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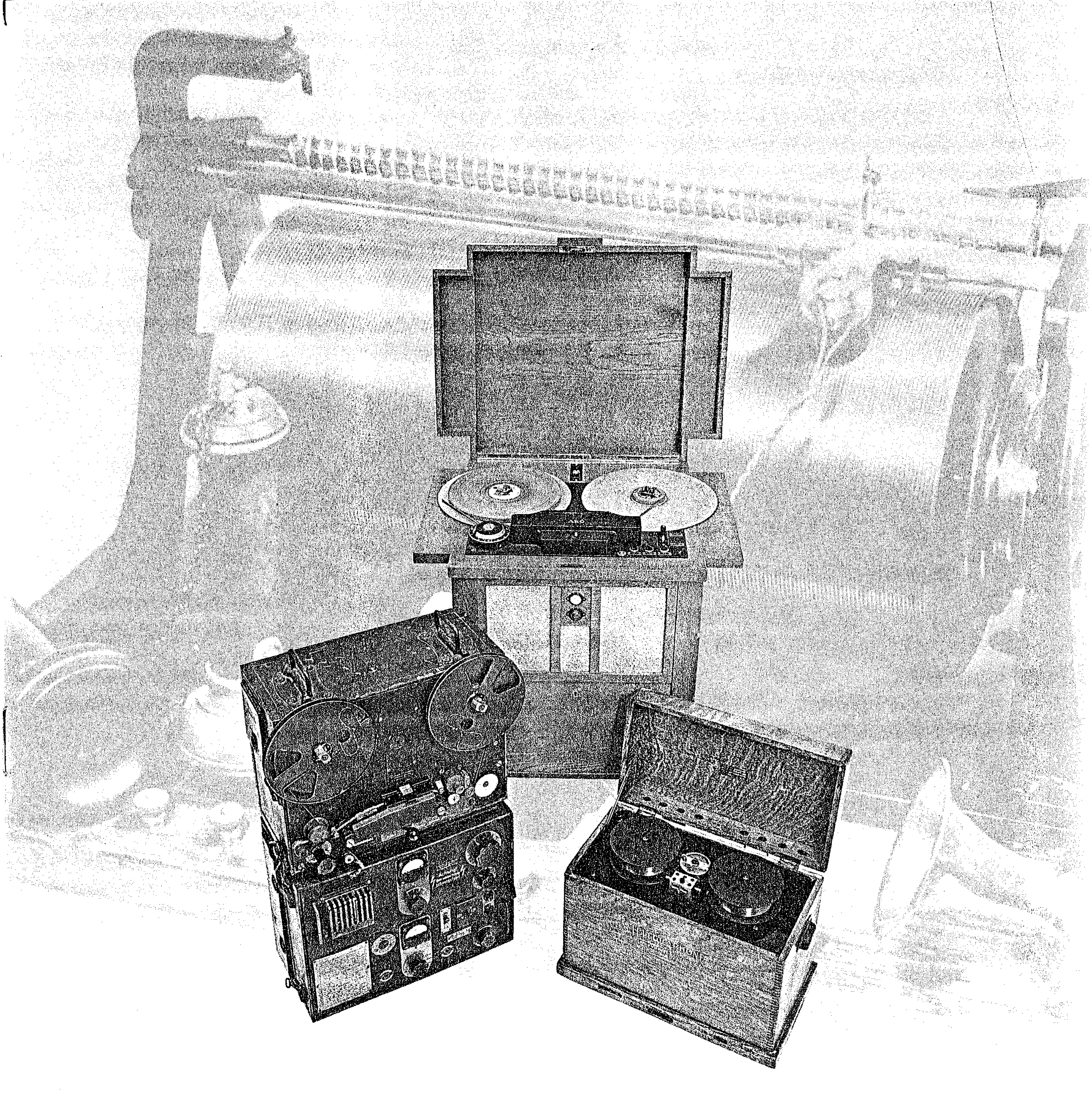


About The Cover

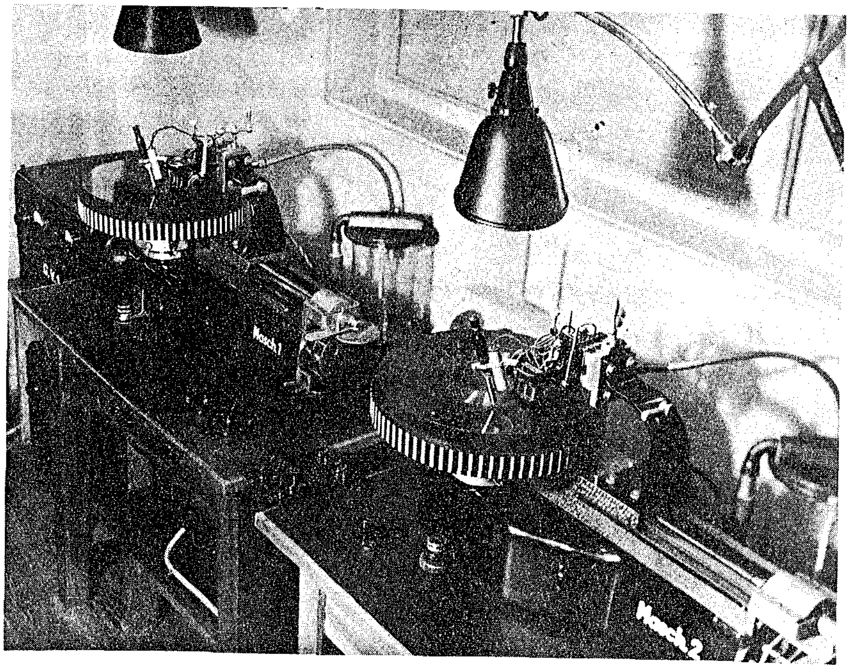
• This month's cover features (from left to right) the Tonschreiber B ("Berta"), made in 1939; the Magnetophon FT-2, made in 1936; both tape recorders and the Telegraphone wire recorder, circa 1910*. Photos courtesy of the Ampex Museum of Magnetic Recording.

**In the background is the first Poulsen Telegraphone from 1898.*

PETER HAMMAR and DON OSOSKE

The Birth of the German Magnetophon Tape Recorder 1928-1945

The following article is based on research done in the past year in Germany. Author Hammar talked to sources at BASF, Agfa, AEG-Telefunken, the German radio stations, the Deutsches Museum and to various retired engineers.

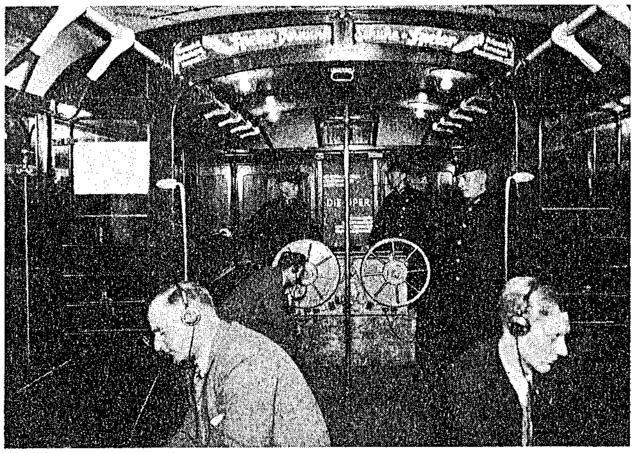


Neumann wax disc recording lathes at Sender Hamburg in 1931. Recording lathes were the forerunners of the Magnetophon in German broadcasting. (Photo courtesy of the Norddeutscher Rundfunk Archives, Hamburg, Germany.)

THE DEVELOPMENT OF MAGNETIC recording was not exactly an overnight event. From its introduction in 1898 as the Telegraphone wire recorder to the controversy of today's digital technology, magnetic recording has gone through stormy times.

Peter Hammar is consulting curator, Ampex Museum of Magnetic Recording. Don Ososke is with Ampex's Standard Tape Laboratory.

Valdemar Poulsen, the Edison of magnetic recording, invented almost every known form of magnetic storage. His first idea, in 1896, was a magnetic version of Edison's cylinder phonograph. Poulsen spiralled piano wire around a brass cylinder, with a laterally-moving magnetic pick-up head pushed along by the rotating cylinder. Playing time was thirty seconds. By 1899, the Dane had developed magnetic recorders that used spools pulling wire past the record head at two meters per second, with a recording time of several minutes. Poulsen also



October, 1934 Sender Hamburg remote broadcast recording on a Hamburg commuter train, using the Lorenz Steeltone machine. (Photo courtesy of the Norddeutscher Rundfunk Archives, Hamburg, Germany.)

made a machine that used a steel band to record sound. He even made a magnetic disc recorder whose pick-up head moved along a spiral guide, very much like the magnetic disc video slow-motion recorders developed by Ampex and others in the 1960s. And all this before 1900!

Unfortunately, marketing people regarded Poulsen's technical breakthroughs in magnetic recording as a curiosity, a toy. In 1905 the Danish engineer sold his Telegraphone patents to the highest bidder and went on to do research in other areas of electricity, including radio transmitters.

Lee DeForest, the inventor of the modern vacuum tube, wanted to perfect magnetic recording—many of DeForest's early Audion tube diagrams used a wire recorder as the theoretical sound source. However, DeForest's efforts were frustrated by lack of cooperation from Poulsen's successor, the American Telegraphone Company.

For shipboard radio recorders in the 1920s, U.S. Navy researchers Carlson and Carpenter improved the Telegraphone with vacuum tubes, and added something new to the record circuit—AC bias. But their Navy sponsors lost interest in communications recording and the two were forced to drop the project. Had the Navy had a bit more foresight (easy for us to say today), we might have had relatively high fidelity magnetic wire recording as early as 1923. The Navy's reaction reflected an attitude that continued from Poulsen's day: magnetic recording was more a curiosity than a practical tool.

The next attempt to commercialize magnetic recording was made almost a quarter-century after Poulsen, when Curt Stille in Germany formed the Telegraph Patent Syndicate in 1927. Stille envisioned magnetic recorders for dictation, automatic telephone answering, and even music reproduction. None of the members of the syndicate was very successful in their attempt to commercialize magnetic recording, although the Lorenz Company in Berlin almost succeeded.

Around 1933, under the direction of S.J. Begun (who later headed Brush Development in Cleveland), the Lorenz Company began work improving one of Curt Stille's ideas, using a steel band as the recording medium. Lorenz had enough faith in magnetic recording to design its "Steeltone Tape Machine" for use in radio stations as a transcription device. In fact, by the mid-1930s, several European radio services, including the Germans and the British, had used steel recording on the air. Steel-band recorders had reached a quality level almost equal to the broadcast wax disc.

During the world-wide depression of the 1930s, people relied increasingly on radio at home for entertainment. For broadcasters, the Thirties was a time of tremendous growth in entertainment programming. Most radio stations used recording lathes to cut lacquer or very thick wax discs for use in time-delayed broadcasts. However, the wax discs could only be played two or three times before the grooves were worn. Also, the radio engineer could not easily edit a program recorded on a disc. The necessary disc-to-disc transfers to edit out mistakes led to high generational loss of sound quality.

Naturally then, magnetic recording on a long, thin strip of material offered the broadcaster editing and multiple-replay capabilities that he did not have with discs. But the Lorenz Company's steel-band recorder was out of date before they could get their machine to the broadcast market. Steel as a recording medium was impractical at best. You edited with solder and a welding torch. A fifty-minute reel of steel tape measured over two feet in diameter, and weighed almost 40 pounds!

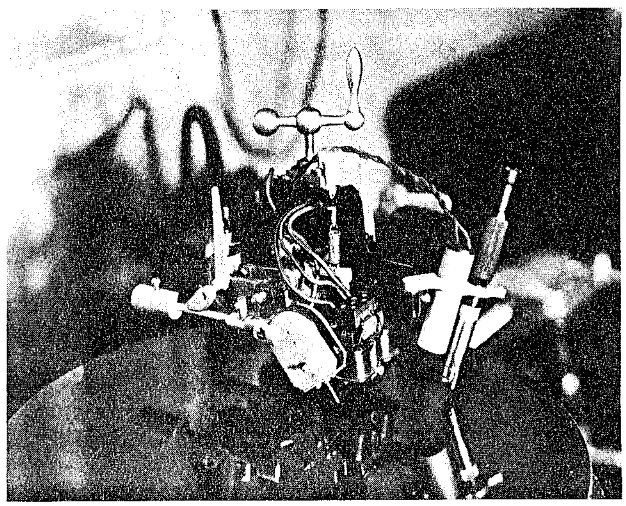
The machines could even be dangerous for their operators. The English version, the Blattnerphone, used at the British Broadcasting Corporation until as late as 1950, was operated in a metal cage so that if the steel band flew off its reel during fast-forward or rewind, the engineer on duty wouldn't lose a hand, or worse.

We have no figures on the cost of solid steel tape, but the expense was high enough to prompt the German radio service's chief engineer H. J. von Braunmühl to look for an alternative to steel. There had to be a better answer to magnetic recording than the steel band.

FROM STRAWS TO CIGARETTES TO MAGNETIC TAPE

In Dresden, Germany, the Universelle Company had been building cigarette manufacturing machines since the turn of the century. One of their engineering consultants in the 1920s was Fritz Pfleumer, whose previous discoveries included drinking straws made of plastic, as well as new forms of foam rubber.

One of Universelle's machines was designed to make cigarettes with a thin band of real gold around the mouthpiece. Even for 1928, using gold on cigarette mouthpieces was becoming expensive, so the company put Pfleumer to work finding a substitute for the gold. Pfleumer developed a bronze powder that he mixed with lacquer, spread on a wide, long strip of paper, and then slit into tiny pieces for gluing onto the cigarettes.



Neumann disc cutting head, in use circa 1931 at Sender Hamburg. Both wax and lacquer discs were used for the broadcast-quality recordings. (Photo courtesy of Norddeutscher Runkfunk Archives, Hamburg, Germany.)

Pfleumer was somewhat of an audiophile. He liked good-quality radios and recording devices, and did much experimenting on his own. Of course, like most engineers, Pfleumer knew about the wire Telegraphone and the early experiments with steel-band recording.

Around 1928, Pfleumer was in Paris on a business trip. While sitting in a cafe, he was thinking about magnetic sound recordings. He reasoned that, instead of using expensive, heavy steel tape for recording, he could use his cigarette-mouthpiece-label technique to make cheap, lightweight magnetic tape. Instead of bronze powder, iron powder could be mixed with lacquer and spread on a paper tape.

Pfleumer's combined knowledge of paper tapes from his cigarette work, and his understanding of magnetism and electro-acoustics was crucial to his success in making the world's first magnetic tape recorder. He knew, for example, that the iron particles had to be as small as possible to achieve the highest possible frequency response. For Pfleumer, the all-important binder material to glue the particles to the tape was no problem at all. He just used the same lacquer he had used for the bronze on the cigarette mouthpieces.

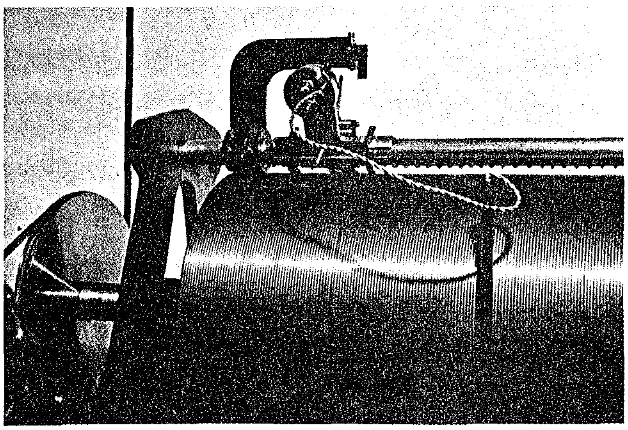
Pfleumer's first tape recorder, built in 1928-29, sounded just awful: distortion, background noise, wow, and flutter. But the point was, the thing *worked!* One did not need a solid piece of ferrous material to record sound magnetically. The engineer described his recording tape as "a 300-meter-long roll of the recording material which lasts twenty minutes and costs only one Mark 50 Pfennigs (about 25 cents) to make. The paper, called Pergamine, is only 0.04 mm thick." He pointed out that, with his new recording system, the tape editor could trade his welding torch for a pair of scissors.

Unhappily for Fritz Pfleumer, the German patent office in 1936 denied him his 1928 patent, finding the American J.A. O'Neill's 1927 magnetic tape patent valid. As far as we know, O'Neill never did make workable magnetic tape or a recording device of any kind.

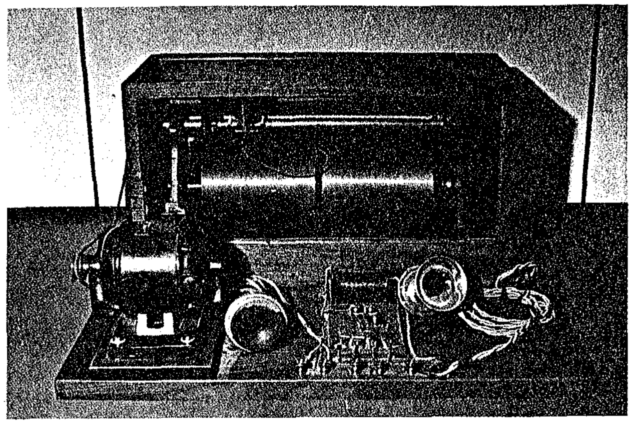
In 1929, Pfleumer took his invention from Dresden to Berlin, to sell it for development. Newspapers there ran stories about the new recorder, after several private demonstrations. AEG (*Allgemeine Electricitaets Gesellschaft*, or "General Electric Company") in Berlin, today affiliated with Telefunken, was Germany's second-largest electronics company, after the Siemens Company. AEG designed and manufactured professional and consumer electronic products, much as its business associate General Electric did in the United States.

At AEG in 1930, Pfleumer's first demonstration of his tape recorder, which he called a "sound paper machine," was less than convincing. This magnetic recorder, like others before it, sounded poor. However, for the first time in history, engineers and managers were far-sighted enough to see the potential for tape recordings. By 1932, AEG had signed a contract with Pfleumer to buy his patent outright and develop tape recording.

The engineers at AEG tried to make their own tape at first, according to one account, buying carbonyl iron at the corner drugstore and spreading it on paper "ticker tape." The sound they got from the tape was terrible, and they soon realized that the problems of spreading thin coats of iron-filled lacquer onto strips of paper tape were best left to a chemical concern.



Detail of the Telegraphone record/playback head. (Photo courtesy of the Deutsches Museum, Munich.)



Poulsen Telegraphone, complete (1899). Poulsen intended this device—record/PB time = 30 seconds—to be an automatic telephone answering machine. (Photo courtesy of the Deutsches Museum, Munich.)

THE FIRST TAPES

In the early 1930s, the chief executive officer of AEG, Herman Buecher, heard about his engineers' problem. He called his old friend in Frankfurt, Carl Bosch, who was the head of the powerful IG Farben chemical combine, to see if the two companies could make the development of the magnetic tape recorder a joint venture. In 1932, AEG's Buecher and IG Farben's Bosch arranged for a member of the IG Farben group BASF, (*"Badische Anilin und Soda Fabrik"* or "Baden Anilin [dye] and Soda Factory"), in Ludwigshafen, to begin intensive research into the problems of making good magnetic tape for the new AEG machine that they called the "Magnetophon".

The first BASF tapes made in 1934 for the Berlin Radio Show were made of pure, powdered carbonyl iron. The iron, which looks like black dust, was mixed with lacquer and spread onto a cellulose acetate film, which was then cut into five millimeter-wide strips (6.35 mm = ¼ inch) several hundred meters long. BASF's first tape had no trade name, and was simply called "IG Farben carbonyl tape." Capstan problems with AEG's prototype Magnetophon postponed the planned 1934 unveiling of the new recording process until the Berlin Radio Show the next year.

By 1935, the researchers at BASF had progressed from carbonyl iron to iron oxide with smaller magnetic particles that resulted in better electrical performance. Today's iron oxide tapes are essentially refinements of these early BASF formulations.

At the start of their joint venture with AEG, BASF switched from paper to a cellulose-acetate film. The early carbonyl iron tape was brittle, but much stronger than the first paper tapes. BASF's trade name for their acetate basefilm was "Cellite," so they called their new iron-oxide formula tape "Type C." Manufactured through 1942, Type C tape had a rust-colored oxide with a gray backing.

By 1943, BASF had introduced a third kind of tape, Luvitherm or "Type L," a homogeneous tape/basefilm of polyvinyl chloride. Though much stronger than the Type C acetate tape, the PVC did stretch. Type L tape was made by dumping the iron oxide into the PVC vat, and then extruding the mixture into a solid film. Because the iron oxide was mixed throughout the tape, Type L could be recorded on either side. Another IG Farben member, Agfa at Wolfen, later joined BASF in the production of recording tape. In 1944-45, American GIs invading Northern Europe found a lot of Type L tape. Both BASF and Agfa were able to steadily increase their tape production until war's end in May of 1945.

The origin of today's one-quarter inch tape width standard came from a combination of good engineering and coincidence. In 1935, just before the introduction of the first AEG/BASF recorder and tape, the companies jointly decided to widen the tape from its original 5.0 mm to 6.5 mm (just a hair over one-quarter inch). The engineers chose the wider tape for greater strength and better electrical performance. We still do not know why they chose the number 6.5 mm.

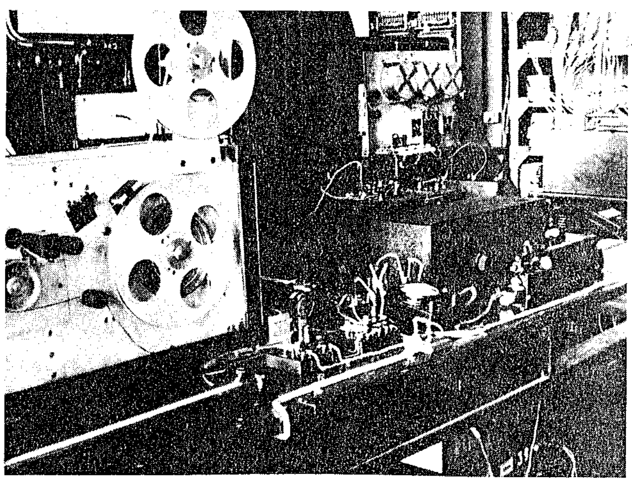
When the Allied engineers examined the captured Magnetophons and their BASF/Agfa tapes, they measured the 6.5 mm width as a quarter inch, plus or minus "a tiny bit." The 0.15 mm difference between a quarter inch and 6.5 mm was really not worth noticing. With the interruption of German tape manufacturing at the end of the war and the importation of American 3M (Scotch), Orradio (Irish), Audio Devices and other tape, the official width of magnetic tape there became 6.35 mm as well.

THE MAGNETOPHON

Our thirty inches-per-second base tape speed also originated in Germany with the Magnetophon. Until 1935, the AEG/BASF R & D team used one meter-per-second as their nominal standard tape speed. However, slight variations from machine to machine in motor performance and capstan diameter made interchangeability of tapes impossible. In 1935, the selection of a newly-designed asynchronous motor for the capstan drive solved this problem. In an effort to simplify future production of Magnetophons and set a world-wide standard, the engineers specified a capstan diameter of 10 mm, ±0. A ten-millimeter capstan with AEG's asynchronous motor and the BASF tape produced a tape speed of 76.8 centimeters-per-second. If the production of the Magnetophons could be standardized, an odd tape speed really would not matter.

When Major Jack Mullin, one of America's tape pioneers, and his U.S. Army Signal Corps engineers measured the Magnetophon's tape speed, they were surprised to measure almost exactly 30 inches-per-second (76.2 cm/s). Mullin's captured Magnetophons inspired the creation of the Ampex Model 200, America's first commercially-successful professional recorder. In 1947, Harold Lindsay, the Model 200's chief designer, used Mullin's 30 ips figure in the American machine's design, which later became the U.S. standard. Mullin had lent Lindsay some of his precious pre-recorded Magnetophon tapes for test purposes, thus the logical choice of a 30 ips tape speed for the American machine.

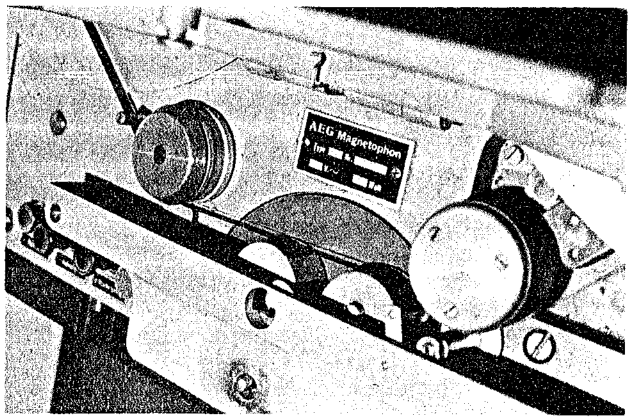
With the postwar dismantling of the Magnetophon factories, American machines dominated the European recording market in the early 1950s. The Germans adopted the U.S. figure of 30 ips, converting the number back to the metric 76.2 cm/s. No one ever seemed to notice the difference.



The first laboratory prototype of the AEG "Ferrotone" tape recorder in the fall of 1933. The one-motor machine used 5mm-wide carbonyl iron paper tape that was pulled past the heads at one-meter-per-second. (Photo courtesy of the AEG-Telefunken Archives, Braunschweig, Germany.)

From the start of the Magnetophon project, AEG faced the difficulty of making good heads. Both Pfleumer's and AEG's prototypes used record/reproduce heads similar to those originally developed by Poulsen and found on wire and steel band recorders: pole pieces with sharpened points pushed by springs into the surface of the recording medium. Naturally, the pointed head pieces quickly ripped the thin paper apart. Even the later acetate and PVC-backed tapes could not stand more than a pass or two from the points.

AEG's early experiments with the old-style pole-piece heads showed that, in addition to tape destruction, these heads had electrical disadvantages. The magnetic lines of force from the pointed heads with their separate pole pieces were both horizontal (parallel to the axis of the tape travelling past it) *and* diagonal. The lines of flux which intersected the tape were unfocused and mostly unusable, even interacting with each other to create distortion.



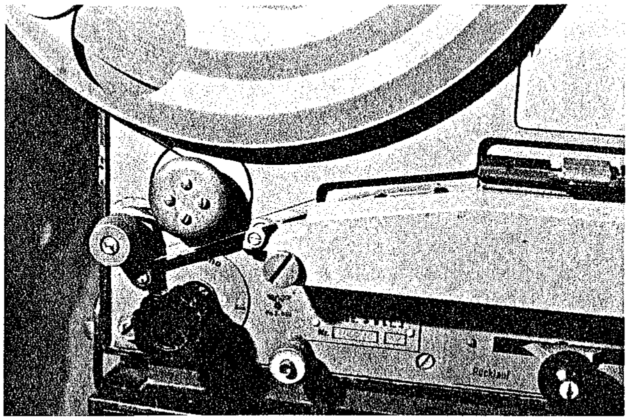
View of head assembly and tape path of AEG Magnetophon K-2 (1936), the portable version of the FT-2 shown on the March db cover. (Photo courtesy of AEG—Telefunken and Ampex.)

THE RING HEAD

The solution was an invention by Eduard Schueller: the enclosed ring head. Schueller had worked as a research assistant at the Heinrich Hertz Institute, a technical "think tank" in Berlin, and by 1932 was already experimenting with ideas of magnetic recording. Schueller found that the most important part of successful magnetic recording was the head. He decided to improve on the open pole-piece head design. The result was his experimental ring head. Naturally, as soon as AEG heard about Schueller's work, they offered him a key position on their tape recorder development team.

Schueller's ring head was not only very easy on the early tapes, but also created the nearly ideal magnetic flux pattern necessary for better fidelity recording. The lines of flux were concentrated in their most useful direction, horizontally (in the direction of the tape).

Thanks to the AEG-Telefunken Archives, BASF, the German Radio Archives in Frankfurt, and Hans Westphal of Berlin, we have copies of the earliest recordings made on the AEG prototype recorder in 1933. On the first recordings, the frequency response limit was not more than 3 or 4 kHz, harmonic distortion was about ten percent, and the signal-to-noise ratio was quite poor. By 1935, with the introduction of AEG's first production machine, the "Magnetophon K-1," fidelity had been increased, with frequency response to beyond 5 KHz and with less distortion.



Spinning head (4 gaps, 90 degrees to tape path) of Tonschreiber "Berta"; made by AEG, Berlin, circa 1939. (Photo courtesy of AEG—Telefunken and Ampex.)

Although AEG initiated the development of the modern tape recorder, it was BASF who gave the machine its name. The engineers at AEG in 1932-33 dubbed their new machine "Ferroton." At BASF, they were calling their tape "Magnetophonband" or magnetic phonograph tape. The name stuck, and in 1935, AEG started calling the machine "Magnetophon."

By 1935, the Germans had three of the four necessary ingredients of modern tape recording: 1) a stable transport, which the steel band recorders such as Lorenz had; 2) good tape, which the researchers at BASF had created; and, 3) the ring head from AEG's Schueller, with its good magnetic properties and gentle treatment of fragile tape. The fourth element of magnetic hi-fi recording, good electronics, would have to wait until 1939-40, after the Second World War had started.

From Valdemar Poulsen at the turn of the century until the late 1930s, direct-current biasing was the only method known to European engineers to reduce noise and distortion and increase frequency response. As late as 1939, the DC-bias Magnetophon sounded no better than an average 78 rpm transcription disc.

