A New Recording Medium For Transcribed Message Services

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A magnetic recording medium composed of rubber impregnated with magnetic oxide and lubricant is particularly suited to applications requiring the continuous repetition of short transcribed messages. It affords exceptional life, reliability, and economy in telephone applications, where it is utilized in the form of molded bands stretched over cylinders of the recording mechanisms.

In the Bell System there are several applications requiring the repetition of short voice announcements. Some of the existing applications are weather announcements, intercept of calls to vacant and unassigned numbers, quotations of delays on long-distance calls, and certain leased industrial services, such as stock price quotation. Most of these require continuous repetition of messages between 5 and 60 seconds in length. In some the message remains fixed but in others it is changed at frequent intervals.

Magnetic recorders offer particular advantages for services of this nature, because they require a minimum of equipment and operating skill to produce durable records which are instantly reproducible without processing. For several years the Bell System has used a magnetic recorder employing a loop of Vicalloy tape in the 3A announcement system to furnish weather announcements, and a similar type of recorder has been used in a leased industrial system at the *New York Times*.

Recently these Laboratories have undertaken the development of transcribed message facilities to meet additional service applications. It was required that the new facilities should provide satisfactory transmission quality and afford considerable flexibility in regard to message length, but the paramount requirement was for reliability and long life.

It did not appear practicable to extend the techniques of the Vicalloy tape machine to give the flexibility, convenience of operation and reliability desired in the new applications, and attention was therefore directed to two new classes of magnetic recording media which have been developed in recent years. These are the electroplated media and the powdered media.

In recent years magnetic recording media have been commercially produced by an electroplating process by the Brush Development Company of Cleveland, Ohio. Evaluation by Bell Telephone Laboratories shows that such a plating does not easily deteriorate, gives a relatively high signal output and is capable of excellent transmission characteristics. But in order to realize consistently satisfactory transmission, it is necessary to maintain intimate contact between the recording medium and the magnetic recording and reproducing heads. The expense of providing the relatively precise mechanisms necessary to obtain the desired performance objectives suggested the exploration of other media which might simplify this problem.

The powdered magnetic media have evolved from German work dating back to about 1932 and from American work since about 1941. In these media the active magnetic material is a finely divided ferro-magnetic powder, usually iron oxide. This is usually applied with a binder as a surface coating on a tape of plastic or paper, but the Germans at one time produced a tape which was a homogeneous mixture of oxide and plastic. In their present state of development, media of this type offer excellent transmission characteristics and are relatively economical. In the past four or five years they have found widespread commercial application in the form of coated tape in all fields of recording and transcription work.

Attempts were made to employ commercial types of these coated tapes in various forms of continuous-loop mechanisms, but none met the desired requirements in regard to life, reliability, and flexibility of operation. An analysis of the experimental results indicated that most failures were due to physical failure of the media as a result of the tension, flexion and abrasion to which they were subjected, but the magnetic records were substantially undeteriorated even when physical failure of the supporting base occurred.

It became apparent that a specialized recording medium would have to be developed to meet the Bell System requirements for transcribed message services. Development effort was concentrated on the field of powdered media, because these media offered attractive transmission properties and because the expanding commercial importance of this field promised a continuing industrial development and production program which would provide an economical source of high quality magnetic materials. The following premises guided the development program:

(1) The recording medium should be subjected to the least possible physical manipulation in use to minimize failures. To accomplish this it was decided to develop the recording medium in a form suitable for use on the surface of a rotating cylinder and to use a helical recording track on this surface when the message length required more than one revolution of the cylinder. It was hoped that with this arrangement, physical failure of the recording medium would be eliminated, and the service life would be determined by the wear occurring between the medium and the magnetic pole pieces.

(2) The recording medium should exhibit some compliance to facilitate intimate contact with the magnetic pole-pieces.

(3) The transmission quality should meet present-day telephone standards for transmission of speech. The higher quality necessary for the recording of music, while desirable, should not be considered a requirement.

A number of experimental powdered media were prepared and tested. These all utilized commercially available iron oxide powder with a coercive force of approximately 250 oersteds, and the samples included coated media, made by dipping, spraying and doctoring the coating on various base materials, and impregnated media, prepared by mixing the oxide in the base material and forming the mixture.

