75 years of magnetic recording

3—From steel to plastic

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From 1939 the Magnetophone entirely supplanted other methods of master recording in German broadcast studios. It was this unique state of affairs, discovered by the Allied forces after World War II, that was to revolutionize design in Europe and America from 1945 and sound the death knell for steel tape and wire.

The national political situation in Germany was explosive and international relations were deteriorating fast, the dark years of World War II were drawing in on the Western World. For those outside Germany it was as if the Magnetophone had never been; very few reports on the machine had been written and fewer engineers had heard it. The war was to reduce information on the Magnetophone to nothing and it was not until 1945 that the world (that is the recording world) was to be rocked by the progress made during the war.

In America, progress was slow, probably due to the early embargo on published information about the Telegraphone set by Rood, the President of the American Telegraphone Company some years earlier. Bell Laboratories developed experimental steel tape machines,[38] and in 1939 made the first ever stereo recording on a magnetic recorder. In this instance the machine used steel tape on two reels locked in synchronism on the same machine. In 1937 the Brush Development Company produced its Soundmirror, a steel tape-loop machine designed for laboratory investigation of transient phenomena. By 1939 they had also introduced a black oxide paper tape, presumably for the Soundmirror.

In 1941 Brush, General Electric and the Armour Research Institute went into production with wire recorders for the armed services.[13] A young man with a brilliant career ahead, Marvin Camras, developed the long-forgotten a.c. bias method and Armour Research applied for a patent on it. In 1942 Camras designed the Model 50 wire recorder, bought for use by the BBC[39] and used extensively in airborne service, followed by the Webcor wire recorder used by the US Navy.

Just before the end of World War II, Brush asked Minnesota Mining (3M) to develop better tapes and under Dr Ralph Oace, work commenced in 1944.

The revelation—1945

With the war over and the Allied Forces occupying Germany it became possible to see just how much tape recording had progressed. There are many quite amazing and fascinating accounts of those who studied the German recording techniques, some quite official, forming part of Government committees such as the British Intelligence Objectives Sub-Committee (BIOS) and FIAT the American equivalent, others being quick private investigations by those who had a fascination for these things. Many post-war companies specializing in the production of tape recorders or tape were started by these men, including the Mincom division of 3M, initially Crosby Enterprises, and Rangertone run by Col. Ranger, one of the American Army engineers in Germany at the end of the war.

The first surprise for those who investigated broadcasting in Germany was the extent to which magnetic recording had been adopted. All broadcast stations had Magnetophones and in addition they were in use in the signals sections of the German Army, the Intelligence and in some cases in use in the telephone system. Almost none of the radio station output was live, since tape was used as a method of censoring the programmes. This idea was developed way back in 1939 as an expediency for political broadcasts, all of which were carefully vetted.

The really surprising feature of those machines at the radio stations was the quality of the output. This had been due to the development by Dr Braummühl and his colleague Weber of the a.c. bias system, first applied experimentally to the K4 Magnetophone. In fact the variety of machines had proliferated and just to give an idea of what had become available the following is a list of those for which the author has documentary record. The K4, also designated R.24 by the RRG was made with d.c. bias [illegible] verted in some instances to a.c. bias by RRG and called the R22. It was originally introduced in late 1938. There was a dictating machine, the FT-3 few details of which are available. The Tonschreiber b: portable field unit used by the Wehrmacht for signals, fitted with a rotating pitch restoring lead. Tonschreiber c: spring-driven lightweight signals recorder. Tonschreiber d: conversion of the Tonschreiber b for use by war correspondents. Tonschreiber f: dictating machine used as a successor to the FT-3. The A1000—L40 naval communications recorder also known as the RE-3. The R-26: spring driven portable for war correspondents. The model HTS: a high quality studio recorder with a.c. bias, also designated the R122a by RRG.[40] The K7: studio machine developed in 1945, produced in immediate post-war period.