Until 1945, most engineers around the world had not heard of the German tape recorder. It was the combination of DC bias and World War II that kept the Magnetophon in obscurity. Jack Mullin has said that, "Once you hear DC-bias recording, you'll never want to hear tape again!" Sir Thomas Beecham, having heard his London Philharmonic on tape in November of 1936, reportedly was so horrified by what he heard that he didn't use tape again until 1950.

In 1936, AEG sales people took their new Magnetophon to America for a secret demonstration at General Electric in Schenectady, New York. The DC-bias unit sounded so bad to the Americans that they decided that magnetic recording, at least in that form, was not practical.

The most promising market for the then-unperfected magnetic recording machine in Germany in the 1930s was the Berlin-based German radio monopoly, known as the RRG (*Reichs Rundfunk Gessellschaft*, or Empire Radio Company). The chief of the RRG engineering section, H. J. von Braunmühl, was against using magnetic recording for broadcasting. He liked the tried-and-true wax disc recording lathes with their Neumann heads. However, the progress of the AEG and BASF engineers interested him.

Von Braunmühl bought several DC-bias Magnetophons and put his best engineer, Walter Weber, to work to see if the machines really could be improved enough to be used on the air. Meanwhile, the people at AEG were also hard at work trying to perfect magnetic recording.

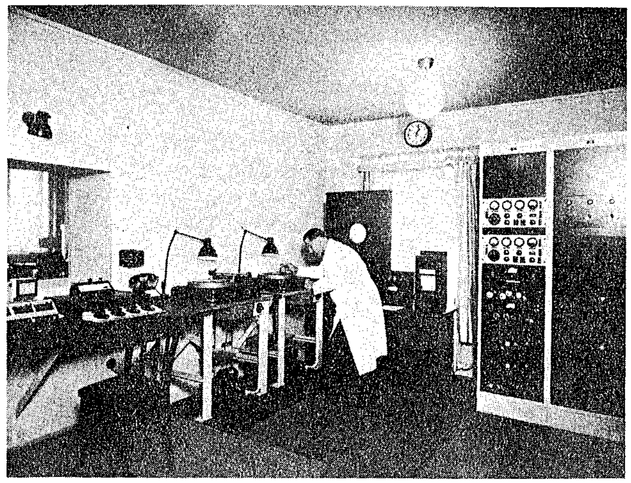
Weber at RRG had an idea of how to improve the signal-to-noise ratio. He cancelled some of the noise by adding an inverting bridge circuit with a "dummy" record head to the record amplifier circuit. The resulting 180-degree phase shift reduced tape noise about three dB.

AC RECORD-BIAS

One day in 1939, Weber was experimenting with this circuitry, making recordings of music and speech as well as pure tones. Weber kept logs of which recorder he had used, time of day, and what he had recorded. Later, while playing back one of the tapes, Weber found that the sound was fantastic! He was hearing true high fidelity on tape: extended frequency response, low noise, and low distortion. He traced the recording back to a Magnetophon that used his new noise reduction circuit, checked that circuit, and found that it was in constant oscillation, dumping high-frequency feedback into the record circuit. Weber realized that AC record-bias was *the* answer to hi-fi tape recording. He spent the rest of 1939 and much of 1940 perfecting his AC-bias discovery.

After the boss of the AEG Magnetophon lab across town heard the results of Weber's breakthrough at RRG, he went to his own researchers and said, "What in the world have you guys been doing here, sleeping? Over at RRG, they've just discovered AC bias and turned *our* machine into a high-fidelity recorder. We've got to get on the ball here!"

In fact, AC biasing of the record circuit was nothing new. But times were different, and engineers often missed each other's progress. Back in 1927, the U.S. Navy engineers Carlson and Carpenter, using a Telegraphone, had noticed the improvement of AC bias on wire recordings of telegraph messages. About the same time that Weber discovered AC biasing for tape recorders, Marvin Camras of the Armour Research Institute in Chicago had a similar discovery for use with his improved wire recorders.



The disc transcription room, Sender Hamburg, circa 1935. (Photo courtesy of the Norddeutscher Rundfunk Archives, Hamburg, Germany.)

With the war already in progress in Europe by 1940, it wasn't too surprising that Weber and Camras had not heard of each other's discoveries. In the late 1930s, the Japanese, under Kento Nagai, also discovered the AC-bias phenomenon on solid magnetic material.

After the war, the Allied Commissions in Germany and Japan declared all international patents of the Axis powers invalid. That left the quite advanced Armour patent as the finisher in the post-war AC bias license field.

For AEG, the beauty of Weber's discovery was that they could take their existing DC-bias design and simply add the relatively simple AC-bias circuit, while changing the record head only slightly. The playback of the DC-bias Magnetophon was quite good, although its full potential was never realized before AC-bias recording. The last production DC-bias

Magnetophon had a specified frequency response of 50 Hz-6 kHz, a dynamic range of 40 dB, and harmonic distortion of 5 percent. The first AC-bias Magnetophon was rated at 40 Hz-15 kHz, with a 65 dB dynamic range, and under 3 percent distortion.

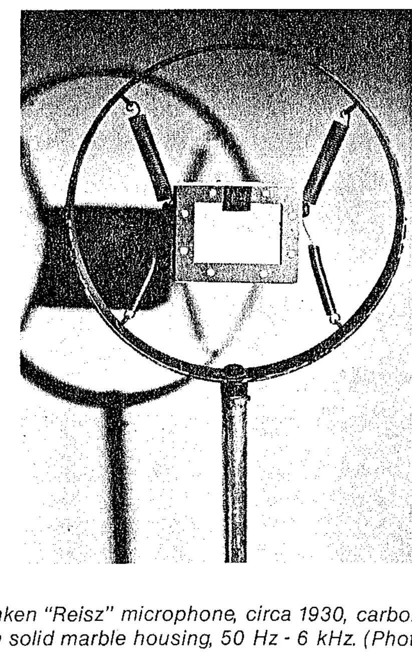
Most of the studio Magnetophons in use at the end of World War II were designed as early as 1938. The first production Magnetophon, the portable K-1, appeared in 1935. ("K" stands for the German word *Koffer* or "portable case.") The machine came in three cases, one for the transport, another for the electronics, and a third holding the loudspeaker. At the same time, AEG produced the cabinet "FT" series Magnetophon *Ferngesteuertes Truhe,* or "remote control cabinet"). The K-2 and FT-2 were introduced in 1936. The only FT-2 in existence that we know of is now a part of the Ampex Museum of Magnetic Recording in Redwood City, California.

The K-3 and FT-3 in 1937 were followed by the final Magnetophon in the pre-1945 series, the K-4, in 1938. The K-4 is the best-known pre-1945 Magnetophon. This is the machine that Jack Mullin and his partner, San Francisco filmmaker William Palmer, used to introduce America to the new technology of hi-fi tape recording.

The 1938 K-4 had DC biasing, and after the introduction of AC bias in 1941, a few early K-4s were updated. AEG also made an agreement with the RRG radio people to deliver K-4 decks built to RRG specifications incorporating the AC-bias design. The radio station console machines that Jack Mullin first saw at the Radio Frankfurt substation at Bad Nauheim in July in '45 were special K-4 HTS *(Hochfrequenz Truhe Speziell*, or AC-bias cabinet special models.)

When the war started, everyone in Germany was ordered to switch over to building military products. That was as true for tape recorders as for coat buttons. AEG produced a very rugged, portable DC-bias version of the Magnetophon that they called the *Tonschreiber* or "sound writer." The best-known of the Tonschreibers was the Type B, or *Berta* machine, which appeared in 1939-40. Berta was unusual because the machine had an extra, spinning head which could be used to compress or expand sound for high-speed transmission of information.

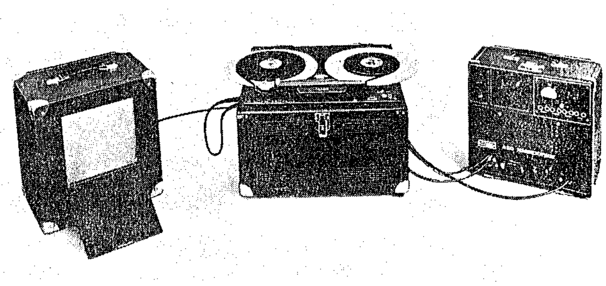
An amazing fact of World War II was that no one on the Allied side seemed to have heard about the hi-fi Magnetophons until the end of the war. This ignorance is even stranger when you consider that popular German magazines and newspapers, publicly sold in neutral Switzerland, printed numerous feature articles about German radio stations. Had the Germans classified all information about the AC-bias Magnetophons as "top secret," the Allied probably would have known about the machines before the end of 1940! As it was, they had to wait another five years.



Telefunken "Reisz" microphone, circa 1930, carbon-type, in solid marble housing, 50 Hz - 6 kHz. (Photo courtesy of AEG-Telefunken Archives and Ampex Museum.)

During World War II, the Allies were sometimes confused about Hitler's location. Live-quality broadcasts of his speeches simultaneously came from all parts of Germany. The Allies suspected some sort of high-fidelity recording device, but they overlooked the fact that the Germans had an extremely advanced radio network. A complex web of high quality land lines (10 kHz bandwidth, 600 ohm balanced line, less than 1 dB loss per 1000 km) allowed remote broadcasts from any location to any other location. In addition, time delay broadcasts had been standard procedure in Germany since the mid-1920s. To this day, old RRG engineers are amazed and baffled to hear that Americans thought that the Magnetophons were being used to deliberately confuse the Allies as to the location of high Nazi officials.

In England between 1942 and 1944, Major Jack Mullin and others had been hearing late-night German broadcasts of live-quality orchestral music. Mullin thought that even a madman like Hitler could not compel tempermental musicians to play at three a.m. However, the audio quality of the transmissions was much better than any recording device Mullin knew. What he heard was the routine use of the Magnetophon, which had been developed as a professional and consumer entertainment device.



An AEG Magnetophon K-4, circa 1938. The DC bias version had a frequency response of 50 Hz - 6 kHz, 5 percent distortion and a dynamic range of 40 dB. Once modified with Walter Weber's AC record bias, the frequency response improved to 40 Hz - 15 kHz, with a 65 dB dynamic range and less than 3 percent distortion. (Photo courtesy of the AEG-Telefunken Archives, Braunschweig, Germany.)

The Magnetophon tape recorder naturally got sucked up into the German war effort. The chief of the AEG Magnetophon lab during the war, Dr. Hans Schiesser, said that he had received specific orders from the Nazi government to work exclusively on the DC-bias military Tonschreibers for use by the army, air force, and navy, and to ignore civilian tape recorder development. However, Schiesser kept a secret set of lab notes which he still has, in which he wrote of his work on high-fidelity magnetic recording. Schiesser's work included the development of stereo record and playback heads, which he quietly did on the side, at some personal risk. For Hans Schiesser and many others at AEG and the RRG, the Magnetophon tape recorder was the exciting way into the future of high fidelity reproduction of sound. ■

Peter Hammar welcomes participation in the Ampex Museum of Magnetic Recording. If you have old equipment, information, or are just interested, contact him at the Ampex Museum, c/o Ampex Corp. (MS 3A-14), 401 Broadway, Redwood City, CA 94063; telephone: (415) 367-3127. Public visiting hours are 11:30 am to 1:30 pm Monday through Friday; other hours by appointment. Please contact the Ampex public relations department at the above-mentioned address, or call (415) 367-4151.

April 1976

by John T. Mullin

Creating the Craft of Tape Recording

When a GI sent a German tape machine back home to America, he only glimpsed what it would mean to his—and recording's—future.

IN 1944—LIKE THOUSANDS of other GIs just before D Day—I was in England. Because of my background in electronics, I was assigned to the Signal Corps, troubleshooting a problem the Army was having with radio receivers that were picking up severe interference from the radar installations that blanketed Britain.

I became so intrigued with what I was doing that I would work until two or three in the morning. I wanted music while I worked. The BBC broadcasts filled the bill until midnight, when they left the air. Then, fishing around the dial in search of further entertainment, I soon discovered that the German stations apparently were on the air twenty-four hours a day. They broadcast symphony concerts in the middle of the night—music that was very well played, and obviously by very large orchestras.

I had some experience with broadcast music and knew what "canned" music sounded like. The American networks wouldn't permit the use of recordings in the early 1940s, because they claimed the quality was inferior. You could always spot the surface noise and the relatively short playing time of commercial 78-rpm discs. Even transcriptions had some needle scratch and a limited frequency response. There was none of this in the music coming from Germany. The frequency response was comparable to that of a live broadcast, and a selection might continue for a quarter of an hour or more without interruption.

In Germany at that stage, of course, Hitler could have anything he wanted. If he wanted a full symphony orchestra to play all night long, he could get it. Still, it didn't seem very likely that even a madman would insist on live concerts night after night. There had to be another answer, and I was curious to know what it was.

As the Allied armies moved on Berlin, my unit was reassigned to Paris and lodged in a building that had been a maharajah's palace. It was quite something. Each of us had a big room of his own, with lots of space to store equipment in. We were given the job of rooting out technological developments—particularly those with military applications—that the Germans had made in electronics during the war. That meant taking trips into Germany from time to time.

On those trips, I kept finding battery-operated portable magnetic recorders: about a foot long and eight inches wide with tiny reels. All of them used DC bias, which meant fairly poor signal-to-noise ratio, limited frequency response, and distortion in the high frequencies. But that didn't matter, because they were intended for dictation in the field; bare intelligibility was the prime criterion. We found so many of these recorders that we started dumping them in the maharajah's courtyard. When I left Paris there was quite a pile of electronic hardware out there, rusting in the rain.

In July 1945 a Lt. Spickelmeyer and I were sent to

Germany to look into reports that the Germans had been experimenting with high-frequency energy as a means to jam airplane engines in flight. Our mission was to investigate a tower atop a mountain north of Frankfurt. There, in an enormous basement room, were two gigantic diesel engines and generators, apparently designed to pump out high-frequency energy to resonate the ignition systems of enemy planes. Nothing ever came of it.

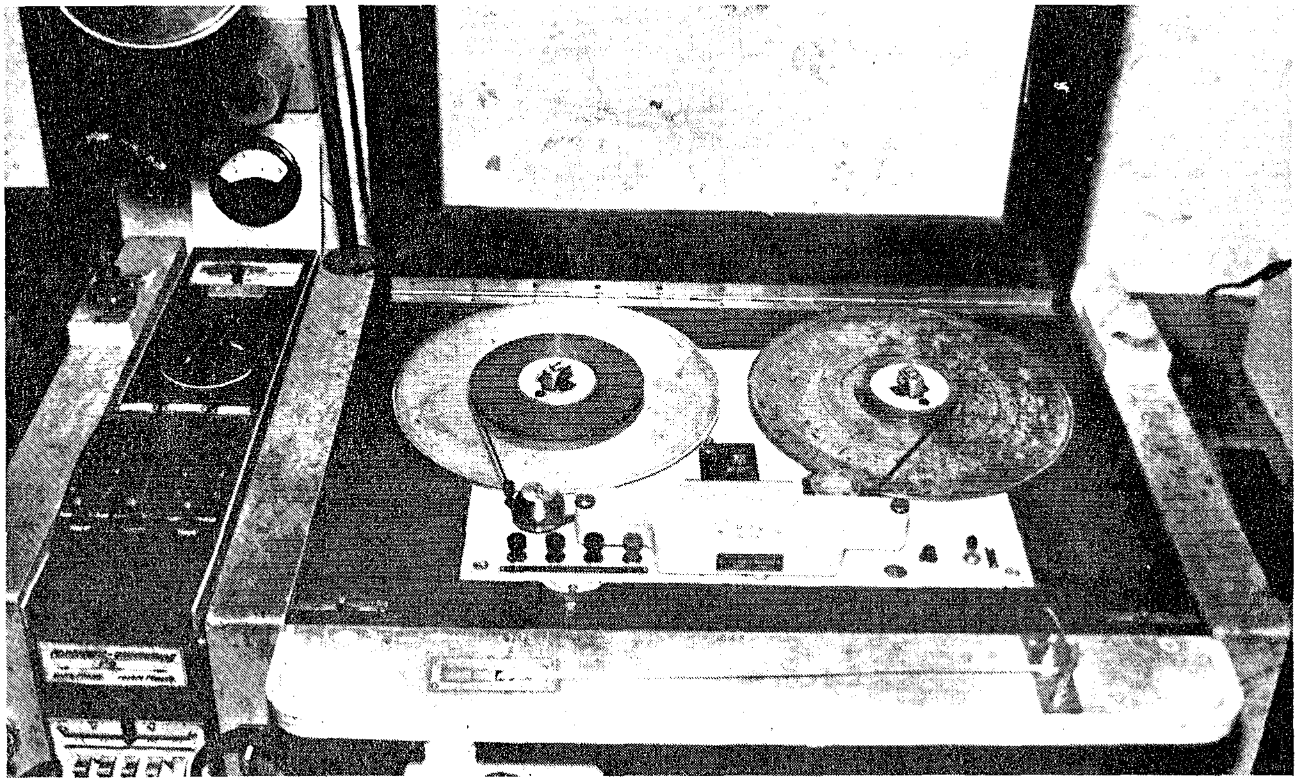
While we were poking around I met a British army officer who was there on the same mission. The subject of music and recording came up, and he asked if I had heard the machine they had at Radio Frankfurt. When he told me it was a Magnetophon—the term that Germans used for all tape machines—I assumed it was similar to the recorders we had been junking in Paris. He raved about the musical quality of this recorder and urged me to listen to it, but I thought he simply didn't have a very good ear.

On the way back to my unit, we came to the proverbial fork in the road. I could turn right and drive straight back to Paris or turn left to Frankfurt. I chose to turn left. It was the greatest decision of my life.

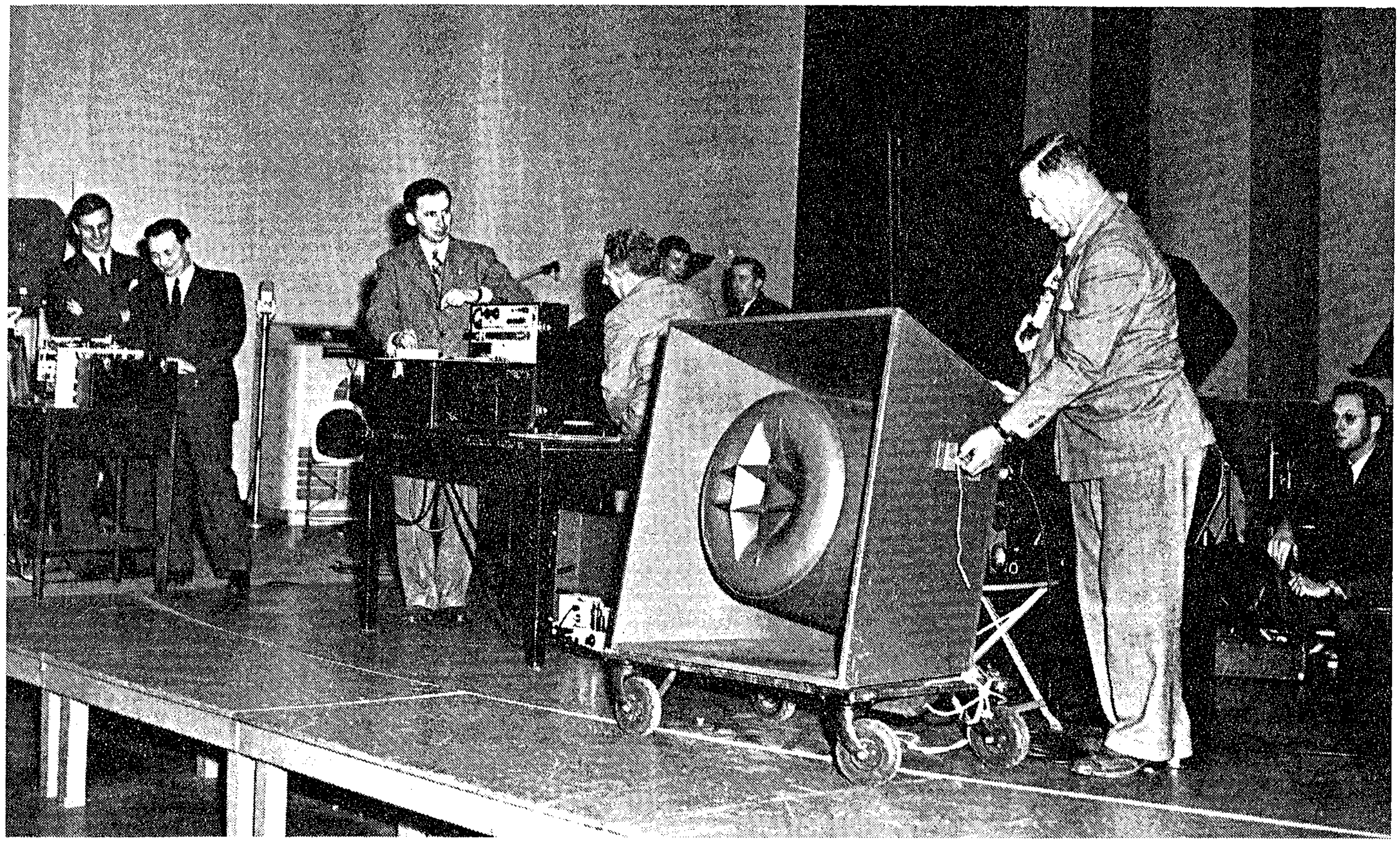
The radio station actually was in Bad Nauheim, a health resort forty-five miles north of Frankfurt. The station had been moved into a castle there to escape the bombing of Frankfurt, and it was then being operated by the Armed Forces Radio Service. In response to my request for a demonstration of their Magnetophon the sergeant spoke in German to an assistant, who clicked his heels and ran off for a roll of tape. When he put the tape on the machine, I really flipped; I couldn't tell from the sound whether it was live or playback. There simply was no background noise.

The Magnetophon had been used at Radio Frankfurt and at other radio stations in occupied Germany by the time I stumbled onto it, but there was no official word that such a thing existed. The people who were using it to prepare radio programs apparently were unaware of its significance. For me, it was the answer to my question about where all of that beautiful night-music had come from.

Lt. Spickelmeyer and I went to work photographing all the manuals and schematics. I saw to it that the Signal Corps got two Magnetophons. When we came upon more, I kept two for myself. During my last few months in the Army, I took these machines apart and sent them home to San Francisco in pieces. Regulations specified that a war souvenir had to fit inside a mailbag in Paris or it couldn't be sent. I made little wooden boxes for the motors, shipping each one separately. In all, it came to thirty-five separate items. Any one of



A Magnetophon from the wartime Frankfurt radio station, similar to those discovered and sent home by the author. Machines such as these were the source of the strange nighttime broadcasts heard by Mullin when he was a GI stationed in England during the war.



John. T. Mullin, center at Magnetophon, gives the first demonstration of professional-quality tape recording in America for the San Francisco chapter of the Institute of Radio Engineers on May 16, 1946. Mullin's partner, William Palmer, is second from left. The unusual doughnut-shaped nine-celled folded-horn speaker in a four-foot-square enclosure, dubbed "the tub," was made by Western Electric.

those boxes could have been lost or damaged, but all of them arrived safely. Reassembly, early in 1946, must have taken me three or four months, including the assembly of the electronics, which I wired anew with American parts.

Once I got the units together, I started showing them to audio professionals. The chairman of what was then the Institute of Radio Engineers (now the Institute of Electrical and Electronics Engineers) heard about them and asked me to give a demonstration at the May 1946 IRE meeting in San Francisco. With Bill Palmer, my business partner in those days, I had recorded some music at NBC and at station KFRC in San Francisco. The station had a pipe organ, which was particularly effective for showing off the Magnetophons.

In the audience for the first San Francisco demonstration was Harold Lindsay, who, a few months later, was retained by Ampex. That company had been making aircraft motors during the war but was now looking for a new product, preferably in professional sound. The tape recorder seemed to be a natural.

In June 1947, before Ampex really got involved, I was invited to give another demonstration—this time for Bing Crosby. He had been with NBC until 1944, doing the *Kraft Music Hall* live. He's a very casual person, and he resented the regimentation imposed by live broadcasts. Some weeks he wasn't in the mood and hated doing a broadcast. At other times he was ready to do two or three at a crack. He didn't like having to keep an eye on the clock and being directed to speed things up or draw them out.

The obvious solution was to record the shows. But NBC had told Crosby flatly that it wouldn't air a recorded show on the network: It never had, and it wasn't about to start. So Crosby took a year off, and when he returned it was with Philco on the new ABC network. ABC and Philco had agreed to let him record.

But because the process involved recording and re-recording on transcription discs, quality did suffer—at times to the point where the sponsor threatened to cancel the show because, during that first year at ABC, the audience rating was falling off. Philco blamed the poor audio. Crosby's voice didn't always sound very good after two or three transfers.

During the 1946-47 season ABC's engineers recorded each show in its entirety on 16-inch transcription discs at 33 rpm. If everything went perfectly, there was no problem—they simply would air it as transcribed—but that seldom happened.

Mullin, with Bing Crosby, listens to a tape-edited show being played back via the Magnetophon.

Almost invariably, there was editing to be done. That meant copying some discs onto new ones, making adjustments as they went, maybe substituting a song that had gone better in rehearsal for the final take. Since they recorded everything in rehearsal as well as what took place before the audience, there were plenty of bits and pieces to work with.

Sometimes it was necessary to make what were called predubs. Say they wanted to use three cuts from three different discs, all within a matter of a few seconds. That didn't allow enough time to get each one cued up during re-recording. So they would make little pre-transfers, or predubs, making copies until all the cuts were added. The final record, therefore, might be two or three generations removed from the original.

Bill Palmer and I had been using tape for soundtrack work (he already had a going business in the film industry before we joined forces), where magnetic recordings were far better in quality and more easily edited than the optical tracks that were standard for films at that time. We were introduced to Murdo McKenzie, the technical producer of the Crosby show, through our Hollywood contacts. And after our demonstration we were invited back to record the first show of the 1947–48 season. Crosby's people didn't say, "You have the job." They only wanted to see how tape would compete with the disc system they had been using. When I taped that first broadcast, they asked me to stay right there after the show and edit the tape, to see if I could make a program out of it. I did, and they seemed to like what they heard.

Once the Crosby people bought the idea, they had to find a place for me to work. The American Broadcasting Company had been the Blue Network of NBC until, a short time before this, the government ordered NBC to sell it. NBC and ABC were still in the same building at Sunset and Vine in Hollywood. Crosby broadcast from what had been one of the major NBC studios.

Prior to the breakup, there had been what they called a standby studio, scarcely larger than a hotel room, with two little control rooms at one end. One was the Blue control room, the other was for the NBC Red Network. There was nothing in this studio but a piano, a table, and two microphones. If one of the networks lost its feed from the East, as they did once in a while, somebody could dash into the standby studio to play the piano. An engineer would run into the control room for whichever network was out, and it was on the air again with local programming.

Once the networks split and ABC had adopted the principle of using recordings on the air, there was no need for the standby studio. So that's where they set me up. I installed my machines, moved in a sofa and a couple of chairs, and it became a little living room. It was a delightful place to work.

Crosby's taping schedule was determined by two factors: when he was available, and when Bill Morrow, the writer, could come up with the material. Sometimes we went right up to the wire. At other times we would be two months in advance. We might do three shows in a row—one a day—particularly if we were in San Francisco, where Crosby liked to work because of the audiences.

Murdo McKenzie was a very meticulous man. It was his responsibility to make sure that a studio was available, that the musicians would be there, and that Morrow would have the script. After the show was recorded, it was Murdo's responsibility to satisfy Bill that his script had been handled properly. And if there was anything at all that indicated where I had made a cut, I would have to rework it until it was inaudible—either that or abandon it. Sometimes it would take me a whole week to put a show together after Bing had performed it.

I had two recorders and fifty rolls of tape to work with—just what I had sent home from Paris. With those fifty rolls I was able to do twenty-six Crosby shows—splicing, erasing, and recording over the splices.

There were no textbooks on tape editing in 1947, so I had to develop my own techniques. There was no such thing as actual splicing tape, as we have it now. I began with a cement very similar to that used in film editing. The problem with it was that you could hear the splice—a sort of thump—if there wasn't complete silence where it occurred. I then switched to ordinary Scotch mending tape, along with a pair of scissors and a can of talcum powder. Mending tape was fine for the first day or so, but before long the adhesive would begin to bleed. sticking one turn of tape to the next. Then the tape would break, and we would have a real mess. Before I used a roll, I always went through it and rubbed powder on the back of every one of those splices. That would get me by for a while, but soon they would be sticky again.

When the show was finally assembled on tape, it had to be transferred to disc because nobody—including me—had confidence that this newfangled thing could be relied on to feed the full network. When someone asked me what would happen if the tape were to break, I didn't have an answer. Since each roll ran for twenty-two minutes (at 30 ips), a half-hour show took two rolls and required the use of both machines. I would have no backup if the machine that was on the air failed.

We continued to record all of the material from the afternoon rehearsals. Crosby didn't always know his songs very well, and he might start one and blow it. John Scott Trotter, the music director, would play the tune on the piano. When Bing got it, we would record two or three takes.

