the power transformer is connected to the amplifier tube filaments. No voltage is applied, of course, since the primary is open. When the equipment is turned on, a

HOME RECORDERS

The home recorder is another form of special p.a. system that the radio serviceman is sometimes called upon to repair. Such a recorder can be used both to make records and to play them. The recording section consists of a microphone, an amplifier, a cutting head, and a phonograph turntable. The playback section consists of the same phonograph turntable, a pickup head, the same audio amplifier, and a loudspeaker.

The general arrangement of these components in a recorder is shown in Fig. 25. As you can see from this block diagram, microphone signals are

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Courtesy Rudolph Wurlitzer Co.

FIG. 24. Schematic diagram of Wurlitzer 750 juke-box amplifier.

fed through the amplifier and applied to the recording head, which is more or less the reverse of an ordinary phonograph pickup. In other words, electrical signals applied to the recording head cause it to move a special kind of needle, called a stylus, that cuts a groove in a blank record that is turned by the turntable. Once made, the record can be played back in the conventional manner through a phono pickup.

We shall not discuss the techniques of recordings and the types of recording heads in this Lesson. Here we are interested in the audio amplifiers used in home recorders. Such amplifiers are rather simple, but, since you may be called upon to repair one of them, it is worth while to discuss a typical example.

One feature of the recorder amplifier that is not usually found in other types of audio amplifiers is the volume level indicator. These indicators are used in recorders because it is necessary to keep the level of the signal applied to the cutting head below a certain maximum value and above a minimum level. The value differs for different types of equipment, but, for each type, there is a particular level that must not be exceeded; if it is, overloading and distortion, and perhaps even actual mechanical damage to the record, may occur. The minimum level is set by the noise level of the equipment; if the signal is too weak, you can hear nothing but noise. Some of the more elaborate professional systems use a dual indicator; one must record loudly enough to stay above the minimum, but not so loud as to exceed the maximum. However, on most home recorders only the

maximum is indicated; it is expected that the performer will speak loudly enough to stay above the noise level.

In professional recording equipment, a meter is used to indicate the level of the signal applied to the cutting head. A home recorder is not usually equipped with such an elaborate indicator; instead, it usually has a magic-eye tube that indicates the output signal level.

The schematic diagram of a typical home recorder is shown in Fig. 26. This device can be used as a recorder, as a record player, and as a small p.a. system. In this last use, the mircophone, amplifier, and speaker are the only components that are used.

As you can see from the diagram, the microphone input is fed to the grid of a 6J7 voltage amplifier. The signal then goes to the triode section of a 6Q7 dual-diode, single-triode tube and from there to a 6K6 output tube. The output of this tube is applied through a transformer either to the driving mechanism of the cutting head or to the loudspeaker, depending upon the position to which a three-way switch in the output circuit is thrown.