A stereo Magnetophone had been developed by RRG starting about 1942 using the R22 version of the K4. Approximately four machines were made with stacked stereo record and replay heads.[41]

The Magnetophone

One of the most remarkable features of the Magnetophone machine produced by AEG was how little it differed, in mechanical detail, from those studio and high-quality domestic machines we see today.

Fig. 1 is an early K4 Magnetophone showing how the tape is spooled on open platters with a large hub of similar dimensions to the now commonly known NAB reel. In this, and all other machines up to about 1948, the tape is reeled with the oxide out, thus siting the head block, which is interchangeable, on the near side of the machine facing to the back.

On the left of the head block [illegible] contains erase, record and [illegible] is a heavy guide [illegible] longitudin[illegible]

take-up spool.

The transport arrangements also included a lifting device which allowed the tape to be moved away from the heads during fast rewind. Three, or in some cases four, motors were used to transport the tape, two being used as reel motors. These motors had an inverse torque versus speed characteristic and were originally commutator-type, series wound. Later versions used a.c. motors without commutators.

Constant-speed tape drive was achieved with a two-phase capacitor-type of synchronous motor. Solenoid-operated brakes were fitted to each reel motor and an interlock was provided on the record and play button, reducing the chance of accidental erasure of the tape. The K4 mechanism and subsequent machines to the end of World War II, all followed this arrangement but differed in detail from model to model.

After the general adoption of the K4 by the Reichs Rundfunk-Gesellschaft (RRG) in 1939, there was considerable co-operation between them and AEG in the development of further models. In fact in late 1939, Dr Hans Joachim Braummühl and Dr Walter Weber of the Research Department of RRG developed the a.c. bias system for use in the K4 types in broadcast service[21]. The broadcast version of the K4 was designated R22 or R22a and the subsequent modified versions with a.c. bias were redesignated R122 or R122a.

One of the novel features of all of the Magnetophone models was the use of ring-core heads and longitudinal recording instead of the previous arrangements used on steel-tape machines. A parallel development seems to have been made by British Thompson-Houston in December, 1933, since they made an application for a patent[42], granted in 1935, which describes various configurations of ring-core heads, including the notion of cross-field biasing* and the use of compressed iron powder cores for erase heads.†

Several non-broadcast tape recorders were also produced by AEG during the war years, one of the most remarkable being the version known as the Tonschreiber b. This machine was used principally by the Wehrmacht to record high-speed telegraph signals from a radio[43]. A secondary playback head could then be brought into use to "slow down" the replayed signals without loss of pitch. The head was a rotating drum assembly, shown on the left of the main head block in Fig. 2 and marked with the number 11.

It consisted of four reproducing heads equally spaced around the periphery and a commutator which connected each head to the replay amplifier for 90 degrees of the revolution. This complete assembly could be driven by a separate variable-speed motor which would revolve the drum in the same direction as the tape. This effectively reduced the head-to-tape speed and thus the pitch of the tone without reducing the rate at which the total signal could be transcribed.

The Tonschreiber b had the facility of being operated at any one of nine tape speeds from 9cm/s up to 120cm/s, this being achieved by altering the frequency of the master oscillator supplying the speed-regulating synchronous control motor. This low-powered motor was directly coupled to a more powerful non-synchronous motor which provided most of the torque required to transport the tape. Using this double-motor arrangement thus reduced the power requirement from the oscillator.

The BBC carried out some voice tests using this recorder, and which the author has heard. The effect on playback is quite peculiar, being somewhat akin to the sound of someone talking down a long length of metal pipe. Obviously not intended for high-quality recording, the Tonschreiber b was, however, a very clever device designed for pure signals use.