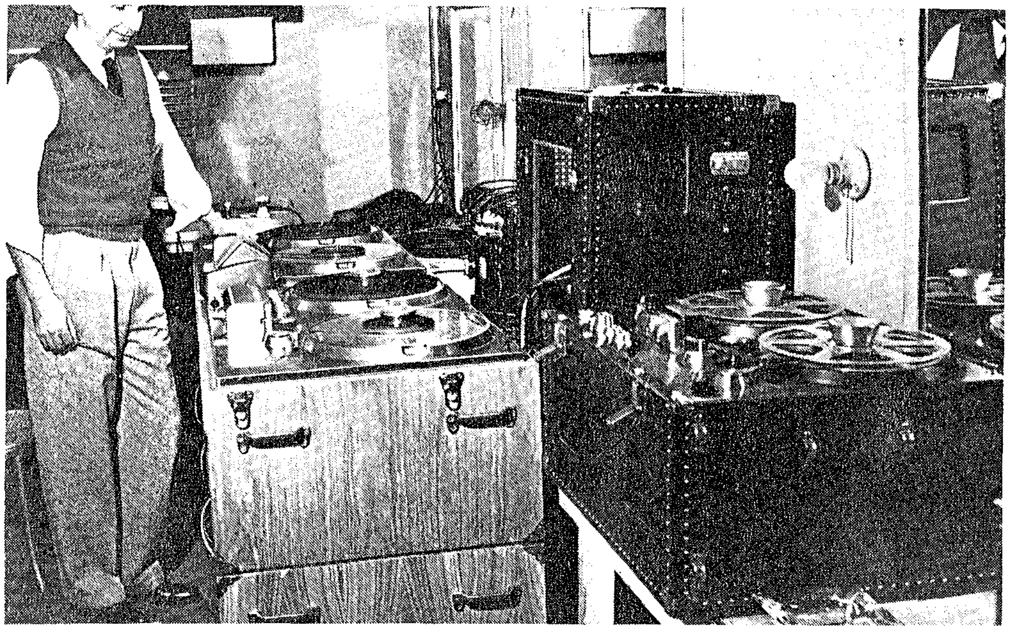
In the evening, Crosby did the whole show before an audience. If he muffed a song then, the audience loved it—thought it was very funny—but we would have to take out the show version and put in one of the rehearsal takes. Sometimes, if Crosby was having fun with a song and not really working at it, we had to make it up out of two or three parts. This ad-lib way of working is commonplace in recording studios today, but it was all new to us.

The BASF tape I was using had the iron particles imbedded in the plastic instead of coated onto it, and since the tapes were not of a consistent thickness the sound quality and volume would change from one roll to another. The thicker the tape, the louder the low frequencies. So, having put together a show with various rolls, it was necessary for me to take them apart again afterward and sort the pieces by thickness. I didn't dare throw away an inch of that German tape, because I didn't know where I could get any more.

The salvaging of the tape is a story in itself. Many a night I stayed in my studio, doing just that. In those days, the building was supposed to be closed after hours. The guard would try to throw me out, but unless I stood my ground there would be no tape for the next day's recording session.

In order to get some sleep, I made use of the Buzz Bomb Effect. In England during the war, if a

Above, Crosby with Bob Burns, whose off-color jokes provided the program material for the first canned laughter. Right, the show's cadre: writer-producer Bill Morrow, with bow tie; music director John Scott Trotter; and technical producer Murdo McKenzie.



Mullin in 1950 with two "portable" Model 200 Ampex tape recorders (note the handles) and the first Model 300 to leave the factory. With these three machines, Mullin had available a full range of advanced editing techniques.

buzz bomb came our way, we woke up. But if it created a Doppler effect, that meant that the bomb was going over to one side, and we stayed asleep. That kind of sensitivity will develop after a while. So I would put a low-frequency tone onto the tape, with the machine set to monitor this tone, and lie down on the couch for a little sleep. When the level of the tone changed, I'd wake up, stop the machine, take the tape apart, sort out the new piece onto the correct roll, and go back to sleep.

The first two Ampexes (modeled on the Magnetophon) finally appeared in April 1948 and were followed immediately by twelve more for ABC. The ABC order had, in fact, made possible the final financing of the first two—Ampex Model 200, serial numbers 1 and 2, which were presented to me. They went into service on the twenty-seventh Crosby show of 1947-48. Still, ABC insisted on broadcasting from discs until its technical people were sure of their backup capacity and of the reliability of tape. But we retired my Magnetophons, which were getting pretty tired by that time.

As we became more familiar with tape, and as blank tape became available from 3M and others, we found that we could do all sorts of things that weren't possible on disc. One time Bob Burns, the hillbilly comic, was on the show, and he threw in a few of his folksy farm stories, which of course were not in Bill Morrow's script. Today they wouldn't seem very off-color, but things were different on radio then. They got enormous laughs, which just went on and on. We couldn't use the jokes, but Bill asked us to save the laughs. A couple of weeks later he had a show that wasn't very funny, and he insisted that we put in the salvaged laughs. Thus the laugh-track was born. It brought letters, because those big guffaws sounded ridiculous after the corny jokes.

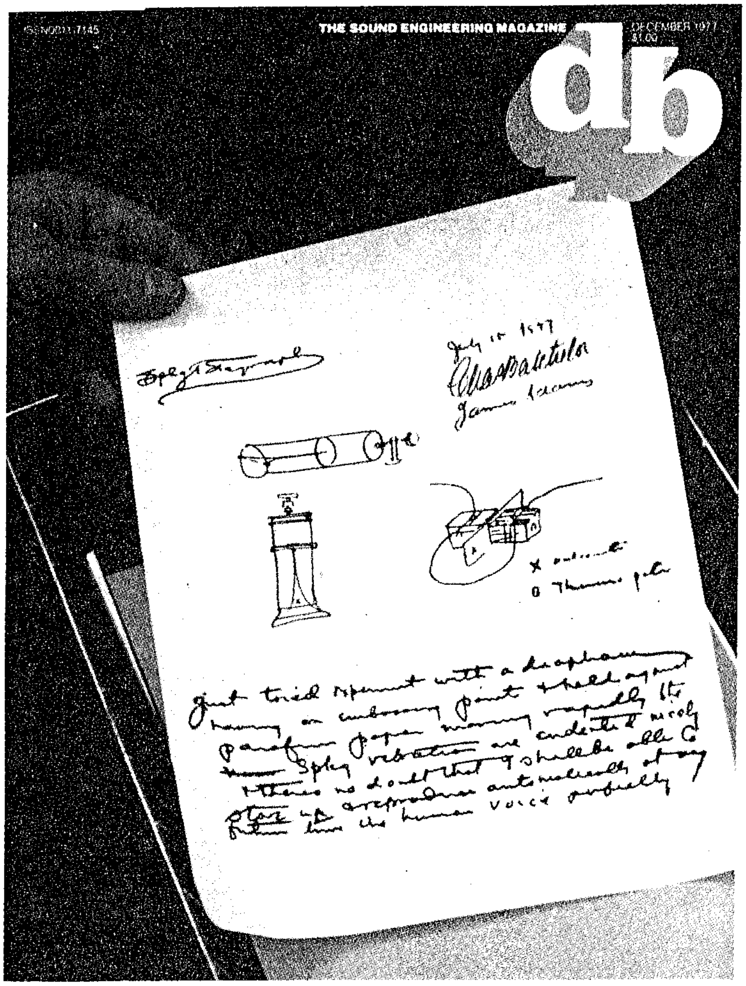
We considered the ability to splice in laughs a technical achievement. We had to trim carefully so that, where we went into or came out of a laugh, the levels would be the same as those on the laugh we were replacing. It was pretty tricky; we had no way of fading in or out.

About two years later, Chesterfields had replaced Philco as sponsor of Crosby's show. One night Bing had a cold. While doing a commercial with announcer Ken Carpenter, Bing said, "If you like smoking (cough)"—and blew it right there. The audience laughed. As soon as the show was over, the ad-agency men were in my control room. In the end, we had to re-record the commercial.

Then there was the time that Crosby was ad-libbing with Bob Hope. Hope loved to take the script that Morrow had written and throw it out into the audience, saying, "Let's go on from here without a script." Crosby didn't like that very much, but they would make a good show of it. On this particular occasion, Hope said, "It's a lucky thing for you that . . . ." Before the show was over the people from Chesterfields were in demanding, "What can you do about it?" I didn't know what they were talking about. "That reference to Lucky Strike," they explained. We had to replay the tape, find the offending word, and assure the sponsors that it could be removed.

Much of what we did—things like making up a song out of several takes, "inventing" canned laughter, tight editing to take out offending material—has become commonplace. But I had to learn for myself. It was part of a process of discovery—sometimes serendipitous—that began at that fork in the road outside Frankfurt. Sometimes I wonder what would have happened had I turned toward Paris. Perhaps, for the tape recorder, the story would have had much the same outcome; for me it would have been quite different. ■

HAROLD LINDSAY

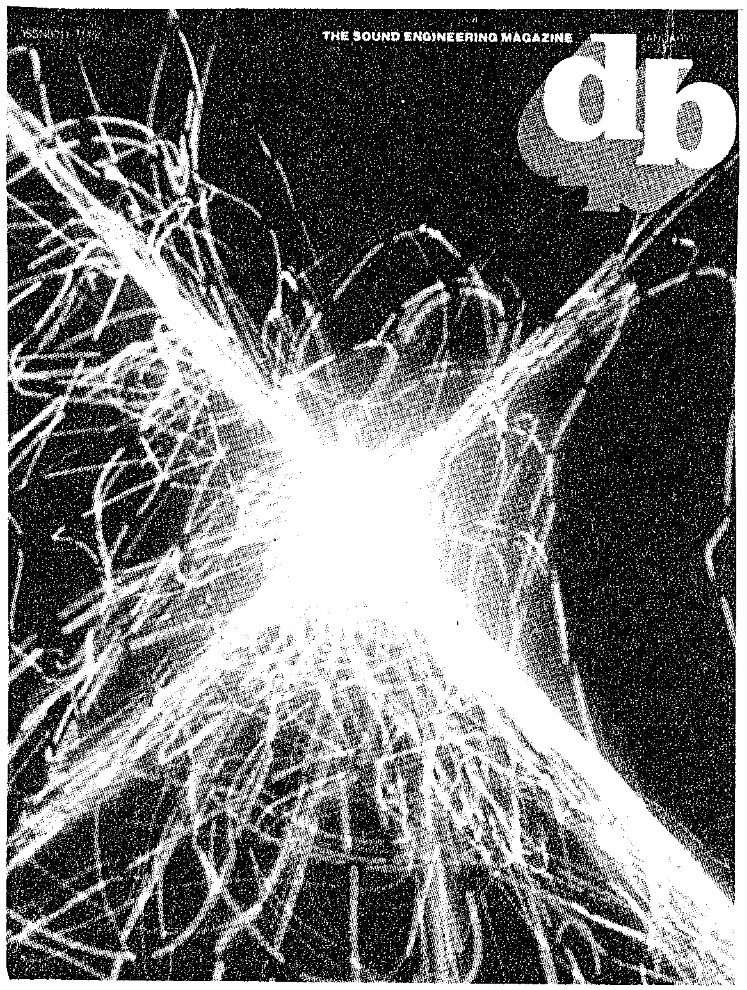


Magnetic Recording Part I

A tantalizing proposition—reproduce a machine with no information regarding its electronics.

Magnetic Recording Part II

From Todd-AO to digital recording; one thing led to another.



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The following two-part article appeared in the December, 1977, and January, 1978, issues

HAROLD LINDSAY

Magnetic Recording Part I

A tantalizing proposition—reproduce a machine with no information regarding its electronics.

THE YEAR 1977 marks one hundred years since the invention of the first demonstrable sound recording devices, and thirty years since an event that profoundly influenced the development and acceptance of magnetic sound recording—the first radio show to be aired in the United States from a magnetic recording of acceptable professional quality. This event was to revolutionize broadcasting transcription practice.

Early in the evening of May 16, 1946 my wife Margery and I drove the 35 miles north from Redwood City, California to San Francisco to attend an Institute of Radio Engineers (now known as I.E.E.E.) meeting to be held in Studio A of the NBC/ABC complex. Little did we realize as we set out that this event would serve to change the whole course of our lives and many others as well.

The speaker of the evening was John T. (Jack) Mullin and his subject the "Magnetophon." This was to be the first public presentation in the United States of this remarkable recording device, which had been first demonstrated in August 1935 at the Radio Exhibition in Berlin, Germany. The device, developed by Germany's A.E.G., in conjunction with I.G. Farben, used tape consisting of carbonyl iron powder coated on cellulose acetate. In January, 1938 the German Reichs-Rundfunk-Gesellschaft had adopted the Magnetophon and magnetic tape as the future standard for radio broadcast recording in Germany.

Further refinements in machines as well as tape continued throughout the war and somewhat beyond its end. In all, three different types of tape were produced along with at least six different models of the Magnetophon.

It is nothing short of astonishing that while researchers here were still struggling with steel tape and wire recorders, our wartime enemies were fully a decade ahead of us—and we didn't even know it. People engaged in the audio professions in this country were not even aware of the advancements that had taken place overseas until after the war's end. Only then did military intelligence and communications personnel take an interest in this "new" technology and recognize its potential.

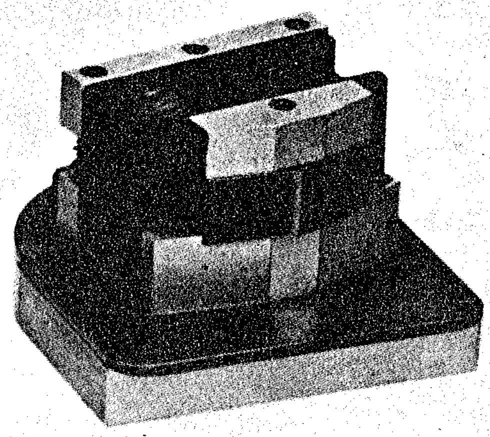
By that time, Germany's industrial capacity was in a state of near collapse. At least two of the "Magnetophone Union" factories had been bombed out, and production of recorders and tape was at a virtual standstill. One of the last operating factories to produce type "L" tape used in the machines was confiscated and shut down by Russian occupation forces.

Therefore, the machines on which Jack Mullin demonstrated the use of magnetic tape were exceedingly rare, representative of what had become an extinct species. And the tape on which they depended was rarer still; there was no possible way of getting more. The fact that Jack Mullin later shared some of his precious tape with the people from Ampex will always be remembered with gratitude.

MULLIN'S DEMONSTRATION

The studio in San Francisco was packed to the foyer. We could sense the feelings of anticipation and excitement

Harold W. Lindsay, a distinguished audio pioneer and internationally recognized authority on magnetic recording, helped lead Ampex Corporation to success and growth and is currently special consultant to that company's magnetic tape division.



Original prototype Ampex playback head (enlarged 3.5X). This is the actual head that was proportioned to allow mounting in Mullin's Magnetophon head housing for proof of performance.

as the crowd viewed the puzzling array of sound equipment crowding the stage. Jack Mullin opened his presentation with a slide-illustrated technical description of the Magnetophon. Then came the demonstration.

Previously recorded musical numbers were played back while, intermittently, live music from a small jazz combo in an adjacent studio was switched with an A/B switch back and forth from live to tape. No one, but no one, in that audience of critical ears was able to detect a difference between live and tape. This brought forth a standing ovation from the spellbound listeners. Equally amazing was the demonstration of the fascinating capabilities of tape editing, including a one-minute stretch of program containing twelve splices, none of which was detected by the listeners.

A deluge of questions followed the formal presentation, and Jack fielded the queries in fine academic fashion. Adjournment brought a crush and jam of the technically inclined to the lecture platform for a close look at the fantastic Magnetophon.

Margery and I waited until the crush had thinned out before inspecting the equipment. Quite overcome with excitement, I burst out to Jack, "I've got the feeling this development is going to change the lives of millions of people. That's what I'd like to do someday—work with magnetic recording."

Jack smiled as he shook my hand. "I hope you do. If I can be of any help, look me up." As we parted, little did I realize that this offer, so lightly made, would be taken up in earnest only six months later.

My first contact with the Ampex Company came in September, 1946 while I was working in the engineering department of the Dalmo Victor Company in San Carlos, on the San Francisco Peninsula. Forrest Smith, general manager of Ampex, frequently visited Dalmo Victor in connection with the precision permanent magnet motors and generators Ampex had been supplying to Dalmo for assembly in the APS-6 airborne radar for Sperry Gyroscope and the U.S. Navy.

Mr. Smith and I became quite friendly. Then one day he surprised me with a message from his employer, Alexander M. Poniatoff, asking to meet with me at my earliest convenience for a technical discussion. The meeting arranged for the following week became another turning point in my life. Mr. Poniatoff explained that with the end of their war-time contracts in view, he and the people at Ampex were anxious to find a post-war product to help them stay in business They were considering studio-type turntables, but felt they should have some consulting expertise to assist in the final decision. Mr. Poniatoff proposed that I serve in a part time consulting capacity to Ampex in this matter of new product selection. I accepted, and a series of meetings ensued.

AMPEX CONTACTS MULLIN

After many weeks of discussion and review I finally conjured up enough nerve to suggest to Mr. Poniatoff that he consider looking into the German Magnetophon with the idea that the design be upgraded where possible and adapted to suit radio broadcast practice in the United States. His response was immediate and favorable, which was typical of Mr. Poniatoff when presented with a new and intriguing idea. I described the May 16th I.R.E. meeting to him and when I related Jack Mullin's parting comment, Mr. Poniatoff was fast to interrupt: "Let's phone him!"

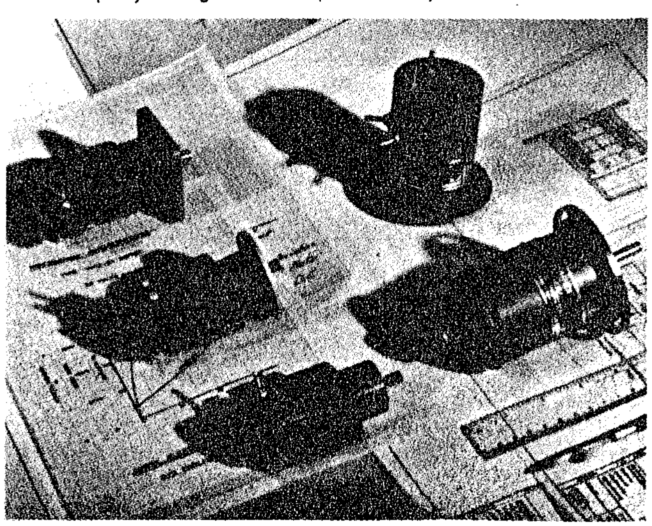
Jack was cordial but apologetic. He was all packed and ready to depart for Los Angeles to attend the annual convention of the Society of Motion Picture Engineers (SMPE—there was no "T" for television then). He suggested that Mr. Poniatoff try to make plans to come down to this affair where he could meet Jack and see the equipment demonstrated. After hasty arrangements, Mr. Poniatoff was on his way.

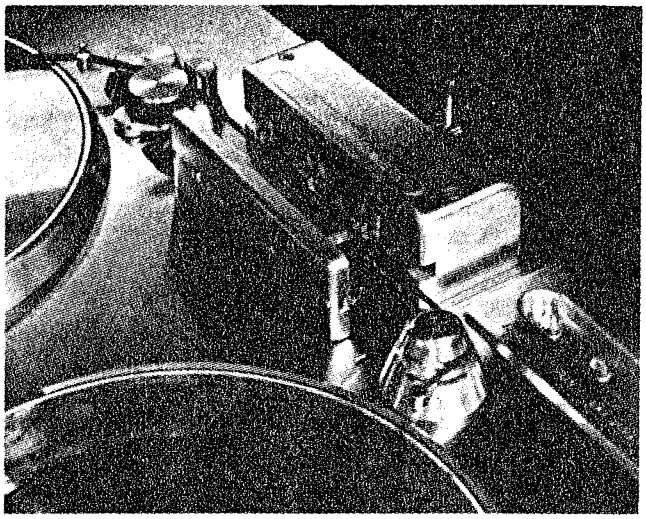
He returned with a display of enthusiasm for the tape recorder, which unmistakably meant Ampex was about to enter a new field. His first comment, directed to me, was, "I want you to become a full-time member of Ampex and assume responsibility for the development of our first magnetic recorder." How could I refuse? My wish had become a reality.

THE DEVELOPMENT PROJECT

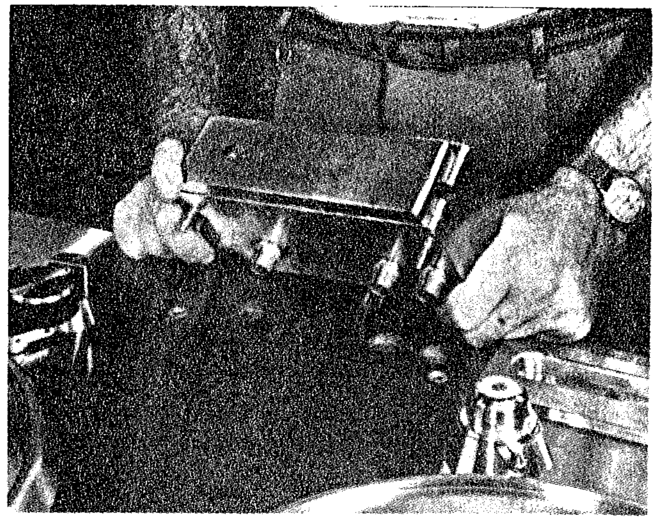
On the 10th of December, 1946, not quite eight months after that memorable I.R.E. meeting we were on our way toward the development of a magnetic tape recorder. None of us in our wildest dreams could have visualized the full

Ampex's first products. Precision permanent magnet motors (left) and generators (1944-1946).





Partial view of top-plate showing cast Meehanite head housing with gate forcibly extended beyond its regular open position permitting view of magnetic heads. Note alloy inner shield cans. Far left head is play-back with laminated shield can. Also shows straight-line threading path of tape.



View illustrating plug-in feature of magnetic head assembly. Slotted cap screw at left of head gate covers hole for editing pencil insertion over playback gap.

impact of what lay ahead, but I remember saying to Mr. Poniatoff, "If we succeed, one day people will be beating on our door to get these products."

At the outset of the development project, the immediate challenge was where to start and how to divide the work load. In fact, the division of labor was quite simple. There was Myron Stolaroff, the electrical engineer who had done much of the design work on the radar motors and generator, and myself. That was the entire engineering team at my disposal as project leader!

A good suggestion as to the best starting place came from Jack Mullin, whom we had phoned for advice. Based on his experience with the Magnetophons he had found there was no question that the most critical part of the entire recorder rested in the design and construction of the magnetic heads, especially the play-back head. With this in mind, he urged us to attempt a play-back head design and to construct a model for performance tests. Success with this should give encouragement to continue the whole project; but should we fail we would be better off dropping the idea of ever producing a magnetic recorder!

In proposing these early head tests, Jack of course realized that we would be in no position to perform them without the availability of an already operable recorder, so he kindly extended an invitation to test our head design, when ready, on one of his two Magnetophons. By designing our play-back head so that at least its mounting requirements would be adaptable to the Magnetophon's head housing, we would be able to make performance tests using the German erase and record heads.

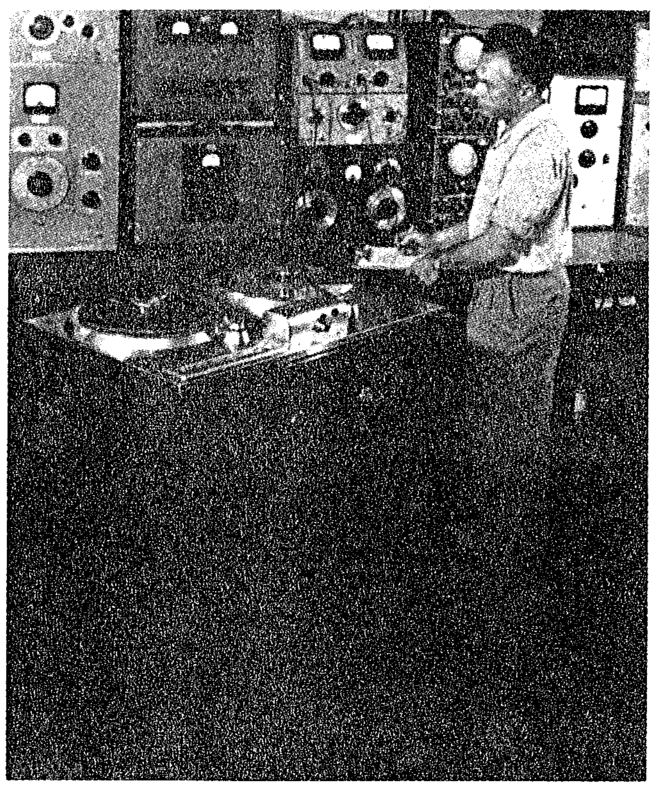
THE MOMENT OF TRUTH

In the spring of 1947, after several months involving construction of lamination dies, a hydrogen annealing furnace, core stacking and lapping fixtures, and many tedious hours of stamping, stacking, hand lapping and winding, we were at the point of final assembly and static testing. We believed we had gone as far as we could without tape—we were ready for that long sought, but now almost frightening moment of truth, the final test. I phoned Jack and set a date. The following evening found an excited but nervous Ampex group on its way to the W. A. Palmer Studios in San Francisco, where Jack Mullin and Bill Palmer had been using the Magnetophons for over a year in their commercial film production.

The first tests were to be subjective listening tests using the best master taped material in the Palmer studio. We listened critically to this as it was played back with the normal Magnetophone head, using their best monitoring equipment. After replacing the German reproduce head with the Ampex prototype and rewinding the test material, we were ready.

I have always remembered that next moment, just before pressing the start button, as one of the most anxious

Author Lindsay checking out Model 200 (January 1948).



times in my entire life—so much hung in the balance: a dismal failure or the beginning of an exciting future.

The tape whipped up to speed; we were stunned, entranced, suspended in an eternity of mere seconds. Then cheers and hand shakes and clapping—the sounds of a wild celebration. Our ears had just told us what measurements later confirmed—we had outperformed the Magnetophon head. We were destined not to failure, but to fame.

We followed the playback head with a successful record head and finally one for erase. These head successes and Alexander Poniatoff's unbending courage and confidence served to carry us through the very difficult months ahead, months when finances would dwindle to the near vanishing point, plus loss of credit, inability to get supplies when needed, weeks without pay checks and experimental and developmental reverses. Nevertheless, in the face of all these obstacles we continued, stubbornly unwilling to give up.

During these rough months Jack Mullin was helpful in many ways and on many occasions, allowing us to examine the mechanical portions of the Magnetophon, but never the electronics. This puzzling situation was later explained when we were told of his previous commitment and contract with Col. Richard Ranger who was also hoping to produce a domestic version of the German recorder. Jack had made certain improvements in the electronic circuitry which were to be exclusively used in the Rangertone equipment.

While unable because of these commitments to show us any of the electronic assembly beyond the front panel, Jack did, however, help us in many ways. His moral support, encouragement when going was rough, loan of a number of reels of German "L" type tape when he had precious little on hand, design suggestions, and last but certainly not least, his promotional efforts in Hollywood on behalf of our forthcoming product were vital to us.

THE TAPE CRISIS

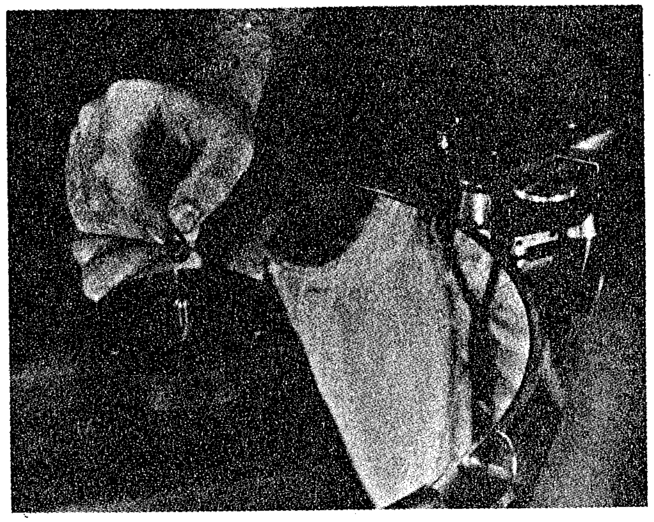
As development of the prototype model of the Ampex 200 reached the tape pulling stage, we began to get very uneasy feelings. Up to now, Jack Mullin had been sharing his slender stock of type "L" tape with us. But the sources of the tape were no longer in existence. If we didn't develop a tape to go in our machine, we'd be all ready for production with no place to go.

But fate was moving along with us. One day a gentleman came into our office, introducing himself as a representative of Audio Devices, an eastern manufacturer of disc recording blanks. They'd heard through the grapevine about our project and wondered whether we would cooperate with them in using our new machine to test some new tape they were developing. Needless to say, we were more than happy to oblige.

It seems almost incredible, but a few weeks after the Audio Devices arrangement had been made, we again had an unannounced visitor. This man seemed to be in a great rush, somewhat nervous. In a hurried manner, he explained that his firm in the middle west believed that there was a great future for magnetic recording. They'd embarked on an intensive project to develop an acceptable tape product. However, like Audio Devices, they were stymied because they didn't have suitable recording equipment on which to test their tape. They also wanted to use our new equipment.

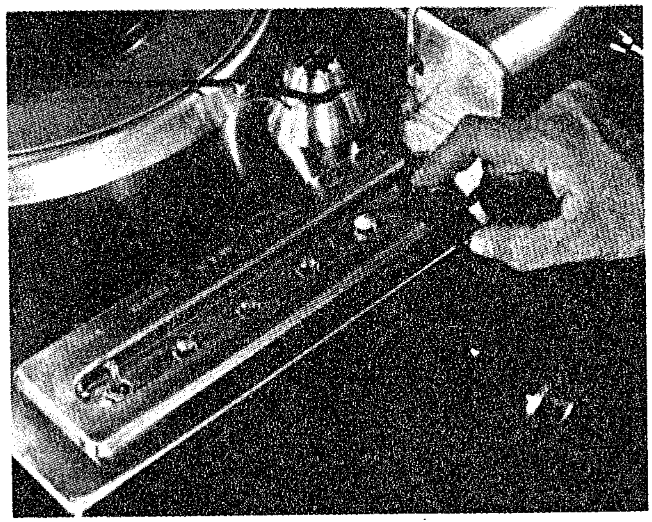
Without identifying the other company, we told him about our previous arrangement.

