REPRODUCING EQUIPMENT FOR MOTION PICTURE THEATERS*

M. C. BATSEL AND C. N. REIFSTECK**

Equipment for reproduction of sound motion pictures is located in two places in every theater. The loud speaking or reproducer equipment is on the stage behind the sound screen, and the sound head and amplifiers are in the projection room, usually located at the rear of the theater.

The main elements for successful reproduction of sound accompanying a picture are:

(*1*) A sound head used for translation of the photographic sound record into minute electrical energy.
(*2*) Amplifying equipment to increase the minute electrical energy from the sound head to a value that will operate the loud speakers at the required volume.
(*3*) Loud speaking equipment which translates electrical energy to acoustical energy or sound.

In addition to these three major elements, there are other associated parts used as part of the complete equipment to insure proper performance in the theater. Some of these are: change-over switching systems to transfer the amplifier from one machine to another for continuous performance; a monitor speaker for the projectionist; and, in some installations, a remote volume control located in the auditorium.

(A) THE SOUND HEAD

The sound reproducing attachment or sound head is used in conjunction with a standard motion picture projector. It contains all the optical, electrical, and mechanical equipment necessary to convert the variations in opacity of the photographic sound record into electrical currents.

A recent high-fidelity sound head, known as the rotary stabilizer type, is shown in Fig. 1. This designation refers to the system employed for imparting a steady motion to the film at the point where the translation takes place. This type of sound head is considered a decided improvement over previous types used.

The first types of sound heads employed fixed sound gates consisting of stationary guide plates and pressure shoes for holding the film in the position where it was pulled by a sprocket past the translation point. Experience demonstrated that these gates required almost constant attention to prevent the accumulation of wax and emulsion upon the polished surfaces of the film guides and pressure shoes to prevent the film from chattering or being scratched, which would result in noisy reproduction of the sound. The frictional resistance to the film passage resulted in wear of the guides and pulling sprockets.

A major problem in the first types of sound heads was the achievement of a constant speed of the film at the translation point. Many attempts were made to

* Reprinted from *RCA Review*, I (Jan., 1937), No. 3, p. 65.
** RCA Manufacturing Co., Camden, N. J.

make the pulling sprocket directly below the gate revolve at a uniform velocity by the use of elaborate mechanical filters between the driving motor and the sprocket. In the best of these systems some ripple was present in the sound reproduction from the film, due to uneven motion of the film resulting from imperfect mechanical parts. A serious flutter or rapid variation in the motion resulted from the use of a sprocket to pull the film through the gate by means of the perforations in the film.

The rotary stabilizer type of sound head was designed to eliminate all the objections of the gate type. This was accomplished by the use of a rotating drum to