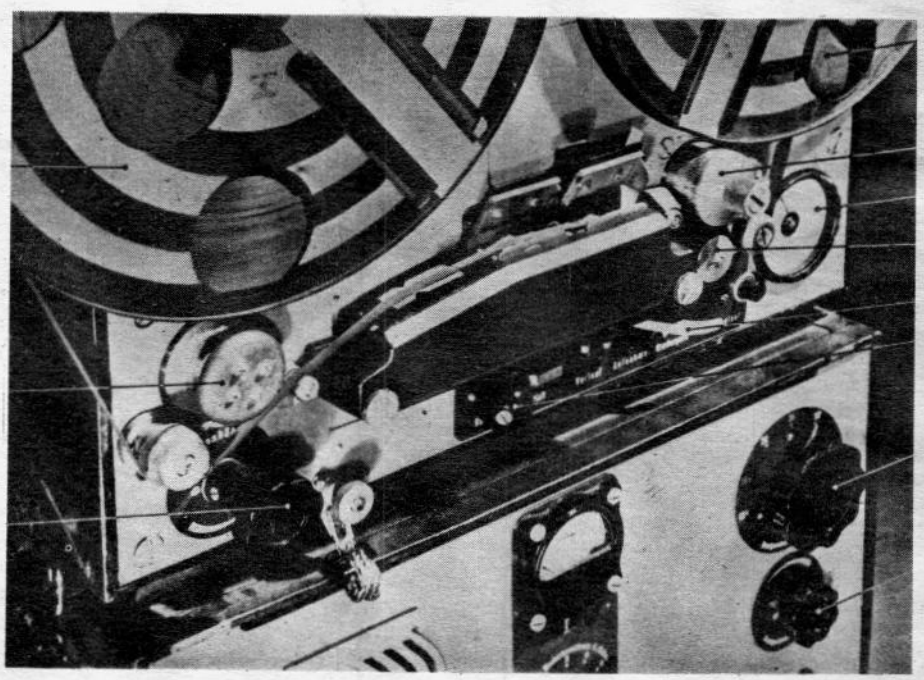


Fig. 1. An early K4 Magnetophone. The amplifier and speaker were contained in two other separate boxes. (Courtesy AEG Telefunken.)

Fig. 2. A close-up of the transport arrangements of a Tonschreiber b. The picture is taken from a BBC Research Department Report and carries their legends. (Courtesy BBC.)

Stereophonic recording

Although P. O. Pederson had described a method of multiplexing two audio signals on to a telegraphone wire in 1903 and Bell had succeeded in making binaural trans-

* See concluding part of this series.

† In practice, BTH may have had some sort of co-operative agreement with AEG since a later patent was taken out by BTH on behalf of AEG.

missions[44] by telephone in 1892, there had been few attempts to record a genuine binaural or stereophonic signal by the time of World War II starting.

There had been one classic example of a stereo magnetic recording made at the American World's Fair in 1939 by Bell Laboratories[4], but this used a steel-tape machine with two reels of tape of a new alloy called Vicalloy, clamped in parallel on the same transport and driven by a common shaft. The tape speed for this new type of tape had dropped to 16 inches per second, a cut of more than half the speed of the Blattnerphone machines.

However, as far as magnetic recording is concerned, this is where the matter seems to have rested—except for Germany. The broadcast organization RRG had, in 1942, commenced experiments with some prototype models of stereo tape recorders. These were adapted from the model K4 (R122 type) by RRG Laboratories and fitted with the first known examples of a multiple ring-core head with the tracks in the same vertical alignment[41].

No record pre-emphasis appears to have been applied, the entire equalization being achieved in the replay chain. This was not an entirely satisfactory state of affairs and in the immediate post-war period suggestions made by the BBC to divide equalization between the record and replay amplifiers was adopted.

By the end of the war the Magnetophone had become quite highly developed. The broadcast versions then in use, type HTS, were capable of a very good performance at a tape speed of 77cm/s—relative, that is, to the steel-tape and wire machines in use elsewhere. Frequency response was ±4dB from 60Hz to 10kHz with a signal-to-noise ratio of 35dB, which improved to 50dB when the excessive hum in the replay chain was filtered out. The replay amplifier was not particularly well designed since it had a signal-to-noise ratio of only 55dB[45].