He was not shaken. "Why not help us both? The results can easily be kept confidential. Furthermore, if you have

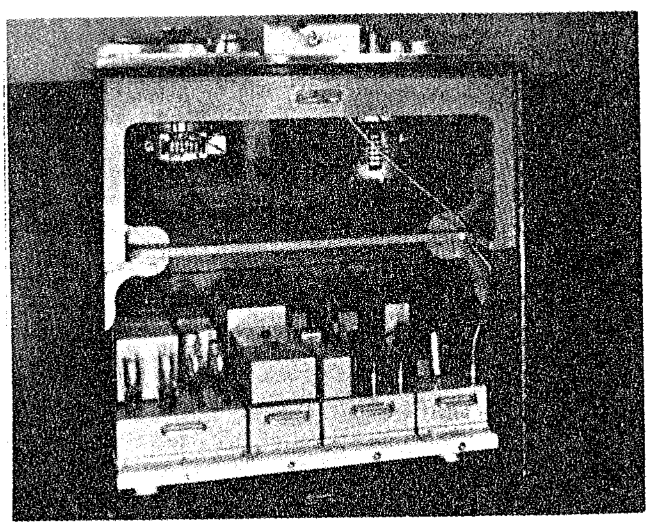


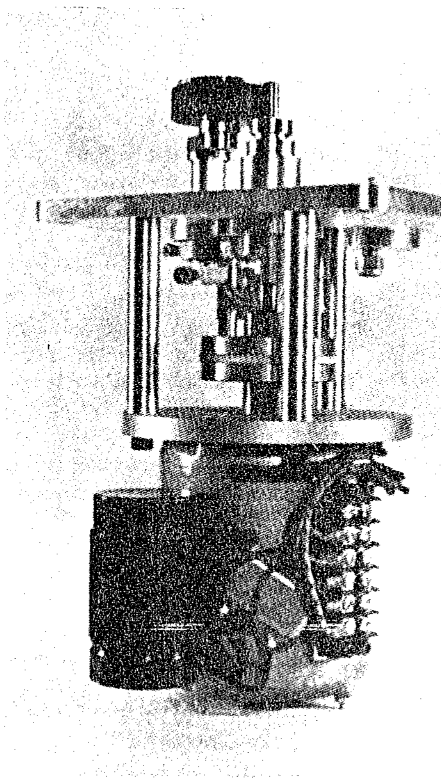
Threading the 14"-diameter open-faced "reel." Reel held 5400 ft. 0.002" thick tape. Torque/threading pin mounting circle dimensions have carried over to present day N.A.B. Standard Hubs as inside (hub bore) driving slots.

Recessed push-button control center. Buttons of Lucite were illuminated, recessed to reduce chances of mis-cueing.



Front view with cabinet doors opened. Note modular electronic assembly on vibration-isolated base. Removable modules are (left to right) power supply, control logic assembly, record module, and playback module.





Capstan drive sub-assembly removed from top-plate.

two tape sources, this will double your chances of arriving at the marketplace in time with tape."

This aspect of the proposal was too tempting; we couldn't turn it down. As he rushed to leave I called after him, "Pardon me sir, may we have the name and address of your company for our records?"

He replied, "I come from Minneapolis, and my company makes pressure sensitive tape products labeled 3M."

MODEL 200 STEAMROLLERS

As mid-summer 1947 arrived, the Model 200 project was accelerating. Six- and seven-day work weeks, as well as many around-the-clock sessions were stepping up progress, but not without their toll on the participants. By this time (July) trials of Mr. Mullin's reworked Magnetophons were also accelerating at ABC/NBC's Radio Center in Hollywood. We had heard of the misfortune Col. Ranger suffered when the "Rangertone" failed in its comparative demonstration with the Magnetophon (held in the NBC recording department).

However, Jack Mullin's successful demonstrations for NBC and ABC as well as for the Bing Crosby/Philco radio show people had served to stir up great interest in the potential use of professional quality magnetic tape recording equipment for broadcast applications.

The next step would be an actual trial on the air, and the Crosby people were in a position to benefit handsomely from its successful use. They were willing to go ahead but had two principal concerns. With the failure of the Rangertone unit, who would supply the needed equipment for back-up should the German machine wear out, and where would be the source of new magnetic tape when the German "L" tape was eventually consumed by splicing operations?

Jack Mullin called us long distance and explained that since the Rangertone fell by the wayside the Crosby and Philco people were anxious for Ampex to succeed. It seemed we were being put on the spot to quickly produce an acceptable unit, but it was also a fantastic opportunity for recognition and the establishment of credibility. There was an ominous mandate: we must not fail.

The Crosby people visited us at Ampex and, satisfied with what they saw in a partially completed machine, encouraged us to notify them when it was finished and to bring it to Hollywood to Crosby's "listening room" at ABC/NBC Radio Center for demonstration.

THE CROSBY CONNECTION

After conferring with Jack Mullin, the Crosby/ABC people decided to go ahead with the Magnetophon taping of the Philco show. That decision was based on Mullin's assurance that he felt Ampex would produce an acceptable recorder within a reasonable period. The decision called for initially recording on tape, editing, and performing a single-generation dub to a Scully cut disc from which the program would be broadcast. It was hoped that when the additional recorders were available, the operation might be ultimately expanded to the use of tape playback directly to the network.

In August Jack Mullin set up his two Magnetophons in a small studio in the NBC building and started recording and editing an average of one show a week.

In the meantime, there was rapid progress on tape development. Audio Devices and 3M were moving along on somewhat parallel paths. Both concerns were supplying test samples at frequent intervals to Ampex for evalution. 3M also supplied samples to Jack Mullin with the assurance that they were most anxious to cooperate in any way possible to help make the application of magnetic tape practical. Both firms arrived at the marketplace with acceptable tapes in time for use on the first Ampex machines.

Toward the end of August, our prototype Model 200 had reached the stage of final testing. We phoned Jack and a date was set for early in September for the Crosby demonstration. During the course of final testing and adjustment, a decision was made for a slight alteration in the record and bias circuits. To our dismay we experienced severe degradation of signal quality in the record mode. We feverishly worked night and day in an effort to restore the original circuits and performance, but to no avail. Our date at Radio Center was less than a week away and it appeared that we would have to cancel out. We needed more time to rectify our error.

In desperation we phoned Jack Mullin and explained our situation. His first question was, "Will it play back?" On being assured that the playback performance was excellent he implored us not to cancel the appointment. This was one of those rare opportunities which might never come again.

TAPE SPEED

It was now that a decision made some eight months previously was to pay off. In our early discussions with Jack with respect to transport design direction, the question of tape speed was considered. It was thought that in the interest of interchangeability of recorded tapes between the Magnetophons, with their 76.2 cm/sec tape velocity, and the Model 200, that we should adopt the same speed. A simple conversion from the metric provided an answer of 30.0 inches per second. This speed was adopted in our design and it has continued as a reference base for tape speeds throughout the industry's expansion.

This simple decision made it possible to demonstrate our prototype on a playback-only basis in Hollywood, using excerpts from the Crosby show tapes as source material. The Ampex 200 was set up in Crosby's listening room at Radio Center, and to our surprise the event turned out

MAGNETIC RECORDING: HIGHLIGHT SUMMARY

1898 The Danish physicist Valdemar Poulsen introduced the "Telegraphone," first of the early magnetic recording and reproducing devices of practical design. Danish Patent No. 1260, British Patent No. 8961.

1900 U.S. Patent 661,619 issued to V. Poulsen covering the "Telegraphone."

1907 U.S. Patent 873,033 issued to V. Poulsen and P.O. Pedersen covering the principle of d.c. bias.

1912 Dr. Lee De Forest's invention of the vacuum tube.

1918 Leonard F. Fuller was issued a patent covering the use of high frequency current for erasure of magnetic recordings.

1920 Dr. Kurt Stille of Germany recognized the real value of magnetic recording as applied to a variety of uses.

1921 U.S. Patent application by W. L. Carlson and Glen W. Carpenter for the use of d.c. bias on a wire telegraphone. This was finally issued as Patent No. 1,640,881 in 1927.

1927 J. A. O'Neill granted U.S. Patent No. 1,653,467 covering powdered recording media. December 20, 1927.

1928 Dr. Fritz Pfleumer, German Patent No. 500,900, January 31, 1928, British Patent No. 333,154, August 5, 1930, covering application of magnetic powders to paper or plastic backing media. Seeking technical help for the development of his idea he approached the German electrical company Allgemeine Elektrizitats Gesellschaft (A.E.G.) of Berlin. A.E.G. in turn interested I.E. Farbenindustrie Aktiengellschaft of Ludwigshaven in the project. Concurrently with the tape development at I.G. Farbenindustrie the A.E.G. carried on a project resulting in a product to be known as the "Magnetophon."

1931 Ludwig Blattner, a German, exploited Dr. Kurt Stille's ideas and introduced the steel tape "Blattnerphone" to the British Broadcasting Co. where it was used for radio transcription purposes.

1935 The A.E.G. developed the Magnetophon using tape consisting of carbonyl iron powder coated on cellulose acetate. It was publicly demonstrated in August 1935 at the Radio Exhibition in Berlin. The eight models displayed were sold during the show.

1938 In January, German Reich-Rundfunk-Gasellschaft adopted the Magnetophon and magnetic tape as the future standard for radio broadcast recording in Germany.
His "Telegraphic Patent Syndikat" obtained rights to various magnetic recording patents, along with some of its own, and issued licenses for commercial exploration.

1938 Dr. Hans-Joachim von Braunmuhl re-discovered a.c. bias and patented it.

1946 May 16, 1946, Institute of Radio Engineers (now I.E.E.E.) San Francisco Chapter local meeting featuring John T. (Jack) Mullin as speaker of the evening. Subject: "The German Magnetophon Magnetic Tape Recorder."

PATENTS

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British Patent	319,681	Kurt Stille	1930
British Patent	331,859	Kurt Stille	1930
British Patent	333,154	Fritz Pfleumer	1930
Danish Patent	1,260	V. Poulsen	1898
German Patent	500,900	Fritz Pfleumer	1928
German Patent	*	Braunmuhl/Weber	
*(Published in U.S., U.S. Property Custodian Ser. No. 413,380) 1934			
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U.S. Patent	836,339	P. O. Pedersen	1906
U.S. Patent	873,033	V. Poulsen & P. O. Pedersen	1907
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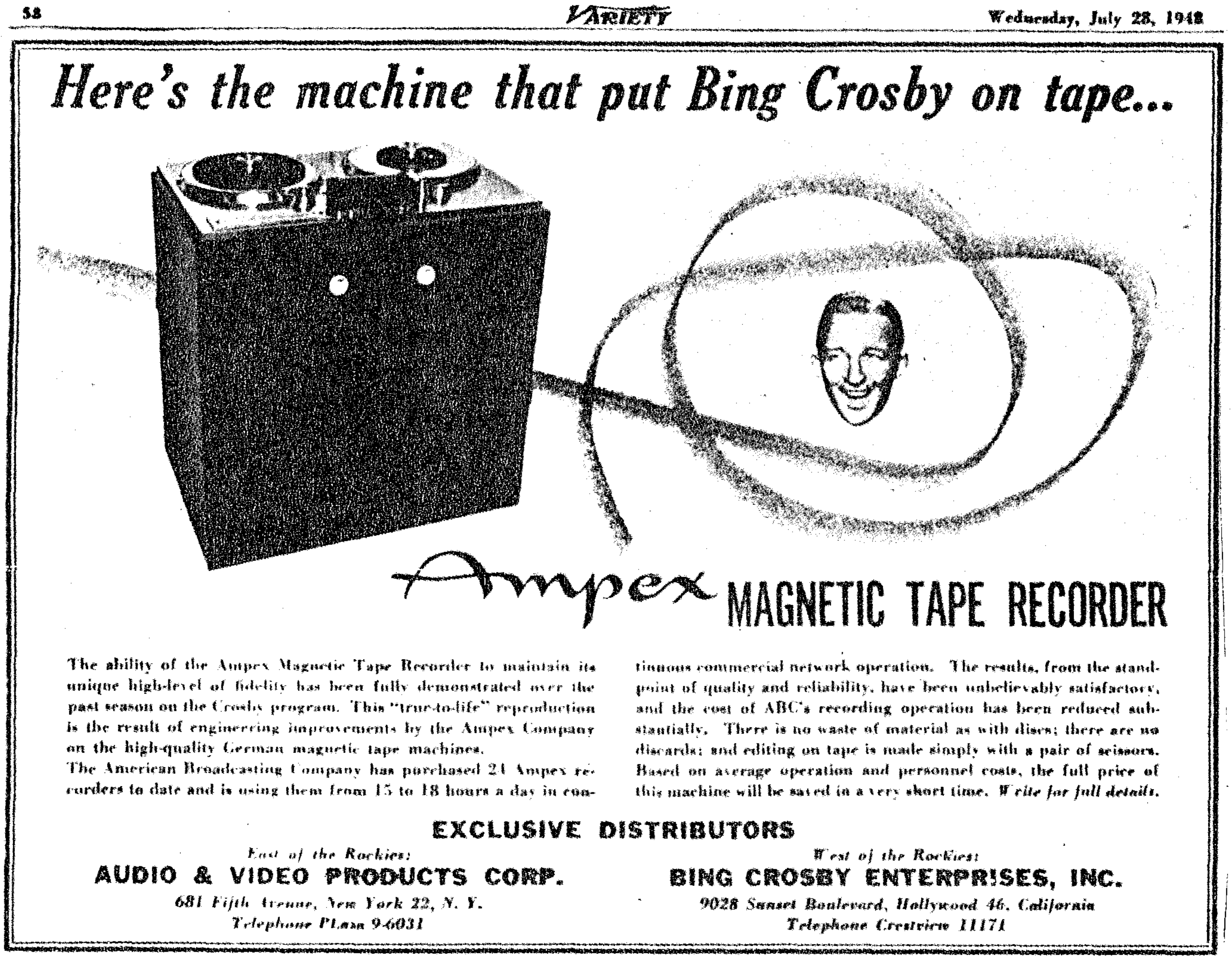
U.S. Patent	2,643,130	Kornei	1953
U.S. Patent	2,778,637	G. Eash	1957
U.S. Patent	3,052,567	Gabor et. al.	1962
U.S. Patent	3,761,311	Perrington et. al.	1973

to be much more demanding than we had been led to believe in the planning discussion. Early in the day playbacks were made for the Crosby principals and crew, and while they were in progress a waiting line began to form outside. It was composed of engineers and technical people from all over the area—from the networks, disc recording studios, and the motion picture industry, as well as others. The word had gotten around and they were not about to miss what they were inadvertently helping to shape into an informal first showing of an exciting new product. The demonstration room was small, with room enough for only 12-15 guests per playing, and the demos went on all day!

As the last of the admiring visitors left, we of the Ampex crew were left in a state of amazement. We had fully anticipated that among that continuous stream of tech-



Our first advertisement.

nical experts, at least one engineer would have said, "The playback is beautiful, but how about a demonstration of recording!"

A few days after our return to Redwood City, some representatives of Crosby Enterprises called on us. Their comment, "We assume that you know you have taken Hollywood by storm," served to open the subject they had in mind: "Now, what are your plans for marketing it?"

MARKETING

In a somewhat naive manner, we had to admit that we had been so preoccupied with development that there had been no discussion of such plans; as a matter of fact, I think most of us believed that the marketing might in some mysterious way take care of itself.

This seemed to be just the sort of answer they were expecting. They had a proposal: would we be interested in their representing us in the eleven western states as our distributors?

After a short discussion we agreed and signed the contract they had brought along. And then another document appeared from a hidden pocket—a signed order for twenty recorders! These (and ultimately four others) were to be for the American Broadcasting Co. Some were to be installed at each of three locations—New York, Chicago, and Hollywood, and all were to be ready in their respective installations by April 25, 1948.

A few days passed before we re ered from the euphoria induced by this event and were able to start in earnest on the task of planning for our first production run of Model 200s, which of course included parts and material ordering. It was at this point that we became abruptly aware of a serious shortcoming.

Ampex was almost completely devoid of working capital! There were not sufficient funds to purchase the materials and parts necessary to go into production, and the local banks were not ready to make loans for such a wild enterprise.

But good fortune was with us again. Quite unexpectedly an envelope with a Hollywood postmark brought us a check for $50,000—with no strings attached or collateral requirements. The signature it carried: Bing Crosby. ■

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HAROLD LINDSAY

Magnetic Recording: Part II

From Todd-AO to digital recording; one thing led to another.

PART ONE, published last month detailed the beginnings of the fledgling Ampex Company and how its ailing finances during the development of the first American tape recorder were solved by a check bearing the signature of Bing Crosby. . . .

The first two Model 200 machines assembled went to Jack Mullin to help relieve the much overworked Magnetophons. The twenty machines for the A.B.C. installations were operated in their key locations for time-delayed broadcasting of network shows across the country. Their performance in this first application is best related in the following letter which was sent to Mr. Poniatoff at the close of the season:

. . . commencing April 25, 1948, and continuing through September 25, 1948 (a total of twenty-two weeks), the American Broadcasting Company in Chicago recorded on the Ampex, approximately seventeen hours per day. For thse 2618 hours of playback time the air time lost was less than three minutes, a truly remarkable record. We believe that a large share of this successful operation was due to the use of the Ampex tape recorder manufactured by your company.

We wish to thank you for your splendid cooperation in supplying us with this fine piece of equipment capable of withstanding the severe conditions imposed during our delayed daylight saving time program.

Very truly yours,
Frank Marx. V.P. in charge of engineering
American Broadcasting Company

In all, 112 Model 200's were manufactured. At about the halfway point in their production (the fall of 1948), we had acquired enough experience and knowledge, as well as input from our customers, to realize that we should consider the design of a new model. The Model 200 had served to demonstrate conclusively that magnetic recording had a lasting place, not only in radio broadcasting, but as a more convenient and flexible means of mastering recordings for phonograph record manufacturers.

In creating this first product in a field new to us, the key premise in our design philosophy was "uncompromising quality and unsurpassed reliability." In our intense desire to assure that these elements were not jeopardized we found ourselves with a product that was somewhat over-designed.

With our newly developed knowledge and skills, especially in the matter of magnetic head design, we were in a

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Harold W. Lindsay, a distinguished audio pioneer and internationally recognized authority on magnetic recording, helped lead Ampex Corporation to success and growth and is currently special consultant to that company's magnetic tape division.

position to produce a recorder to follow the 200 at half the price; it could also be substantially smaller in size and operate at half the tape speed (15 in./sec.). It was thought that the lower operating cost of 15 in./sec. and the reduced physical size would appeal also to users with smaller monitoring and control rooms.

MODEL 300

In November, 1948, we set to work on a new project, the result of which was to be our Model 300. Tape speed would be halved and the dimensions reduced, but performance and reliability kept as close to the 200 standards as possible. By halving the tape speed, we could reduce the reel size and tape length and still maintain the playing time of the Model 200. This new 10½-inch reel, with later modifications, eventually became the NAB standard. This challenging assignment was pursued on an all-out basis and the first production run was conducted in July of 1949 when fifty units were manufactured. The first machine off the line went to our good friend Jack Mullin.

The response in the market place was beyond our most hopeful expectations. As a result, we were now faced with a new set of problems—how to supply an unending rush of orders. The "300" was an immediate success, and within the first few years of the design's long lifetime in the market place it was to be found in all of the major radio networks as well as widely used in the smaller nets and individual stations. The big name phonograph label record manufacturers were all using the "300" for mastering and editing.

The basic design of the "300" remained virtually unchanged throughout its lifetime until the late '60s; its solid state version was introduced in 1966. In all, somewhere around 20,000 Model 300s were manufactured during this time.

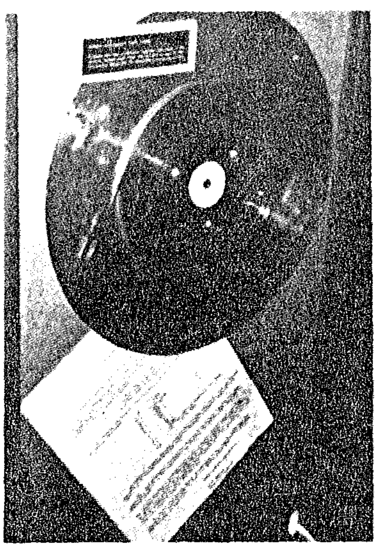
The Model 300 received recognition in October 1950 when the publication *Electrical Manufacturing* presented to Ampex a Certificate of Award for "outstanding achievement in product development, design and engineering."

As noted earlier it had been decided in embarking on the "300" development project to lessen the over-design of the "200." Our goal was reduced size, weight and cost.

The Ampex 300 appeared in early 1949, running at 15 in./sec. speed (also 7.5) and at both reduced size and price from the 200. This was the first ad. Note the specs.

while retaining reliability and outstanding performance. Fortunately, the Model 300 retained a certain amount of over-design, which some two years later, in 1950, proved to our great advantage.

An Ampex alignment tape circa 1948. This is probably the first professional alignment tape made in this country. Ampex made these tapes available to purchasers of Model 200 machines. Photo from Jack Mullin's product museum, as shown at a recent AES Convention.



MODIFICATIONS

By 1950, after the first year of "300" production, Ampex started to receive requests to supply special modifications of the basic "300" to be used, not for normal audio purposes, but for data recording in industrial, military and scientific research. These highly specialized applications were so tempting to us that we succumbed and entered headlong into a development program which spurred us into the new field of instrumentation data recording.

This is where the "excess" capability of the original "300" design paid off. We were able to modify the transport to handle tape speeds from 1⅞ in./sec. to well over 120 in./sec. By this time our skills in magnetic head design and fabrication had advanced sufficiently to enable us to produce narrower gap reproduce heads and multi-channel heads with acceptable crosstalk.

MODEL 3200 DUPLICATOR

These developments enabled us to introduce the Model 3200 tape duplicator system (based on Model 300 modifications), consisting of a high speed tape master playback machine feeding banks of slave recorders. Thus it became possible as well as practical to duplicate master tapes at reasonable cost for retail sales of prerecorded high fidelity tapes.

For instrumentation applications we also introduced frequency modulation recording, as well as pulse code modulation systems. We were then in a position to supply

The author (left) with Alexander M. Poniatoff at the introduction of the Ampex ATR-100.

record/reproduce equipment covering a wide range of data requirements from direct current levels and digital coded information, to high frequency signals well above the audio range. This capability resulted in Models 301, 302, 303/311, and others. Instrumentation magnetic tape recording was here to stay and Ampex was to remain as an important influence on the growth of this new technology.

Entrance into the instrumentation field did not de-emphasize our efforts in the audio field. New audio models were forthcoming. The 400 series, which had been first manufactured late in 1949, was upgraded to become the 401 but turned out to be the least successful of the early introductions, having a relatively short life in the audio market place. In 1952, Model 350/351 was first introduced and became a very popular professional recorder, evolving through the years and a number of revisions.

THE MYSTERIOUS VISITOR

It was at this time (1952) that an interesting incident occurred at Ampex. Mr. Poniatoff received a phone call from a New York banker who stated that an important visitor would soon be coming to our facilities. Though he could not disclose the identity of the mysterious guest or the purpose of his visit, he did indicate that it could result in important new business for Ampex.

On arriving, the visitor introduced himself as "Mr. Edwards," without bothering to disclose why his large gold cuff links and tie pin carried the initials "M.T."

Early in the conversation that followed, "Mr. Edwards" inquired whether the people at Ampex had seen Cinerama (the initial public screenings had occurred just before the visit) and if we could record sound on photographic film prints with magnetic striping.

His next inquiry, whether Ampex had done any work in stereophonic sound recording, was effectively answered by a very impressive demonstration. Our demo of three-channel stereophonic playback, using theater-type loudspeaker systems, satisfied our visitor, who finally confessed that his name was not Edwards at all, but Mike Todd!

Mr. Todd was so impressed with what he had seen (and heard) that he made an on-the-spot decision to select Ampex to produce the sound system for the Todd-AO motion picture system (a further improvement on the Cinerama development).

While working on the Todd-AO project, Ampex developed a four-track multi-directional sound system which was introduced in 1953 and was featured in the first Cinemascope film, *The Robe*. Two years later, *Oklahoma!* was premiered with Ampex six-track sound; it was literally an Oscar-winning performance. Other design advances emerged, and by 1967 Ampex had installed sound systems in theaters around the world.

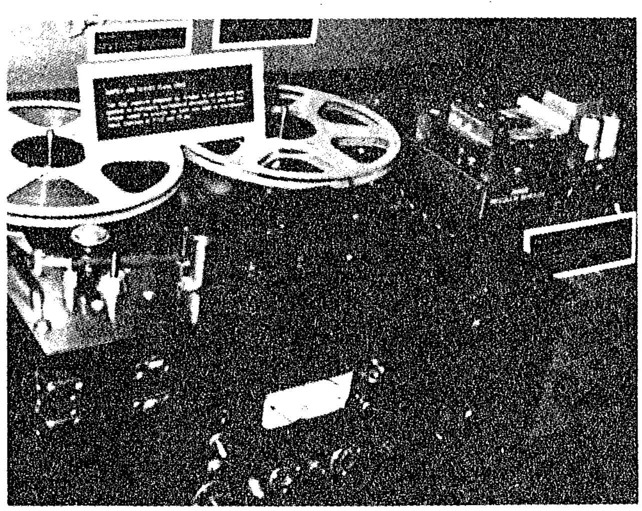
In 1967 we introduced a solid state, improved version of our wide screen multichannel systems. But these systems, though widely acclaimed, remained on the market for only about two years. The interest in super-wide screen presentations was diminishing and sales were dropping off. Ampex had to face facts and retire from the motion picture sound business.

CONSUMER AUDIO

Let us look back now on an earlier year—1954. It was in this year that Ampex introduced the Model 600, intended initially for the professional market as rack-mounted modules or as a single case portable assembly. This recorder became the second Ampex product to achieve distinction by receiving an award for design excellence and has become the Ampex audio product wtih the greatest total sales volume.

The adaptation of this design to produce the Model 612 brought about the company's entry into the consumer audio field. The 612 was shown at the Ampex booth at the National Association of Music Merchants Show in the summer of 1955 and created broad interest as the world's first stereophonic music system for home use. Subsequently Ampex established a consumer division, separate from professional audio and continued with a long series of

A new model appeared in 1950. This is an Ampex 400, the first portable machine designed to professional standards. It was also the first machine to provide for both the level and microphone input. It operates at 7.5 or 15 in./sec. speed. Photo from Jack Mullin's product museum as shown at a recent AES Convention.



product introductions for a period of sixteen years before phasing out of what had become a highly competitive market place.

To cover all of the consumer products developed through that period is beyond the scope of this article. However the following account has such historic significance that it is included.

FOUR-TRACK STEREO TAPE

In attempting to develop interest in home music applications for prerecorded tape, Ampex, in introducing the stereophonic Model 612, had by 1957 come to the realization that tape could not compete price-wise with phonograph records unless higher tape packing density could be achieved. The resulting engineering effort brought forth in 1958 the four-track stereophonic head. With the introduction of this new head Ampex hoped to coax tape duplicators into immediately bringing out four-track prerecorded tapes, and thereby stimulate sales of stereo tape recorders. The idea didn't take hold, so Ampex decided to take the initiative and enter the duplicating field. The importance of such a facility to the developing home music industry is suggested by the fact that within eighteen months following Ampex's introduction of four-track stereo heads, 750,000 tape recorders had been sold by major manufacturers!

In June 1959, Ampex formed United Stereo Tapes (later Ampex Stereo Tapes) and acquired duplication rights for some of the leading phonograph record labels. These included Verve, MGM, Warner Bros., Mercury, and later London. Elk Grove Village, a suburb of Chicago, became the company's custom duplication center. Equipment consisted of Ampex 3200, and later ADM-500 and AD-150 duplicators. Through the years this facility has developed into one of the largest and most complete establishments of its kind.

During the decade 1955-1964, Ampex audio engineering personnel found themselves under heavy pressure to carry on the development programs in which they had become involved. These were the consumer product lines, tape duplication equipment and motion picture sound systems. For the most part new product introductions in professional audio had slowed down.

Only two new professional recorders were introduced in this period; the PR-10 in 1959 and the MR-70 in 1964. The PR-10 enjoyed good acceptance and was continued until its successor, the AG-500, was marketed in 1967. The MR-70, an outstanding design concept for its time, was to have been a state-of-the-art recorder at its introduction, incorporating many mechanical refinements and the best that advanced tubes and nuvistors had to offer. Unfortunately, the development project was timed badly, starting too late to put the recorder in the market place before the onset of the solid-state audio era.

The last of the 350 series, the AG-350 (with transistor electronics), became the basis for the design of a new line of very successful recorders, the AG-440, released in 1967. The years 1967 and 1968 brought many new product introductions. During this time the AG-500, AG-440, AG-440-8, AG-600, the 3400, and the large (12, 16 & 24-track) multichannel AG-1000 and MM-1000 machines were released.

MULTICHANNEL RECORDERS

The decade which followed 1967 to the present brought great emphasis on engineering large multichannel recorders and high speed duplication equipment. Duplicators appeared in 1969 with the BLM-200, in 1971 the CD-200 and in 1972 the AD-15. Introduced in 1973 was the multichannel MM-1100.