A medium consisting primarily of an elastic rubber band impregnated with magnetic particles was found to be particularly suited to applications requiring long life in continuous service. A study of compounding and manufacturing processes for this medium was made by the rubber products group at these Laboratories under the direction of H. Peters, and the compound which evolved consists primarily of synthetic rubber loaded with magnetic iron oxide, and containing small amounts of lubricants, inhibitors and curing agents. The compound is decidedly rubber-like in character, and is utilized in the form of seamless bands about $\frac{1}{32}$ to $\frac{1}{8}$ inches thick, which are stretched over the surface of cylinders about 10 per cent larger than the bands.

The bands are prepared by thoroughly milling together the following:

100 Parts by weight type GN neoprene
100 Parts by weight magnetic iron oxide
5 Parts by weight zinc oxide
4 Parts by weight magnesium oxide
2 Parts by weight paraffin

and forming the compound into bands by conventional rubber molding and curing techniques. The resulting bands show a tensile strength of about 2500 pounds per square inch, and the elongation before breaking is about 700 per cent. No particularly difficult manufacturing problems are encountered, and present evidence indicates that satisfactory overall quality control can be achieved by carefully controlling the compounding constituents, the milling and the molding.

Several bands which are used in telephone services are shown in Fig. 1. These bands are utilized in recorder-reproducer mechanisms by stretching them over a cylinder, on which pivoted magnetic pole-pieces trace a cylindrical or a helical track as it rotates.

When the bands are first taken from the mold they exhibit a high coefficient of friction. After a few hours enough paraffin migrates to the surface to form a thin, slippery film. If the bands are then put into service the pole-pieces form a polished track and the continuing migration of paraffin maintains the lubricating film between the band and the pole-pieces.

If this recording medium is used intermittently, the self-lubrication may cause difficulty. The migration of lubricant to the recording surface is continuous, and the lubricant may accumulate on the surface in sufficient thickness to impair the contact with the magnetic head if the recording equipment is not operated for several weeks. It may then be

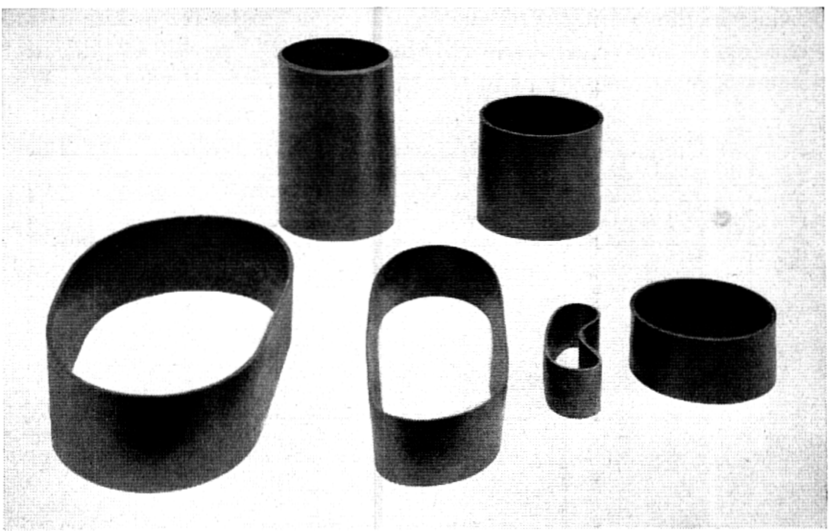

Fig. 1—Typical magnetic rubber bands used in telephone applications.

necessary to wipe the excess lubricant from the surface to obtain satisfactory operation.

The lubricant in this particular recording medium was chosen for operation in central offices and similar locations where temperature ranges are moderate. If extreme temperatures are to be encountered the lubricant problem will have to be re-examined. Continued research in this field should result in improvement in this characteristic.

In life tests, five million message repetitions have been obtained with insignificant wear of the band and the magnetic head, and with no measurable deterioration in the level and quality of the recording after an initial level drop of about 2 db which occurs during the first few reproductions. The head pressure is a significant factor affecting the life, and in these tests a head pressure of 25 grams was used with a 0.100 inch wide head.