At the end of the war a new type of Magnetophone was being developed, called the K7. Parts for the first 16 production models were found in the French sector of occupied Germany and an arrangement was made for these to be assembled and divided between the French, British and Americans[46]. This machine had several improvements made in the transport, and the bias frequency had been raised to 150–200kHz, but the erase frequency remained at 60kHz.

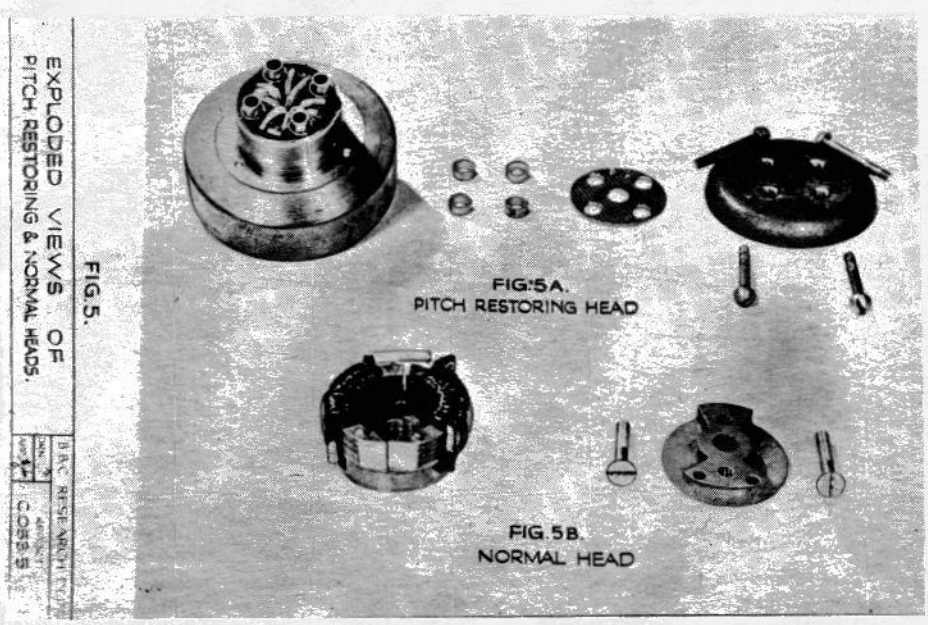
Before passing on to note the tape developments in Germany in the period 1939–45, mention should perhaps be made of other interesting machines[49]. The first, called the Kassetengerät, was a playback-only machine using a continuous loop cartridge of 9 × 5 × 0.25in. Inside the cartridge was 300 metres of tape, a free loop of which was brought across a rectangular hole cut in the cartridge case. The loop of tape would be slipped over the replay head and capstan and the tape driven at 28cm/s. The high-frequency cut-off point was said to be about 4kHz.

The second idea was a proposal for recording signals on a sheet of magnetic material in the shape of a quarto sheet of paper. No models of this seem to have been made.

Tape manufacture

Mention has been made of the experimental tapes first produced by Fritz Pfleumer and his subsequent co-operation with AEG and IG Farben. By 1936 steel-tape recording had become quite popular in broadcast applications, even to the extent that AEG felt it had to maintain a foothold by patenting a novel thin layer steel foil mounted on a paper backing tape[47] However, the two companies had by then formulated several satisfactory forms of tape[46]. The earliest of these consisted of spherical particles of iron of 10–15 micrometres diameter, glued to a paper or cellulose tape with an organic compound[48]. Shortly after, in 1934, it was realized that an improvement in the structure of the coating could be obtained by using a film-casting technique[49]. Here the magnetic powder was mixed with cellulose or p.v.c. and a solvent, and was then cast on to a continuous travelling metal band having a highly polished surface. When set, this layer would be affixed to a paper of cellulose base and slit into tape form.

