MODERN RECORDING--*A Summary of Methods*

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Author's Note: This article is designed to acquaint the technical man not actively engaged in recording with some of the more pertinent aspects of this interesting industry.

IT IS A LONG WAY back to the point in history when Edison invented the phonograph in 1877. However, it would be unfair not to pay tribute to this great man whose genius and the outgrowth of whose developments are responsible for the gigantic recording business of today.

The original recorder as conceived by Edison utilized sound waves to actuate a diaphragm and needle. As sound reached the diaphragm, the needle caused an indentation (recording) on tinfoil, which could then be used in reverse to recreate the original sound waves. Since that day, many changes, innovations, and improvements have been added to produce modern methods of recording. (Notable contributions to the art of recording are shown in Fig. 1.)

Early recording systems were severely limited, as to both frequency response and dynamic intensity range of reproduction. Such limitations in phonographs did not detract at first from their universal acceptance, because people as yet had not become accustomed to the superior reproduction of music and speech on the radio and the sound motion picture.

Most of the early acceptance of the phonograph was based upon novelty and a wide choice of recorded music. Subsequent to the introduction of the vacuum tube amplifier, which also produced broadcasting, the early acoustical phonograph appeared doomed on two counts: quality was lacking in comparison with radio, and the quantity of recorded material appeared inadequate. In an attempt to improve quality, the Orthophonic Victrola was marketed. Although the quality of music reproduction was noticeably improved, as the result of a more efficient design of the acoustical horn, it could not compare with that of electrical recording and reproduction, and, therefore, soon gave way to present-day systems.

As an aid to understanding the wide choice of present-day recording methods, it is well to keep in mind that the early machines were powered by acoustical energy and that only after the important invention of the vacuum tube amplifier could the most worth-while improvements take place.

SOUND STORAGE METHODS

Basically speaking, sound may be stored in one of three ways: by employing either a **mechanical,** an **optical,** or a **magnetic** sound track. Let us examine in some detail definitions of these three forms of storage.

The mechanical track is either a lateral cut or a vertical cut, depending upon whether or not the needle vibrates crosswise to the groove at a uniform depth, as in lateral recording, or vibrates up and down with varying depths, as in vertical recording. The grooves may be formed by either the engraving process or embossing. In engraving, a chip or thread is removed from the surface of the material, whereas in embossing, the groove is formed by an indentation of the record material, purposely caused by a sufficiently large needle force. The mechanical track method is largely used in present-day record players employing flat discs and in dictating machines using cylindrical records.

The optical track employs a light source made to vary in one of two ways: (a) by varying the area of the optical image; (b) by varying the light transmission of an optical track of constant width. Optical methods are used primarily in the motion picture industry.

The magnetic track stores sound by magnetizing the record material in either a lengthwise direction or a transverse direction with relation to the sound track. These variations may be thought of as applying to the magnetic recording process in the same way that the terms "lateral and vertical" apply to the mechanical track process. Two additional terms used in magnetic recording are **DC Bias** and **Supersonic Bias.** These designations deal with alternate methods of preparing the magnetic material to receive and magnetically store the variations of sound. The magnetic track method is commonly known as magnetic wire recording or magnetic tape recording. Although originated several decades ago, this method has become popularized only recently through further developmental work and modern publicity. It has been used quite extensively during and since World War II for commercial purposes, and an interesting application has been made in connection with furnishing entertainment on passenger trains. New uses are coming to the fore every day, and one of these which doubtless will enjoy a big future is in the development of the application of sound to home movies.

Although three basic systems of sound storage have been described separately, two of them already have been combined in the Phillips-Miller method of tape application. This utilizes a V-shaped needle which cuts vertically through a black-coated surface, thus producing both a mechanical and an optical sound track. When the recording is played back, only the optical track is used. The Phillips-Miller method has the advantage of constant track speed, resulting in fixed frequency response and long-time playability. This method has not become very popular to date, possibly because of the greater all-over expense involved. It has been used at radio station WOR in New York.

