A Sound Projector System for Use in Motion Picture Theaters[1]

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SYNOPSIS: The general problem involved in the design of a system suitable to be used to record and reproduce sounds such as are required for "talking" motion pictures is outlined. The general method of attack is indicated. There follows a description of the several pieces of apparatus which comprise the theatre equipment, including a discussion of some of their salient features and of the part each plays in the sound projector system.

IN order to reproduce in a theater the pictorial record of events accompanied by the sound associated with those events, it is, of course, necessary to add equipment to that installed to produce only the silent motion picture. It is the purpose of this paper to outline and discuss briefly the major items of such equipment as developed by Bell System engineers.

In the design of sound equipment a primary requisite is that there shall be freedom from distortion. Distortion may be of the sort which is independent of load and is evident in that the intensity of some portion or portions of the sound spectrum is increased or decreased in comparison with the rest; or there may be the distortion which is a function of the level at which the device is operated and is characterized by the reduction of a pure tone into fundamental and one or more harmonics. This latter condition is most often the consequence of operating a vacuum tube amplifier above its proper energy handling capacity.

It is the resonances of vibrating strings or reeds or air columns or vocal cords that give us the music we record but we are careful that a minimum of the resonances of the recording system itself shall go into the record, and that any resonances of the reproducing system shall not appear in the output of the sound projectors. Aside from the effects of overloading, the prevention of distortion is largely a matter of getting away from resonance phenomena since it is the characteristic of the resonant system to respond with disproportionate amplitude to stimuli in the region of its own natural period. The whole story of the passage from sound energy through the various recording and reproducing devices back to sound energy again is one of contest with this fundamental physical phenomenon.

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There are in general two things one can do to avoid the harmful effects of resonance in vibration transmitting or transforming apparatus: (1) the period of resonance of each piece of equipment can be moved outside the range of frequencies one wishes to transmit, at the same time providing damping means to minimize free vibrations; (2) the distortion produced by resonance in one piece of apparatus can be compensated for or equalized by similar and opposite distortion

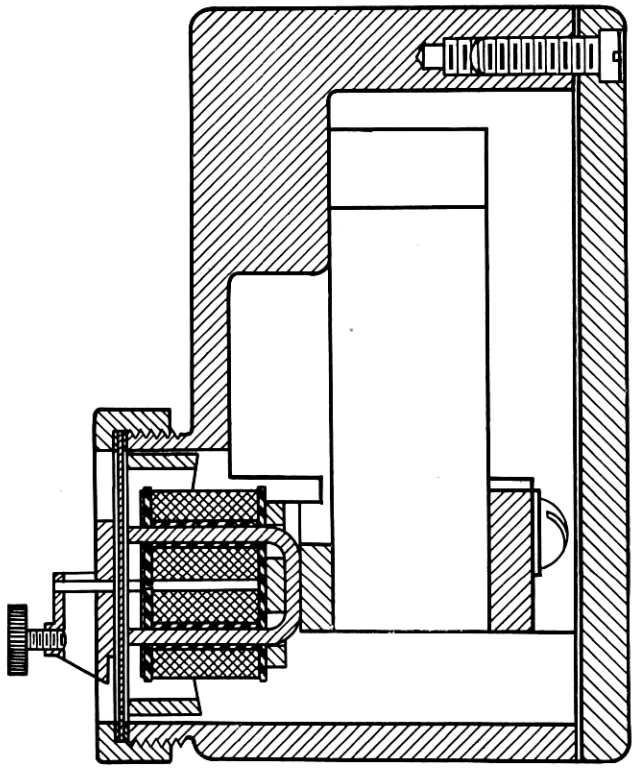


Fig. 1—Reproducer for disc record.

in some associated apparatus. The first is not always easy of practical accomplishment in any particular device and generally results in an instrument of very low inherent efficiency; the second usually involves loss of energy. In both cases increased amplification is required.