The years 1974 and 1975 were without new audio product introductions and some concern was shown in the industry; was Ampex about to give up its position of leadership in professional audio? What was not known by outsiders at the time was that this two-year stretch was devoted to perfecting products to be announced in 1976. a new and improved multitrack, the MM-1200, a highly perfected portable, the ATR-700, and a state-of-the-art analog audio recorder, the ATR-100.

The public display and demonstration date for the latter unit was the May 4, 1976 opening of the 54th Convention of the Audio Engineering Society in Los Angeles.

ORRADIO INDUSTRIES

It is pertinent at this point to recall an event in 1949, although at the time it was not related in any way to Ampex. It was destined in years ahead, however to play a prominent part in the affairs of the company.

We have already referred to the two German Magnetophons that had been sent home after World War II by John T. Mullin and how they influenced Ampex's entrance into the field of magnetic recording. Somewhat paralleling this development was the establishment of ORRadio Industries in Opelika, Alabama, in 1949 by Major Herbert Orr. Orr had also sent home a war souvenir Magnetophon and had, in addition, acquired a formula for making tape. Ten years later the firm, then known as Orr Industries, producing *Irish* brand tape, was acquired by Ampex and eventually became the magnetic tape division.

From this point forward the Ampex tape division placed increasing emphasis on tape development and improvement of manufacturing processes along with the development of a responsive marketing organization. All of this over the years added up to wide acceptance and the winning of an important share of the tape market.

ATR-100

The acquired skills of tape design, formulation ,and processing which allowed the tailoring of a new product to specific performance parameters paid off in a big way during the development of the ATR-100. For now Ampex had the advantage of being a company with design skills in both recorder and tape technologies. The result was the introduction of the ATR-100 and Ampex 456 Grand Master tape as "go together" products. One was designed to be used with the other to bring out the maximum performance of each in true synergistic relationship.

History had repeated itself, for just forty years before, the German A.E.G. & I.G. Farben companies had teamed up with their respective skills to create the Magnetophon and its tape.

As we pause at the close of this commemorative year, it may be useful to survey the state of our knowledge and accomplishment, and address the question: Just how far have we come in these past thirty years? Perhaps some insight can be derived from a simple comparison of the performance specifications of two products representative of then and now, i.e. the Model 200 and the ATR-100.

DIGITAL VS. ANALOG

As I look over my shoulder at some thirty-plus years of trying to meld art and science in this expanding industry, a thought keeps recurring: in a rapidly evolving technology, today's state-of-the-art can be ancient history by tomorrow.

Model 200 vs. ATR-100: Comparative Performances

Measurement	Ampex Model 200	ATR-100 Ampex
Overall Frequency Response at @ 30 in/sec	Within ± 1 dB 30 to 15 kHz	Within ± 0.75 dB 200 Hz-20 kHz Within ± 2.00 dB 35 Hz-28kHz
Signal-to-noise-ratio taken at 30 in/sec AES full-track.	30 Hz to 15 kHz Unweighted over 60 dB	30 Hz-18 kHz Unweighted 77 dB
System Distortion	Using 3M Co. Type 55 Tape 4% intermodulation distortion at peak meter reading with "harmonic" distortion not exceeding 5% 10 dB above peak meter reading.	Using Ampex 456 (Grand Master) tape SMPTE intermodulation distortion < 1.0% at recorded flux level of 370 nWb/m(OVU)
Flutter & Wow	"Undetectable wow and flutter content even in the most susceptible program material"	NAB rms unweighted at 30 in/sec 0.03%
Speed Accuracy	± 0.03%	± 0.03%
Rewind Time	5,400 ft. (0.002" thick tape) (36 min. P.T.) 1.75 minutes	2400 ft. (0.0015" thick tape) 2.7 minutes

Already the industry is looking to digital audio recording. Digital-to-analogue conversions of 15 bit/50 kHz scan and greater need no longer be regarded as "humpty-dumpty" propositions. It is now possible to make the analogue-digital conversion and put all the pieces together properly. High performance systems are at hand and these most certainly will find their first use in super-critical mastering applications.

Will analogue audio recording survive the challenge of the digital assault? As a practical and relatively simple approach, analogue recording should continue unretarded in its amazing growth. Its position in the industry should be strengthened through supportive interaction with the newer technology rather than being reduced to obolescence. We can all recall that the advent of magnetic tape did not spell doom for the disc, but instead helped greatly in its revitalization.

In the foregoing we have glanced back some thirty years. At this point do we dare guess what may lie ahead over a similar period?

Other audio recording possibilities have already suggested themselves. Vastly improved optical and electron beam recording systems are just around the corner. But where will the next giant step take us? We should not overlook the progress which has already taken place in the development and miniaturization of magnetic core memories. With their almost limitless potential as memory storage devices, there are exciting possibilities for magnetic recording/playback static systems, sans-tape, where motion stability will no longer be a concern, when the only moving system elements will be magnetic lines of force and electrons. ■

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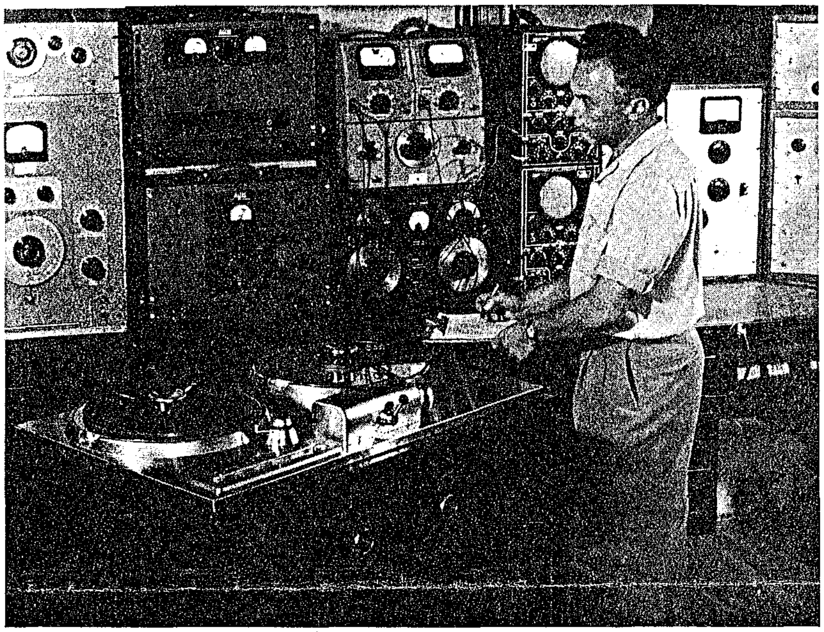


Harold Lindsay, chief designer of the Ampex Model 200, does final checkout on one of the first 200s in early 1948.

The audio world lost a good friend on April 1st. **Harold W. Lindsay,** the man who designed America's first professional audio recorder, the Ampex Model 200, lost a battle with cancer on that day, one month short of his 73rd birthday.

Four engineers in audio history have been crucial to the success of modern magnetic recording: the Danish electrician Valdemar Poulsen, inventor of the first wire recorder in 1898; Fritz Pfleumer, the German inventor who built the world's first working tape recorder (1928–30); John T. Mullin, the first American to build a prototype high-fidelity tape recorder from German Magnetophons (1946), and Harold W. Lindsay, who designed America's first commercially successful hi-fi tape recorder in 1947–48. All four of these men are the unsung heroes, the Edisons, of our profession. This is Harold Lindsay's story.

Born in San Diego in 1909, Harold spent his formative years in Oakland, CA. A good electrical engineer implements his good ideas deliberately, to avoid electrocution, if nothing else. Imagine young Harold, age 6, budding engineer, carefully lowering a paper clip tied to a long string into a hot light bulb socket. The small explosion that followed confirmed his ideas about electricity! The incident characterized Harold's approach to engineering: always willing to venture into the unknown, yet doing so with care and intelligence.

The Crash of 1929 interrupted Harold's education at the University of California at Berkeley. His first engineering job was at Shell Development Co. near Oakland, where he began to perfect the skills that he would later need to build the Ampex Model 200: drafting, industrial design, metallurgy (including hydrogen annealing), electronic design and measurement, machining and manufacturing, and quality control.

Early on, Harold also demonstrated the one quality that endeared him most to his fellow workers and his companies' customers: he deeply cared about other people, always thinking how his designs would give others the most benefit and the least trouble.

During World War II, after moving from Shell to the Lawrence Laboratory in Berkeley, Harold designed a product he knew *had* to satisfy his "customers." Allied airmen, badly wounded and unconscious in midflight at 20,000 feet during bombing runs over Germany, were routinely dropped by parachute to almost certain medical treatment as prisoners of war. A last parachute drop into enemy hands was always safer than certain death on the long flight back to base in Britain. But the wounded airmen were freezing and suffocating with their parachutes opening at 20,000 feet. At Lawrence, Harold designed one of the first barometrically-activated parachute releases ever made for mass production. A postwar review of carefully-kept German war records on downed Allied airmen showed that not one of the Lindsay-designed releases ever failed to open. During the war, Harold continued his work at Lawrence on the Manhattan Project, designing control and measurement equipment used in atomic research.

In 1946, Harold went to work as a design and test engineer at Litton Engineering, later joining Dalmo Victor in San Carlos, CA. It was at Dalmo that he met Alexander M. Poniatoff, a founder of Ampex, a tiny motor subcontractor for Dalmo. It was Poniatoff who convinced Harold to join Ampex's search for a professional post-war product. But it was Lindsay who convinced Poniatoff that a new German recording technology called "magnetic tape" could be made and sold in America. Jack Mullin's 1946 May 16 San Francisco demonstration of his German Magnetophon recorder was the catalyst for

Harold.

Since his youth, Harold had been a lover of good music and good sound. Like Valdemar Poulsen, Fritz Pfleumer, and Jack Mullin, Harold was a dedicated audiophile, gradually turning his hobby into a profession. From the 1930s, his close contacts with audio pioneers such as James B. Lansing kept Harold in touch with all the latest developments in high-fidelity sound reproduction.

Imagine the delight of summer picnickers at Tilden Park in the East Bay hills across from San Francisco, who, from 1940 to 1950, were treated to Sunday afternoon recorded "concerts in the park" through Rek-o-Kut turntables, Lansing Iconix loudspeakers and amplifiers of Harold's own design. The image of those happy music lovers still brought Harold warm memories 30 years later.

In December of 1946 Alex Poniatoff made Harold Lindsay project engineer and chief designer of the Ampex Model 200, as that first machine was called. Myron Stolaroff, his associate on the project, completed the two-man team. Remember that the idea of tape replacing tried-and-true transcription disks in studios and radio stations was, to all but a few visionaries, a wild idea. Sure, you could edit tape with a pair of scissors and make consistently high-quality, uninterrupted recordings for 20 minutes and longer, on a reusable product that was cheaper to use than blank recording disks. But broadcast and studio executives and engineers are a cautious lot. Harold Lindsay knew that the first Ampex tape recorder had to be as "rugged and reliable"—probably his two favorite words—as the Scully or Westrex disk lathes then in use. America's first tape recorders, the Brush BK-401 Soundmirror and Richard Ranger's Rangertone were not good enough to convince audio engineers that tape was a professional recording medium. Harold knew that the Model 200 would have to prove to broadcasters that tape was rugged and reliable enough for the daily pounding the machines would get. The recorder had to be more than good.

And it was. The way wasn't always easy. Reportedly, not a few times Harold had to convince the cost-conscious Alex Poniatoff to use better motors, better brakes, better metal—everything to make the machine meet the recordists' high expectations of a professional machine. Harold succeeded. The Model 2000 made tape recording a commercial reality in the U.S.

Although the Ampex Model 200 sold for more than a year's salary in 1948—$4000—American broadcasters in 1948 accepted tape as their new medium, quite literally overnight. The initial skepticism about tape at ABC's New York headquarters (despite Bing Crosby's success the same year with Jack Mullin's two Magnetophons) quickly vanished with the success of the Model 200.

Frank Marx, ABC's engineering chief, wrote in 1948 that after 22 weeks of constant use for daylight savings delayed-broadcasts and for the Crosby and other shows, the network had lost only 3 minutes out of 2,618 hours of on-air recording!

The Ampex Museum of Magnetic Recording's collection includes a Model 200, serial number 66 (only 112 were made) donated by Craig Curtis of NBC Burbank's recording department that was on-line there for 31 years. With no major repairs or modifications, this machine still can record some fine-sounding tapes! In fact, tapes carefully mastered in 1948 on the Ampex Model 200 meet most of today's criteria for "professional-quality high-fidelity" audio reproduction.

Joined at Ampex in 1948–49 by other talented engineers such as Walt Selsted and Frank Lennert, Harold Lindsay went on to help design the standard of all U.S. professional audio recorders, the Ampex Model 300. The same dedication to quality and reliability, his never-ending concern for the *people* who would use the machines, carried through to the Model 300 and subsequent Ampex audio, data, and video recorders.

If Alex Poniatoff had wanted to name the one engineer most responsible for Ampex's success over the last 35 years, he would have had to choose that talented man who cared for people above all else. We shall all miss Harold Lindsay.

PETER HAMMAR

Remembering Harold Lindsay

Ampex is indebted to audio pioneer Harold Lindsay.

It was Lindsay's work as project engineer and chief designer of Ampex's Model 200 magnetic audio tape recorder, the first professionally acceptable machine of its genre, that helped establish Ampex as a high technology company. And it was Lindsay's inimitable personal style and dedication to a variety of interests that brought the company further acclaim as an associated participant in the communities Lindsay served.

Harold Lindsay — doer, believer, inventor extraordinaire — died April 1 in his Los Altos Hills, California, home. He was 72.

The memorial service held April 3 in his honor did more than offer eulogies. It also illustrated yet another of Lindsay's living legacies.

Through the church's sound system specially designed and installed by Lindsay himself, company employees Fred Pfost and Don Ososke and Ampex museum curator Peter Hammar respectively recited a poem, sang a prayer and reminisced about Lindsay the man. The Menlo Park (California) Presbyterian Church's fine acoustics were simply one more testimony to a lifetime of achievements.

When Lindsay became a full-time company employee in December 1946, he played a major role in turning Ampex, then a small subcontractor of electric motors, into a major high technology company.

He was lured to the firm by Alexander M. Poniatoff, the founder of Ampex, to help develop a professional audio recorder. Lindsay

**HAROLD W. LINDSAY
1909-1982**

became project engineer and chief designer of the Ampex Model 200, the first professionally acceptable magnetic tape recorder ever produced.

The Model 200 was demonstrated in October 1947. The ABC Radio Network's subsequent purchase of the first 20 production units marked the beginning of the regular use of tape by U.S. radio networks. By April 1948, the recorder was being used nationally to broadcast the Bing Crosby show.

The Model 200 established Ampex as the leader in audio recording technology. While the firm is best known for its development of the first videotape recorder, Ampex has continued to be a leading producer of audio recorders for the radio, television and recording industries.

Following the success of the Model 200, Lindsay directed the development of later generations of Ampex audio recorders, and set-up the first quality control and industrial design departments at Ampex. During his involvement in the latter project, Lindsay developed the industrial design for the VR-1000, the first videotape recorder introduced by Ampex in 1956.

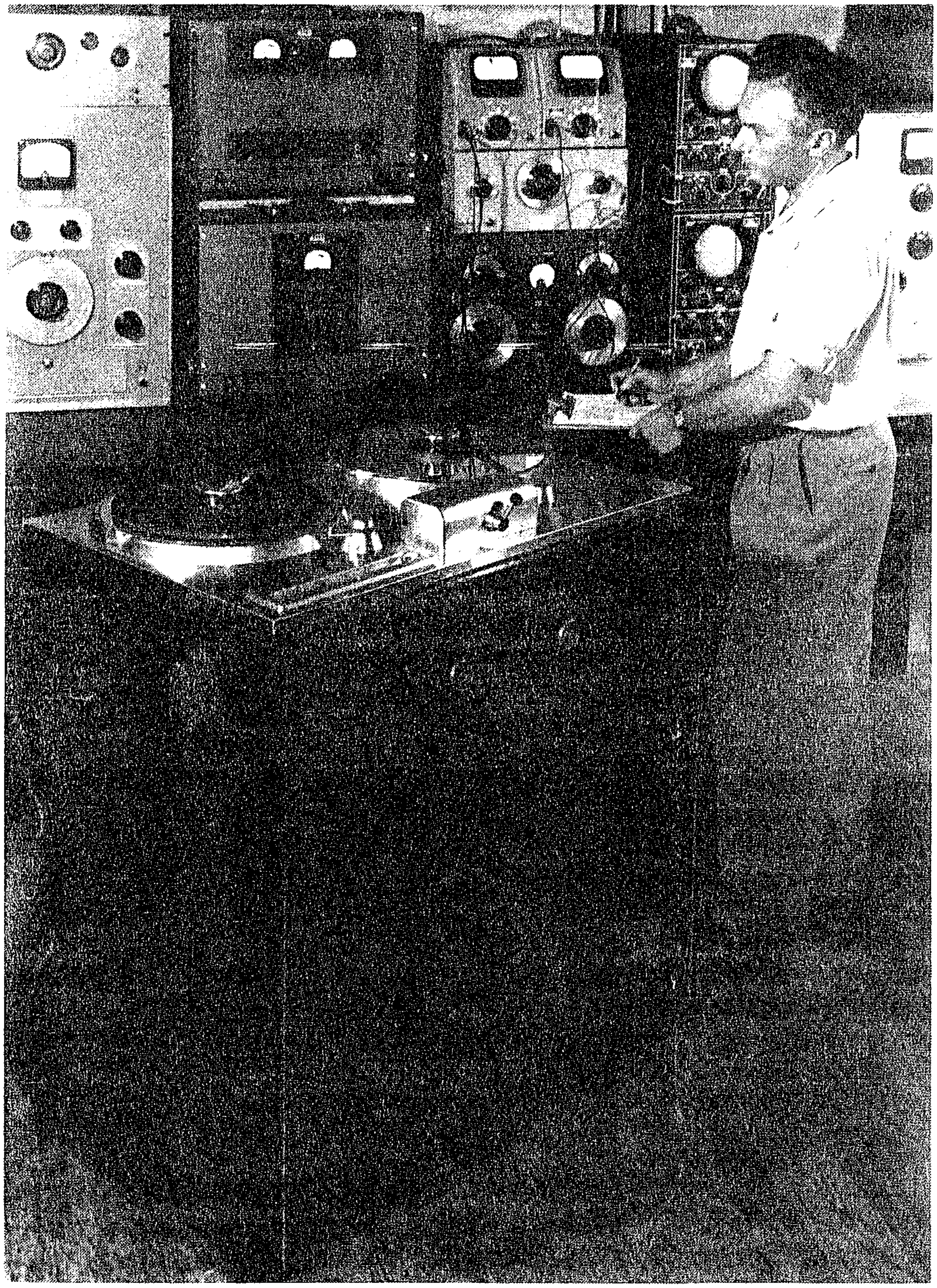
Lindsay then spent 5½ years as technical assistant to Alexander Poniatoff, and later became corporate consultant on audio technology in the advanced research and technology department.

He was named manager of the audio engineering department in 1965, and left that post in 1969 to become a corporate consultant.

After a 30-year association with the company, Lindsay retired from Ampex in 1977, but he continued to consult for the company on various audio and magnetic tape projects. He also served as a guest speaker for employee orientations and most recently assisted in the design of the new Ampex Museum of Magnetic Recording.

A native of San Diego, Lindsay studied at the University of California at Berkeley and held engineering positions at Shell Development Company, Litton Engineering Laboratories, and Dalmo Victor before joining Ampex.

Also, during World War II, he was employed at the University of California, where he worked on the Manhattan Project and helped



THE AMPEX MODEL 200, the magnetic tape recorder developed by Harold Lindsay in the late 1940s, revolutionized the recording industry.

design the special control equipment employed in atomic research. For another Berkeley project, he helped develop an automatic barometric release to open parachutes.

For many years Lindsay was active in the development and use of audio recording and amplification techniques in Northern California.

He designed and operated the sound system at the first Monterey Jazz Festival in 1958, and did similar work for the pageant staged by Walt Disney to open the 1960 Winter Olympic Games at Squaw Valley.

Another interest, working with architects on the acoustical design of buildings, led to numerous projects in the construction of schools, theatres, and churches, including the church where Lindsay's memorial service was held. His work on the First Baptist Church of San Jose, which attracted international attention, required more than five miles of electrical wiring, 300 jacks and 123 amplifiers.

Harold Lindsay always laughed at the idea of sitting for even an hour on a porch rocking chair. In a 1977 newspaper interview, he described his approaching retirement time as the "prime of his life." He also said he could not understand people who didn't know what to do with their spare time.

Ever curious, undeniably inventive, Harold Lindsay was often dubbed the "gentleman genius" for his alert, yet soft-spoken ways. He was one who made the most of his time, first, last and always.

A Selected History of Magnetic Recording

by Friedrich Engel and Peter Hammar

The Premiere of the Magnetophon Audio Tape Recorder in Berlin, 1935

The Magnetophon machine created a great deal of interest at the exhibition. The dealers recognized the fact that this machine was the "hit" of the show, something we heard as well. They realized the many important applications of the machine, including its use as a dictation and news-gathering device, as well as the perfect replacement for phonograph records. Many inquiries about the delivery of 25 or 50 machines at a time were heard. Many people indicated their desire to see variations of the Magnetophon: combined with a telephone; an auxiliary unit for a radio; pre-recorded music and entertainment tapes; a special version to create artificial reverb for open-air concerts; feedback control for indoor performances with sound reinforcement; a device for "speed telephoning", that is, recording a speech at normal speed, playing it back over the phone at a higher speed with the recorder on the other end of the line also working at the increased speed, and then playing back the tape at a normal speed.

These were the words of Friedrich Matthias of BASF, the company that produced the first-ever coated magnetic recording tape. He was reporting on 4 September 1935 to BASF (then called I.G. Farben, Ludwigshafen works) headquarters about the introduction at the German Radio Exhibition of the AEG Magnetophon audio magnetic tape recorder and BASF tape. The machine was one of the main attractions at the AEG booth . Even this formal report reflects the enormous excitement that the new audio recording technology generated at its first public demonstration. After only two-and-a-half years of development, a promising new product family was ready, thanks to the cooperation of two large companies, AEG and BASF. An AEG team in Berlin had designed and built the Magnetophon hardware, consisting of the tape transport, the magnetic heads, the electronics, and the loudspeakers, while a BASF team in Ludwigshafen had done the research and development leading to the production of the first mass-produced magnetic tape. By 1940, when the quality of the magnetic recording process had increased significantly, tape was firmly established for the next six decades as a universal recording method.

The Development and First Implementation of Magnetic Recording

In 1935, magnetic sound recording was by no means a new technology. Much had already been developed in the previous 60 years. Realizing the imperfections of the Edison cylinder phonograph introduced in 1877, a 38-year-old American named Oberlin Smith in the summer of 1878 sketched out the fundamentals of magnetic recording and performed some basic experiments. Smith represented the quintessential 19th Century inventor, an engineer with a wide technical background. He primarily made his living manufacturing forges, machine tools, and metal presses in Bridgeton, New Jersey. Smith's favorite proposal for magnetic recording suggested the use of a cotton thread interspersed with short, thin steel wire pieces run at a constant speed through the core of an electro-magnetized spool of wire. Smith did not take out a patent on the process because he could not create a working model of his idea, presumably absorbed by the increasing demands of his business. Ten years after sketching out his theoretical proposals on magnetic recording, Smith published his findings in the 8 September 1888 issue of the American technical journal, *The Electrical World*, under the title, *"Some Possible Forms of Phonograph"*. Although the article created almost no interest in magnetic recording in the new industry of recorded home entertainment, Smith's position as a magnetic recording pioneer was assured.

In 1896, the Danish electrical engineer Valdemar Poulsen designed the first working magnetic recording device, which he called the "Telegraphone". The wire recorder, patented in 1898, was enthusiastically received at the Paris World Exhibition of 1900. Following that success, Poulsen developed important variations of his magnetic recording design. Besides wire wrapped on spools, the inventor built steel-tape recorders, and even a coated steel disc recording device for short dictation, whose basic function resembled the Winchester hard disk recorders widely used in computers 80 years later.

In practice, the Poulsen magnetic recorders could not succeed because of their lack of electronics. Poulsen introduced his machines before the invention of the vacuum tube , so that the lack of amplification on playback, as well as good microphones, doomed the machines to commercial failure. The mechanical gramophone continued to reign supreme in audio recording. Suitable amplifiers did not arrive in Europe until the introduction of tube amplifiers by the Austrian Robert von Lieben. Von Lieben's patent of December 1910 suggests its possible use with magnetic audio recording. In America in 1913, "Audion" tube inventor

inventor Lee DeForest also wrote about the application of his audio amplifier to the Telegraphone wire recorder.At the end of the 1920s, the German chemist Curt Stille introduced a steel-tape machine for use in production and distribution of the newly introduced technology of movies with sound, "talking pictures". A film producer named Louis Blattner acquired the rights to the steel-tape recorder, which he renamed the "Blattnerphone". Blattner later sold the invention to the British company Marconi, which, in 1932, built for the British Broadcasting Corporation (BBC) its own version of the steel recorder: 3 millimeters (mm) wide, 50 micrometer (μm) thick steel tape, running at a speed of 1.5 metres per second. The machine could record for 30 minutes on a 9 kilogram, 60 centimetre - diameter reel. Similar machines remained in use at the BBC until 1954.

In Berlin, Germany, electrical engineer Semi J. Begun designed comparable steel-tape recorders for the C. Lorenz Company, the "Steel Sound Machine", which was put into service at the German national broadcasting company, the Reichs-Rundfunkgesellschaft (RRG), in the mid-1930s for use as both a studio recorder and as a news-gathering device. Begun had much experience in the construction of magnetic dictation machines, including his 1931 "Dailygraph", a device featuring recording wire contained in a cassette.

Steel tape was not only heavy and clumsy to handle—if not properly threaded and tensioned, the spool would explode like a watch spring flying apart—but also was difficult to edit, theoretically one of the main advantages of the linear magnetic medium. A steel tape could only be edited using solder or welding material. After the tape was red-hot, the edit point lost its magnetic flux, meaning the sound dropped out at every edit. Steel tape that met constant specifications was difficult to manufacture. The impracticality of wire and steel-tape recording seemed to assure that wax, lacquer, and acetate transcription discs (78 rpm records) would remain the mainstay of the professional and consumer audio recording industries for some time to come.

Magnetic Recording Using Paper, Iron Oxide Powder, and Glue

As so often happens in the development of technology, progress came from the work of people who were outsiders to the mainstream of the industry. Practical magnetic tape recording originated with an Austrian inventor living in Dresden, Germany, named Fritz Pfleumer. In the 1920s, sales of cigarettes boomed, and the manufacturers wanted a cheap alternative to the expensive gold leaf band that decorated the tips of the most expensive cigarette brands. An expert in special paper and related processes for industrial uses, Pfleumer succeeded in creating a process for striping a cheap gold- coloured bronze band on the cigarette paper. Pfleumer was interested in the magnetic recording process, and reasoned that he could use his cigarette-paper manufacturing process to create a magnetisable paper recording tape that would replace expensive and impractical wire and steel.

The inventor glued pulverised iron particles onto a 16 millimeter-wide strip of paper, creating the first magnetic tape. He also built the first tape recorder in the modern sense. For his discovery, Pfleumer received German patent DRP 500 900 on 31 January 1928. He called his process "sounding paper". The audio tape recorder produced poor quality sound that nonetheless offered great promise. The paper tape tore readily, but could also easily be repaired with glue instead of the welding method of steel and wire. In his promotion of the invention, Pfleumer pointed out that editing and assembling the edited pieces of his recording tape were as easy as handling movie film, a well-established technology.

Realising that he needed help developing his invention into a commercial product, Pfleumer determinedly approached several companies. The German electronics group "AEG"—German General Electric—showed the greatest interest and signed a contract with Pfleumer. In 1931, AEG set up a development laboratory in their cable factory on the Oberspree River in the Berlin suburb of Oberschoeneweide. Under the direction of Theodor Volk, AEG technicians assembled their first prototype paper-tape recorder and began experimenting with methods of manufacturing the tape.

The AEG engineers quickly found they were better at designing electronics and tape transports than they were at experimenting with the chemical processes of iron powder, glues, and coating methods. So they contacted the logical people to help them with the job, the BASF division in Ludwigshafen of the giant chemical combine I.G. Farbenindustrie. The chairman of the AEG board of directors, Privy Counsellor Hermann Buecher, had taken a personal interest in the tape recording project, and contacted the managing director of BASF, Wilhelm Gaus. The two made a "gentlemen's agreement", later formalised in a written contract, that AEG would build the machines and BASF would make the tape, with their development teams cooperating closely.

The BASF chemists decided that a product they had been manufacturing on a large scale for years, carbonyl iron used in high-frequency coils for telephone transmission and radio applications, would be a suitable magnetisable material with which to coat the tape. Realising that paper was a poor choice as a "basefilm" for the new product, the team of chemists also worked on finding a better base on which the magnetic material could be coated. The company already had some experience in the production methods of film-like plastic bases. By late 1932, the team's experiments were pointing in the right direction: they coated a 30 μm thick cellulose acetate basefilm with 20 μm of carbonyl iron powder mixed with more cellulose acetate to bond chemically with the basefilm—thus creating a genuine coated tape.

In June, 1934, AEG and BASF had decided to call their "magnetic phonograph" machine and tape "Magnetophon". The Ludwigshafen chemists produced 5000 metres of tape for the introduction of the machine at the 1934 Berlin Radio Exhibition. However, shortly before the show, AEG encountered technical problems—bad hum from the interaction machine's motor, brake magnets, and electronics—and cancelled the machine's debut. They also found the tape broke quite easily. It was "back to the drawing board" for both AEG engineers and BASF chemists.