RECORDING MATERIALS

The three main processes of sound storage have been described with little or no mention of the form or the materials used in the record itself. The shape of the record may be, as in Edison's original device, a cylinder, or it may be a disc, a tape, or a wire, depending upon the process used and the application of the finished product. When discs are used for receiving and storing sound, they may be either metal, wax, shellac, modern plastics, or consist of coatings such as lacquer applied on metal, bristol board, or glass. Material for the optical process is the usual photographic emulsion, such as is used on motion picture film. Materials for the magnetic process are either steel tape or other types of tape coated with magnetic

dust. This latter tape may be any one of several different kinds, among which are motion picture film and paper. For wire recording, ordinary small-gauge steel wire is used.

TRACK SPEED

The recording track speed may be either constant or variable, depending upon choice and execution of the mechanical drive. For example, Edison's original cylinder, plus the film, tape, and wire forms, is of the constant track speed variety, while the usual home phonograph has a variable track speed, resulting from a spiral groove on a constant **angular** speed turntable. Track speeds vary from 15 to 180 ft per minute. The higher the sound track speed, the better is the frequency response possible and the higher the cost of material. The use to which the finished record is put and the frequency response desired should determine the original recording speed.

CHOOSING A RECORDER

One might question the need for such a large diversification in the process, form, material, and speed used in the entire field of recording. Some of these differences were undoubtedly designed to circumvent patents, while others were worth-while contributions to the art of recording. The person concerned with choosing a suitable recording system should consider the following three groups of factors, the meaning of which will be described later:

PERFORMANCE FACTORS:
- Frequency range
- Signal to noise ratio
- Distortion
- Uniformity of response
- Signal stability

MACHINE FACTORS:
- Initial cost
- Operating cost
- Size and weight
- Ease of operation and handling
- Recording time available
- Reliability of tracking
- Ease of spotting and editing
- Instantaneous speed accuracy
- Cumulative speed accuracy
- Life of machine
- Time interval between recording and playback
- Effect of temperature and humidity
- Ease of maintenance
- Adaptability to automatic operation
- Adaptability to field or mobile use
- Adaptability to synchronism

RECORD FACTORS:
- Cost per hour
- Size
- Weight
- Breakage
- Ease of handling
- Life and number of playbacks possible
- Re-use
- Editing
- Duplication
- Shipping
- Storage space
- Fire hazard
- Effect of temperature and humidity

In view of the length of this list of factors dealing with the choice of a recording system, it is obvious why we have such a diversification of recording methods now in use. No one machine can completely satisfy all requirements, ranging from the minimum performance of a child's toy, to the demands of business and the large amusement industry. In making a choice, minimum requirements as to performance, and then specific machine and record factors, should be accorded

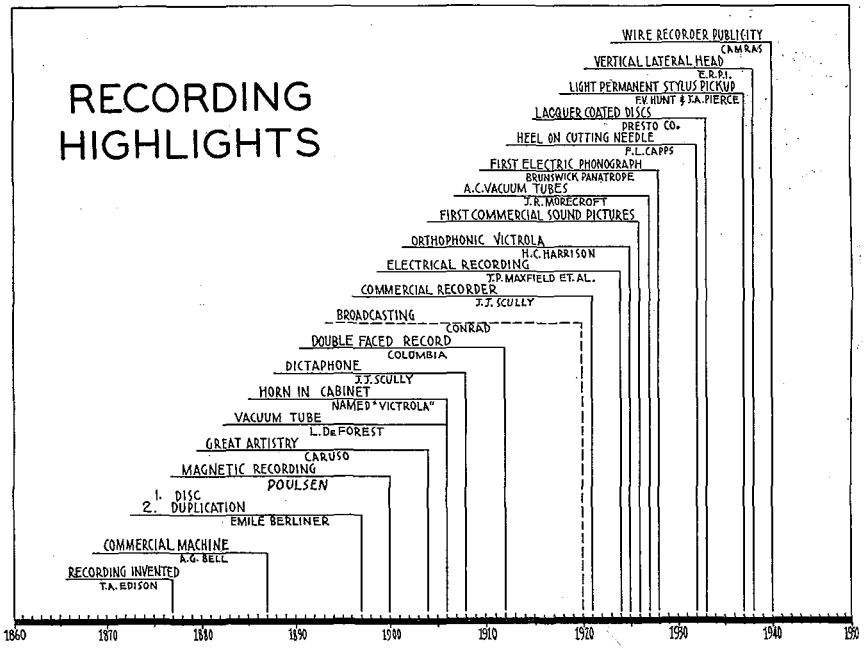

Figure 1

careful thought. While the primary concern is performance, it is quite possible that any one of the other factors may govern the choice of a recording machine in a specific instance. Since performance factors are of such importance, an explanation of each is now in order.