The sound record comes to the theater either as a wavy groove in a composition disc or as a striated track of varying density at one side of the picture film. It is the function of the apparatus being considered to derive from these records an electric current in which

all the variations in pitch and loudness are accurately represented, to suitably amplify this current, to effect its conversion into sounds approximating those from which the records were made, and to so direct those sounds as to reasonably create the illusion that sound and picture are cognate.

The disc records do not differ essentially from those used in the ordinary phonograph except that they are considerably larger and run at a much slower speed so that a single record will play throughout an entire reel. The reproducer used is in some ways similar to that

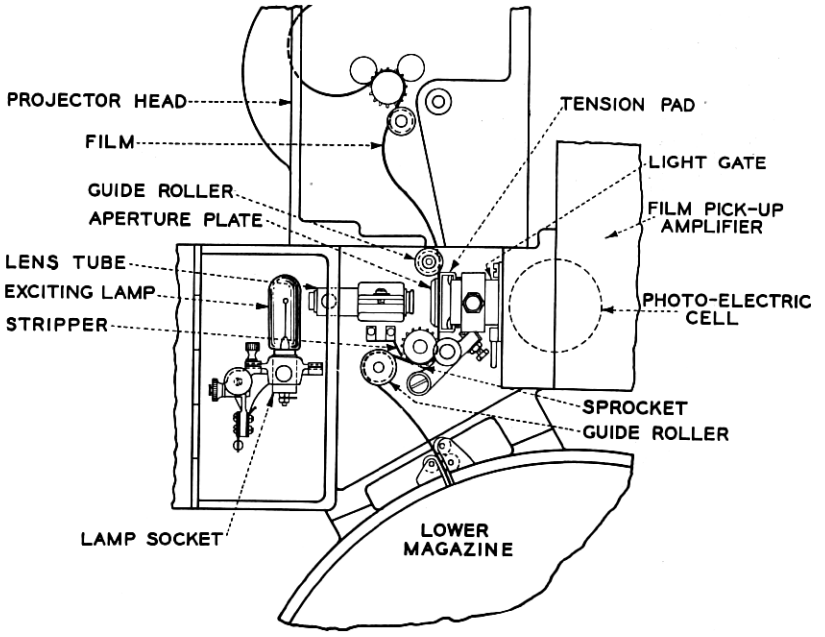


Fig. 2—Diagram of motion picture projector equipped for reproducing sound from film.

used on the acoustic phonograph, the needle holder being connected to a clamped diaphragm. This diaphragm is of highly tempered spring steel and to it there is fastened an armature made of a special high permeability alloy and so arranged that as the diaphragm vibrates the flux in the air-gap of a permanent magnet varies correspondingly, thereby inducing in appropriately placed coils currents which are the electric representation of the wavy groove which the needle travels. This reproducer is shown in Fig. 1. Although the energy delivered by this instrument is comparatively low it has a very uniform response over a wide frequency range. This result is largely brought about

by moving all resonances out of the working range and by filling the magnet chamber back of the diaphragm with a heavy damping oil. The film used with the disc record, called a synchronized film, differs from ordinary film only in that one frame at the beginning is specially marked to give the starting point.

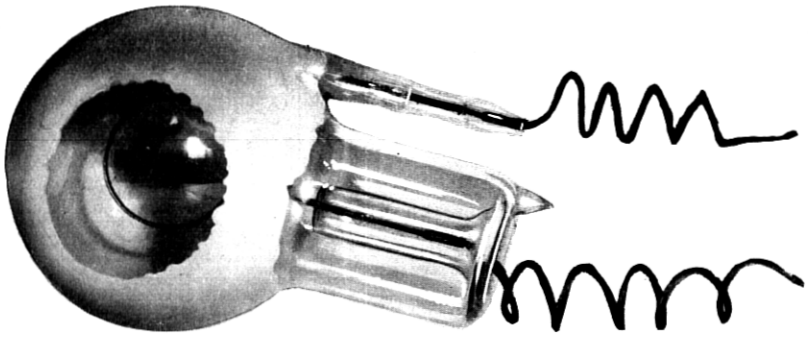


Fig. 3—Photoelectric cell.

