in turn provide some impetus to this snowballing effect.

Summary

A pattern of utilization of educational film based on a classroom film library is much more feasible with 8mm than with 16mm. But 8mm does not guarantee, in and of itself, that a classroom film library pattern will develop. There are collateral requirements which must be met — requirements in terms of film design and of making the educators aware of the possibilities. Organized effort is needed and can do much at this stage of development.

A Self-Contained Recorder for Motion-Picture Sound

By WILLIAM V. STANCIL

New techniques in motion-picture production now require compact camera and sound equipment. A self-contained, battery-operated and transistorized tape recorder is described which provides synchronization with both spring-driven and motor-driven cameras. The 13-lb recorder may be used in conjunction with 35mm, 16mm or 8mm cameras, and the resultant sound may be transferred to sprocketed film for editing and subsequent release, or it may be synchronized with projectors for double-system viewing.

When sound was originally introduced to motion pictures, it created tremendous interest, and the public accepted the relatively static performances. Through the intervening years, both the producers and directors have sought more compact equipment to free them from fixed locations and confined areas. While the cameras have remained approximately the same size, new acoustical housings are available which greatly reduce their bulkiness. The sound equipment has made tremendous strides in departing from the original telephone company concept of centralized transmission racks down to hand-carried, self-contained units.

The volume of program material demanded for television has somewhat reduced the production standards that motion pictures have always tried to achieve. The sheer bulk of television productions precluded the many dramatic techniques and the excellent quality which motion-picture people had come to expect. Since now more people see television than ever before witnessed theater motion pictures, perhaps the public's viewing standards are somewhat lower. With this transition of both techniques and standards has come the increased demand for mobility involving the documentary type of dramatic presentations.

A number of evolutions had to transpire to permit a fluid type of motion-picture production, whether it be for theater or television release. The feeling has always been that since 35mm cameras were large and heavy, there was little incentive to reduce the motor-drive systems and power supplies. Hence, with heavy and large camera equipment, not too much concern was felt about the size and efficiency of the accompanying sound equipment. All the technicians associated in the editing and processing of both the sound and pictures felt no urgency to depart from their recognized procedures. With the excellent progress made in Europe in the tape-recording field, some of the motion-picture studios worked out methods of synchronizing nonsprocketed tape with standard motion-picture film. Outgrowths of this work appeared in the United States in the form of a 60-cycle signal recorded transversely in the center of $\frac{1}{4}$-in. tape. The 60 cycles which was recorded was the same as used to drive the synchronous motor on the camera so that on reproduction the 60 cycles was "resolved" and used to control the transfer from tape to magnetic film. Through the years this system has proved very satisfactory, and in the United States and in Canada a number of motion pictures have been and are being produced by this system. Other systems were subsequently employed in the United States wherein a carrier frequency recorded on the same track with the normal audiofrequency was modulated by 60 cycles, and again this signal was used for subsequent transfer. Two of the well-known magnetic recorder manufacturers in the United States employ this system.

These several systems did prove that synchronized tape could be successfully handled with the sprocket hole film. Perhaps the approach of directly recording 60 cycles has proved slightly more satisfactory because of the ease in recording and reproducing 60 cycles. High-frequency carrier signals have often been subject to dropouts and other interferences resulting from poor tape contact or foreign material which ultimately accumulated on the tape surface.

Experience With Miniature Tubes

The flexibility and broad requirements of the electronic systems in motion-picture recorders held back any major reduction in size until the advent of transistors. The Stancil-Hoffman Corp. of Hollywood, Calif., introduced the self-contained Minitape in 1949, and it was its intention to furnish a synchronized soundtrack for motion-picture production. The original recorder used miniature vacuum tubes with a preset recording level. A small d-c motor was speed-regulated by a tuned vibrator to realize high efficiency. It was planned to record two tracks on $\frac{1}{4}$-in. tape using one track for the audio and the second track for a synchronized signal. The state of the art at that time indicated a carrier frequency lower than had been used and yet modulated by 60 cycles. A frequency of 3000 cycles was chosen as this represented the maximum unequalized tape output. The program was not particularly stressed as either microphone mixing facilities had to be provided or automatic volume control incorporated as a means of holding the proper recording level. Extensive work was performed on subminiature tubes, but the inherent noise and "microphonics" of these tubes in high-gain audio circuits proved very discouraging. The corporation established the requirement and program for both a better mechanical system and improved electronics. Fortunately, at this time information was released on the new world of transistors. Projects were then established to design audio circuits with automatic-gain controls for miniature packaging. As a result, Stancil-Hoffman announced, and had in production, one of the first completely transistorized magnetic recorders available.

Presented on May 9, 1961, at the Society's Convention in Toronto by M. M. Elliott for the author, William V. Stancil, Stancil-Hoffman Corp., 921 N. Highland Ave., Hollywood 38. (This paper was received on June 26, 1961.)

