THE BBC VISION ELECTRONIC RECORDING APPARATUS

by

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Reprinted by Technical Instructions Section from the E.B.U. Review, Part A - Technical, No. 49, May, 1958

Reprint Article No. A.14

BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

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by P. E. AXON *

The problem of recording television signals on magnetic tape has been the subject of investigation for many years and we have already published details of equipment developed for this purpose in the United States of America, where such apparatus is beginning to appear on the market. In particular, "E.B.U. Bulletin" No. 46 contained an article by von Braunmühl and Schmidbauer, which described the principle of the "Ampex" system, together with some observations on the advantages of magnetic recording compared with optical recording on film. Again, in the "E.B.U. Review" No. 48-A, we gave a description of the "R.C.A." equipment, which is suitable also for recording colour television.

This present article deals with a new system of recording television on magnetic tape, the first to be developed in Europe. The system is remarkable not only for its novelty, but also for its originality. In contrast with the American systems, which use very wide magnetic tapes, recorded transversally and running at the speed used for sound recording, the B.B.C. equipment uses a tape of more normal dimensions, recorded longitudinally, but running at a considerably higher speed. It will be most interesting to compare the performance of the two systems when they are in operational use by broadcasting organisations, which will in the next few years almost certainly record more and more television programmes on magnetic tape. *Editor.*

1. *INTRODUCTION.*

The use of magnetic recording in sound broadcasting is now common and it has taken over from the disk system the major load of recording work in this field. This is because of the high fidelity which can be obtained, the availability of the recording for immediate reproduction and numerous subsequent reproductions without deterioration, and the ease with which it can be edited. These properties, in particular the immediate availability of the recording for reproduction or editing, have for a long time made the idea of a magnetic system of television recording attractive to broadcasting organisations. In the United States, in particular, the time difference between peak viewing hours in various parts of the continent necessitates delaying, for periods of up to three hours, the transmission of important or expensive programmes to different areas. A system of magnetic television recording [1] is already in successful operation in the major U.S. networks. Although these particular conditions do not exist in Europe, the magnetic system is still very attractive to individual Services for purposes of immediacy and because of its potential cheapness, especially if a picture of good quality can be produced without undue difficulty. It is the purpose of this article to give a general description of a television magnetic recorder which has been developed in the B.B.C. Research Department, successfully demonstrated on transmission and which is to be put into experimental operation in the B.B.C. Television Service shortly. A more detailed description of the machine, by the author and other members of the development team, will be published elsewhere.

The magnetic recording system is of course a waveform recording system, so that video recording is effected in terms of the television standards of the country in which the programme is recorded. The complete recording ideally contains, in some form or other, all the information relating to synchronisation, picture and sound. In the British system, a video magnetic recording must, therefore, accommodate signal frequencies ranging from zero to something approaching 3 Mc/s. With this in mind, it may be helpful, before describing the main features of the B.B.C. equipment, to review some of the problems [2] which have to be overcome in the development of such a system. Needless to say, the existence of particular difficulties determines important features of the design. The problems, as they might apply to a conventional magnetic recording machine, on which an attempt is made to record the video signal, using conventional heads and a single magnetic track, may be summarised as follows :-

(i) Conventional heads are incapable of dealing with the high-frequency information, firstly because of the frequency losses occurring within their cores, and secondly because of their inability to record or reproduce (i.e. resolve) the short wavelengths that correspond to the high frequencies at reasonable tape speeds.

(ii) The signal-to-noise ratio at very low frequencies is inadequate, firstly because the output from the reproducing head decreases with frequency at 6 decibels per octave and secondly because the percentage of useful flux entering the head decreases as the long wavelengths corresponding to very low frequencies become comparable to, or greater than, the overall dimensions of the reproducing head.

(iii) The tape itself is unsuitable when employed for this purpose in such a simple system. It may be

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insufficiently flexible, or of insufficient general smoothness, to allow the intimate contact with the heads required for the recording and reproduction of short wavelengths, and the random occurrence of " drop-outs " will lead to serious line-tearing and other synchronisation difficulties.

(iv) The tape-transport system of the recorder is incapable of providing the speed constancy required. Imperfections in this respect will be manifest on the television monitor, at best as an unpleasant movement of the picture or, at worst, as a failure to synchronise at all.