The film sound record, as has been said, consists of a track of varying density running along one side of the picture. This sound track is 1/10″ wide. Differences or changes in intensity of sound are represented by differences in the density of the record, while pitch

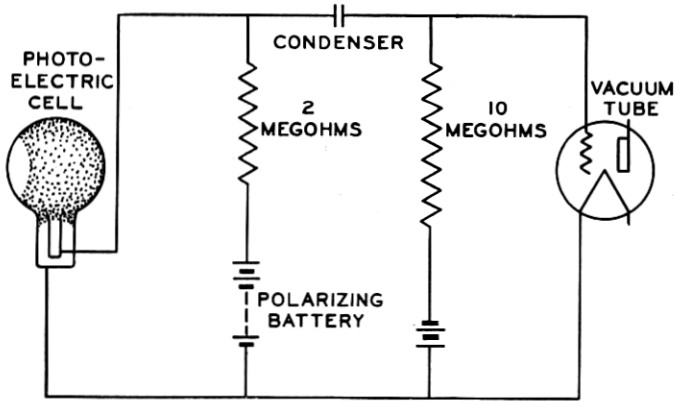


Fig. 4—Photoelectric cell circuit.

is represented by the number of changes from dark to light and back again in a given length of track. This sound record is converted into a corresponding electric current by arranging that a narrow high intensity beam of light shall pass through it and fall upon a photo-electric cell. The arrangement is shown in Fig. 2. The light from

the bright filament of the exciting lamp is focused as a very narrow line upon the film by passing through a system of lenses and an aperture plate. The lamp filament is focused upon a slit of dimensions .0015" x 3/16". The image of this slit is then brought to focus upon the film as a .001" line whose length has been reduced in passing through the aperture plate to .080". This reduction in length allows .010" on either side for variations in position of the .100" sound track. The position and focus of the lens tube are fixed, but the carriage of

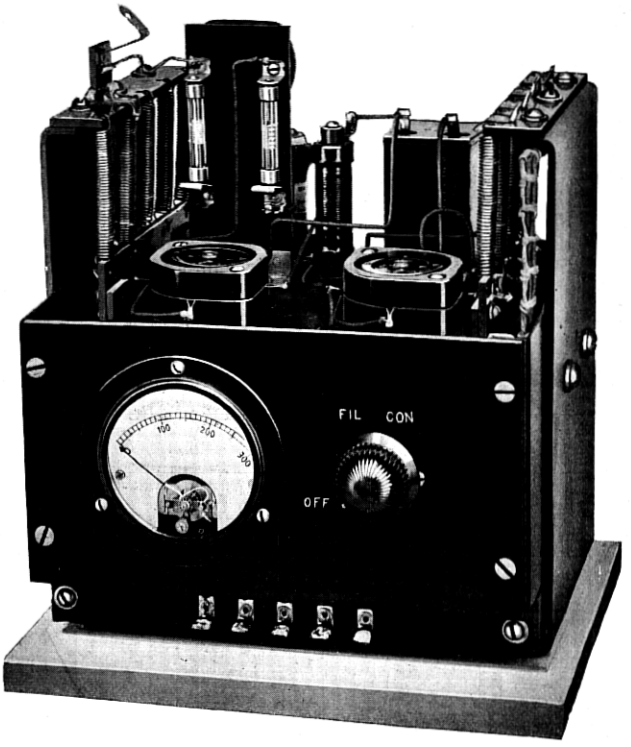


Fig. 5—Amplifier used at projector.

the exciting lamp is movable so that when replacing lamps the filament may be properly brought on focus.

A photoelectric cell of the type used is shown in Fig. 3. The characteristic of this device is that when it is polarized by a proper voltage and is used within proper limits the current through it is proportional to the incident light. The circuit is shown in Fig. 4. It is to be noted that the polarizing voltage is supplied to the photo cell through a very high resistance and there is, therefore, obtained across

this resistance a voltage which is proportional to the light falling upon the cell and accordingly bears a direct relation to the varying density of the sound track interposed between the exciting lamp and the cell.