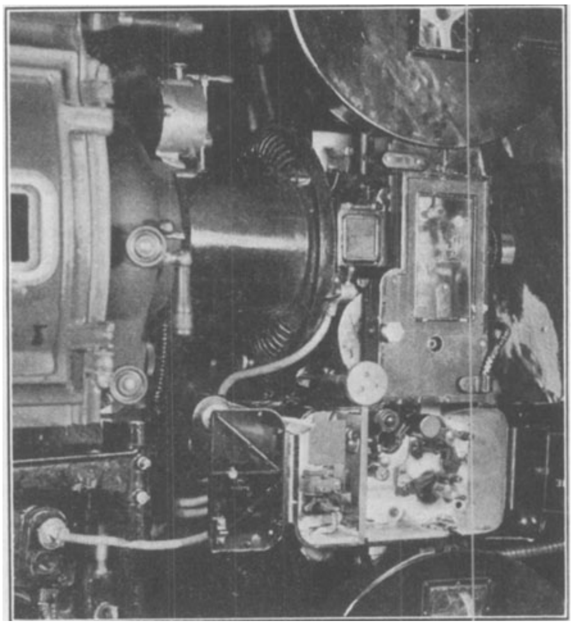

FIG. 1. *Rotary stabilizer type of sound head.*

which is attached the rotary stabilizer elements. Special care was taken to see that the film as it passes through the sound head is bent into as wide a curve as possible, insuring that it would lie flat and all points of the sound-track would be in focus. The free-running sound drum shaft is mounted in ball bearings so that the friction is reduced to such a small amount that it is possible for the film to drive this drum without appreciable tension. This tension is so light that the film is never pulled taut except at the start. The film being in contact with the drum, rotates with it. This prevents any possibility of film scratching. The film assumes a curved path after leaving the sound drum. The stiffness of the film serves as a compliance which, in conjunction with the mass of the rotating elements, acts as a filter to eliminate variation in the motion of the film at the translation point.

The best known expedient for uniform rotation is the fixed flywheel on a shaft. This, however, is unsatisfactory for control of the drum shaft because the flywheel would continually hunt or oscillate with the springy film loop in the same manner that a weight suspended from a coiled spring would oscillate under the slightest disturbance.

The theory of the rotary stabilizer principle was discovered several years ago and was later further elaborated and expanded. This work led to a device for controlling the drum speed that fulfilled the conditions required for a satisfactory reproducer, namely that the system be damped so as to prevent oscillation of the mass of the rotating system when propelled by a spring for absorbing irregularities in the motion of the driving mechanism. The practical form of this reproducer sound head consists of a light case constructed as a short cylindrical casing firmly

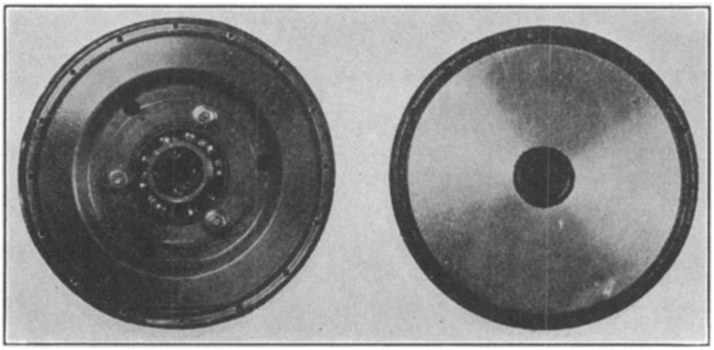

FIG. 2. Rotary stabilizer.

fastened to the drum shaft. Inside the casing upon a hub forming part of the case, a heavy free-floating flywheel is carried on a ball bearing. (Fig. 2.) A light oil fills the remaining space inside the case. The oil acts as a viscous driving medium between the heavy flywheel and the case. The case is sealed so as to be oil-tight. Any tendency for oscillation between the stabilizer assembly and the film loop is prevented, due to the fact that the energy of the disturbance is dissipated in the oil when there is relative motion between the casing and the flywheel, which does not follow rapid changes in the motion of the casing because of its inertia. The relative moments of inertia of the casing and flywheel are approximately one to eight.

To keep the film in proper position upon the drum, it passes between two flanged rollers mounted directly above the drum. To accommodate film of various degrees of shrinkage, one flange is movable. The fixed flange is on the sound-track side, and is known as the guiding roller. The flange assembly is also adjustable within limits so that the sound-track may be adjusted to the correct position for being scanned by the light-beam passed through it to a photocell.

The light-beam is approximately 0.001 by 0.084 inch. It is obtained by focusing an image of a slit in a diaphragm (five times as large) upon the film. The diaphragm in which the slit is put is illuminated by a 10-volt, 5-amp. lamp and a condensing lens. A small collector lens is mounted in the drum over which the film passes. This directs the light to a photoelectric cell. The cell is connected through a transformer of suitable impedance ratio for connecting to a 500-ohm line to the amplifier.

To eliminate possible noise due to vibration of the lamps or photocell, the motor is mounted upon rubber, and the rotating sound drum, optical system, photocell, photocell transformer, and exciter lamp are also mounted upon one plate and resiliantly mounted to the main case of the unit.