PERFORMANCE FACTORS

The sound spectrum is generally considered to be composed of ten octaves, ranging from 16 to 16,000 cycles per second. Edison's early cylinder probably utilized not more than three of these ten octaves. Its **frequency range,** therefore, can be thought of as limited to about 30 per cent of the total. However, although limited in range, the early acoustical phonograph was acceptable because the middle portion of the frequency band is of greater importance than either end. See Fig. 2.

The Signal to Noise Ratio is important because it defines the degree of sound intensity or dynamic range which can be accommodated. Noise tends to mask the desired signal when that signal is weak or of low intensity.

Distortion deals with the lack of faithful reproduction of the original sound; that is, whether the shape of the original wave is reproduced faithfully or disturbing harmonics are added to the original frequency components.

Uniformity of Response means freedom from any abnormal or extreme intensity peak or valley within the transmitted band. In this connection it is well to remember that the loudspeaker is by far the most outstanding example of apparatus having non-uniform response because of extreme variations in its efficiency or its ability to convert electrical energy into acoustical energy. Instead of producing a uniform sound wave at different frequencies, even the best loudspeaker contains intensity peaks and valleys throughout its frequency range.

Signal Stability applies to the constancy of reproduction of a steady input signal. For example, if a steady signal, such as a single frequency tone, were applied to the recording machine, the same steadiness or stability of the original wave should be obtained upon

playback. Lack of signal stability may be termed amplitude modulation.

After the first requirements of performance have been met, other factors are important in the selection of a recording machine. The meaning of most of these factors is rather obvious. The **cost** of the initial installation, plus that of operation, is of great concern. Modern plastics fit in with the desire for low operating cost. In comparison with the cost of using home phonograph discs, amounting to approximately $4.00 an hour, film costs in embossed recording can be obtained at as low a rate as $1.00 an hour for comparable quality. In contrast with the usual five-minute disc recording, a continuous film will record without interruption for nearly two hours, or, if necessary longer. When records are not to be kept on file, magnetic materials are lowest in cost following the initial investment.

Size and weight of a unit mainly concern those who have use for a portable machine or for one adapted to dictation and general office work. Machines vary in size from permanent studio types somewhat resembling an average machine-shop lathe to those used for recording "on the spot" broadcast programs and communication recorders for aircraft flight tests, the latter about the size of a small suitcase. Toward the end of the war the Navy had contemplated the use of "pack" recorders which were similar to pack transmitters in portability and battery operation. They were a completely self-contained, lightweight unit. Weights of portable recorders vary from 25 pounds to about 150 pounds.

Ease of operation and handling is again mainly desirable in machines intended for the general public. In a professional studio, where technicians are specially trained to operate the intricate machine, numerous controls are available. These adjustments allow the operator to set for proper cutting angle, depth of groove, and throw of the engraved chip, plus numerous controls of the electrical system. Such adjustments are considered desirable for trained personnel in order that the highest signal to noise ratio may be maintained simultaneously with the least distortion and the least tendency to over-modulation. It is interesting to note that a well-known recording company, when first organizing its recording department, assigned members of its technical personnel unselectively to the work of making recordings. After numerous failures, it was realized that the job required considerable training and experience, and therefore, a special department was created so that each technician might gain the knowledge required to make nearly perfect recordings.

Length of recording time available varies with the purposes involved. Magnetic tape machines have been known to operate for a period as short as ten seconds. A machine of this kind might even be used to add reverberation to a program otherwise lacking in proper acoustics. Such a reverberation machine might operate with several playback heads so spaced along the tape that a controlled portion of energy from each succeeding head could be added to the original pickup, thus giving the illusion of repeated sound reflections occurring to the original sound. Other machines have been built for continuous 24-hour operation without reloading. These are mainly used for verbatim transcription work.

Reliability of tracking applies to mechanical recording where it is possible that the playback needle might jump out of the groove and repeat an adjacent groove, or even skip across the record at the least provocation. This may happen on ordinary disc phonograph machines either because of excessive motor vibration or because of a lateral thrust existing at the needle point, the effect of friction between needle and groove.