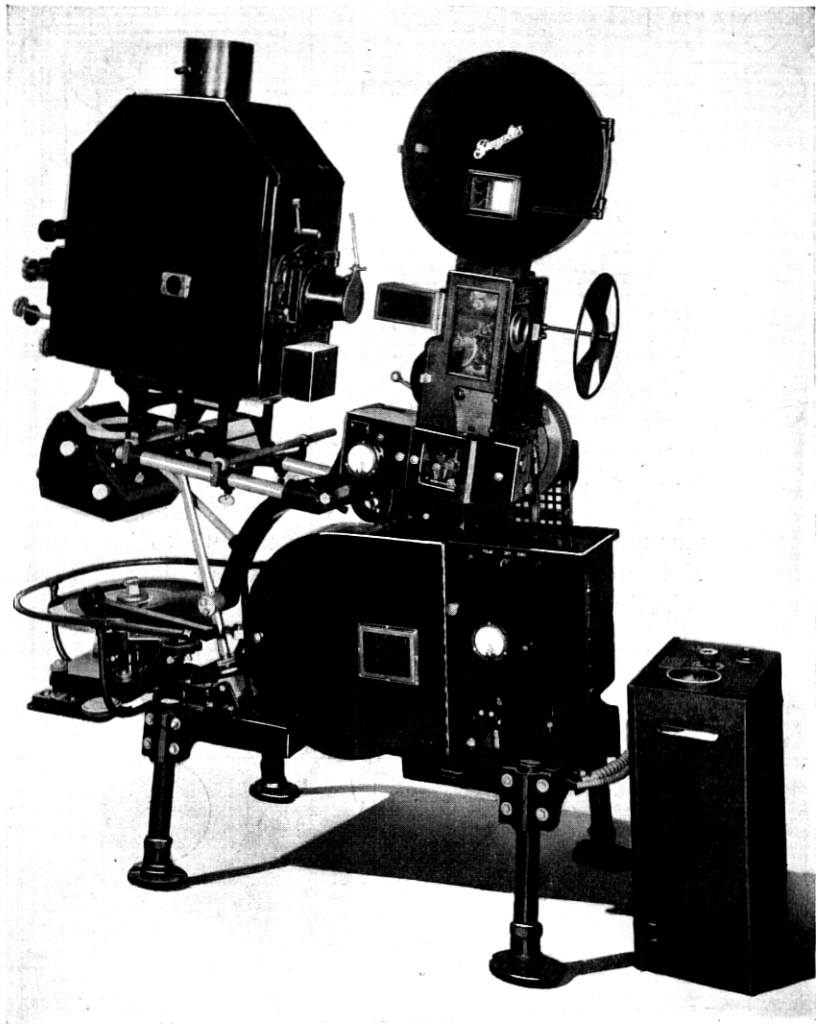


Fig. 6—Sound projector equipped with Simplex head.

The photo cell circuit is inherently one of high impedance. In such a circuit there are two matters which require attention. (1) Local interference—"static," to use the radio expression, is most readily picked up, and at this point where the energy level is low,

may be appreciable in comparison with the sound currents themselves; (2) also the shunting effect of capacity between the electrical conductors becomes noticeable, particularly at the higher frequencies.