The problems summarised above are, of course, not independent of one another. For example, it would be of little avail to develop a head capable of resolving some given short wavelength unless the surface smoothness of the tape available is adequate and the losses due to effective separation between head and tape at that wavelength are small. In practice it is necessary to raise the recording speed for video recording well above that employed in normal sound recording, so that the wavelengths of the higher video frequencies are increased to a value at which the resolution problems are reasonable and the separation loss is acceptable. This, in turn, affects the design of the tape transport system. Again, low-frequency difficulties can be overcome by the use of carrier systems, but, if the whole of the video band is to be borne on a carrier, the mean frequency must be high and even greater demands will be made on the high-frequency response of the system. Compromises must, therefor, be made in various features of design to resolve the often conflicting requirements of high and low frequencies, long and short wavelengths and mechanical considerations. It is, however, possible to state with certainty that satisfactory compromises can be made and telerecordings of high quality can be obtained using a magnetic system.

2. *DESCRIPTION OF THE APPARATUS.*

2.1 *General.*

The B.B.C. Vision Electronic Recording Apparatus has been designed to record the vision and sound signals of television programmes for subsequent reproduction at any time after the recording has been effected. A photograph of one machine is shown in *Fig. 1.* An operational channel consists of two such machines, controlled from a central control desk. The machine employs magnetic tape 0.5 inches (13 mm) wide and a reel of diameter 20½ inches (52 cm) such as those shown in *Fig. 1* will accommodate fifteen minutes of programme. Continuous recording is possible by the use of two machines and the control desk. The tape speed adopted in the present model is 200 inches/sec (508 cm/sec) and the magnetic tape used may be thin-base recording tape of good quality as used for sound recording.

The machine employs a three-track system of recording, two of the tracks being devoted to the storing of the video signal and one to the storing of the sound signal. Separate recording and reproducing head-stacks are employed, each stack containing three identical heads separated from each other by copper screens and aligned with respect to one another in the manufacturing process to the accuracy required. The recorded picture and sound can be monitored continuously during the process of recording.

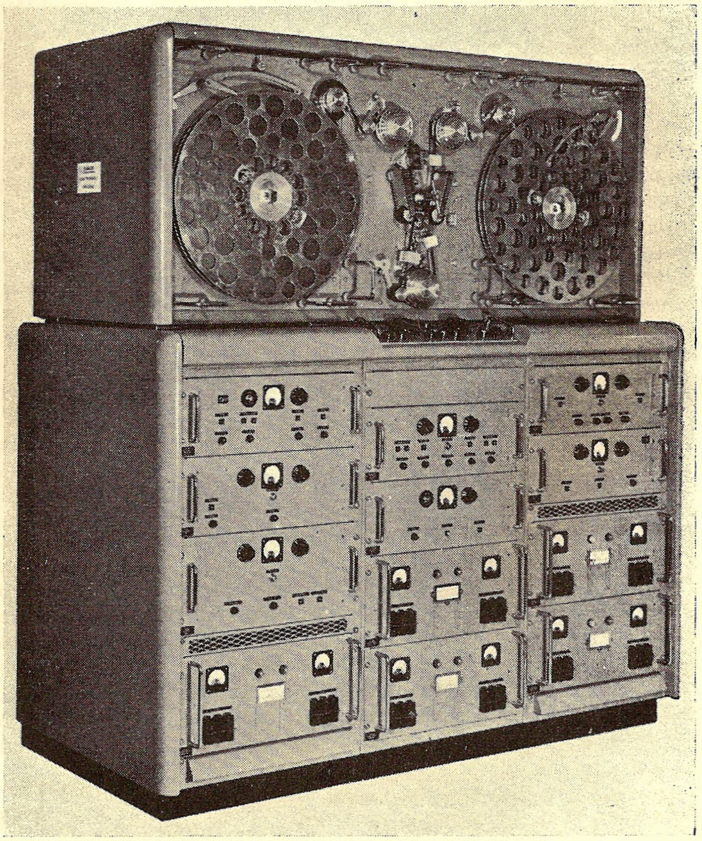

Fig. 1. — General view of Vision Electronic Recording Apparatus designed by the B.B.C.

(B.B.C. photo.)