This medium represents some compromise in the attainable transmission properties to favor the physical properties desired for reliability and long life, but the transmission is entirely adequate for the intended applications.

A typical frequency response characteristic is shown in Fig. 2. This is representative of the results obtained when the equipment is maintained by field personnel. The output level, also indicated by Fig. 2, is from 8 to 12 db below that obtained from commercial coated magnetic tape. This is largely because the concentration of magnetic oxide, on a volume basis, cannot be made as high in the impregnated material as is possible in the coating of conventional tape. This is not a serious disadvantage, however, as the level is high enough to permit amplification without special precautions in regard to noise.

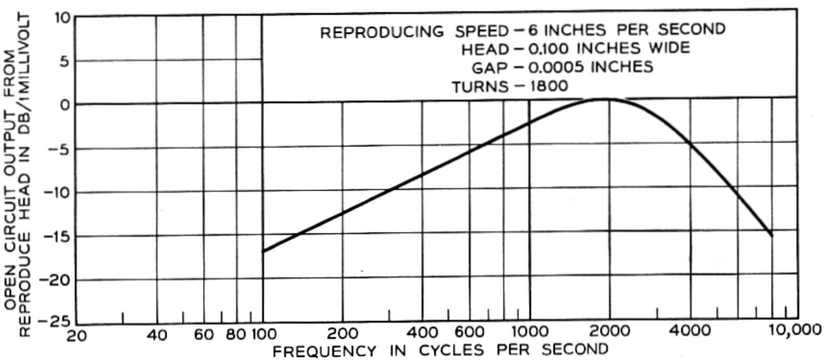

Fig. 2—Frequency response of magnetic recording equipment using iron oxide impregnated molded neoprene bands.

When ring type magnetic heads are used for recording, these bands exhibit frequency response characteristics quite similar to coated tapes using the same magnetic oxides, although the bands are of homogeneous magnetic material up to $\frac{1}{8}$ inch thick and the tapes have magnetic coatings less than 0.001 inches thick. This is because the field from the recording gap becomes ineffective at a distance of about 0.001 inches, and the signal is recorded only on a thin surface layer of the medium, regardless of its total thickness.

The noise characteristic of this medium is somewhat unusual. It has been shown* that the reproducing process is not restricted to the surface layer of the medium, but that to a first approximation, when the medium has low permeability, the signal from a magnetized element at any depth in the recording medium will be attenuated with respect to the signal produced by the same element in intimate contact with the reproducing head by the factor:

$$\frac{55 \text{ decibels} \times S}{\lambda}$$

where S = distance between magnet and head
λ = "wavelength" of magnet

This indicates, for example, that the signal from a magnetized element at a depth of $\lambda/2.75$ will be attenuated by only about 20 db and may therefore make significant contribution to the total output.

In the Bell System telephone applications, where a transmission bandwidth of 100 to 4000 cycles per second is required, the belts are run at a speed of about 6 inches per second. The wavelength at 100 cycles per second is then 0.060 inches, and at this frequency significant output can be obtained from a layer about 0.02 inches thick. The desired recording is limited to a layer about 0.001 inches thick, but a layer of about twenty times this thickness may contribute to noise. As a consequence, at low frequencies this medium tends to exhibit higher background noise than do the coated tapes. The magnitude of the noise is appreciably affected by the method of erasure.

Two methods of erasing a magnetic record are known to the art. These are the saturation erase, in which the magnetic record is exposed to a unidirectional magnetic field of saturation intensity, and the neutralization erase in which the magnetic record is exposed to an alternating field which reaches saturation intensity and decreases cyclically to zero

* R. L. Wallace, Jr., "Reproduction of Magnetically Recorded Signals," *Bell System Tech. J.*, Oct., 1951.

over a period of several cycles. It is well known that a neutralization erase results in a residual background noise which may be as much as an order of magnitude below that produced by a saturation erase. The neutralization erase is therefore widely used in tape recording, and is obtained by energizing the erase head with alternating current of a frequency several times the highest signal frequency passed by the recording equipment.