The diode section of the 6Q7 furnishes a varying d.c. voltage that is used to operate the 6U5/6G5 magic-eye indicator tube. When the switch in the output circuit of the recorder is thrown to the cutting position (position 1), signal voltage is applied to this diode section from a voltage divider that is across the cutting head. Thus, the value of the voltage applied to the diode at any instant depends on the output voltage of the amplifier at that instant. The half-wave rectifying action of this diode produces a pulsating d.c. voltage across the diode load, which is essentially R_{13} and R_{14} in parallel. The d.c. portion of this voltage is applied through the a.c. filter R_{18} and C_{12} to the control grid circuit of the 6U5/6G5 magic-eye tube. The average d.c. value depends on the average audio level, so condenser C_{12} is thus charged to a d.c. voltage, the amount of which at any time depends upon the value of the a.c. output voltage of the amplifier. This voltage across C_{12} acts as a changing bias for the magic eye tube, closing or opening the shadow on the tube as the output voltage increases and decreases. If the audio input is properly controlled, the eye indication
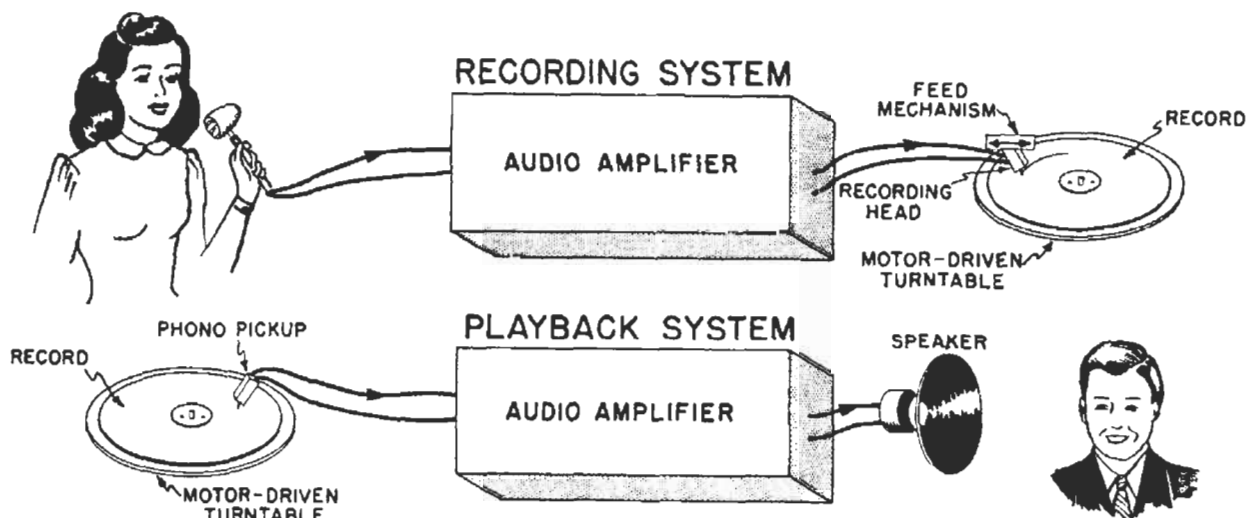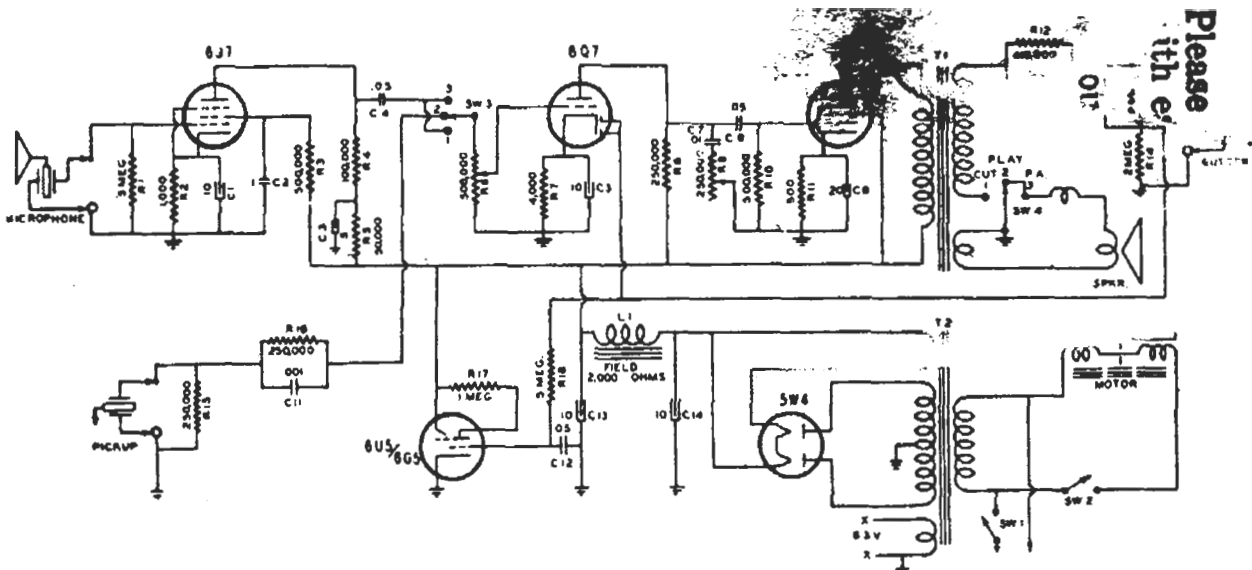

FIG. 25. Block diagram of home recorder system.

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Courtesy Wilcox-Gay Corp.

FIG. 26. Schematic diagram of Wilcox-Gay Model A72 Recordio home recorder.

can be brought to a predetermined level that indicates full recording but not overloading. Any excessive peaks will over-close the eye, indicating a need for reduced input. Below-normal levels will not close the eye sufficiently, so the minimum level is also indicated.

As you can see from the diagram, switches SW_3 and SW_4, which are ganged, control the use to which the recorder can be put. When they are thrown to position 1, both the microphone and the cutting head are connected to the amplifier; this is, therefore, the switch position that permits records to be made. When the switches are thrown to position 2, the pickup head and loudspeaker are connected to the amplifier; this is the playback

position. When the switches are thrown to position 3, the microphone and the loudspeaker are connected to the amplifier. In this last position, the recorder can be used as a small public address system.

The tone control for the equipment consists of a fixed condenser in series with a variable resistor connected from the plate of the 6Q7 triode section to ground.

We have seen how typical amplifier systems are constructed, planned, and installed. We have also learned something about the functioning of various special forms of p.a. equipment. In a succeeding Lesson, we shall learn how these amplifiers are maintained and serviced.

Lesson Questions

1. Why is it impractical to install a p.a. system in a location where the noise level is well over 100 db?

2. What is the advantage gained by paralleling the cathodes, grids, and plates of the dual triodes used in the driver stage as in the Bogen HO125 amplifier?

3. What would be the effect on the output of an amplifier if poor power supply regulation permitted the screen grid voltage on the output tubes to increase when the control grid voltage decreased?

4. What benefit is gained from the use of cathode-follower coupling to link the driver stage to the output stage as in the Bogen HO125 amplifier?

5. In a p.a. system in which several amplifiers are to be used, is it better from the servicing viewpoint to use parallel inputs and parallel outputs or to use parallel inputs and separate outputs?

6. Why is it necessary to provide a constant-load loudspeaker switching system in a multi-channel p.a. system used to furnish several programs to hotel rooms?

7. Under what two conditions is it necessary to use master units at all stations of a wired intercom system?

8. How do signals get from one unit to another in a wireless intercom system?

9. For what reason do some juke-box amplifiers contain a circuit that applies an above-normal filament voltage to the tubes when the equipment is turned on?

10. Why is it necessary to keep the volume of sound to be recorded above a certain minimum level?