The Definitive Version of Magnetic Tape Recording

The joint development team decided they would show the improved Magnetophon at the Radio Exhibition in Berlin in 1935. The intervening time was put to good use. AEG built a completely new machine they called the model "K 1", "K" standing for "Koffer" or portable case. The machine set the pattern for the modern tape recorder, in respect of the placement of its reels, heads, and tape path, as well as its three-motor design, the best for tape handling. The same transport and electronics were also offered as the basis of an office dictation system in an oak cabinet, the model FT 1 "ferngesteuerte Truhe" or "remote-controlled cabinet" model. The 6.5 millimeter-wide tape ran past the heads at a speed of one meter per second.

By the spring of 1935, BASF chemists moved their "Magnetophon Tape Type C" from development to production when they put four experimental coating machines into operation. Test recordings of music and speech made on 27 April 1935 show the progress they had made in their formulations. For the Berlin Exhibition scheduled a few months later, the chemists produced 50,000 meters of Type C tape.

Effective playback and recording heads form the basis for the quality of any analog tape recorder / reproducer. The man who became the AEG Magnetophon chief engineer in 1935, Eduard Schueller, had developed a "ring head" to replace the pointed magnetic heads designed for steel tape recorders. The older sharpened-head design tore paper and plastic tape, while the smooth face of the new ring head was perfect for use with the BASF acetate tape. Schueller's ring head, the basis for all future magnetic recording heads, was patented on 24 December 1933 (DRP 660 337), and was truly a Christmas present for the future of magnetic recording.

The AEG model K 1 and Magnetophon Type C tape were a sensation at the Berlin exhibition that week in August, 1935. People were amazed to be able to hear their voices an instant after being recorded. The product roll-out was overshadowed, however, by a fatal fire midway through the show that destroyed the hall in which the prototype machine and tape were being demonstrated. The AEG team across town worked day and night and produced a second prototype K 1 tape machine that was shown only two days later during the final days of the exhibition in a makeshift booth .

The enthusiastic report about the Magnetophon at the Berlin show written by the 39-year old Friedrich Matthias of BASF (see above), combined with the dedication of the 33-year old Eduard Schueller and his AEG team to replace the burned-up prototype before the show ended, demonstrated the high value that they and others placed on the invention. After only two-and-a-half years of cooperative development work by AEG and BASF, the promising system was ready. The price was attractive: the recorder cost 1350 Reichsmarks, and an hour of tape cost 36 Reichsmarks, about a seventh of the price of steel tape for the competing Lorenz "Steel Tape Sound" machine. By comparison, a trained technician earned about 250 Reichsmarks per month. Clearly, the recording technology was beyond the means of most consumers and was aimed at the professional audio and government markets.

Despite the relatively high cost of the AEG machine and its BASF/I.G. Farben tape, the sales outlook of the new recording medium in various markets looked bright. BASF geared up to make tape in volume. By the summer of 1936, the Ludwigshafen team had modified a photopaper manufacturing machine from the Koebig company in Dresden with which they could produce a long sheet of cellulose acetate basefilm and then immediately coat that base with magnetizable iron particles mixed with a "binder"—a kind of glue. The production machine consisted of a narrow cabinet containing a continuous 28 meter-long, 70 centimeter-wide copper belt. Liquid cellulose acetate was spread onto the belt to create a 65 cm-wide "web" or sheet of cellulose acetate basefilm. Then the newly made basefilm web was run through the air another 12 meters to dry it.

In the final step of the tape-making process, the treated sheet of cellulose acetate was coated with a liquid mixture of acetone, cellulose acetate, and carbonyl iron. After about 26 meters , the finished tape was dry enough to leave the support of the copper belt and be wound into a wide spool of finished bulk tape, ready for slitting into 100 Magnetophon tapes, each 6.5 mm wide. The tape basefilm was 30 µm thick, with a 20 µm coating, close to the specifications of modern professional audio tape. In the mid-1930s, the speed of the tape manufacturing machines was limited to only three meters per minute. For a run of 1000 meters of tape, the process required six hours, from which 100 tapes with a playing time of 22 minutes each could be made. (Today's magnetic tape manufacturing process yields over 400 meters per minute.)

In the summer of 1936, the BASF chemists replaced carbonyl iron with magnetite as the tape's magnetizable component. This type of iron oxide, Fe_3O_4, offered a higher coercivity and greater remanence, meaning higher fidelity audio recordings. Instead of light gray , the Magnetophon tapes were now black.

The first formal test of the new "Magnetophon Type C" tape product came on 19 November 1936, when BASF technicians recorded a concert by Sir Thomas Beecham and the London Philharmonic Orchestra in the "*Feierabendhaus*", the employees' auditorium on the factory grounds. Unfortunately, the poor-quality DC-bias electronics still produced recordings not as good as the competing wax transcription discs used by recording companies and radio stations in Germany.

The State of the Art of Tape Recording by 1936

With his pioneering Telegraphone, Poulsen had added a DC current to the signal—a process called "biasing"—to attempt to reduce distortion and noise in the recording. Biasing "pre-magnetizes" the magnetic medium to reproduce more precisely the magnetic flux from the recording head. Poulsen's DC-bias designs did not work well; all wire, steel tape, and early paper and plastic tape recorders used DC bias and made noisy, distorted recordings with limited frequency response. By 1936, even after much research at AEG and BASF, little had changed in record bias designs. The Magnetophon K 1 with its DC-biasing circuit produced a distorted signal with a frequency range of 50 Hz to 5 kHz, and a dynamic range of less than 40 dB.

Engineers knew there had to be a way to improve the performance of the new technology. The answer was AC record bias, i.e., a high-frequency alternating bias current oscillating thousands of times a second sent to the record head at the same time as the audio signal to be recorded. Ironically, in 1934, BASF physicist Erwin Lehrer had experimented with AC bias while testing magnetic materials, but was unable to make the process work well. AEG Magnetophon engineer Eduard Schueller also unsuccessfully tested AC bias but was unaware of Lehrer's work. Another six years passed before Walter Weber of the Reichs-Rundfunkgesellschaft, the German broadcasting service, in 1940 made the definitive step towards truly "high fidelity" recordings. If the Magnetophon had had AC bias as early as 1935, who knows what the machine's quality would have been?

Comparing the specifications of the Magnetophon of 1936 with today's analog audio tape recorders reveals the difficulties faced by the first tape makers and machine builders in their new world of magnetic recording. For chemists and electronic engineers, creating a tape recorder and its tape meant a step-by-step exploration of magnetism, mechanics and motion theory, and advanced audio electronics. The teams had to explore basic scientific and technical theories that we take for granted today in the design and manufacture of magnetic recorders and tape. In the 1930s, measurement of the hysteresis loop of magnetic materials, a common practice today that takes under a minute, took one to two hours. Lack of efficient measuring equipment presented one of the first obstacles, solved by BASF physicists Erwin Lehrer and Friedrich Bergmann. They and their associates developed measuring devices to establish objective electronic, magnetic, and mechanical quality parameters, which they often first had to define. Their work offered alternatives to purely subjective listening tests.

At the end of the 1930s, tube amplifier desigers started to use "negative feedback" in order to reduce distortion caused by all-too-simple circuits. Initially, the advantage of this feedback procedure was not understood. The negative feedback meant reducing the gain, but resulted in better audio quality. AEG engineers incorporated the technique into the Magnetophon's amplifier design.

After AEG had built only ten to fifteen Magnetophon K 1 models, which ran tape at one meter per second, the company introduced the K 2 in 1936, most of them with the slower speed of 77 centimeters per second. Planned or by chance, the new speed was almost exactly half the 1.5 meters-per-second speed of the still-competitive steel-tape magnetic recorders. Around 100 K 2s and the successor K 3s were built in the next two years. AEG introduced in 1938 its first commercially successful tape recorder, the Magnetophon K 4, with its modern amplifiers and modular magnetic head stack. The K 4 was the best of the DC-bias machines. All of the K 1 to K 4 types consisted of three units: tape transport (motor and head assembly), separate amplifier, and a loudspeaker, each contained in ist own portable case.

The German radio service, the Reichs-Rundfunkgesellschaft (RRG), in one of the earliest known examples of "electronic news gathering" (ENG), tested magnetic recording in the field in 1934 with the Lorenz steel-tape machine in the streets and trains of Hamburg. In 1938, the RRG declared the Magnetophon to be one of its future recording devices. They recognized the cost and performance advantages of magnetic tape—including the ability to record uninterruptedly for 20 minutes—over their current recording standard, the wax transcription disc, which could record for only four or five minutes, but at a higher quality level. At first, the RRG used DC-bias Magnetophons for non-critical recordings such as speeches and interviews. The director of the RRG electronics development laboratory, Hans-Joachim von Braunmuehl, was sure that the Magnetophon could be improved enough to record music, so he put RRG engineer Walter Weber to work perfecting the new tape technology. The RRG magnetic tape lab operated independently of the AEG Magnetophon R&D operation across town.

The first implementation in German radio stations was the R 22, based on the AEG Magnetophon K 4 tape transport, but with special amplifiers developed by RRG engineers. The RRG realized the importance of the new Magnetophon for ENG operations, and, working with AEG, helped develop the Magnetophon R 23 in 1939, a compact, battery-powered portable deck—still with the inferior-sounding DC-bias record circuit.

The German military in the 1930s naturally adopted any technology that would advance its cause, and found many uses for magnetic recording. The Army "Propaganda Corps" and other departments used portable recorders in a variety of field applications. The military versions of the AEG recorders were called "Tonschreiber" or "sound writer". R-23s and other models were modified and dubbed "Tonschreiber Dora" or just "Tonschreiber D". Other models appeared at the same time, including the Tonschreiber Caesar ("C"), a tiny, spring-driven machine, the most portable magnetic recorder yet created. The most interesting and technically advanced pre-war Tonschreiber was Berta ("Tonschreiber B"), a transportable deck and amplifier with variable recording speeds from 9 cm/s to 120 cm/s. In addition to the normal head stack, the field recorder featured an additional four-gap spinning head assembly for playback at variable speeds without a change in pitch, in other words, a way to compress or expand speech or encode and decode telegraphic messages.

By 1939, BASF researchers had advanced the state of the art of tape quality far beyond its 1936 debut. Probably the most important progress came that summer with the introduction of gamma ferric oxide tape, γ-Fe_2O_3, with red iron oxide particles, a formula dating back to a 1935 BASF patent that proved so effective that it was not until thirty years later, in 1971 with chromium dioxide tape, that anything fundamentally better would replace it. Tape formulas in Germany, Japan, and the United States in the 1940s, '50s, and '60s, were evolutionary improvements on this BASF patent. The γ-Fe_2O_3 magnetic particles were considerably smaller than the original Fe_3O_4 formulation, which resisted erasing by the permanent magnet erase heads then in use. With DC-bias Magnetophons, the new tape achieved a signal-to-noise ratio of liitle more than 40 dB and a frequency response remaining 50 Hz to 5 kHz, still unacceptable for "broadcast quality".

Between 1935 and 1943—the last year of BASF Magnetophon tape Type C—the Ludwigshafen chemists used no fewer than three magnetic formulations:

- up to the summer of 1936: carbonyl iron (light-gray. metallic pure iron)
- from the middle of 1936 to the summer of 1939: Fe_3O_4 (black, cubicular iron oxide)
- from the autumn of 1939 to 1943: γ-Fe_2O_3 (gamma-type red, cubicular oxide; needle-shaped variations were developed at the beginning of the 1950s using the same formula).

Throughout the development of these magnetic materials, the basefilm remained the same—cellulose acetate, after which BASF named the product "Magnetophon Tape Type C". Although polyvinyl chloride (PVC) and later, polyester (Mylar) basefilms eventually replaced cellulose acetate, the technology lasted well into the 1960s. Type C tape had advantages in manufacturing. Acetone used in the process was cheap and plentiful, and the cellulose acetate was used in all three parts of the tape: basefilm, magnetic coating, and binder, resulting in a cost-effective and straightforward manufacturing process. One can understand why acetate tape was produced well into the 1950s in Germany and into the 1960s in America.

Acetate tape had its weaknesses—it broke easily and was sensitive to humidity. The product had a clear advantage over its plastic successors: it broke cleanly and did not stretch. When acetate broke, the recording engineer could easily splice the tape back together with no audible break in the sound.

The Great Quality Leap—AC-bias Recording

Joining AEG and BASF in 1938, the Reichs-Rundfunkgesellschaft (RRG) became the third branch of the Magnetophon R&D effort. In 1940, the RRG successfully applied AC-bias to the new recording technology. RRG engineer Walter Weber discovered the AC-bias application through a combination of systematic research and a bit of luck. Weber was not the first to apply AC bias to magnetic recording, although he evidently had no knowledge of the earlier work. The engineer's success was due to his ability to recognize immediately the practical value of his discovery and to use it to improve the Magnetophon's recording quality.

Weber had been experimenting with phase-cancellation circuits in an attempt to reduce the distortion and noise of DC-bias recordings. An amplifier in a test set-up went into oscillation, accidentally creating an AC-bias current in the record circuit. It took some systematic engineering detective work before Weber found what had happened and could recreate the phenomenon. AC bias for the magnetic tape recorder was born! Rumor had it that the AEG engineers on the other side of town were happy that the RRG engineer had solved the problem with AC bias, although they were a little annoyed that they had not thought of it themselves. Weber's supervisor, H.J. von Braunmuehl, worked with AEG to establish patents and licensing of AC bias for the Magnetophon. The most important of the resulting patents, DRP 743 411, was issued 24 December 1943, exactly ten years after Eduard Schueller took out his ring-head patent.

The Magnetophon now had the best audio quality of any recording technology in the world, far better than the old DC-bias tape recording, but also better than the current commercial competitors to Magnetophon tape: optical sound on film; shellac, and wax discs; and steel tape and wire. The superiority of the new "high fidelity" magnetic recording process was clearly demonstrated in Berlin on 10 June 1941 in an AEG-RRG demonstration publicly reported by the local press: *"A fantastic experience in electrical sound recording...a total revolution in sound recording...."* No wonder the journalists were impressed: for the first time in history, a sound recording had achieved 60 dB dynamic range and a frequency response of 50 Hz to 10 kHz (figures based on weighting filters and tolerances of the day).

AEG/RRG researchers soon added stereo recording to their 1940 high-fidelity Magnetophon triumph. As early as 1942, they had made test recordings of the Berlin Philharmonic Orchestra using three condenser microphones made by the famous Berlin company Georg Neumann and a stereo version of the AEG / RRG R 22 studio deck.

While engineers had made progress in its electronics, the "hi-fi" Magnetophon based on the K 4 left room for improvement in tape handling, wow, and flutter. The breakthrough was the Magnetophon model K 7, the first tape deck with synchronous motors, introduced in the spring of 1943. Subsequently, for the first time, even stereophonic "acoustically accurate" sound reproduction was demonstrated to the public, using the latest loudspeakers developed by RRG engineer Hans Eckmiller. Since this was before the era of stereophonic radio broadcasting, all of these recordings went to the radio archives labelled "for archival purposes only". The stereo version of the Magnetophon never made it into regular production, and wartime pressures and post-war chaos ended serious stereo experimentation until the late 1940s.

The German film industry took an immediate interest in the new high-quality sound recording method. Color film had recently been introduced, and the optical sound-on-film suffered from the new color emulsions, which did not reproduce optical sound as well as black-and-white film. In 1941, engineer Karl Schwartz of Klangfilm GmbH in Berlin received patent number DRP 969 763 for his solution to the fundamental problem of synchronizing film-camera and film-projector transports: the use of perforated magnetic tape—oxide coated on clear film stock. Unfortunately, few details of Schwartz's invention are known, although the German film manufacturer Agfa did show a strong interest in the invention and performed some experiments dating back to late 1941, including trial production runs.

Further Wartime Developments

At the end of July, 1943, the BASF Magnetophon tape plant in Ludwigshafen was completely destroyed by a non-war-related, accidental explosion of a tank car. The disaster wiped out all tape-manufacturing machinery in the factory, including the only coating machine for Magnetophon Type C tape, installed in 1936. To meet RRG tape needs as well as wartime military tape consumption required quick improvisation and an alternative manufacturing site. With a world war raging around them and their factory destroyed, with no hope of rebuilding the plant or replacing mixing and coating machinery at Ludwigshafen because of scarce resources, the tape makers found they had three possible solutions to the problem:

1. Plant Relocation: The photographic film maker Agfa in Wolfen, Germany, a fellow member of the I.G. Farben chemical combine, in late 1942 had already begun manufacturing test runs of the Type C formula developed in Ludwigshafen. By the end of February, 1943, the Agfa chemists had sent four 50- to 70-meter-long samples to BASF for analysis. After the Ludwigshafen explosion a few months later, all of the BASF oxide, which Ludwigshafen could still produce in volume, as well as magnetic tape production know-how were sent to Agfa in Wolfen. It took another few months, until well into 1944, before the new Agfa plant was operational and producing Type C tape. The operation was the beginning of Agfa's commercial tape production. After the war, the Wolfen plant, located in the future "German Democratic Republic" or East Germany, became a state film and tape factory called "Orwo". In 1948, tape experts from Wolfen built a new Agfa tape factory in Leverkusen, near Cologne, which was moved to Munich in the 1970s, and finally merged with BASF AG to form BASF Magnetics GmbH in 1991, now based in Ludwisghafen.

2. New Base Material: The second option available to continue tape manufacturing was a change in base material, from cellulose acetate to a new plastic, polyvinyl chloride or PVC, which had been developed and manufactured since the end of the 1930s at the Ludwigshafen plant. As early as 1938, BASF researcher Heinrich Jacqué, inventor of the tensilized PVC foil had suggested putting the oxide directly into the PVC mixture and rolling the result by means of a calendering machine into 50 µm-thick homogeneous tape webs, ready for slitting. The process totally eliminated the need for tape coating and oxide binding to the basefilm.

No one paid much attention to Jacqué's idea until the BASF tape plant burned down, when they realized his method eliminated the coating process, avoiding the necessity of rebuilding the destroyed coating machinery. Jacqué used an available calendering machine to make test runs of the new tape, called "Magnetophon Type L". The "L" stood for "Luvitherm", I.G. Farben's trade name for the PVC manufacturing process. The BASF, Agfa, and AEG people were pleasantly surprised to discover that the new Type L tape performed far better than the old Type C product, with an amazing 10 dB improvement in signal-to-noise ratio. The downside was that the tape's sensitivity also decreased by 10 dB, a special handicap for tube amplifiers. The oxide particles mixed into the basefilm were more dispersed, with some particles physically farther from the recording/playback heads than with coated tape.

In 1944, because of the Allied air raids on Ludwigshafen, the BASF tape calendering machine was moved to Gendorf in Lower Bavaria. After the war, around 1948, Friedrich Matthias, formerly of Magnetophon GmbH, set up a complete tape manufacturing plant in Gendorf, producing tape with the brand name "Genoton". The plant operated until 1956, when it was closed and some of its personnel were transferred back to BASF in Ludwigshafen. Matthias died in 1956 near Gendorf.

3. Modern PVC Coated Tape: In 1942, BASF chemist Rudolf Robl was given the job of finding a way to coat iron oxide onto the new PVC Luvitherm basefilm instead onto the somewhat brittle cellulose-acetate base. He had to develop a new coating process that differed from the manufacture of the original Type C tape. Acetone, the solvent used to make Type C tape, dissolves PVC too well, so Robl had to find a more suitable solvent. Coincidentally, BASF had begun producing THF, tetrahydrofuran, which Robl discovered he could use as a solvent in the PVC coating process.

Unlike the manufacture of Type C tape, in which the basefilm and coating occurred in one long process, Robl had to coat pre-manufactured webs of PVC "Luvitherm" basefilm. The long webs of PVC were difficult to handle during the coating process. Robl's solutions to materials handling formed the basis for tape manufacturing methods still in use today. The PVC basefilm had to be pre-treated to improve the handling of the wide plastic web of tape as it made its way through the coating machinery, as well as to allow the oxide-binder to adhere to its surface. Robl mixed titanium dioxide into the basefilm to improve tape handling and to help the end-user more easily distinguish the back and front of the tape. (Back-coated tape did not appear until the middle of the 1950s.) He called his new tape "Type LG"; "L" for Luvitherm and "G" for the German word "Guss" for "cast" or "coated". Type LG is thoroughly modern magnetic tape: a plastic basefilm with a γ-Fe_2O_3 oxide coating.

By the end of 1943, Robl was ready to go into production with the new Type LG tape. The BASF explosion that summer had eliminated Ludwigshafen as a manufacturing site, with many resources diverted to the Agfa plant at Wolfen to produce Type L tape. Ludwigshafen could, however, still deliver iron oxide (and did so in 50-liter milk cans). The basefilm came from the plant in Gendorf. They set up their man Robl in late 1944 in a truck garage in Aschbach in the Odenwald, about 50 kilometers east of Ludwigshafen. Starting in early 1945, Robl and his five employees produced 1600 kilometers of Type LG tape per month. The Aschbach plant stayed in operation until 1947, two years after the end of the war.

The Magnetophon Company and the Post-War Years

AEG and BASF co-founded "Magnetophon GmbH" or Magnetophon Company in 1942 in Berlin. One of the two corporate officers was Friedrich Matthias. In the summer of 1944, he moved the management operation to Waldmichelbach in the Odenwald, two kilometers from Aschbach, where Robl was making Type LG tape. Waldmichelbach would be the tape-slitting and packaging center for all tape manufacturing operations in Germany: Aschbach, Wolfen, and, later, Gendorf. Those locations sent their wide rolls of manufactured tape to Matthias' new facility, where they were slit into 6.5 mm-wide tape, wound onto hubs, packaged, and sent to end users. Gendorf and Wolfen are each located around 360 kilometers from Waldmichelbach, so one can imagine the wartime transportation and logistical problems that Matthias faced. Magnetic tape was going through the most hazardous phase of its history.

A year after the end of the war, in 1946, the BASF crew began to rebuild their tape-making facility in Ludwigshafen. About 30 employees battled hunger and difficult circumstances to set up a tape plant in a makeshift building. The team's biggest problem was to find enough PVC basefilm: the calendering machine in Gendorf could not be transferred back to Ludwigshafen, since Gendorf lay in the post-war American zone of occupation, while Ludwigshafen was located in the French zone. Immediate post-war Allied politics impeded intra-German trade across zones of occupation. Even the machinery in nearby Aschbach, also in the American zone, was not available to the BASF team, so they had to overcome post-war shortages by scrounging parts to rebuild the tape plant in Ludwigshafen. Necessity is the mother of invention: digging through the ruins of the old tape plant that had been destroyed in 1943 yielded two old slitting machines that they refurbished.

The beginning of the 1950s saw the appearance in Germany of the first consumer tape recorders. Private consumption of tape was on the upswing, although the largest consumers of German-made magnetic tape were still the German and Allied Forces radio stations. Consumers needed tape that would play at speeds slower than 19 centimeters per second with acceptable quality. To meet the need, BASF developed a tape with increased sensitivity, Type LGH, the "H" standing for "hochempfindlich" or "high sensitivity". With increasing sales of home recording decks, the consumer tape market rapidly eclipsed the professional tape segment in size.

Magnetic Tape Recording Worldwide

Practical magnetic recording, started by the Danish engineer Valdemar Poulsen in 1896 with his Telegraphone wire recorder, was about 40 years old at the start of World War II, well after the Germans had adopted tape as their future professional recording standard. However, the technology was still in its infancy in the United States. Although DC-bias tape recording was known in the U.S.—AEG marketers had shown a K-series machine to their colleagues at International General Electric Company in Schenectady, New York in 1936, with no result—magnetics had been largely ignored in America.

To a limited extent during World War II, the U.S. military used AC-bias wire recorders designed by Marvin Camras of the Armour Research Institute and S. J. Begun of the Brush Development Co., but strangely, no one on the U.S. side seemed to have heard of the high-fidelity German Magnetophon studio tape machine. The German technology was certainly no secret, having been featured in articles in popular German publications throughout the war, including the June, 1941, reviews in Berlin newspapers of the first public demonstration of the high-fidelity AC-bias machine. America did not enter the war until six months later, and was still maintaining a diplomatic station in Berlin—evidently staffed with people who did not care about recording technology! Even after the war ended, American and British occupation troops in Germany did little to exploit the technology, although their wartime and post-war intelligence missions included filing detailed official reports (named FIAT, BIOS, CIOS) on all aspects of German technical advances.

It took the initiative of a U.S. Army Signal Corps officer, Major John T. ("Jack") Mullin, to help get the advanced German recording technology to America. While working on radar and other electronics in England before the Allied invasion of Europe, Mullin occasionally listened to German classical music broadcasts from the RRG. An avid audiophile, he noticed the "live" quality of the continuous nocturnal broadcasts and assumed the Germans were using some sort of advanced recording apparatus for high-fidelity reproduction of sound. While based in Paris during and shortly after the war, Mullin led a team of engineers evaluating captured German equipment. The group became acquainted with the AEG K 4 and Tonschreiber DC-bias tape machines, as well as Magnetophon Type C and Type L tapes, but they still had not heard about the AC-bias studio decks in use throughout German radio. The Allies' mysterious ignorance of high-fidelity German tape recording was continuing!

The war ended in Europe on 8 May, 1945, and two months later Mullin visited Bad Nauheim, a "branch" radio station of Radio Frankfurt, and saw the AC-bias AEG/RRG Magnetophon studio machines in use. By that time, the entire RRG broadcasting apparatus had been turned over to the Allied occupation forces for transmissions in their languages, as well as programs for the German populace. Under Allied military supervision, the German technicians at the stations continued their normal routine of using tape recording throughout their 24-hour broadcast day.

Mullin was so impressed by the audio performance of the AC-bias studio decks that he collected information on them, including schematic drawings and specifications, and immediately returned to his headquarters in Paris to file full reports to his Army superiors on the technology. Following strict U.S. Army protocol, he also obtained for his own use the parts for two K 4 Magnetophon transports to ship home to San Francisco, California. In Germany, the post office ran the telephone service. During the war, the "Reichspost" had used Mullin's K 4 "post office" machines as eavesdropping recorders to monitor domestic and diplomatic telephone calls. Mullin took only mechanical components—especially head stacks—as well as many reels of tape, material he knew he could not find in the States. An accomplished electrical engineer, Mullin knew he could recreate using American tubes the entire electronic assemblies for a successful tape recorder. He also accumulated 50 reels of tape, mostly Type L, which remained the only professional tape in America until 1947, when 3M and others began making limited batches of coated tape that closely resembled Type LG: a gamma ferric oxide $(\gamma\text{-}Fe_2O_3)$ formula.

Working with his partner Bill Palmer of W. A. Palmer Films in San Francisco in 1946, Mullin built two Magnetophons with American electronics. U.S. broadcasters and entertainment stars, including the ABC Radio Network and Bing Crosby, soon heard about the machine, as did a tiny electronics manufacturer in San Carlos, California, named Ampex Corporation. Ampex wanted to be the first in the U.S. to build professional tape recorders. With help from Jack Mullin and Bill Palmer, the little company succeeded.

Ironically, the American entry into tape recording—and the country's immediate dominance in the shattered post-war world economy—meant that the tape width and recording speed specifications established by the joint AEG-BASF team ten years earlier were changed forever. When Mullin and Palmer measured the tape width of 6.5 mm, they decided to assign a nominal width of a quarter inch, or 6.35 mm. The tape speed of 77 centimeters per second became 30 inches per second, nominally 76.2 cm/second. The differences were so negligible that the English measurements became the dominant world standard, even in Germany. The quarter-inch tape and 30 ips speed also became the standard measure on which most future audio, video, and data tape formats were based, from the audio "Compact Cassette" to two-inch "quad" video tape.

Starting in 1948, dozens of American companies joined the race to build the best or the cheapest or the largest or the smallest professional and consumer tape recorders. 3M's "Scotch 111" audio tape brand became the world sales leader. The Americans made rapid progress in their research in and development of magnetic recording technology. BASF accepted the fact that 3M had made certain technical advances in tape manufacturing by naming their 1953 consumer tape series "Magnetophon Tape Type LGS". Only industry insiders knew the "S" designation meant "Scotch-compatible", indicating the technical compatibility of Type LGS with the new 3M formulation being used on many consumer tape decks of the time.

Cellulose acetate tape such as Scotch 111, whose basefilm was almost identical to Type C tape, was widely used in America until well into the 1960s, when it was replaced with polyester. American broadcasters who used acetate tape for decades and who hear the story of the birth of German tape are surprised to learn that a plastic-based PVC tape was in use in Germany as early as 1943.

From its rebirth in America, magnetic recording spread rapidly around the world in radio broadcasting, consumer sales, professional and military data recording, including computers, and the motion picture industry. Since the post-war Allied Commission had invalidated most German patents and therefore the rights to royalties on their pre-war and wartime inventions, AEG, BASF, and Agfa received no immediate benefit from the tremendous worldwide growth of their inventions. Patents filed after the war by the German companies and by European newcomers such as Studer/Revox and Kudelski in Switzerland and EMI in Britain later re-established Europe as a place of magnetic recording innovation. Japanese companies also began to play an increasingly important role in post-war magnetics, with Sony Corporation's entry into the field in the late 1940s, followed by Matsushita (Panasonic), Toshiba, and others.

The birth of the Magnetophon in Germany and the quick adoption of the technology in America led directly to the rapid and important advancements in videotape recording. While working for Bing Crosby, Jack Mullin invented the first prototype magnetic television recorder in 1950 using one-inch-wide tape with fixed heads. Ampex in 1956 introduced the world's first practical videotape recorder, the VR-1000, which used two-inch tape and spinning heads. The machine used 3M's new Scotch 179 video tape. Originally, the video technology was designed to time-delay programs to bridge the three-hour time difference between the U.S. East and West coasts. But almost immediately, magnetic video recording revolutionized the production methods in television studios worldwide.