2.2 *Electronic Design - The Video Signal.*

A block schematic diagram showing the connections of the principal electronic units embodied in the machine is shown in *Fig. 2.* For storing the video signal the two video tracks are associated, on the recording side, with a band-splitting system in which the video signal is divided into two frequency bands of approximately 0-100 kc/s and 100 kc/s-3 Mc/s. The 0-100 kc/s video band is made to frequency-modulate a carrier, which is then recorded on one track. In this frequency-modulation system, the bottom of the synchronising pulses corresponds to 1 Mc/s and the peak-white level of the picture to 500 kc/s.

The low-frequency content of the video signal is thereby transferred to a frequency band corresponding to shorter wavelengths so that both the low-frequency and the long-wavelength difficulties inherent in the conventional magnetic-recording system are avoided. What is even more important is that the amplitude-limitation normally associated with the reception of frequency-modulated signals may be incorporated in the reproducing chain to eliminate undesired amplitude fluctuations. The degree of limiting available with the frequency deviation ratio employed enables the system to overcome most of the " drop-out " difficulties, even when employing thin-base sound recording tape not specifically manufactured for video or instrumentation purposes. The higher video band, from 100 kc/s upwards, is recorded simultaneously on the second video track in a conventional manner.

On reproduction the output from the frequency-modulated video track is limited, demodulated and added to the output from the higher-frequency track to reform the composite television waveform. Before transmission the synchronising information, including horizontal and vertical synchronising signals and suppression periods, is extracted, reconstituted and added to the video signal.

It is, of course, obvious that the higher-frequency video band, which employs a conventional recording/reproducing system, will be subject to the same unwanted amplitude-modulation which is eliminated by the frequency-modulation system employed to record the lower-frequency video band. It is, however, an important finding that in practice reasonably transient and random variations in the higher frequency band do not noticeably degrade the subjective quality of the picture as long as the corresponding information relating to synchronising signals and the main brightness structure of the picture, which is contained in the lower (0-100 kc/s) video band, is maintained intact by the frequency modulated channel by which it is handled.

2.3 *Electronic Design - The Sound Channel.*

All the low-frequency and long-wavelength difficulties which, in the case of the lower video frequencies are overcome by the use the carrier system, will also be manifest in the sound channel if a conventional recording of the sound signal is attempted under the higher tape-speed conditions dictated by the video-signal requirements. These difficulties are, however, overcome by a similar technique to that employed to store the lower video frequencies. Accordingly the sound signal is, before recording, made to frequency-modulate a carrier of mean frequency 250 kc/s and deviation $\pm$ 75 kc/s which is recorded on the third track. On reproduction the carrier is limited and demodulated to provide a sound signal of high fidelity exactly synchronous in time with the video information reproduced from the other two tracks.

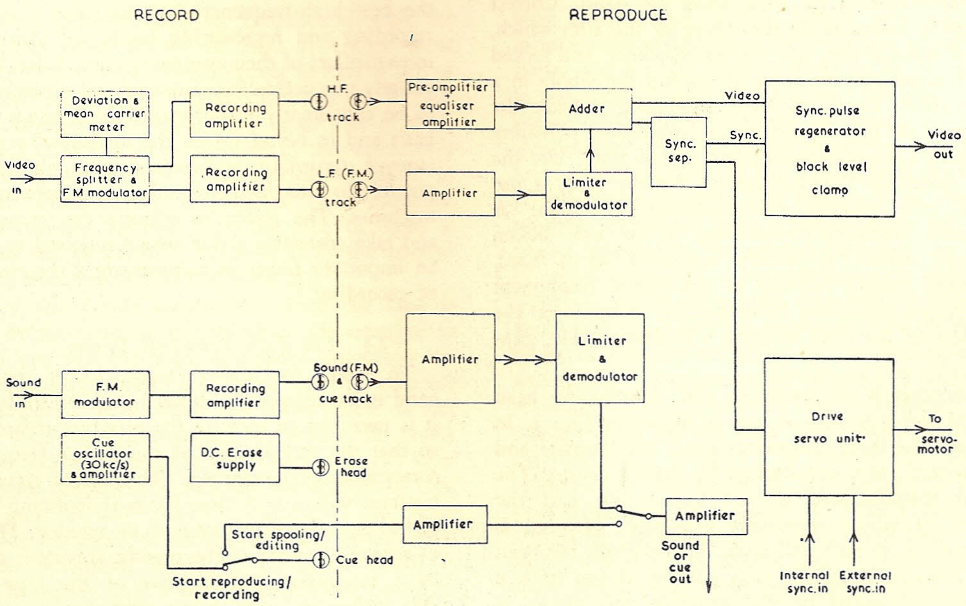

Fig. 2. — Block schematic diagram of the principal electronic units.