The needle in a home phonograph is mounted to rotate about a fixed pivot, rather than being held always tangential to the groove. A friction force acts in the direction tangential to the groove. A small component of this tangential force tends to cause the needle to jump out of the groove and swing about the arm pivot. For broadcast service this behavior of jumping cannot be tolerated. To the broadcaster this problem is more important than a correlated problem of tracking distortion caused by the head's being non-tangent to the groove. The relative merits of the so-called offset head with relation to the problem of groove-jumping are important to the designer, but beyond the scope of this article.

Ease of spotting and editing does not ordinarily concern those who use records for entertainment, as they usually play records from beginning to end. On the other hand, in movie work, conference recording, communication monitors, and occasionally in broadcasting it is desirable to be able to spot, delete, or rearrange portions of a continuous program. It is advantageous, therefore, to be able to identify and spot portions of a recording and to start and stop the sound track. Some machines are able to start and stop between syllables of a word, while others require several seconds to reach proper speed.

Maintenance of constant **speed** is most important in recording machines intended for music rather than speech. Such speed changes as do occur can be classified as either instantaneous speed variations, amounting to momentary speed fluctuations, or cumulative speed variations, indicative of the average speed. Cumulative speed accuracy should be maintained to within one half of one per cent. This will keep the music on pitch and insure that in re-broadcasting a previously recorded fifteen-minute program the reproduction will properly fall within the time allotted. . The allowable time variation equalling one half of one per cent means four and one-half seconds in a fifteen-minute period. Instantaneous speed fluctuations produce wows or flutter, depending upon the rapidity of fluctuation. Naturally, the more rapid the speed of fluctuation, the more noticeable is the change in pitch of a sustained musical note. To date, the recording industry has not recognized the more desirable method of rating machines according to rate of change of speed (acceleration), but continues to rate them according to the maximum per cent change of speed.

Perhaps one of the reasons for laxity in rating a machine according to acceleration is the difficulty in measuring a transient phenomenon having such small instantaneous inaccuracies in the driving mechanism, such as occur because of normal manufacturing tolerances of gears, sprocket teeth, and variable friction of moving parts. In short, any change in load offered to the drive motor will be reflected as a change in speed of the recording. In particular, drive belts which are not absolutely uniform tend to whip or vibrate. Such vibration, in turn, causes a speed fluctuation.

For home use, the **life** of a machine should be comparable to that of other technical apparatus. Thus far, technical advances in design have caused machines to be superseded rather than discarded because of wear.

Time interval between recording and playback may be important to commercial concerns in order to determine immediately whether or not a recording is technically acceptable. If a particular recording is not acceptable, it may be repeated during the same recording session; otherwise added expense is required to