Magnetic Recording— A Recording Medium with a Future

All of today's video recorders and tapes are direct descendants of that first Ampex machine and 3M tape, which are, in turn, the offspring of the first AEG Magnetophon and BASF tape—as are all data tape recorders, computer floppy and hard disks, and the billions of consumer audio "Compact Cassettes" and cassette decks around the world. The decision of AEG and BASF/I.G. Farben in the 1930s to build high-quality audio recorders and tape—despite the worldwide economic depression -, and the decision of the RRG to make the technology its recording standard, showed tremendous foresight. The success of the tape recording, especially in the face of the total destruction of a world war and its grim aftermath, demonstrated the great engineering talent and sheer determination of all of the hardware and tape development teams working on the Magnetophon project.

Today, some recording industry pundits have labelled magnetic tape a dying or dead recording medium. In fact, reliable marketing studies indicate that the descendants of the German technology—consumer and professional audio and video cassettes—will show some growth in sales through the year 2005. Especially with the advent of digital audio and video recording with very high data rates, linear and non-linear magnetic media still offer the greatest data packing density at the lowest price compared to all other currently available recording methods.

The recent market successes of magnetic digital formats demonstrate the depth of the technology and the faith of the market in its future: in audio, DAT (Digital Audio Tape), ADAT and DTRS eight-channel recorders using modified S-VHS and Hi8 cassettes, multi-channel 24-, 32- to 48-track DASH and PD-standard studio recorders; in video, the new digital D-VHS, Digital-S, Digital Betacam, and 19 mm and half-inch studio digital formats, as well as the tiny DV, DVCAM, and DVCPRO digital video formats. The all-digital DV format offers incredible specifications: for the first time in a consumer videocassette recorder, truly professional video and audio quality is possible. The"large" four-hour/30-minute DV cassette can hold 50 gigabytes of data. The "small" mini-DV cassette (around the size of a DAT tape) records an hour of video and audio, and has the capability of reproducing an HDTV signal. Future DV versions could hold two hours/15 minutes of 48-channel 24-bit audio.

Analog audio and video recorders use formats, that is, the manner in which the signal is recorded on the tape. Digital recording is beginning to loosen the burden of adhering to formats, and the industry is moving toward the creation of universal digital recorders, sometimes called "bitstream recorders". JVC is already proposing its new D-VHS format, based on the half-inch VHS/SVHS cassette, for use as a universal digital recorder for all forms of recording—audio, video, and data. Interfaces or codecs downstream would decode the information into its appropriate form. The dense, magnetizable coatings on these digital tapes such as DV and D-VHS, are expensive to produce, but can hold increasingly large amounts of data, keeping the recording medium cost-effective. A five-hour JVC D-VHS cassette, which has a recording density equal to DV, could theoretically hold seventy hours of video and audio using MPEG-2 encoding!

The development of these new tape formats DV and D-VHS leaves no doubt that magnetic recording has a great deal of life left in it. Far from obsolete, the linear tape technology lends itself not only to current audio, video, and data applications, but also to future uses where digital access time plays a less important role than storage and archive capability, for example in data archival storage and entertainment playback in applications including pay-per-view and on-demand movies. Tape's incredible packing density will lead to innovative, cost-effective applications for storing vast amounts of data storage, continuing its success as a reliable archival medium for both analog and digital sources. Magnetic tape will accompany us well into the 21st century.

About the authors

Friedrich Engel worked for more than two decades with the Application Engineering Department of BASF Magnetics GmbH, Ludwigshafen. His special interest in magnetic tape recording history led to some papers on selected subjects (Oberlin Smith and Walter Weber), of which this one is a preliminary version of a complete presentation of the story of magnetic sound recording.

Peter Hammar also has a strong interest in the history of entertainment technology. As a magnetic tape historian, he created and ran for many years the Ampex Museum of Magnetic Recording, in Redwood City, California. Hammar also did additional research and the English translation for this paper.

Conversions from the Metric to the English Measurement System

All figures are approximate
Official abbreviations:
millimeter ⇒ mm;
centimeter ⇒ cm;
meter ⇒ m;
kilometer ⇒ km;
meter per second ⇒ m/s;
centimeter per second ⇒ cm/s;
kilogramm ⇒ kg

page 2, At the end of the 1920s ...:
3 mm ⇒ 1/8 inch; 50 μm ⇒ 2 mil,
1.5 m/s ⇒ 5 feet/second;
9 kg ⇒ 18 pound; 60 cm ⇒ 23 ½ inch
The inventor glued ...:
16 mm ⇒ 2/3 inch
The BASF chemists decided ...:
30 μm ⇒ 1.2 mil; 20 μm ⇒ 0.8 mil (1 mil ⇒ 25.4 μm)

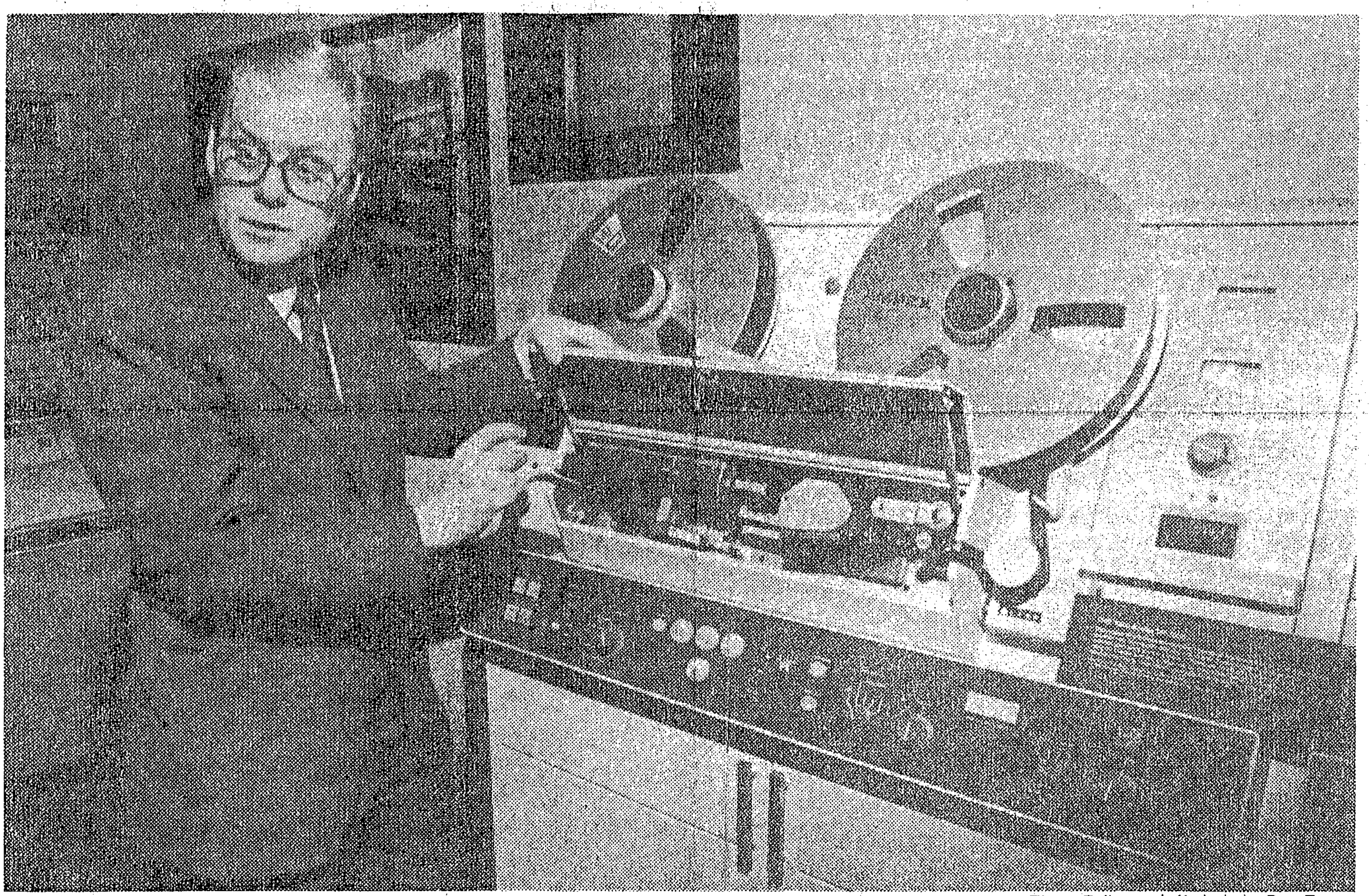
page 3, The enthusiastic report ..:
1350 Reichsmarks ⇒ 320 US$ (1935!)
Despite the relatively high cost ...:
28 m ⇒ 92 feet; 70 cm ⇒ 27 ½ inches;
65 cm ⇒ 25 ½ inches; 12 m ⇒ 39.3 feet;
In the final step of the tape-making...:
26 m ⇒ 85.1 feet;
6.5 mm ⇒ ¼ inch (exactly 0.256 inch);
30 μm ⇒ 1.2 mil; 20 μm ⇒ 0.8 mil;
400 m/min ⇒ 1300 feet/min

page 4, After AEG had built ...:
77 cm/s ⇒ 30.315 inches per second;
1.5 m/s ⇒ 59.06 inch/s
The German military ...:
9 cm/s ⇒ 3 ½ inches per second;
120 cm/s ⇒ 47. 2 inches per second

page 6, Plant Relocation ...:
50 m ⇒ 164 feet; 70 m ⇒ 230 feet

page 7, By the end of 1943 ...:
50 liter ⇒ roughly 12 gallons;
50 km ⇒ 31 miles; 1600 km ⇒ 1000 miles
AEG and BASF co-founded ...:
6.5 mm ⇒ ¼ inch (exactly 0.256 inch);
360 km ⇒ 225 mi
The beginning of the 1950s ...:
19 cm/s ⇒ 7 ½ inch per second

Ludwigshafen, Friday, 19. July 1996



Times Tribune staff photo by Dan Evans

Peter Hammar, curator of the Museum and Archives of Magnetic Recording in Redwood City, shows off one of the museum's antique videotape recorders. The museum was created by Ampex Corp.

New museum records history of tape

By Janet Reinka
Times Tribune staff

REDWOOD CITY — Harold Lindsay was not an excitable man. But his retelling of the story of how sound came alive pulses with an anticipation as fresh as if it were, once again, a certain spring evening in 1947.

"I have always remembered the next moment, just before pressing the start button, as one of the most anxious times in my entire life," Lindsay wrote in 1977. "So much hung in the balance — a dismal future or the beginning of an exciting future.

"The tape whipped up to speed; we were stunned, entranced, suspended in an eternity of mere seconds. Then cheers and handshakes and clapping — the sounds of a wild celebration. Our ears had just told us what measurements later confirmed: We had outperformed the Magnetophon head. We were destined not to failure, but to fame."

Perhaps it was not to be the "household word" fame of a George Eastman, whose Kodak put Rochester, N.Y., on the map, or the celebrity of Thomas A. Edison, the man who was known worldwide as "the Wizard of Menlo Park (N.J.)" for inventing the incandescent electric light.

But anybody who tunes in a radio, flips on a television set or jogs to the beat of a portable stereo has much for which to be grateful to Harold Lindsay and dozens of fellow pioneers. They helped to perfect magnetic recording tape.

More than 35 years after Lindsay's achievement, he and the engineers who followed him are recognized in the new Ampex Museum of Magnetic Recording. The board of directors of Ampex Corp., headquartered in Redwood City, agreed in May 1980 to create the museum, long a dream of pioneers in the field.

Many of them remain unsung and unknown except to those within the industry, although they helped bring about a revolution in sound and video recording whose impact is hard to overestimate.

Before magnetic tape was perfected for commercial use, sound was transcribed in the United States onto wire, steel bands or transcription discs, like records. The quality was marginal.

Although it was not yet known here, recording in Germany was significantly more advanced by 1935, largely owing to the efforts of Dr. Fritz Pfleumer and AEG-Telefunken, which developed the early recorder called the Magnetophon. Sound was recorded onto cellulose acetate tape coated with iron powder.

After the war, Jack Mullin, a U.S. Army signal corpsman who had managed to get a captured Magnetophon, shared his booty by demonstrating it to a radio engineering club in San Francisco. In the audience that night in 1946 was Lindsay, and the rest, as they

Please see MUSEUM, B-4

MUSEUM

Continued from B-1

say, is history.

The history in the Ampex museum is told through equipment valued at more than $1 million and explanatory storyboards. Included in the collection are gems such as the Telegraphone, a telephone answering machine developed in 1910. Owned by Ampex founder Alexander Poniatoff, the Telegraphone turned up during a search of a company warehouse.

The 1936 AEG Magnetophon is also displayed, as well as the Ampex Model 200, the prototype of which Lindsay demonstrated that memorable evening in 1947 for a nervous and excited group from Ampex. The machine was first marketed in 1948.

Lindsay was one of those who had long hoped that someday a museum commemorating the history of magnetic recording could be created. The dream was one of the few he did not live to see realized. He died in April 1982, shortly before the museum opened for a preview showing. Some of the equipment displayed is from Lindsay's personal collection.

Until now, the museum's existence has been publicized only in trade journals. For the past year, enthusiastic audio- and videophiles have been paying homage at their industry's magnetic Mecca, the most complete museum of its kind in the world.

"We've had people from Hollywood, Chicago and New York trying to figure out ways to get out here to see this museum," said consultant Peter Hammar, who was hired by Ampex to assemble the collection. "To them, it's an incredible nostalgia trip."

The museum, which is open to the public by appointment, was designed so it can be understood and appreciated by everybody — from the technician to the easy listener. Located on Broadway near the employee cafeteria, the museum is arranged in a series of 28 stations, each with its own television monitor.

At each display there are the traditional photos and text. Hammar deliberately designed the placards to be temporary because of the inevitable corrections volunteered by experts. By late 1983, visitors also will be able to view on TV screens computerized graphic information about each station in the museum.

Hammar said the Ampex board gave him free rein to tell the full story of magnetic tape recording, both from the audio and video ends, not as a vehicle to promote the company. Hammar said his neutral status as a consultant enabled him to obtain assistance from such industry pioneers as the 3M Co., BASF, AEG-Telefunken, Agfa-Gavaert, Studer and Sony Corp., as well as CBS, ABC and NBC in gathering information and rounding up equipment.

But local pride can't help but strut a bit. A tour of the museum demonstrates that the story of magnetic recording is very much the Ampex story. At almost every station in the museum, an Ampex machine was "the first."

"The criterion (for selection of the machines displayed) was being first," Hammar said, laughing. "It's true! It's embarrassing almost."

The museum points out the roles of the local Edisons — Lindsay, Charles Ginsburg, Myron Stolaroff, Charles E. Anderson, Shelby Henderson, Fred Pfost, Alex Maxey and others who worked to develop recorders like the Model 200 audio tape recorder or the Ampex VRX-1000, America's first successful videotape recorder. It revolutionized television broadcasting when it was introduced in 1956.

(The only one of the engineers whose name achieved the status of a "household word" was Ray Dolby, a whiz kid who graduated from Sequoia High School and Stanford University and went on to work at Ampex. His name appears on movie marquees across the country where the Dolby noise reduction system is used.)

To a non-expert, one of the most remarkable aspects of the museum is the marriage of necessity and invention, as consumer demand accelerated refinements in the technology of recording.

One of the most familiar examples is how crooner Bing Crosby's career was "rescued" by the new tape technology. Crosby did not like to perform live on radio, and those famous golden tones sounded tinny when recorded on discs.

"His Hooper rating had dropped from the high 90s to the 60s," Hammer said. "ABC said if it dropped below 60 he had to go live."

Crosby's show was broadcast on Oct. 1, 1947 — on tape with prototype Ampex equipment.

"The station was flooded with calls from people asking, 'Why didn't you tell us Bing was going to go live?' " Hammer said.

Shortly afterward, when Ampex exhausted its working capital, a grateful Crosby advanced Ampex a $50,000 check — no strings attached — for production of the Model 200.

At the museum, visitors can listen to the advancements in recording, from the raspy discs to the German broadcasts, followed by Crosby's crystal-clear, taped rendition of "My Heart Is A Hobo" from the 1947 broadcast.

Much of the history of tape recording is also the result of lucky accident. Hammar believes if Ampex had failed in its experiments, the Germans would have dominated the market.

"Yes, maybe (these machines) would have been invented," he said, "but perhaps not as soon. You could say that somebody would have come up with videotape. Maybe. But maybe it would have been delayed."

Groups wishing to tour the museum should contact Ampex's public relations department at (415) 367-4151 on weekdays between 8 a.m. and noon and 1 p.m. to 5 p.m.


HIGH-FIDELITY TAPE RECORDER
DEVELOPED LOCALLY
AMPEX ELECTRIC CORPORATION
FIRST NATIONAL
BANK of San Mateo County

#16069-2-7

INDUSTRY FIRST: Peter Hammar, curator of the Ampex Museum of Magnetic Recording, reviews the features of an Ampex Model 200 audio recorder, the first successful tape recorder produced in the United States. The sturdily-built machine was introduced in 1948 and produced just one channel of audio, but the Model 200 proved the practicality of tape recording and revolutionized the recording industry throughout the world.

# # # #

AMPEX CORPORATION
401 Broadway
Redwood City, California 94063

George Boardman, (415) 367-4151


AUDIO
MAGNETIC
RECORDING
MEDIA
1898 - 1965
sound tape

#16069-7-9

COMPREHENSIVE DISPLAY: The Ampex Museum of Magnetic Recording recounts the history of the technology's development in 28 separate displays. Pictured above on the left wall are examples of magnetic recording media--including wire, steel band, and tape--covering the period 1898 to 1965. Four examples of early portable and home audio tape recorders are shown at the right.

# # # #

AMPEX CORPORATION
401 Broadway
Redwood City, California 94063

George Boardman, (415) 367-4151

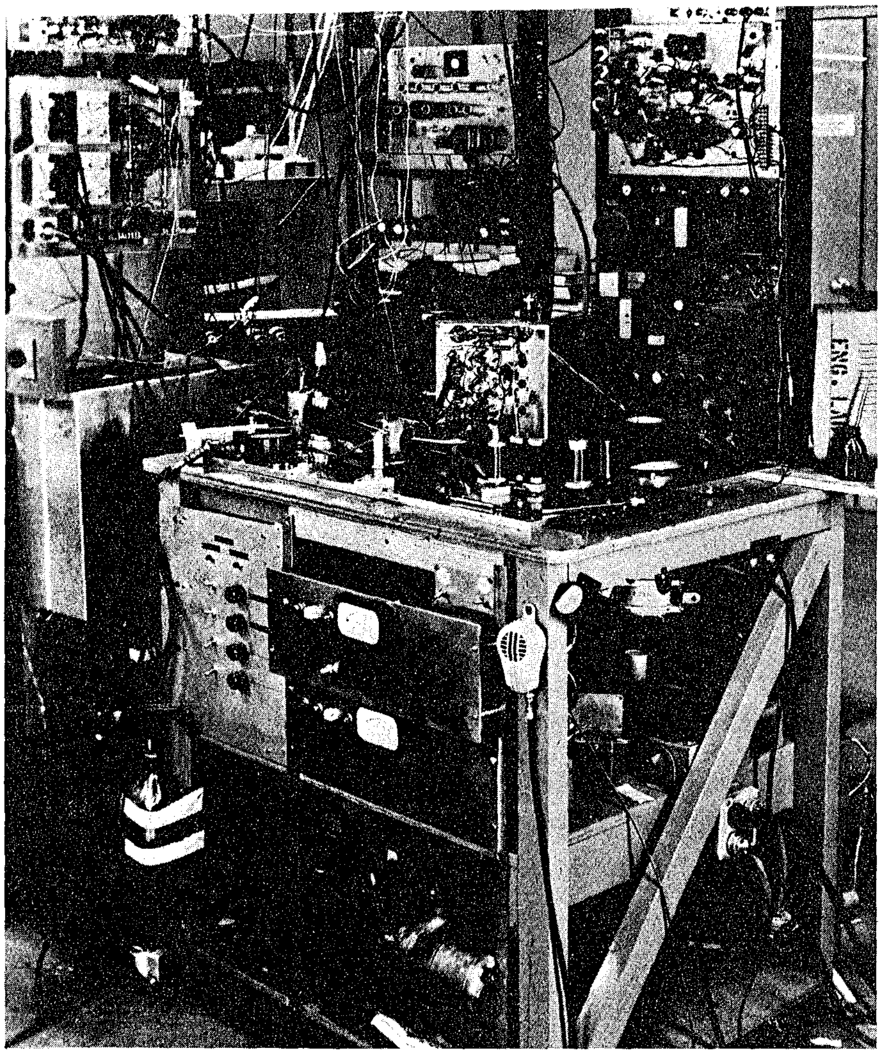


Figure 1 First working breadboard of a videotape recorder.

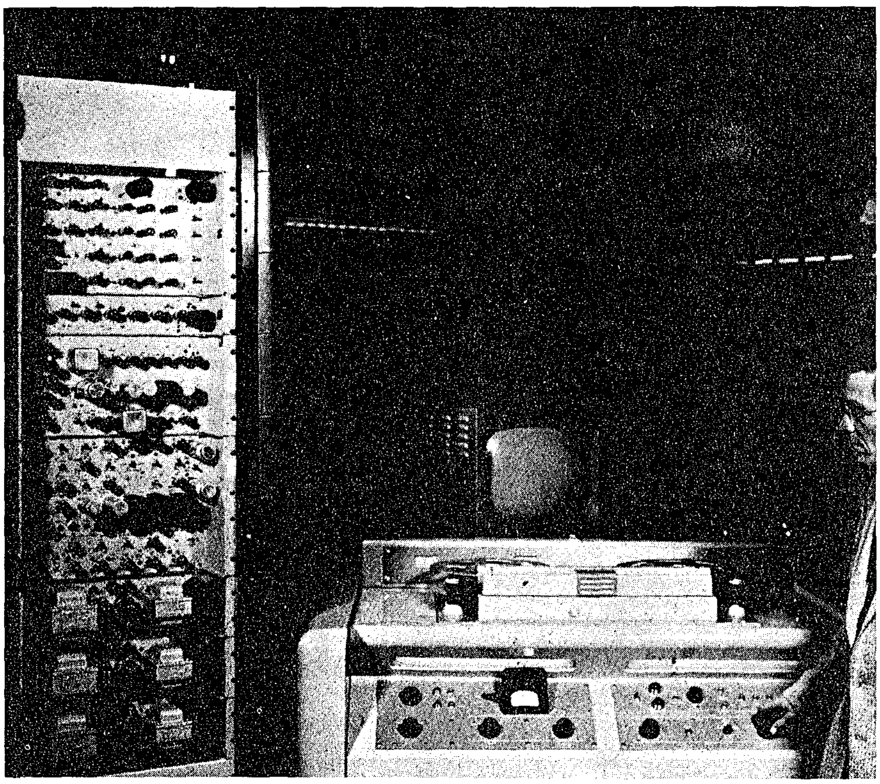


Figure 2 VR-1000, introduced in 1956.

Technology report:

The development of the Ampex AST System. An exclusive report on the development and technology behind the off-tape, broadcast quality, slow-motion, still-frame system.

By Mark Sanders, Ampex

When Ampex Corporation received an Emmy Award on September 8 from the Academy of Television Arts and Sciences for the development of the Automatic Scan Tracking (AST) System for helical scan videotape recorders, it marked the culmination of eight years of trials and triumphs that led to this remarkable device.

And, the result was certainly worth the effort; along with the digital time-base corrector, the AST System has been called the most significant breakthrough in recording technology since high-band recording was first introduced in the 1960s and ushered in the color television era.

Beginnings

It is often the case that a great idea is sparked by a bad problem, and AST is a prime example. To

__Sanders__ is general manager of the video recorders group, audio-video systems division at Ampex. He has been involved in the development and marketing of helical scan recorders for eight years.

understand this, the earliest days of the videotape recorder and the parallel paths of transverse (quadraplex) and helical scan recorder development must be examined.

The invention and introduction of the world's first commercial videotape recorder is a well-known story, and many readers will probably recognize this photograph of the first videotape recorder, from 1955 (Figure 1). This recorder led to the introduction in 1957 of the VR-1000 (Figure 2). What is not so well-known is that along with this transverse project, helical scan recorders were also in development. Figure 3 shows a variety of helical scan videotape recorders from early 1957 to 1960. Figure 4 is a close-up of an early slant track recorder, circa 1965.

Why two VTR programs?

The answer to this question is an argument which continues amongst VTR engineers to this day. Transverse (quad) recorders are complex and expensive, but very forgiving of many types of mechanical problems. Helical scan recorders are simpler, capable of certain *tricks* (like still framing), and potentially less expensive. Unfortunately, helical recorders inherently have two weaknesses which in the 1950s seemed insurmountable.

To understand these two problems, look at three well-known VTR formats: quad, ¾-inch U-standard and the Type A format shown in Figure 5. In all video recorders the tape is transported past a scanning head which traces a path as shown.

Predictably, in any real VTR there are imperfections in tape speed (longitudinal tape motion) and in tape guiding (vertical movement). In addition, tape slitting errors, weaving, etc., make contributions to imperfect tape motion.

In the case of quad, vertical

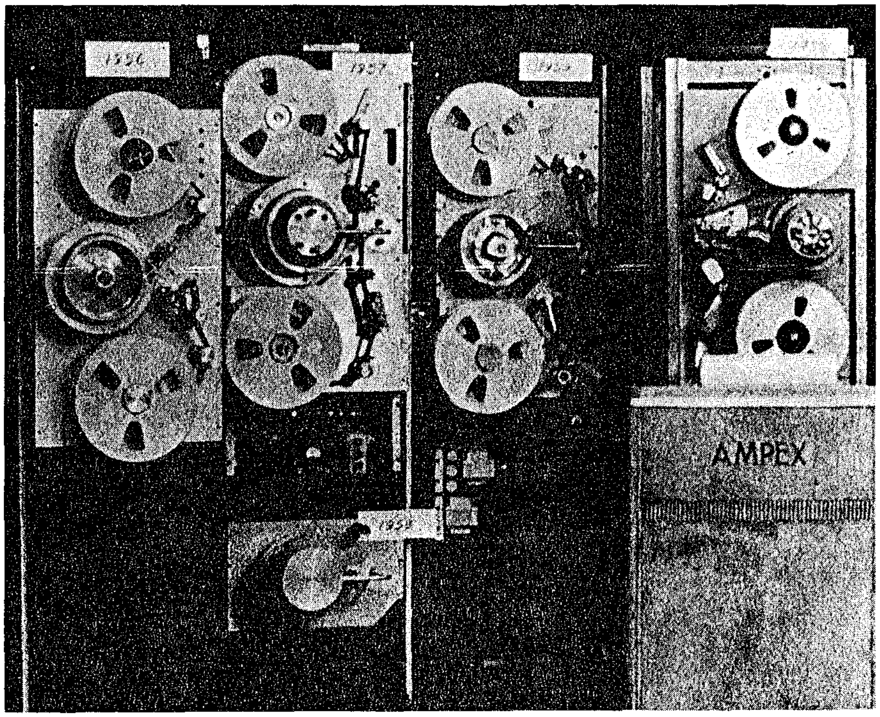


Figure 3 A variety of helical scan VTR breadboards, 1956 through 1960.

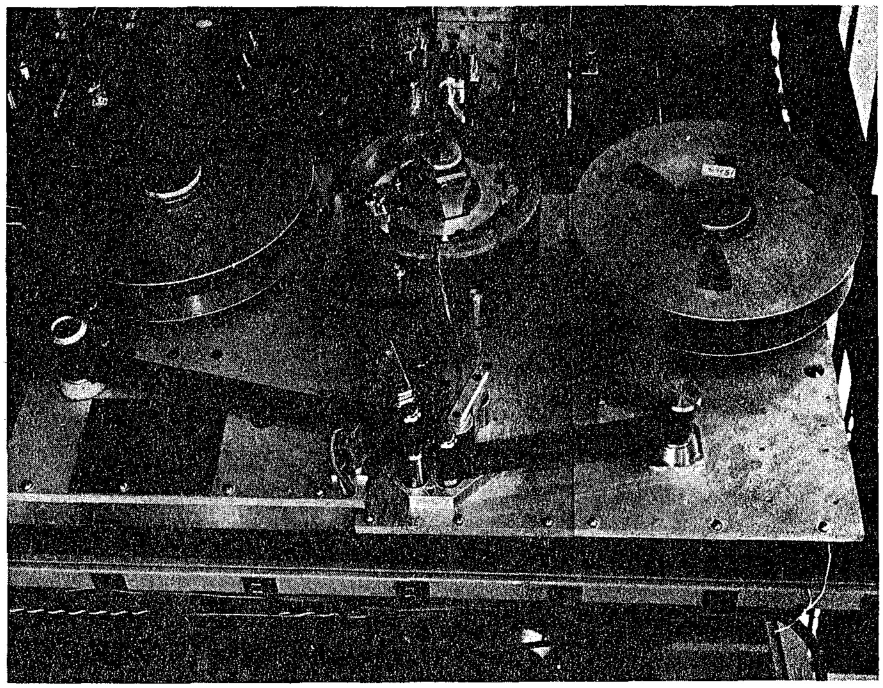


Figure 4 An early helical scan VTR, about 1965.

motion, which is relatively minute, has no effect other than small time-base errors, since it is in the same direction of the scanned track. Horizontal perturbations can cause some loss of signal as the playback head goes off track, but again this is a slight effect. Thus, quad is very forgiving of tracking and tape speed variations since the scan is *transverse* to tape direction. The helical format is the opposite. Vertical (tracking) errors can move the tape track off the playback head path, and longitudinal speed variations translate directly into gross time-base errors.