2.4 *The Magnetic Heads.*

The development of magnetic heads with sufficiently low losses at high frequencies and with the high resolution required is one of the major problems of video recording. Eddy-currents are the main cause of frequency losses in laminated heads of the conventional type at video frequencies. These losses can, of course, be reduced by the use of thinner laminations, but satisfactory recording and reproduction of the higher video frequencies requires a lamination so thin, if the magnitude of the losses is to be acceptable, that the handling of the laminations in the construction of the head ceases to be a matter of practical routine manufacture. As in many applications where high frequencies are involved, therefore, suitable ferrites must be chosen for the head cores. The mechanical properties of ferrites are unfortunately quite unsuitable for the proparation of gap edges and working surfaces of the accuracy and durability required in high-resolution heads. Although, by careful grinding and polishing, comparatively smooth surfaces and sharp edges may apparently be obtained, the result for recording purposes is illusory and the surfaces and edges quickly deteriorate in contact with the abrasive magnetic tape. Accordingly it is necessary to adopt a technique such as that described by Kornei [3] and to face the head with a suitable magnetic material of superior mechanical properties. The front faces of the heads manufactured in the B.B.C. for the present machines are of " Mumetal ", but the much harder magnetic alloy " Alfenol " (4) will obviously be preferable for this purpose when it is available. To provide the resolution required in the heads a gap length of the order of 2 x 10^{-5} inches is required. In early heads manufactured for the machine very satisfactory results were obtained using mica spacers. Pieces of suitable mica film of the thickness required may be obtained, given a judicious mixture of skill and patience, by progressive tearing of mica sheet by hand. Correct thickness is indicated by the colour of the film which, when of suitable size, may be "sandwiched" and locked between opposite pole faces by potting the whole in a casting resin. Pieces of mica projecting outside the confines of the gap are removed in subsequent polishing operations. Clearly, however, the use of mica, like the use of extremely thin laminations for the core, is not a very easy routine manufacturing operation. A convenient alternative, however, is to use silicon monoxide, which is widely employed as a hard, transparent coating material in the optical component industry, and which can be evaporated in vacuo on the pole faces of the head to form a durable, stable, gap-spacer [3].

A photograph of recording and reproducing head stacks of the type now in use is shown in *Fig. 3.* In each stack the three component heads are identical and are separated from one another by copper screens. The stack is manufactured in two halves and half the thickness of silicon monoxide gap-spacer required is evaporated on to each half-stack. In practice it has been found difficult to obtain film stability if too thick a film, as represented by the complete gap spacer, is evaporated on to one pole. With satisfactory films in position the two half-stacks are joined, using suitable jigs to the accuracy required, the whole being potted in a casting resin inside a metal case. The objective in the manufacture of this stack is to obtain three gaps which are in accurate alignment with one another, and which lie in a plane at right angles to the base of the head. The head-mounting on the actual machine is provided with adjustments which enable (a) the alignment of the head-stack to be correctly set on installation with respect to the direction of motion of the tape and (b) the lap of the tape over the heads to be varied to give the best high-frequency response. The designs of the recording and reproducing heads are identical except in particulars of their energising coils. It has been found entirely practicable for recording and reproducing heads to be consistently manufactured on a batch production basis and to be set up on the machines to give simultaneous recording and reproduction. It is therefore possible to interchange recorded tapes between heads or machines. The ability to monitor the recorded signal and take corrective action where required is, of course, an important factor in maintaining a consistent quality of recording.

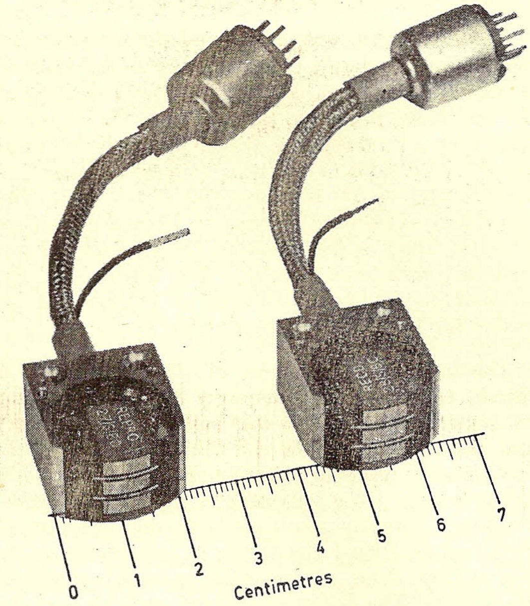

Fig. 3. — Recording and reproducing head stacks.
(B.B.C. photo.)