With the impregnated recording medium, the recorded signal can be successfully erased by using a conventional ring-type erase head energized with high-frequency current. The field from this type of erasing effectively neutralizes the surface layer which contains the recorded signal, but does not penetrate appreciably beyond. Therefore, if precautions are not observed, the lower layers of this medium beyond the reach of the erase field may acquire a random cumulative magnetization from switching surges, accidental exposure to magnetized tools and strong fields, and this will be evidenced by a gradual deterioration in the signal to noise ratio at the low-frequency end of the transmission band. The quality, however, remains entirely adequate for commercial telephone use.

The foregoing limitations are minimized by an erasing method which has been developed at these Laboratories for applications where it is convenient to erase the entire message in one revolution of the recording cylinder, preparatory to recording a new message. This method employs an erasing structure in the form of an E-shaped stack of magnetic laminations, carrying on the center leg a coil which is energized by low-frequency (60 cycle) alternating current. The lamination stack is approximately the width of the recording medium, and the gaps between the center leg and each side leg are about $\frac{1}{4}$ inch wide. When this structure is spaced about $\frac{1}{16}$ inch from the surface of the recording medium traveling at 6 inches per second or less, and is energized by 60-cycle power to produce a maximum field of about 2000 gauss, the entire thickness of the recording medium is subjected to an alternating magnetic field which reaches saturation intensity and over a period of several cycles decreases progressively to zero. This effectively demagnetizes the full thickness of the recording medium. If the current is switched off with the erase structure in operating position, those elements of magnetic material within the field at that instant would be subjected to no further reversals and would consequently behave substantially as if they had been subjected to a direct-current magnetic field of the same intensity as the alternating-current field at the time it was interrupted. The section of record medium under the influence of the erase structure at the time it was de-energized would exhibit excessive noise in comparison with the remainder of the record-medium which was subjected to the normal alternating-current erase. This effect becomes negligible if the separation between the record medium and the erase structure is increased by $\frac{1}{2}$ inch before the current is interrupted. This is accomplished by using a solenoid-actuated mounting for the erase structure so arranged that the structure normally is retracted from the erasing position and holds open a switch in the circuit to its coil. When erasure is desired, the solenoid is actuated. This moves the erase structure into operating position and releases the switch to energize the coil. When the erase cycle is completed the solenoid is de-energized, and the erase structure retracts, opening the switch at the end of its travel. Fig. 3 is a sketch

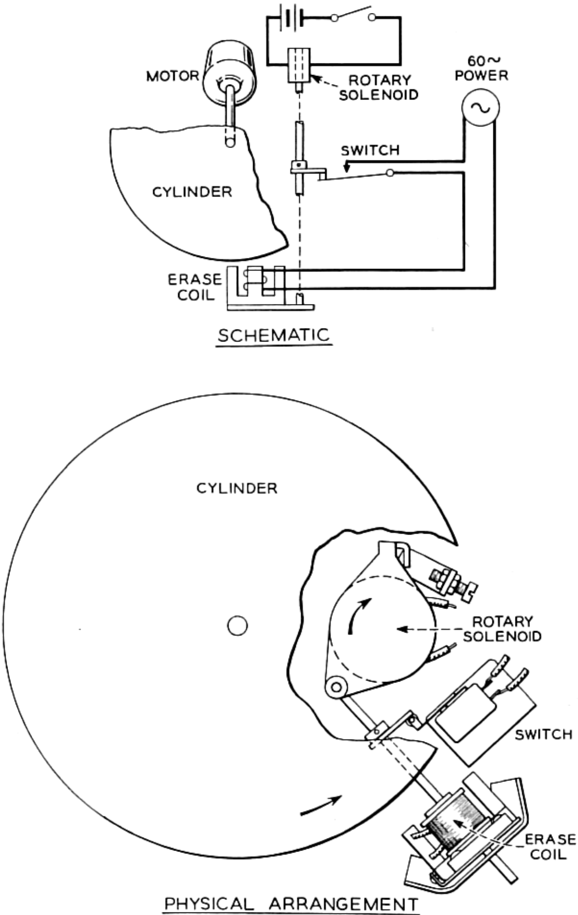

Fig. 3—Method of erasing magnetic recorder.