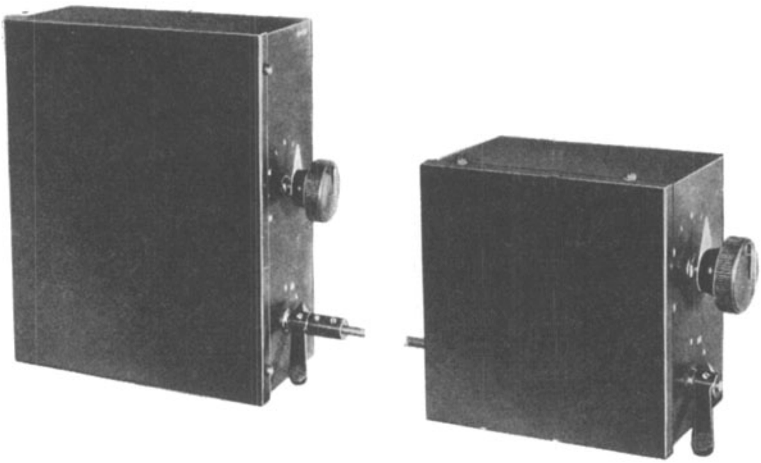

FIG. 3. Fader box.

(B) AMPLIFYING EQUIPMENT

A current type of amplifying equipment consists essentially of a fader box (Fig. 3) mounted upon the front wall of the projection room at each projector; a main amplifier (Fig. 4); a monitor speaker amplifier; a monitor speaker (Fig. 5); and an exciter lamp and loud speaker field supply unit (Fig. 6).

The fader system is used to connect the sound head to the amplifier at the time the picture changes from one reel to another. It consists of a switch for exciter lamp change-over and a 20-db. variable attenuator pad. This pad serves to preset the volume from the machine to a predetermined level, or to eliminate changes in volume at the change-over due to different sound level on the film. By this means the projectionist need not leave his position at the projector to make adjustments of volume after the change-over.

The main amplifier in Fig. 4 is the type used in the larger theaters. It is so constructed that all parts can be removed from the front for ease of service. It consists of a voltage amplifier and one or two power amplifiers. The equipment is,