2.5 *The Tape Transport System.*

To enable the higher frequencies of the television band to be adequately resolved in the recording system, it is necessary to increase the effective recording speed so that the wavelengths of the higher frequencies are correspondingly enlarged. This speed must remain constant within very close limits if irritating movement of the reproduced picture is to be avoided. The increase of recording speed in the present apparatus is obtained by a straightforward increase of the tape speed to 200 inches/sec., this being sufficient, in conjunction with the heads that have been developed, to provide the required resolution. This is an entirely practicable tape speed, provided that the tape transport system and its controls are properly designed for the purpose. A diagram of the tape transport system embodied in the machine is shown at *Fig. 4*.

The correct conditions necessary to avoid damage to the tape when quickly starting and stopping large reels, or engaging or disengaging the drive at the speed employed, have of course to be ascertained. When this is done, the operations are best accomplished, with the safety factor necessary for equipment of this nature, by making the whole process automatic. Starting and stopping of the machine, including the correct timing for the engagement or disengagement of the drive and the release or application of brakes, is done by single push button operations which control the rotation of power-driven cams working in conjunction with the pressure-roller arms shown in *Fig. 4*. Under these conditions modern tapes would appear to have a life of several hundred playings without deterioration. In fact, all tapes improve with use over a large part of their life as their surface becomes polished by movement over the heads and other parts of the mechanical chain. In any event, when editing is practised on a magnetic system it usually follows that the life of tape is determined not so much by the wear as by the amount of editing which is carried out upon it.

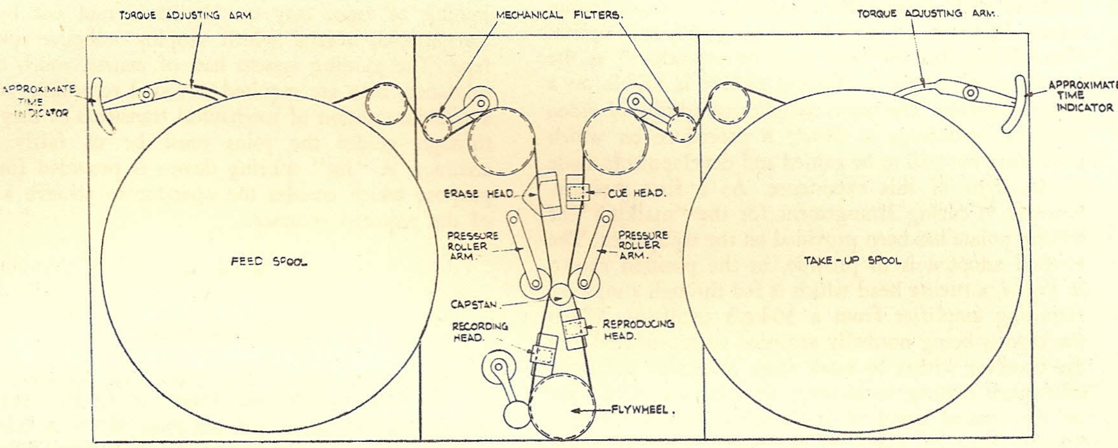

Fig. 4. — Schematic diagram of the tape-transport system.