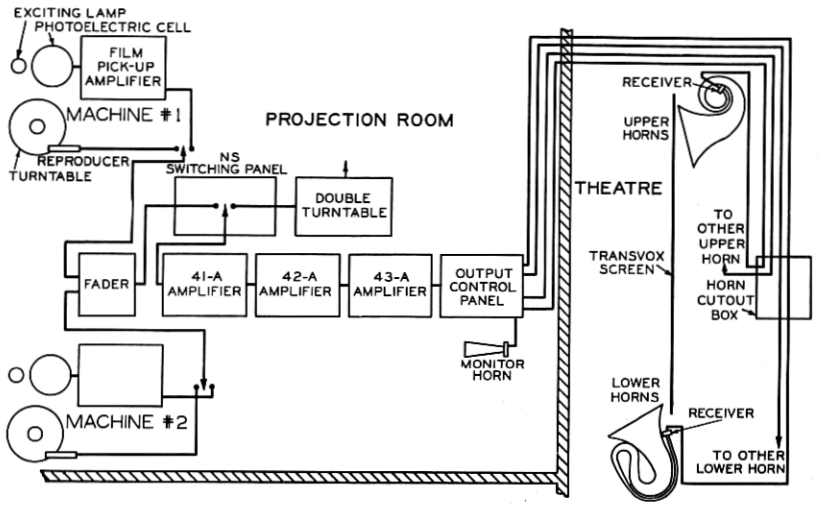


Fig. 7—General layout of equipment.

Hence a vacuum tube amplifier, which serves both to increase the energy and to make that energy available across a low impedance circuit, is closely associated with the cell upon the projector itself.

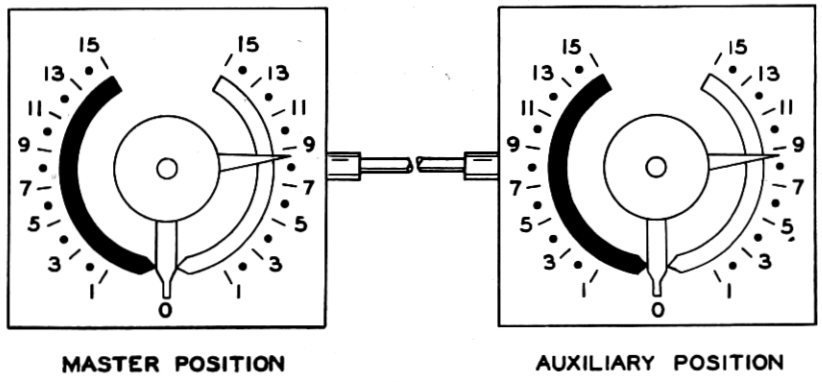


Fig. 8.

The cell and amplifier are enclosed in a heavy metal box or shield which is made fast to the frame of the projector and the projector itself is carefully grounded. This amplifier is shown in Fig. 5. It is designed to bring the level of the electric counterpart of the film sound

record up substantially to the same energy value as that obtained from the magnet coils of the disc reproducer. The filaments are heated from a 12-volt storage battery. Small dry batteries supply its plate