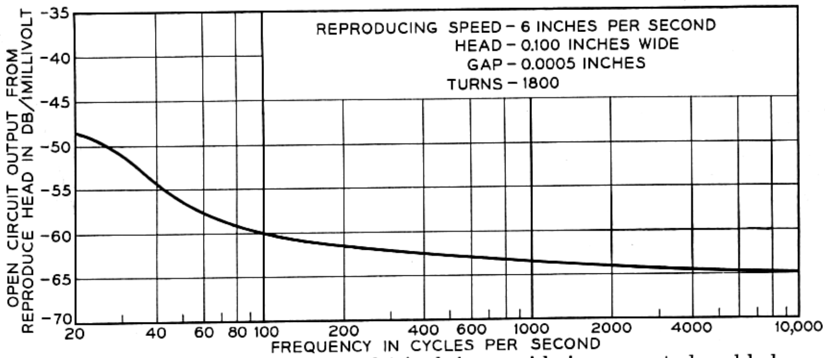

Fig. 4—Typical noise spectrum of $\frac{1}{8}$-inch iron oxide impregnated molded neoprene bands measured in 200 cycle bands after neutralization erase with 60-cycle ac field.

showing the application of this erase method to a cylinder-type machine. This method of erase results in a background noise level measured unweighted over a 4000-cycle band which is at least 45 db below a 1000-cycle signal recorded with 4 per cent total distortion. A typical background noise spectrum is shown in Fig. 4.

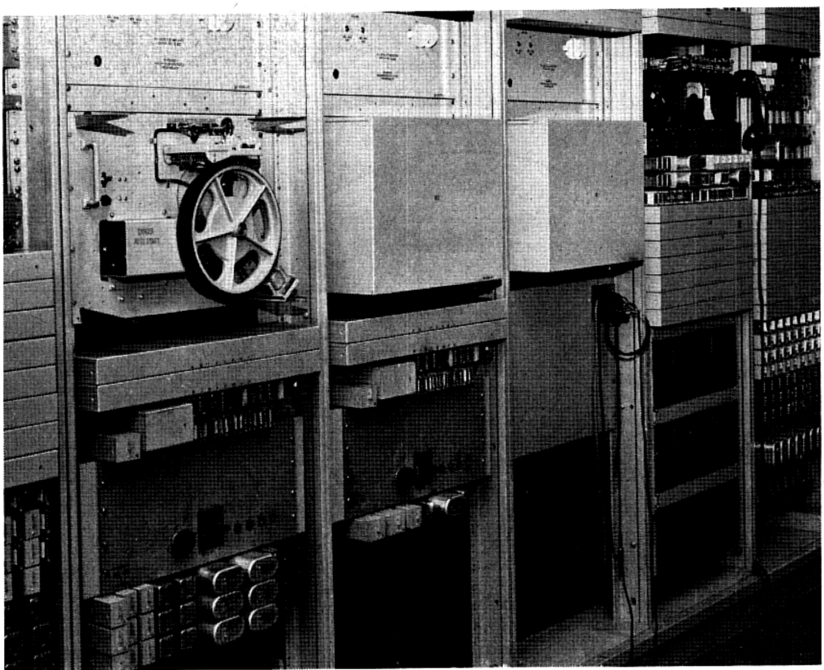

Fig. 5—General view of recording machines in 3A announcement system at Cleveland.