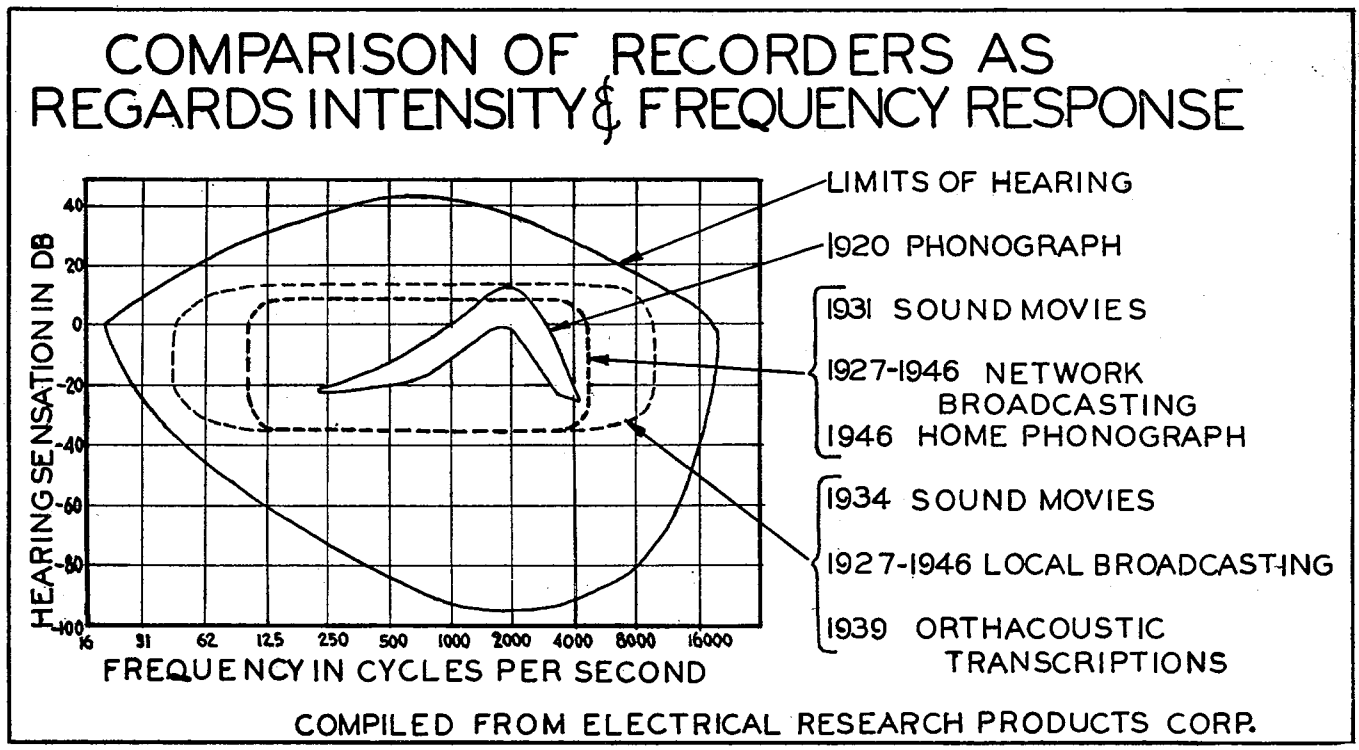

Figure 2

re-assemble the artists at a later date for a repeat recording.

The harmful effect of **temperature and humidity** upon technical apparatus has been emphasized by recent war experiences. In the United States only the southern central part of the country need be watched for harmful effects.

Ease of **maintenance** is more important in recording than the average person realizes. Dust, dry bearings, and worn friction drives all contribute their share of unwanted speed variations. An occasional check of the frequency response of the system, plus the necessary adjustments, rightly falls within the field of maintenance.

Adaptability to **automatic operation** is especially important to the large and thunderous juke box industry.

Adaptability to **field or mobile use** is one way of saying that the equipment is light-weight and may be used under conditions of shock. Some recorders have successively operated in airplanes and tanks under active battle conditions. In the field of **mobile use**, the usual disc machine is not suitable, because of vibration affecting the playback tracking. That is to say, when mechanically shocked, the needle may be thrown out of the groove. On the other hand, it is possible to provide both recording and playback on a wire, tape, or film machine by using mechanically fixed or guided heads.

Adaptability to **synchronism** applies primarily to the motion picture industry and its little brother, television, where picture and sound are synchronized.

While the discussion given above applies to machine factors, many of the same principles apply to the medium supporting the sound track, that is, to the record. **Cost of operation** per hour has been discussed. **Size and weight** of the record govern the storage problem for those who must retain copies of recorded material for long periods of time. **Breakage of record material** will be a governing factor where either shipment or preservation is contemplated. **Ease of handling** ties in closely with the operation of the machine. Certainly the ease of handling disc records has been one of the determining factors in their popularity. Other record types adapt themselves to magazine loading, where threading or loading by hand has been reduced to a minimum. **Life of the sound track** and the number of playbacks possible, prior to deterioration and final discard, are important to the advertising industry, which makes repeated use of recorded sales material. Consider also the constant repetition offered to popular records which are subjected to an accelerated life test by the corner juke box.

Re-use of the record material is an advantage which can be claimed by systems using the magnetic process. This is possible by demagnitizing a previously recorded sound track prior to re-use.

Editing of recorded material is primarily accomplished by design of a good spotting device and start-stop mechanism. The **form** of record material also contributes to ease in editing. For example, a tape record with but a single sound track may be edited by cutting and joining at desired intervals.