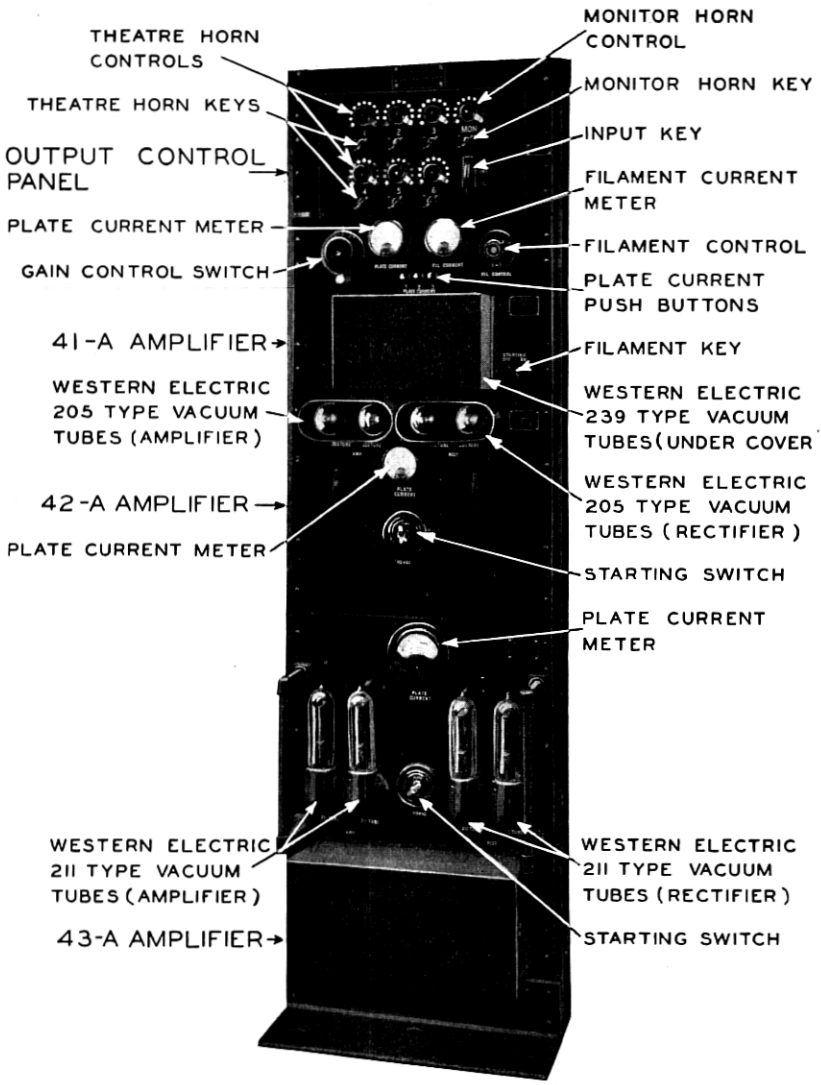


Fig. 9—Amplifier Panel.

current and also the polarizing potential for the photo cell. These batteries and the battery leads are shielded.

Vibration of a vacuum tube often produces sufficient motion of its elements with respect to each other to effect changes in the stream

of electrons which appear when sufficiently amplified as noise from a loud speaker. In spite of all precautions there is a certain amount of vibration of the projector when in operation and it has therefore been necessary to design a rather elaborate shock-proof mounting for the photo cell amplifier.

It is evident from the relative location of apparatus as shown in Fig. 2 that it is not feasible to print the film sound record directly beside the picture to which it applies. As a matter of fact, there is a spacing of $14\frac{1}{2}''$ between picture and corresponding sound record and a certain amount of slack is allowed between the sprocket which carries the picture with an intermittent motion before the picture projection lens and the sprocket which must carry the sound record

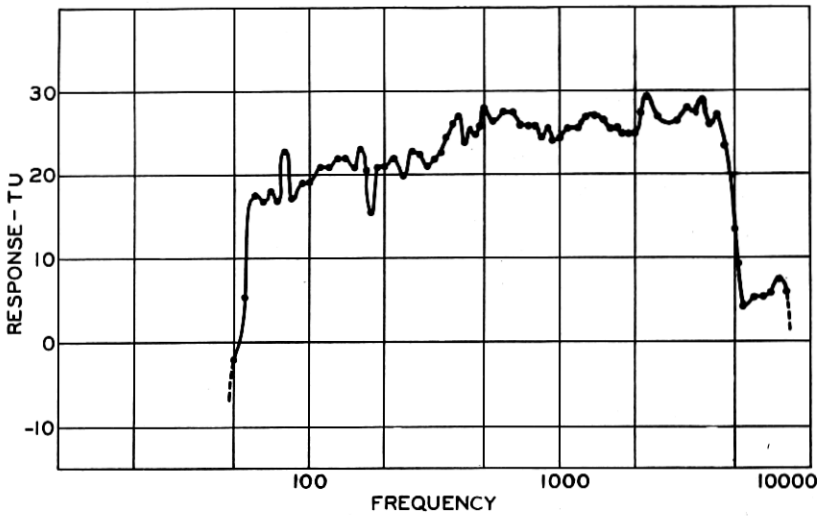


Fig. 10.

with a uniform motion in front of the photoelectric cell. In this connection it is noteworthy that special precautions are necessary in order to prevent vibrations and speed fluctuations due to either varying supply voltage or varying load from affecting the uniformity of rotation of this sound sprocket. This is taken care of by the very effective means of automatically controlling the speed of the driving motor and by means of a mechanical device interposed between the sound sprocket and the rest of the moving equipment of the projector which effectively opposes the transmission of any abrupt change of speed to this sprocket.