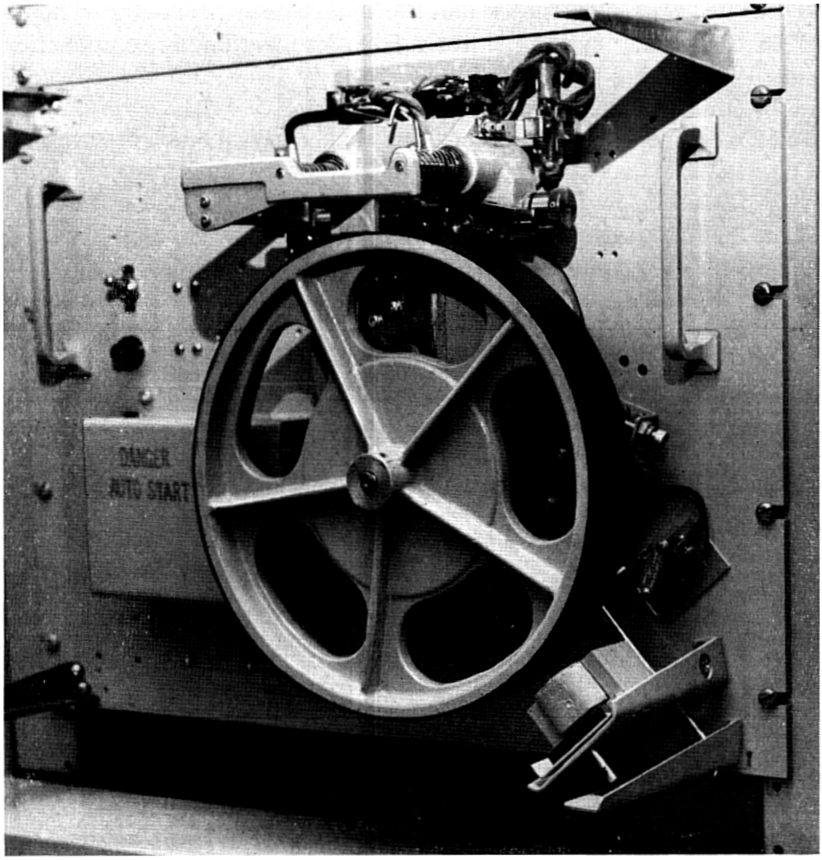

Fig. 6—Closeup of recording machine in 3A announcement system at Cleveland.

The first installation of transcribed message equipment employing this new medium was in the 3A announcement system at Cleveland, Ohio, to supply weather announcement service.

The magnetic recording equipment in this installation is a cylinder-type mechanism with associated recording-reproducing amplifier. The mechanism uses bands $\frac{1}{16}$ inch thick, $1\frac{5}{8}$ inches wide and $7\frac{13}{16}$ inches in diameter, stretched over a cylinder 9 inches in diameter. A single record-reproduce head in a pivoted mounting is cam-controlled to trace a helix on the cylinder. The cam is coupled to the cylinder via a quick-change gear train which gives a choice of a three-turn, a five-turn or an eight-turn helix, and the cylinder is driven from a gear-reducer which allows a choice of two slightly different operating speeds. Six different cycle times, ranging from about ten seconds to about 45 seconds, are provided by the two operating speeds and the three cam ratios. Approximately 90 per cent of any cycle time is available for recording or reproduction, and the remaining 10 per cent is occupied by the return of the head to the beginning of the helix.

The recorded track is 0.100 inches wide, and when an eight-turn helix is used, there is a separation of 0.025 inches between tracks. The previously described low-frequency alternating current erase is used.

The 3A announcement system employs three channels of this recording equipment in a complex control circuit which provides facilities for erasing, recording, monitoring and automatic switchover to stand-by channels in event of failure. Figs. 5 and 6 show the recording equipment in the Cleveland installation.

Other equipments using this recording medium have been designed to furnish transcribed message service for intercept of calls to vacant, changed and unassigned numbers, to quote delays on long distance calls, and to furnish stock quotation service. Some of these equipments are now undergoing service trials preparatory to standardization for Bell System use.

This new recording medium has been developed to provide the maximum attainable life and reliability in applications requiring an enormous number of repetitions of voice messages. Equipment for such applications is usually located in central offices where the temperature range and other operating conditions are fairly well stabilized. These favorable conditions have facilitated the development of a recording medium which has made it possible to design simple and economical magnetic recorders which are sufficiently versatile and reliable to stimulate the use of transcribed message services to an extent hitherto unrealizable.

There are a number of potential Bell System applications for transcribed message services which do not require an extreme number of message repetitions, but put a premium on low initial cost and trouble-free operation in intermittent service under wide extremes of environment. It may prove desirable to meet the life requirements for applications of this type with a different approach to the lubrication problem, with an unlubricated compound, or with a coated medium which would have some transmission advantages. It is expected that further work in these fields will produce improved recording media for applications of this nature, to expand the field of use in the telephone plant.