Duplication of records is imperative for certain commercial applications. It can be recalled that Edison's invention lay comparatively dormant until Emile Berliner produced a successful duplication process, using flat disc records. **Shipping** of records ties in closely with the subject of breakage, and need not be discussed in this article.

Storage space required for old records may be a problem to a communication company that must keep a record of all communications for a certain period of time. In such a case, not only is the cost of operation extremely important, but also the amount of space required for storage.

The fire hazard of a particular material may require special precautions in both handling and storage. We are all familiar with the fire hazard which nitrate film represents, but tend to overlook the same fire hazard which exists when nitrate material is used to coat discs. Unfortunately, when early manufacturers first sold nitrate records, they called them acetate in order to

further their sale. Actually, the chip or thread removed during the engraving of lacquer-coated records is highly inflammable. Abnormal **temperatures** and humid atmospheres may affect record materials to some extent. If one lives where abnormal conditions exist, these factors should be checked.

Naturally, one might wonder which of the three systems of recording is the best; that is, whether the mechanical, the optical, or the magnetic system inherently is best. Or perhaps, whether lateral is better than vertical. It is the writer's judgment that the capabilities of all systems are "about equal", but that the skills acquired by the proponents of each of the systems vary somewhat from time to time. This phase of the matter leads to conflicting opinions. At the moment the highest quality seems to have been obtained under carefully controlled conditions while the record was being played back at the outside edge from an original, lateral-cut, lacquer-coated disc. This effect does not eliminate the possibility that the future may produce a different system with striking results, or that the performance may be readily duplicated on a commercial basis. It is interesting to note that in 1929 the ambitious California Institute of Technology glee club produced a recording of its alma mater song. Those of us who bought a copy of that record were sadly startled to learn that all record concerns had not acquired the art of recording with equal skill. This record quickly found the junk pile. It contained far too much distortion.

Optical methods are particularly well adapted to the cinema, since its primary problem is one of synchronizing sound and picture. Further, photographic techniques are known by the movie industry and it is but a step from such techniques to their application for sound recording. However, these methods are cumbersome and expensive for the use of non-technical personnel. The layman wants a simple machine requiring very little technical skill for operation—possibly only an on-off switch.

A glance at the history of recording will show the very important part which electrical amplification has played in its development. The importance of electrical amplification lies mainly in its ability to handle all frequencies in the audible spectrum and to offer a means for correcting a deficiency in any part of the system by the use of simple electrical correcting networks. Just as the invention of the vacuum tube and the vacuum tube amplifier has played an important part in the development of radio, it has influenced the development of recording more than any other single contribution.

An Airplane is Not a Rabbit

(continued from page 4)

Air Staff and the entire nation are actually being misled, as they **can never get such an airplane in large quantities.** The many individual experimental superweapons found in Germany gave added proof to an often quoted but all too seldom recognized truism: "No nation has ever won a war with a handful of laboratory samples, even though the samples individually surpass any other weapon in the world."

It would appear that nothing can be done until the military engineering divisions are properly set up to handle their full responsibility. However, at least a start has been made within the aircraft industry toward breaking down the "Iron Curtain" which excludes production men from the inner sanctum usually reserved for the advance design engineers. Several models now in the experimental stage have actually been designed from the beginning with the basic structural needs of producibility given full consideration.

How is it possible to incorporate producibility without adding so much weight that all design competitions are lost? Although a strong, farsighted management is essential for their successful combination, the understanding and broadmindedness of individual engineers can go a long way toward achieving the same effect.

It was found that when the production men were fighting with the engineers to get the experimental design **revised** to incorporate some producibility in the production version, most of the changes resulted in a weight increase. The production men had their hands full trying to protect their own interests, and "never mind what it does to the weight". However, when the production men **worked with the designers** at the time the original design was **created,** the production men came up with as many weight-saving ideas as weight-increasing ideas. The result was a high-performance airplane that could be produced in quantity in case of an emergency, with no major redesign or retooling problems.

The best solution is a change of military engineering and procurement policy which will encourage the top management of all companies to follow through in this manner. In the meantime it is suggested that the designer let this one thought come to mind each time he sets pencil to paper: "You have to draw it only once, or maybe twice. Somebody else may have to duplicate it in metal a thousand times in a hell of a hurry, and your life and his may well depend on how fast it can be done."