The control box which contains the apparatus for governing the speed of the driving motor is arranged to hold the record speed the

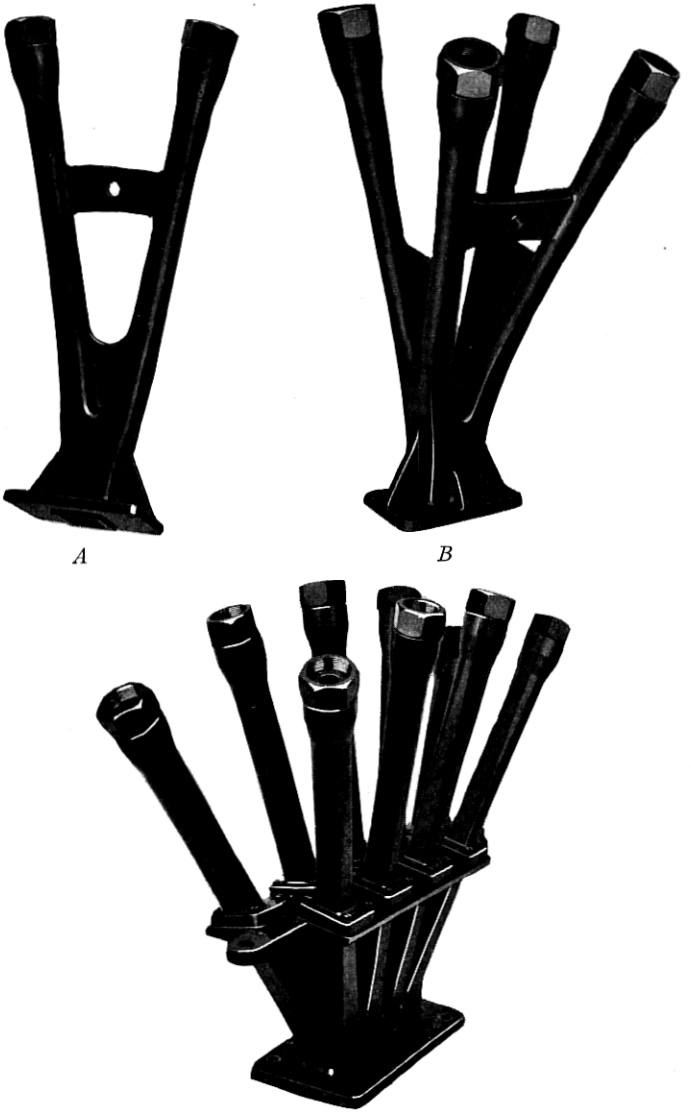
same as that at which the records are made, i.e. 90 feet per minute in the case of synchronized sound and picture productions. By throwing a switch the automatic feature may be cut out and the speed of the machine may then be manually controlled by the operator.

This completes the apparatus associated directly with the projector. The general arrangement of the latest type of projection machine, equipped with a Simplex head, is shown on Fig. 6. Incidentally this projector is also arranged to be fitted with the Powers or the Motiograph head. Fig. 7 shows a typical layout of a sound projector system as installed for use with talking motion pictures.

As in ordinary pictures, in order to run a continuous program, it is necessary to use two projectors alternately. As the picture from one machine is faded imperceptibly into that on the other so the sound record may be faded from one machine to the other without the audience being aware that a change has been made. At the end of each record or sound film the music overlaps the beginning of the next and a device called a fader is employed in making the transition. All that is necessary is to turn the fader knob when the incoming machine is started. This fader is in fact a double potentiometer. In the upper or normal operating range the change in volume in moving from one step to the next is hardly more than perceptible whereas in the lower range used only in fading the steps are large and the volume decreases to zero on one machine and builds up on the other very rapidly. By choosing the proper step in the upper range one can obtain any volume of sound desired within reasonable limits and thereby equalize the level obtained from different sound records. The fader is ordinarily installed with one or more auxiliary dials and handles interconnected so that it may be operated from any projector position. In connection with the fader there is provided a switch for changing from the film to the disc input system and also a key for switching a spare projector in place of either of the regular machines. Fig. 8 shows a fader with one auxiliary position.