Most of the power required to drive the tape is supplied by the spooling motors which are arranged to move the tape past the heads at a speed just below the chosen recording speed, and close to the constant tension required, even when the drive motor is not engaged. This result is obtained by varying the power fed to the spooling motors in accordance with (a) their torque/speed characteristic and (b) the amount of tape on the reels at any particular moment, the latter determining the speed of rotation required of the reels. In normal operation, therefore, the drive motor is required to supply only a limited amount of power to bring the tape speed up to 200 inches/sec. The drive is engaged by lowering two rubber idlers which press the tape on to a common capstan so that a loop is formed which is largely isolated from transient effects in the reels by the combination of the idlers and the heavy flywheel mounted on the capstan shaft, and by the other mechanical filtering elements shown in the illustration. The recording and reproducing head-stacks lie inside the loop and the erasing head is placed at a convenient point outside it, preceding the recording head. The capstan is rotated, nominally at 3000 r.p.m., by a split-field d.c. motor forming part of a servo-system commonly known as the "Velodyne" (5). The motor is coupled coaxially to a tachometer-generator and is used in conjunction with a high-gain amplifier to provide a sensitive speed-control system. In addition to the primary servo loop, formed by the tachometer generator and high-gain d.c. amplifier, a second servo loop is employed in the present application which increases the sensitivity of the correction system to speed errors and enables locking facilities to be introduced in recording and reproduction. During recording periods the driving motor is made to rotate in synchronism with the mains supply by comparing the frequency of rotation of the capstan with the frequency of the mains supply. The frequency of the capstan rotation is obtained from a photo-electric cell which is placed adjacent to the capstan fly-wheel, on the edge of which is painted a variable-area sine wave. As the fly-wheel rotates its painted edge reflects light from a small pilot lamp into the photo-cell. The reflected light varies in intensity according to the variable area track and results in the generation of one full sine-wave per revolution of the fly-wheel. This is compared with the mains supply and the error which results is fed to the high-gain d.c. amplifier to correct the speed. On reproduction the output of the machine is locked in both frequency and phase to station synchronising signals by comparing two 50-c/s wave trains extracted respectively from the station and the recorded synchronising signals. Any error generated is again fed by the d.c. amplifier into the windings of the split-field motor to achieve a close locking system. In this way the machine may form one of a number of programme sources which, as is common practice, are locked to a common master synchronising signal.

2.6 *Editing.*

As in other forms of picture or sound recording, a requirement will arise in the use of magnetic vision recorders for the editing of programme previously recorded. Simple editing, in the form of replaying extracts from a previously recorded programme, may be achieved by starting the machine at any predetermined point in the recording. This facility is available because the machine is equipped with the usual facilities for spooling the tape backwards and forwards to find a desired point in the recording. The method may be extended, as in magnetic sound-recording practice, by cutting and joining extracts from various recordings or different parts of the same recording. Individual frames cannot, however, be examined in a "gate", as in optical film editing, for the tape must be reproduced at the correct speed before a coherent picture is visible on a picture monitor. The more complicated editing of video magnetic recordings is clearly a procedure on which experience has still to be gained and developments made in the light of this experience. As a first measure, however, a cueing arrangement for the "marking" of editing points has been provided on the equipment. The method adopted is to provide, in the position shown in *Fig. 4,* a cueing head which is fed through a separate recording amplifier from a 30-kc/s oscillator. When the tape is being normally recorded or reproduced and the observer wishes to mark some particular point for subsequent cutting, or starting, he presses a "Cue" key on the control panel of the machine which causes a 30-kc/s burst of signal to be recorded on the sound track of the tape. The cue signal will not interfere with subsequent reproduction of the television sound because its frequency is well below that of the frequency-modulated carrier which holds the sound programme and any amplitude effects will be removed by the limiting process which precedes detection of the normal sound signal. However, when the tape is moving slowly past the reproducing head at a fraction of the normal speed, determined by the spooling speed control, the cue signal can be made to produce an audible note in a loudspeaker or head-phones so that the point previously marked is found. The 30-kc/s oscillation may, if required, be modulated over a limited band of speech frequencies so that editing instructions can be recorded, or alternatively, it can be amplitude-modulated by vertical synchronisation pulses so that the equivalent locations of these parts of the signal on the video tracks are known. In practice the cutting point is very largely chosen with reference to the sound context of the programme originally recorded, but this being done, the precise cutting point may be located by the use of the above system in the nearest convenient recorded vertical synchronising signal. In subsequent reproduction this avoids a major phase discontinuity in the train of synchronising signals from which the servo system error signals are derived. The actual joining of tapes may quickly be carried out by the conventional means which employ adhesive joining tape. The guiding system has, of course, much closer tolerances than are required in sound recording, and to avoid the creation of mechanical transients as they pass through guides the joins must be of fairly high accuracy. A "jig" splicing device is provided for this purpose which enables the operator to achieve a join of the required accuracy.

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