Fig. 3. The pitch-restoring head from a Tonschreiber b shown dismantled. (Courtesy BBC.)



Although this was a big improvement there were still problems in obtaining a good high-frequency performance, due to the large size of the magnetic particles used. The search for suitable alternatives led the chemists of IG Farben to the magnetic oxides of iron Fe_3O_4 and gamma Fe_2O_3. Thus, by 1935 the company registered an application describing suitable preparations of these two oxides, for use as magnetic powders on tapes[50]. It would appear that little further development on oxides was to occur from this date until after the war, since it had not yet been realized that there was an advantage to be gained from adopting an acicular (needle-like) form of magnetic particle.

Had this happened the tapes found by the Allies might have been much better as in one patent published, IG Farben had clearly discovered the advantages of using magnets to improve particle packing in the still-liquid casting film, and they would have also therefore discovered the advantages of particle orientation.

Historically, therefore, by the end of the war, three types of tape had been developed by IG Farben. The first of these, based on the old film-casting techniques described above, was type C manufactured at Wolfen using a cellulose acetate base. A later, rather odd type was then developed called type L. This was a homogeneous p.v.c. tape in which the oxide and base material were mixed together, plasticized and then rolled into a single-layer film. The finished product was finally stretched to reduce the possibility of deformation on the tape machine. This tape was not too successful for a variety of reasons and its manufacture appears to have ceased in 1945 or 1946. The original plant, manufacturing type L tape, was at Gendorf which was taken as part of the Russian reparations.

The last development right at the end of the war, was type LG manufactured at Wald-Michebach and Ludwigshaven. This was a coated tape using pre-stretched p.v.c. (Luvithermed) as the base material and a coating of the same sort as type C, which used γ Fe_2O_3 spherical particles as the oxide.

A comment by an investigating official on the quality of these tapes, was that batch uniformity of type C was poor and that, owing to the low elasticity of the base foil, breakage was common[46]. Type L appeared to be quite uniform but suffered from print-through and finally type LG proved a considerable improvement over both types.

During the period 1939 to September 30, 1944, a total of 174,890km of tape had been sold from the Wolfen and Ludwigshaven factories together with 3,332 tape machines. This against a nil return from the rest of the world for this type of tape machine!

Reparations and recovery

After the war the Allies developed a policy

of breaking some of the very large monopolistic companies into smaller units and this was to happen to IG Farben. The factory at Wolfen, which specialized in type C magnetic tape and photographic film, became the now well-known Agfa company and the main Ludwigshaven plant became part of Badische Anilin & Soda-Fabrik (BASF). As for the Magnetophone, it was regarded as quite a novel idea—so much so that many still believe that AEG and IG Farben had deliberately kept its early development secret as part of the initial war and propaganda effort of politicians in Germany before 1939.

Certainly the Allies were not slow to make use of the Magnetophone, a large number of examples being officially and unofficially "exported" to Britain and America. They were also kept in service in the broadcast stations of occupied territories where some were quick to see the same advantages that Hitler had seen—that the tape recording could be used to pre-record political propaganda for simultaneous repeat broadcasts.

This gave rise to one rather amusing incident illustrating a vagary of Magnetophones. It would seem that one of the Allied war chiefs, probably Eisenhower, had to make a broadcast from Radio Luxembourg shortly after its capture and chose to make a tape recording prior to the occasion which would then be transmitted. This was done, and the transmission was well under way, when to everyone's horror Hitler's voice suddenly broke in on the recording. The tape was an old one which had been inadequately erased! The close of this apocryphal tale is that a prompt order came from a furious Eisenhower that fresh tapes were to be used on all future similar occasions.

From here on, the threads representing the development of magnetic recording become much more intertwined, since the rest of the world still had to be convinced that plastic-based tape was better than wire or steel tape.