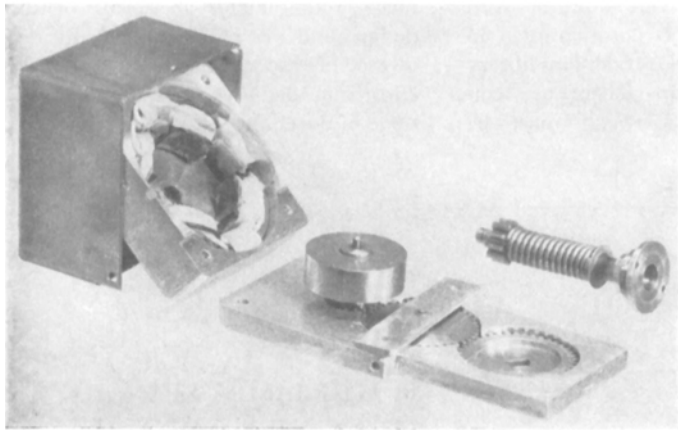

Fig. 1. Disassembled view of 4-pole sync generator, which, when spring-driven at 1800 rpm by a camera, will produce a 60-cycle synchronizing tone which is recorded on the 2-track battery-operated recorder.

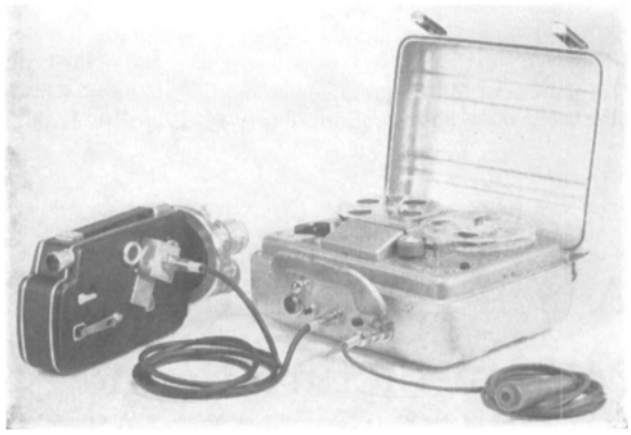

Fig. 2. The 2-track battery-operated recorder with microphone and cable connection along with the cable connection to the spring-driven camera on which a 60-cycle synchronizing generator is installed.

Storage Battery Design

With the improved electronics, a new tape transport was designed and a stable and highly efficient, regulated d-c motor was developed. The new model seemed to provide all the facilities for dependable sound recording and the program was then centered on locating a suitable battery. The earlier Minitape had used lead acid storage batteries with fair success. When a unit is self-contained and offers such extreme portability, it is obviously used in the cruelest of environmental conditions. In the extreme low temperature ranges, the lead acid battery loses a large percentage of its capacity. Furthermore, miniature versions of these batteries require continuous maintenance, which, when coupled with their extremely poor regulation, basically eliminated such a battery for the new recorder. Other batteries had been introduced and extensive tests were made to locate a type of battery which would perform satisfactorily over the extreme temperature ranges and under all the conditions that would be encountered. As an outgrowth of the tests, the nickel-cadmium type of battery was chosen, as it presented excellent regulation and met the temperature requirements. Of importance, too, it was the least expensive of the newer battery designs that were available.

Battery manufacturers were encouraged to produce cells in the 4-amp-hr size. The first battery chosen for the Minitape seemed to offer this capacity and meet the other requirements, although it was a vented battery of the nonspillable type. Production problems in the manufacture of the battery apparently were not solved because many cells exhibited leaks in the plastic seal molding process. A limited number of recorders were released before the leakage tendency became apparent. Fortunately, a leading manufacturer in the United States completed the design of a sealed cell which is now incorporated in the recorder.

The Minitape was now complete. It offered excellent speed regulation, was of rugged and lightweight construction, and used transistorized amplifiers matching all professional standards of recording and reproducing. Stancil-Hoffman then re-established its program of synchronizing tape and film. It was decided that rather than use the 3000-cycle carrier, 60 cycles would be directly recorded on a second track. Since by this time most studios were equipped with two-track stereo equipment, the Minitape sound could be transferred conveniently in most areas.

Two tracks slightly over 90 mils each are recorded on $\frac{1}{4}$-in. tape. The audio track conforms to the practices of present magnetic standards. The 60 cycles is recorded on the second track, and while bias is not necessary it may or may not be used. If line power is available when a picture is being produced, the camera is equipped with a synchronous motor and a small portion of the signal from this 60-cycle source is recorded on the second track of the Minitape. For location shooting, the camera may be driven from rotary converters or other a-c sources so that again this same frequency is recorded.

The major attractiveness of the system, however, is its use away from power lines. The cameras are equipped with a subminiature 60-cycle generator so that they may be driven from either d-c or wild motors at a standard 24-frame/sec speed, and the generator produces 60 cycles. Some cameras lend themselves very well for the simple addition of the generator, whereas others have to be disassembled and gears installed to provide an 1800-rpm output shaft. The Eastman Kodak K-100 16mm motion-picture camera, for example, is one which requires little modification. Cameras such as the Arriflex 16 must be disassembled and a 10 : 1 gear ratio installed from a 180-rpm internal shaft.