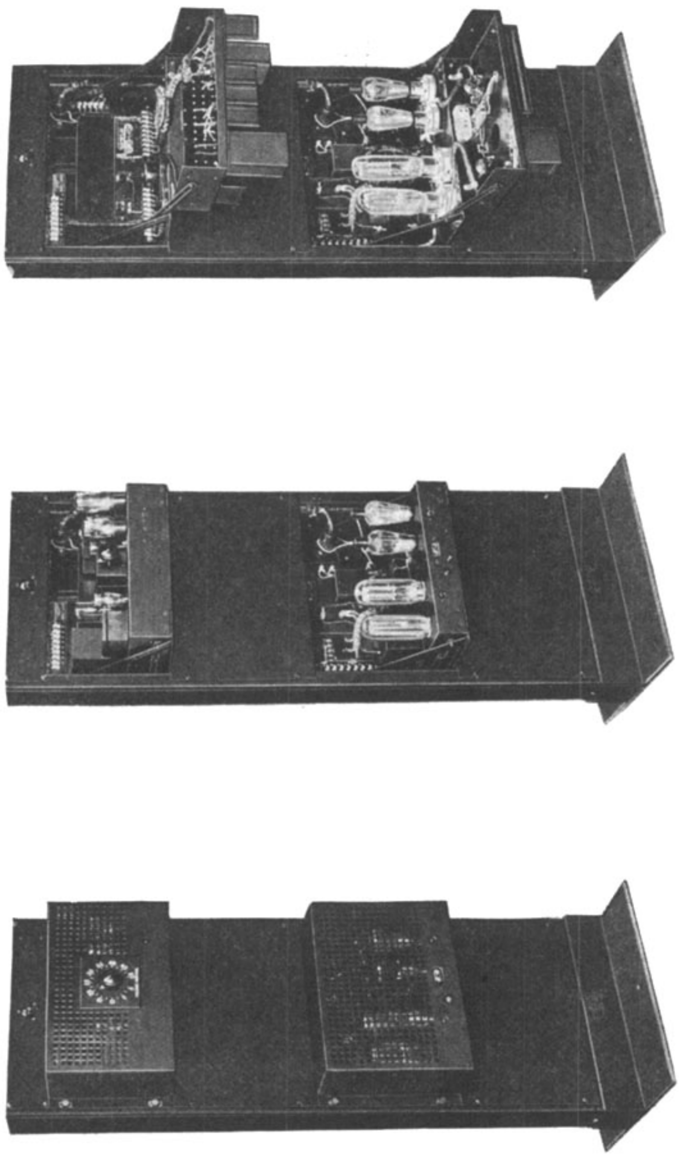

FIG. 4. Main amplifier.

completely a-c. operated and self-contained. Each amplifier is complete in itself including its own rectifiers for power supply. The voltage amplifier has sufficient voltage amplification to drive the power amplifiers when the input terminals are connected to the line from the photocell transformer. Both voltage and power amplifiers are novel in construction. Each amplifier consists essentially of three parts; namely, a vertical panel, a base proper, and a base support. On the vertical panel attached to the rear of the rack are mounted the heavy power supply parts, such as power transformers, filter reactors, *etc.*, and the base support. On the base support are mounted very few parts, as its main function is that of sup-

FIG. 5. Monitor speaker.

porting the main base and the inter-panel cabling. On the main base are mounted the main amplifier parts and the tubes. This main base is so constructed that it can be hinged down for inspection and service. It can also be completely removed without the use of a soldering iron, as all connections are made to the vertical panel through screw terminals. In the circuits employing large capacitors these are segregated into sections in parallel. Important sections of capacitors and points of the circuit are fused against possible trouble. Failure of a section of the filter capacitor that is fused will permit the program to continue until the end or until such time as repairs can conveniently be made.

An indicator of the neon lamp type is placed in the plate circuit of the amplifiers to indicate that the circuit is functioning properly. The lamp is lighted at all times; failure to light indicates no plate current to the tubes. The trend in recent years in electrical equipment has been to eliminate all unnecessary controls and meters. Alternating-current operated amplifiers and modern amplifier tubes do not require tube controls or meters for adjustment. Only one manual control is found on the main amplifier. This is the master volume control, which can be preset and need not be changed for the entire performance. Experience of projectionists (who are occupied in keeping the show going) with this type of amplifier in the past years indicates that the design is practicable and capable of meeting the requirements for uninterrupted service.

The monitor amplifier is self-contained with its power supply, and is mounted

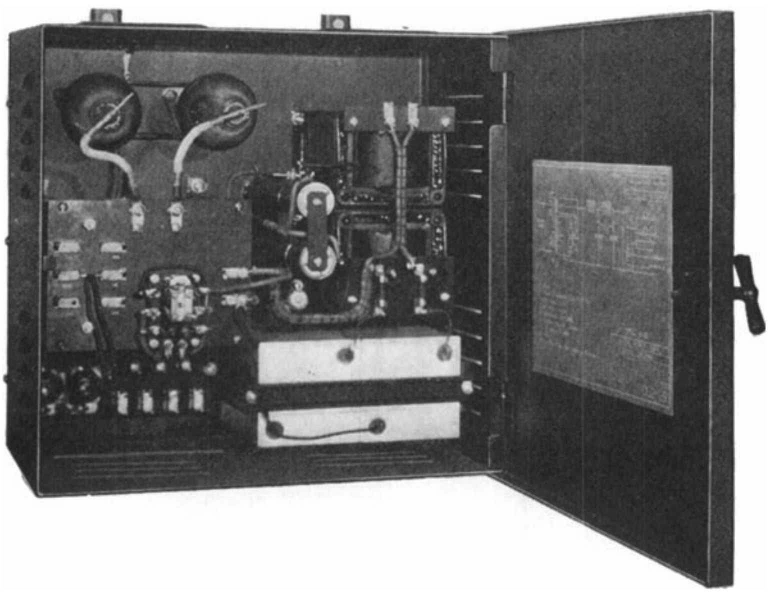

FIG. 6. Exciter lamp and loud speaker field supply unit.