There had been no development in magnetic recording to speak of in the UK during the period 1939–45; the BBC were sticking to their complement of Marconi-Stille machines and a few dozen model GE 50 American wire recorders imported some time late in the war years. In fact eight of these were installed in a mobile unit called the "Octopus" and used during the 1947 Olympic Games. However, there was a strong preference for disc recording and their use was extremely limited.

In America the story was somewhat different with two main areas of development almost competing with each other in the search for more versatile means of magnetic recording. Some time in 1940, Marvin Camras, subsequently responsible for a flood of inventions associated with magnetic recording, joined the Armour Foundation and developed a wire recorder using a.c. bias which was then produced by General Electric as the GE 50 and also by the Brush Development Company. A version found its way into USAF service and as a result of a US Navy contract, Brush went on to develop a steel-tape version.

In 1941 Marvin Camras applied, through Armour Research, for a patent on his a.c. bias method, and in 1942 completed the design for the USAF recorder. During 1943 another American company, Webcor, produced wire recorders for the US Navy and in 1944 Minnesota Mining (later 3M) started its first hesitant steps towards developing powder-coated tapes[13].

This occurred as a result of Brush Development asking Dr Oace of Minnesota Mining to develop a thin tape, coated with magnetic powder. Results were slow in coming, partly because Minnesota had no test gear and had to return samples to Brush for testing. It seems that Minnesota did not even know what they were supposed to be producing until it became obvious, with other developments appearing elsewhere.

In 1946 Brush brought out a new Soundmirror machine quite different from its predecessor, but seemingly entirely developed without reference to the Magnetophone, which by then was well known. The first broadcast use of this machine and its paper tape, coated with spherical particles of Fe_3O_4, was during the 1946 New York State political conventions when CBS recorded continuously for 24 hours and then used the material to edit into a "highlights" programme broadcast at the end of the day[51].

This and later machines and their paper tapes were marketed in the UK from 1949 by Thermionic Products—now Racal Thermionics—who are still firmly in the business of producing magnetic tape recorders.

The birth of an industry

Although tape machines using paper-based tapes were beginning to appear in America during 1946 and 1947, it was the "liberated" Magnetophone arriving in Britain and America that was to lend a tremendous impetus to a totally new industry. Here in Britain, EMI went to work and by November, 1947 announced its first-ever tape recorder for studio use, the BTR1 console machine. Although much was owed to the Magnetophone, there were many modifications which produced a very creditable performance.

By 1948 the Abbey Road studios of EMI were using the BTR1, and some machines had entered service in the BBC. In America two men, Colonel Richard H. Ranger and John T. Mullin, had returned from Europe with samples of Magnetophones and were busily lecturing on their finds. In May, 1946, Mullin demonstrated his machines to a meeting of 250 members of the IRE, and the following day received a visit from Alex Poniatoff and others from Ampex, who showed much interest in the German machines. This meeting led to a fascinating chain of events that started the production of the first Ampex 200 in 1948. John Mullin joined forces with Crosby Enterprises to produce a taped version of the Philco-sponsored Bing Crosby Show for NBC in 1947, an event which was to do much to promote the use of tape in broadcasting. Much later Crosby Enterprises were to become what is now known as the Mincom Division of 3M.

Ranger had also been busy, since he had formed a company called Rangertone, marketing first machines and later tape. Most importantly, tape was a big problem because the German product was far from being completely satisfactory.

By a curious coincidence parallel work by Dr W. W. Wetzel, H. K. Smith and R. Herr of 3M versus Marvin Camras at Armour resulted in the production of an acicular form of γ Fe_2O_3 which Camras was first to patent.

The first practical tape from 3M was called type 100 and was a paper-based black-oxide type produced in 1947. It was followed in the same year by type 110, coated on a plastic base and using the new red oxide.

The world had at last woken up to the tape recorder and if at times the allegiance to the Magnetophone was obvious as in our own RGD domestic console type, much research and development was to ensue, resulting in a vast variety of professional and domestic products by the year 1949.

(To be continued)

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