Following the fader, we come to the main amplifier which raises the energy of the feeble electric currents to a level adequate to supply the loud speakers with sufficient volume to serve the particular theater. Fig. 9 shows a typical amplifier panel. This combination is capable of an energy amplification of about 100,000,000 times and is so designed that all frequencies in the range from 40 to 10,000 cycles are amplified practically equally. A potentiometer is provided on the amplifier but while its handle is readily accessible it is ordinarily not used after having once been set at the time of installation to give proper results in the particular theater. Necessary adjustments are

made on the fader. The amplifier shown consists of three units. The first consists of three low power tubes in tandem, resistance coupled, and requiring a 12-volt battery delivering 1/4 ampere to heat their filaments. The second consists of a single stage of two medium power tubes, connected in push-pull arrangement with filaments



A *B*

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Fig. 11.

heated by low voltage alternating current. Two similar tubes in this unit operate as a full wave rectifier and supply rectified alternating current for the plate circuits of the amplifier tubes of both the first and second units. The third unit has a single stage of high power push-pull amplifier tubes and push-pull rectifier tubes and also operates entirely on alternating current.

These three types are capable of arrangement into combinations to meet the particular need. For small theaters only No. 1 and No. 2 are required. In the larger houses the high power unit No. 3 is added, while to meet exceptional conditions two or more of the high power amplifiers may be operated in parallel from the output of No. 2.

Following the amplifier there is an output control panel. This consists of an auto-transformer having a large number of taps, the taps being multipled to a number of dial switches, to which the sound projectors or loud speakers are connected. By means of this panel, it is possible to match the impedance of the amplifier output to the desired number of horns in order to obtain the most efficient use of the power available and also to adjust the relative volume of the individual horns.

The ordinary theater installation employs four horns, two mounted at the line of the stage and pointed upward toward the balconies and two mounted at the upper edge or above the screen and pointed downward. This combination has been found to give good distribution throughout the house.

The loud speaker unit used with the horns in theater equipments is essentially that recently described by Messrs. Wente and Thuras.[2] As brought out in this article, this unit shows extremely high efficiency; about 30 per cent of the electrical power supplied is radiated in the form of sound. This is important since the higher the loud speaker efficiency, the smaller the power capacity of the amplifier needed in the system. The frequency-response characteristic of a typical receiver and horn is given in Fig. 10. An individual horn may be equipped with two, four or nine loud speakers by using the throats shown in Fig. 11. The power capacity for continued safe operation of the horn with one, four and nine throats is approximately 5, 20 and 45 watts, respectively (electrical input). The number of horns used is dependent upon the particular installation and is related to the directive characteristic of the horn. If it is necessary to disperse the sound over a large angle, more horns are needed than when it is desired to concentrate over a comparatively small angle. This directive characteristic of the horn is important in talking motion pictures as it is responsible for the illusion of the sound coming directly

from the mouth of the horn; that is, from the screen. If the horn is replaced by a loud speaker of otherwise identical characteristics but which radiates its sound over a very wide angle, there is a tendency for the sound to appear to come from a point some distance back of the screen, thus tending to destroy the illusion.

The power supply equipment has been fairly completely covered in discussing various parts of the system. Under ordinary conditions the requisite power is obtained from the electric mains in the theater except for the 12-volt battery required for some of the vacuum tube filaments and for the electromagnets in the loud speakers and the dry cells used with the photo cell and photo cell amplifier. Where 110-volt D.C. only is available there is a projector-driving equipment which operates on this voltage, but a D.C. motor driving a 60-cycle generator is required for supplying the amplifiers. Where 110-volt A.C. is available, it is only necessary to connect the projector motor and the amplifiers to this supply.

[2] *Bell System Technical Journal*, January, 1928—"A High Efficiency Receiver of Large Power Capacity for Horn-type Loud Speakers," by E. C. Wente and A. L. Thuras.