The generator consists of a cylindrical permanent magnet rotating at 1800 rpm within a four-pole field coil structure. Depending upon the inductance of the recording head, the generator output is relatively low. In the case of the two-track Stancil-Hoffman heads, only 0.065 volt is needed for the 60-cycle track.

Adaptation of 8mm Camera

While an 8mm camera would not normally be used for commercial production, the corporation adapted an Eastman Kodak model which had automatic exposure and a zoomar lens. The combination of the Minitape with its automatic volume control and push-button operation, coupled with a camera having fixed focus and automatic exposure, created a "lip sync" motion-picture system for operation anywhere. The camera is small enough to be conveniently carried in one's pocket, and the recorder is easily carried by hand.

Fast color films have sufficient latitude to produce reasonably good quality pictures in night clubs and locations generally not suitable for normal equipment.

The 8mm camera is a production item which would not be suitable for the usual generator attachment. It was disassembled and a pinion gear was installed to be driven from the shutter drive. A shaft from this gear was extended through the mechanism to the rear of the camera where the generator was attached. A small two-wire cable electrically connected the generator to plug into the recorder. Some very interesting and unusual recordings were made on cable cars in San Francisco, on fire engines and horse-driven buggies in Disneyland, at several public indoor meetings. No attention was paid to either lighting or microphone placement, but the results were amazingly adequate for this type of "documentary" coverage.

The zoom-type lens was generally utilized for dramatic interest, and the automatic exposure followed exceedingly well from sunlight to reflected lighting in shadowed areas. In night clubs and auditoriums there was usually sufficient illumination from a spotlight or other stage lighting for reasonable quality. In some instances, the sound was picked up acoustically from the PA system, and in other instances, a direct pickup was made by attaching the microphone to some nearby prop.

The tests indicated the tremendous possibilities of 8mm sound color pictures produced by automatic and inexpensive equipment which certainly would satisfy all requirements for TV newsreel coverage. Some TV stations in the United States have adapted their film chains to accept 8mm projection. Many film-processing laboratories have recognized the challenge of fast film processing vs. video tape. Certainly in its favor is the fact that standard cameras of compact design can be universally used, and the final edited material can be projected throughout the world upon receipt.

Procedures for 16mm Applications

For most commercial applications it is felt that 16mm cameras would be used with the installed generator. On playback, the selected "takes" are rerecorded to sprocketed magnetic film for editing and transfer. The tapes recorded on the Minitape may be reproduced from it or from any standard stereo playback. The audio is fed to the magnetic film recorder and the 60-cycle tone is amplified through an 80-w amplifier to drive the synchronous motor on the film recorder. Obviously, any speed excursion in the camera or the recorder will compensate the speed of the synchronous motor when re-recording so that the time relationship between the picture and sound is always constant.

Any spring-driven camera will indicate a slight speed change as the spring runs down. This will affect the pitch of the recording, but generally on speech this would not be noticeable. Since the time capacity, as a function of the spring power is relatively short, scenes are covered in two or three angles and focal lengths. These are intercut to achieve the most interesting presentations, and the short "takes" do not hamper the end result.

For double-system viewing, a synchronous motor can be outboarded to any of the standard projectors. In this case, the Minitape sound is amplified to drive a loudspeaker, and the 60-cycle tone drives the projector synchronous motor through the separate power amplifier.

A number of methods can be used to establish the sync mark at the beginning of each scene. One method is to use a magnetic clutch to couple the synchronous motor to the projector. The motion-picture film is edited to select the desired scenes, and the clapstick or start mark is retained. The tape is similarily cut for the selected scenes, and a 3000-cycle tone, or other high-frequency tone, is superimposed at the point of the clapstick. In the experimental work accomplished at Stancil-Hoffman, a long strip of 3000 cycles was pre-recorded and $\frac{1}{2}$-in. lengths were affixed over the clapstick modulation. When playing the tape back, the tone energized the magnetic clutch. By having the projector threaded to the start mark with the synchronous motor running, it instantaneously started when the magnetic clutch was energized.

Another method employed was to utilize a loop of tape between the reproduce head and a separate head which picked up the synchronizing signal. By varying the length of this loop, the synchronizing signal could be advanced or retarded to bring a scene in sync. Others have made the sync pickup head placement adjustable so that the distance between the sync signal and audio signal could be changed for retarding or advancing the synchronization.

The Minitape original sound quality will generally satisfy all production sound requirements for 35mm entertainment pictures, as well as the documentary and news coverage. This now provides the directors and producers with a flexible tool for production coverage that cannot be duplicated on the set. Television can greatly benefit by the simplicity and flexibility of the Minitape and compact cameras. While the process is probably too cumbersome for normal amateur shooting, film coverage of trips and expeditions can certainly be enhanced with the addition of sync sound to cover native music, background sounds and sound effects.

We are indebted to John Flory of Eastman Kodak for his encouragement and assistance in the 8mm phases of the sound synchronization.