in some convenient location upon the projection room wall. It is made to bridge the speech circuit to the stage. It has a separate volume control to permit adjustment for noise conditions encountered in a projection booth. Its output is sufficient to drive the monitor speaker (Fig. 5) to give adequate sound at each projector station. Monitor speakers are primarily used to indicate that the speech circuit to the stage is functioning properly, and to give the operator the proper sound cue for change-over from one machine to another.

The exciter lamp and loud speaker field supply rectifier and filter unit (Fig. 6) supplies power for the exciter lamp in the sound head (10 volts at 5 amp.), and 18 watts at 12 volts for each of the loud speakers. Change-over from one machine to another is accomplished by means of a relay controlled by the control switch at each projector station.

(C) LOUD SPEAKER EQUIPMENT

A recent design of loud speaker (Fig. 7) equipment to be installed on the stage consists of two separate speakers, one of which reproduces the frequency range below 300 cps. and the other above 300 cps. A dividing network or filter serves to divide the electrical output of the amplifier accordingly.

The low-frequency speaker is made up of two folded exponential horns, each 40 inches high by 80 inches wide, mounted one above the other. Each horn has

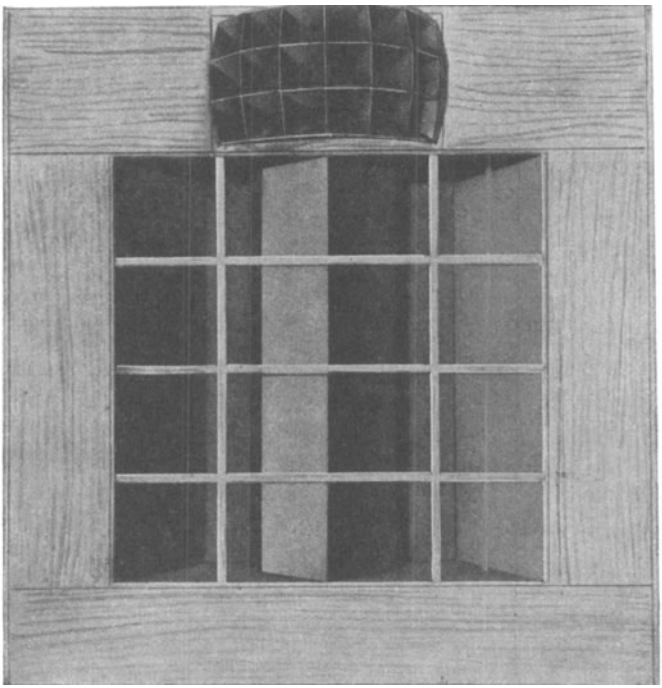

FIG. 7. Multiple section loud speaker.

two 14-inch cone type driver units. The frequency range is from 40 to 300 cps. as used with the dividing network.

The high-frequency speaker is of the exponential type. It consists of a number of small exponential horns, each measuring at the bell opening approximately 7 × 7 inches. These small horns are assembled into clusters, forming the equivalent of a large horn with partitions dividing it into sections. All sections are driven by two speaker mechanisms through a *Y* throat.

A plain exponential horn has a directional characteristic that varies with frequency. The higher the frequency the more narrow the beam becomes. A single exponential horn mounted in place of the multiple-section horn shown in

Fig. 7 would give a resultant "bassy" reproduction to that portion of the audience in seats located well off the axis, and the reverse would be true for those directly upon the axis.

This effect is eliminated if a cluster of small exponential horns is used. The mouth opening formed by the cluster is spherical in shape. Four sizes are used for various types of theaters, each three layers of the small horns in height, and varying in angle from approximately $52^1/_2$ to 105 degrees, in clusters of nine, twelve, fifteen, and eighteen of the small horns. The width of the theater and the acoustical properties of the side walls determine the angle used. The high-frequency speaker operates over a frequency range from 300 to 10,000 cps. The 300-cycle

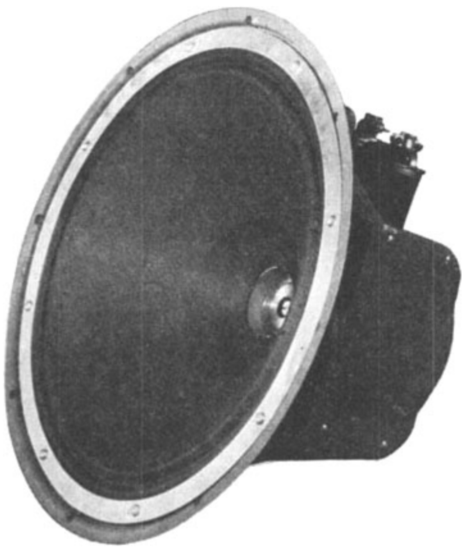

FIG. 8. Low-frequency speaker.

crossover was selected as a compromise on high-frequency horn length. Moving it to a higher frequency is a disadvantage from the standpoint of division of primary speech sounds. The limitation in depth of the speaker assembly is brought about by the necessity of flying the speakers on theater stages where stage presentations are given and the loss of lines for scenery drops is a problem.

The low-frequency driver mechanism (Fig. 8) is a high-efficiency cone type dynamic speaker. Four of these are used per installation. The high-frequency driver mechanism (Fig. 9) is a cone type unit. The cone is molded from a fiber sheet and has no seams. It is treated to make it moisture proof. It has been determined that the strength per unit weight or mass of the diaphragm for this fiber is greater than can be obtained with other materials.

The size of the auditorium and its acoustic properties have a very definite influence upon the size of the equipment to be installed, and frequently the acoustical characteristics of the auditorium require that the characteristics of the equipment be adjusted to compensate for undesirable effects. It may be necessary, due to high absorption of the low frequencies, to supply additional energy to the low-frequency speakers and *vice versa.*

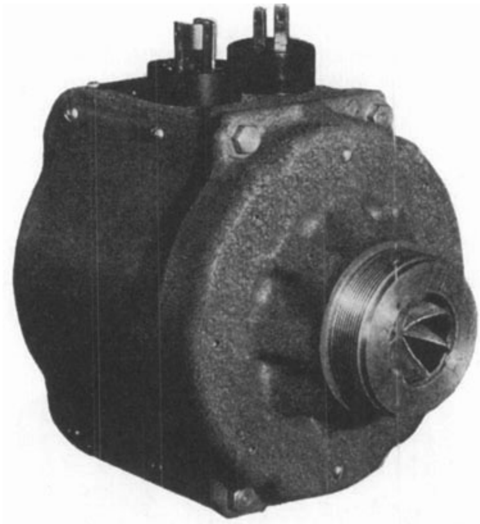

FIG. 9. High-frequency loud speaker driving mechanism.

It is customary to rate equipment according to theater seating capacity and volume of the auditorium. Experience has shown that the following classification of theaters as to size results in a commercially satisfactory arrangement of equipment:

	Cubical contents in cu. ft.
Up to 500 seats	75,000
500 to 800 seats	120,000
800 to 1400 seats	200,000
1400 to 3000 seats	720,000
3000 up—Special custom equipment	

The type of sound head used is not dependent upon the size of the theater. For economic reasons the types and sizes of amplifiers and speaker complements are selected as required for the seating capacity and size of the theater. It is desirable that all equipment be installed under the supervision of factory trained installation engineers who make the final tests and adjustments of the installation.