During the early development, it was obvious that a field per scan helical recorder would not suffer from annoying and hard-to-cure segmentation errors that are inherent in a quad recorder, but it was also obvious that tape handling, time-base errors and tracking were serious problems that would have to be overcome in the helical format.

During the evolution and after the introduction of quad in 1956, parallel work continued on the more subtle and complex helical problems. Ampex attempted to develop a professional quality quad replacement back in 1963, and the VR-8000 helical VTR (Figure 6) was the result. Several prototypes were built, but the basic helical problems had only been partially solved and the model was never manufactured.

Development turned to lower performance units that used lower writing speeds and were aimed at semi- or non-professional markets. Several manufacturers produced equipment in a variety of formats in the 14 years ending in 1976. Ampex alone produced more 26,000 units utilizing 1- and 2-inch wide tape. The last of three types was the VPR-7900A (Figure 7) introduced in 1973.

Knowledge slowly accumulated and by the mid 70s it was possible for Sony Corporation to introduce the highly successful and reliable U-matic helical recorder. The machine reliability and the interchangeability of recorded tapes was made possible by several things. The designers first aimed at modest performance values and thus a

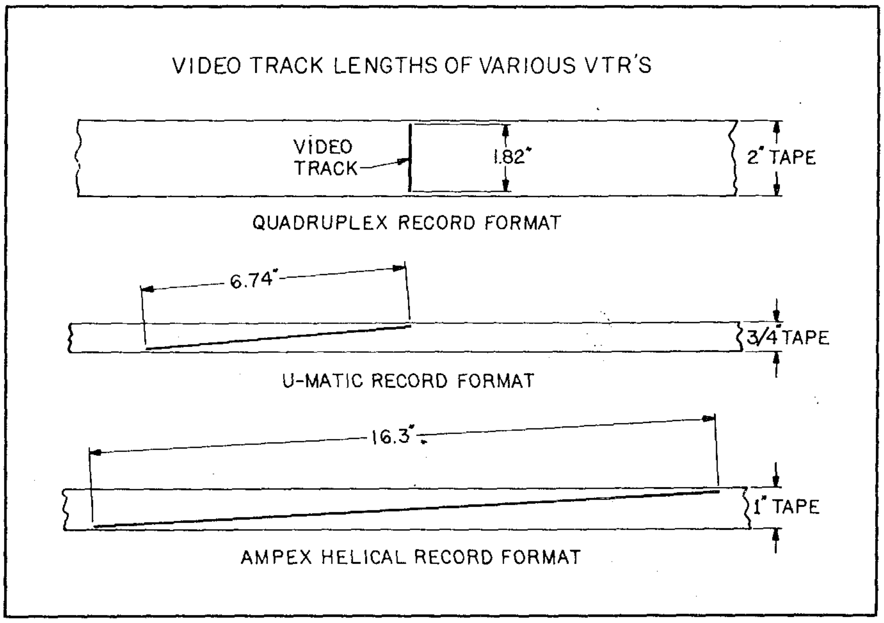


Figure 5 Comparative video track lengths of three well-known VTR formats.

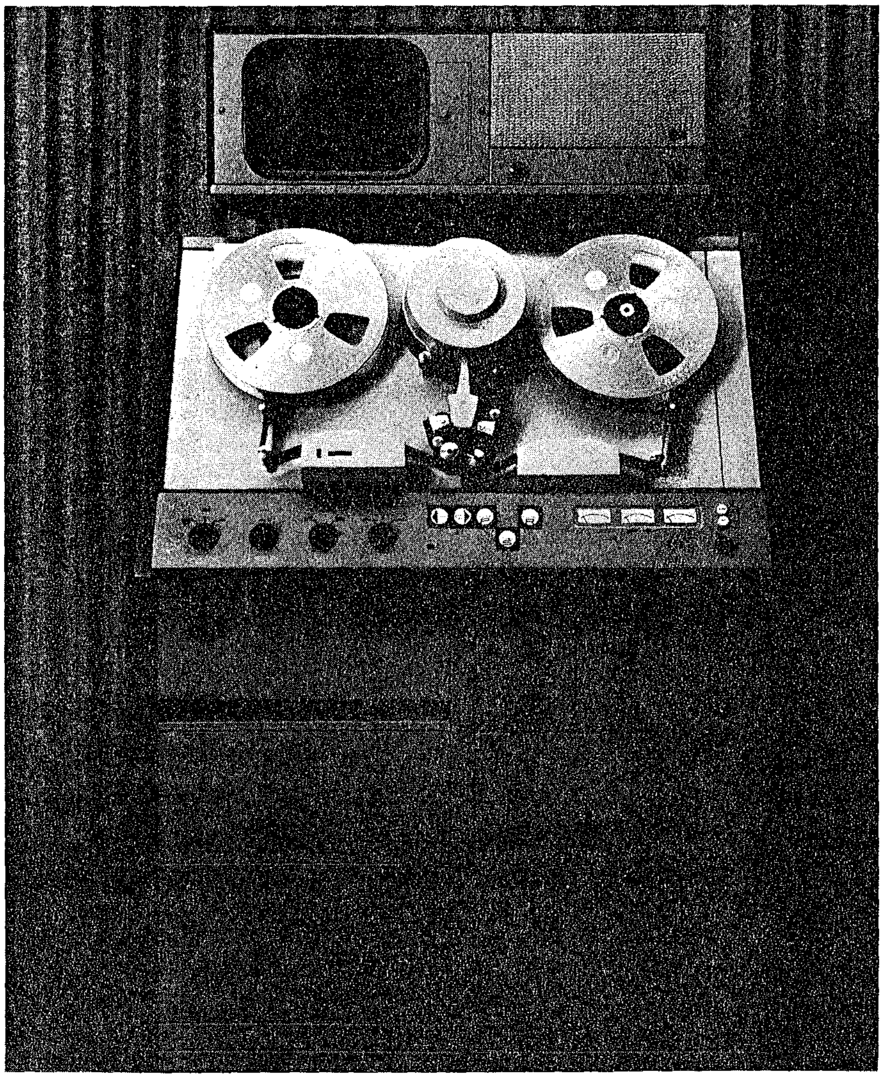


Figure 6 VR-8000, Ampex's first helical VTR.

Figure 7 The VPR-7900A.

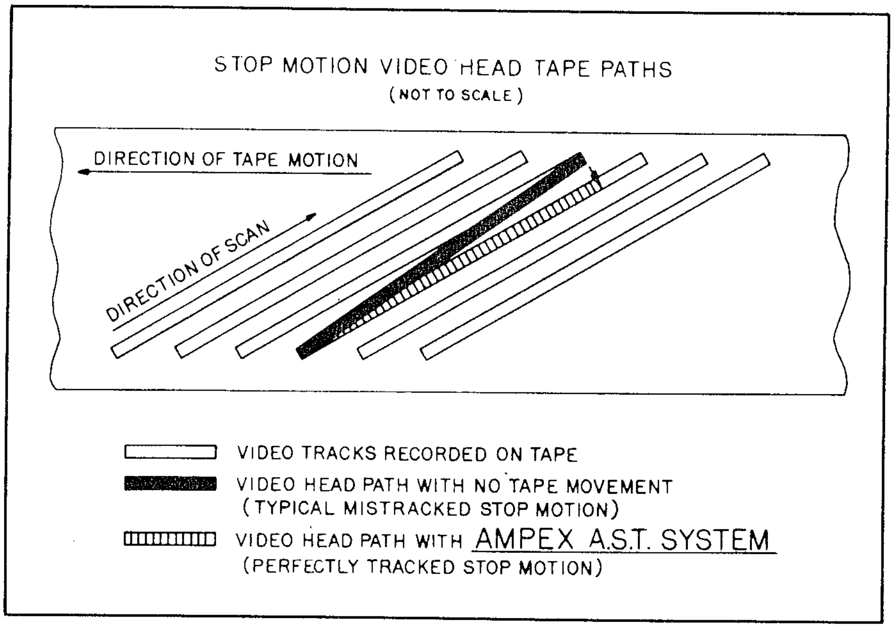


Figure 8 Type C helical recorder tape path.

lower writing speed. That meant a short video track length with its minimal tracking problems. Second, tape handling problems were well understood and solutions well engineered. Finally, precision where needed was achieved with precise factory tooling.

The result was a machine of modest performance that interchanged well and was reliable. Time-base errors were still large and color was achieved by an indirect method that produced a signal suitable for closed circuit use but that could not be broadcast.

At the same time in which the U-standard recorders were introduced, the digital time-base corrector with its ability to correct the very large errors generated by helical recorders was also developed.

At the other end of the helical spectrum were the high writing speed, field per scan (and thus long track) recorders conforming to the Ampex Type A format (VPR-7900). They were capable of high-band broadcast quality performance but required critical adjustments to maintain tracking.

At Ampex, two parallel programs were underway utilizing the A format. One was aimed at solving the tracking problem by applying the accumulated knowledge of 20 years to an all-new mechanical design to solve the problem directly. The other aimed at the development of an automatic tracking systems to correct tracking errors.

Both programs were successful and Ampex embarked on another program which corrected the tracking problem by design. But it became clear that the automatic scan tracking system, while not required for tracking errors, had potential far beyond this initial intent. Why couldn't it be used to provide full quality slow motion and still-frame viewing? At the time, the HS-100 instant replay type of disc recorder was the only system available for television slow or stop motion.

The technical challenge

Figure 8 shows the video tracks recorded on tape as it moves at 10 inches per second past a record head scanning at 1000 inches per second in the Type C helical recorders.

What happens if the tape stops in playback? Mistracking of the playback head occurs, as indicated by the black line. As this happens the head travels into the guardband and the classic helical *noise bar* appears in the picture. This is the flaw of an otherwise unique field-per-scan helical VTR capability. And it occurs at all speeds other than normal play.

How is the problem solved? The solution is to somehow keep the playback head on track at off speeds. Earlier the engineering team looked at electrically switching multiple heads, moving the tape guides or even moving scanner sections. In the end, the head deflection scheme turned out to be the only practical system. It moved the head itself up and down as it scanned the tape.

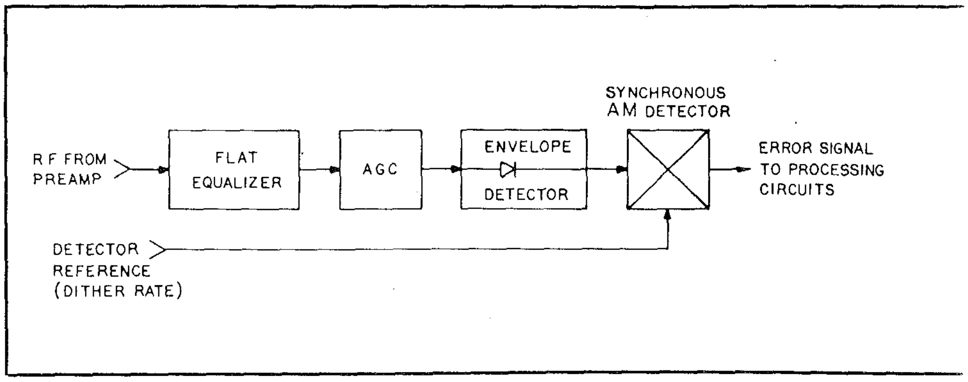


Figure 10 AST Servo error detector block diagram.

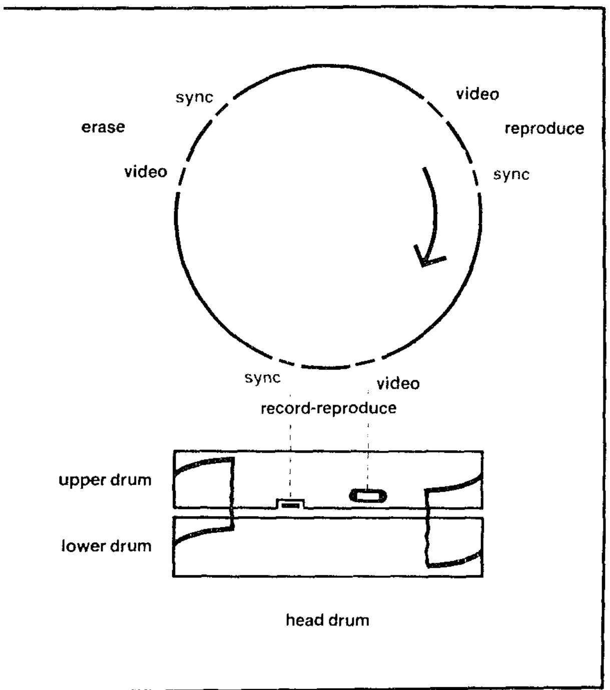


Figure 9 The Type C SMPTE format.

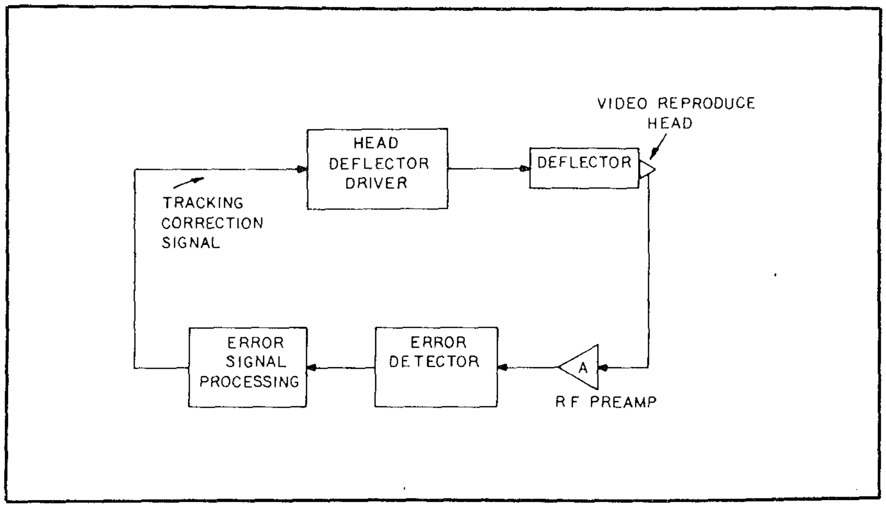


Figure 11 AST Servo system block diagram.

Sounds simple? Not quite. Keep in mind this is a dynamic environment with 1000 Gs of force on a tape track 5 mils wide and almost 17 inches long, and it must move without distortion. Figure 9 illustrates the Type C SMPTE format.

Two ways were considered to deflect the head vertically: Electromagnetically, and using piezoelectric schemes. The former requires an excessively high degree of precision and is too slow. The piezoelectric approach is practical, however.

The first AST-like device was built in 1973. It used a *bimorphic strip* and is graphically represented in Figure 12. The scheme appears simple. Apply a voltage and it will bend up or down, and with a head affixed to the strip, it can be made to describe a track different from normal. Unfortunately, that was only the first step toward a solution.

After life tests in the billions of cycles, the device seemed durable enough, and the big question was, how can it be made to follow the track? There were many predictive methods investigated, but it became clear that the tracking information must come from the recorded signal itself. The R.F. envelope of the video signal could be used to determine if the head was off track, but unfortunately it couldn't tell which direction.

The solution came by *dithering* the head up and down at a very high rate (450 Hz). By detecting both the amplitude and phase error of the AM signal, both error amplitude and direction could be determined without impairing the FM video.

The dither signal was about 10% of the total video signal recorded, and by careful limiting, any ill effects (AM side-bands in the FM carrier) were eliminated. Figure 10 illustrates the error detection system, and Figure 11 is a simple block diagram of an AST Servo System.

Now the engineers had a deflecting head and could make it follow a video track positively. Unfortunately, the bimorph deflectors vary greatly in sensitivity, and the short *retrace* time in Type A and C formats led to unacceptable ringing, a major obstacle. Figure 13 shows the Omega format of Type C recorders, and the narrow gap between the entrance and exit guide represent the interval in which the AST head must jump from the end of one track to the start of a new track. Dead rubber and other forms of damping were tried, but loss of sensitivity and lack of precision were serious shortcomings.

The solution to this problem and the next milestone took advantage of the bidirectional nature of the AST deflector. By splitting the deflector lengthwise (Figure 14) the main portion of the element could

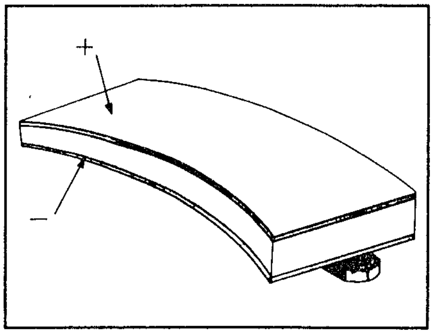


Figure 12 Representation of a simple bimorphic strip and head.

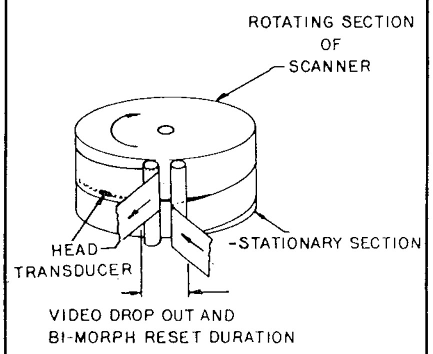


Figure 13 Scanner assembly, omega wrap.

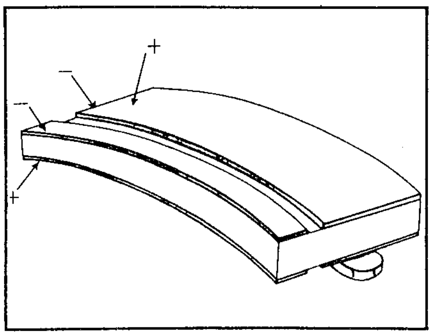


Figure 14 AST deflector with sense strip.

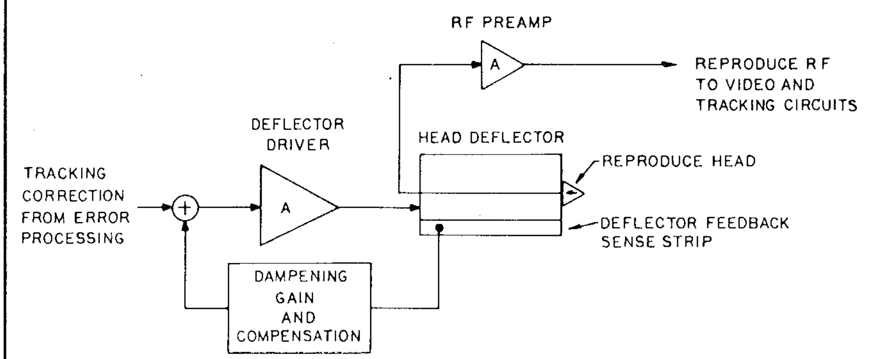


Figure 15 AST head deflector/damping system block diagram.

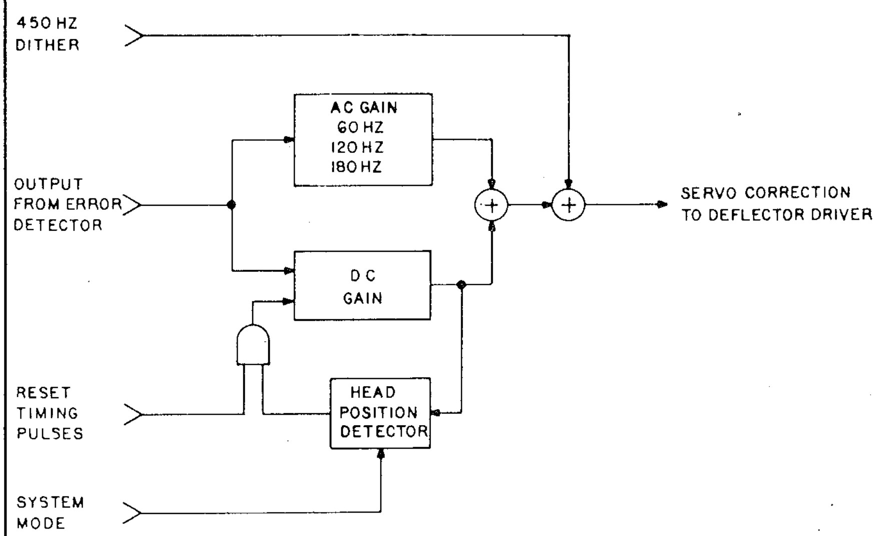


Figure 16 AST servo error signal processing block diagram.

be used to deflect the head, and the smaller portion used to send a signal back to the positioning servo. This signal told the system how far deflection had gone (sensitivity) and additionally provided a means for electrically damping. Figure 15 is the block diagram of this system.

The system still misbehaved. The piezoelectric element must first be electrically *polarized* to function, and in normal operation positive and negative voltages are used to deflect up and down. This can de-polarize the element. The solution came in a unique drive system which takes advantage of the sandwich construction of the bi-morphic strip, which is really two elements bonded to a conductive central electrode.

A separate deflection voltage of the proper polarity is used for each layer of the bi-morph. This insures that each section is never driven in the opposite direction of polarization.

The deflecting head itself is only a part of the system. AST utilizes servo techniques radically different from any which had been applied to recorders before, and in reality is three servos in one. The first is a static (dc) servo which takes care of elevation differences between record and reproduce heads. The second is

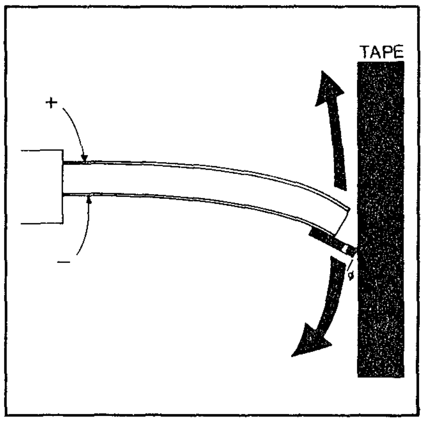


Figure 17 Fully deflected AST, indicating zenith angle error.

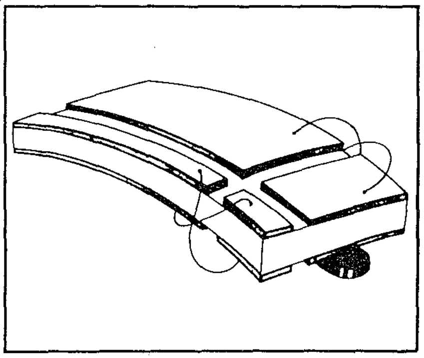


Figure 18 Articulated AST head.

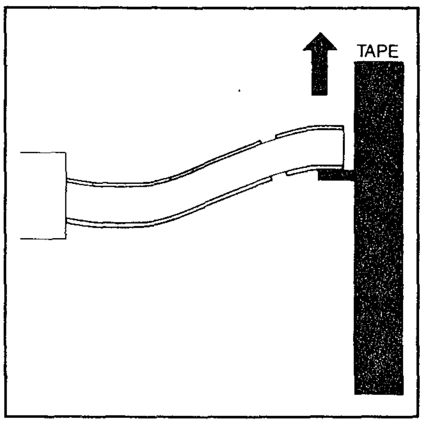


Figure 19 Up deflection.

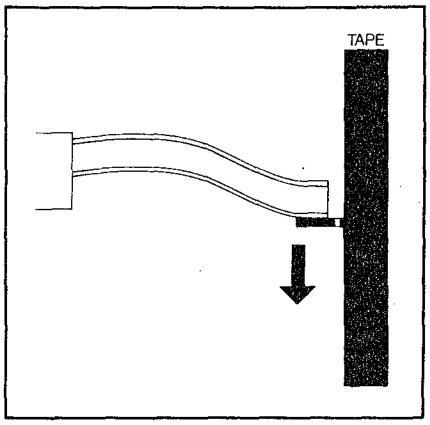


Figure 20 Down deflection.

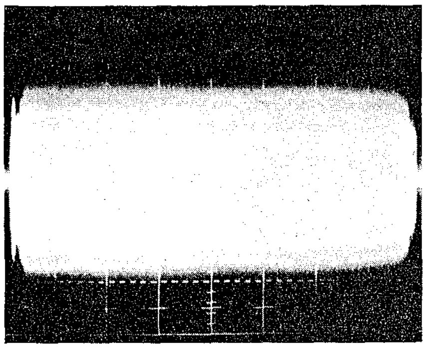


Figure 21 RF envelope of SMPTE Type C VTR at play speed. The square signal represents one field.

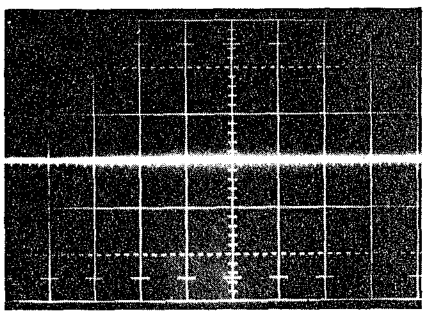


Figure 22 AST error signal of a *perfect* recording. This straight line is a representation of one scanned track (field).

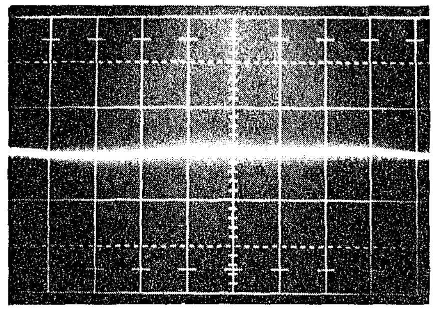


Figure 23 AST error signal for a "normal" recording. Note the slight deflection (amplified) indicating automatic tracking.

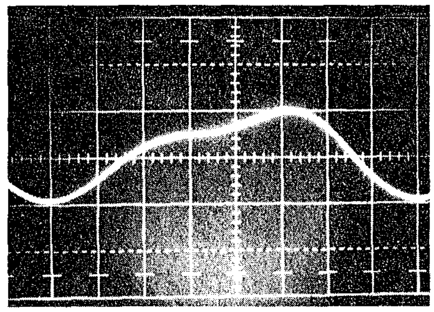


Figure 24 AST error signal for a severely damaged tape. Note the extreme deflection of the head to maintain tracking.

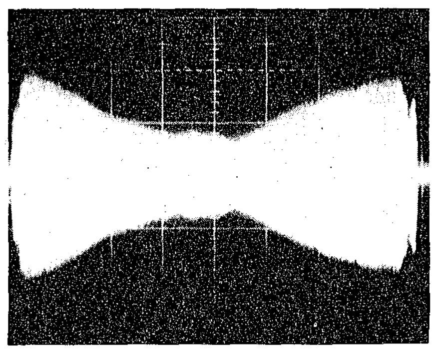


Figure 25 R.F. envelopes for slow motion condition without AST. Note the complete mistracking and loss of signal.

for dynamic (ac) correction, which actively follows the video track. The third is a scheme which electronically compares the actual head position to the next position. Logic then decides when it is time to leave one track and jump to the next, always in the vertical interval, when in the slow motion mode. Figure 16 illustrates this function.

This system locks onto the video signal, and for the first time makes a videotape recorder behave much like a Moviola film editor with perfect still frame, slow motion and automatic tracking.

There is a problem, however. As an AST element deflects to extremes in slow motion further away from play speed where it theoretically does no work, zenith errors appear. Figure 17 shows how the head begins to lose contact with the tape as it is deflected. This can limit reliable playback in slow motion modes.

The solution is elegant. As shown in Figure 18, by splitting the head cross-wise and electrically reversing it, it will articulate in an S curve as it deflects. This recurving always maintains perfect head-to-tape contact, as illustrated in Figures 19 and 20.

The result? A no-compromise slow motion recorder providing a

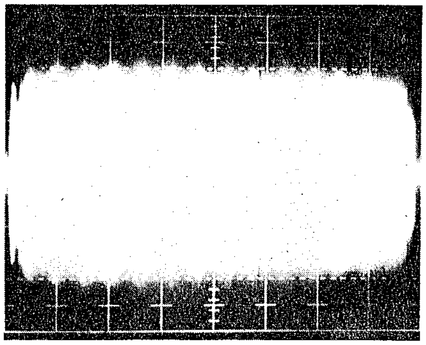


Figure 26 R.F. envelope for the same slow motion signal with AST on. Note the dither signal on the envelope.

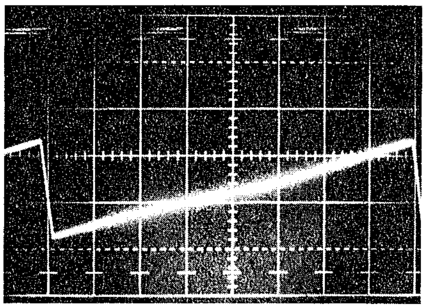


Figure 27 AST error signal for a VTR in still frame. This graphically shows the autotracking (long line) followed by the rapid jump to the start of the same track. This occurs during the vertical interval.

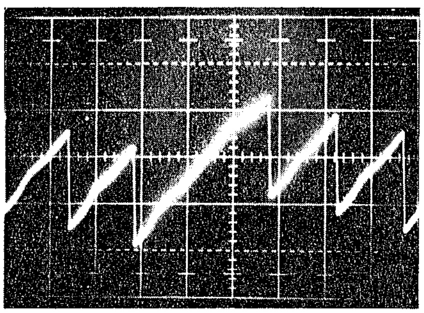


Figure 28 AST error signal for 1/5th speed slow motion. Note that one track is replayed five times before AST jumps to the next.

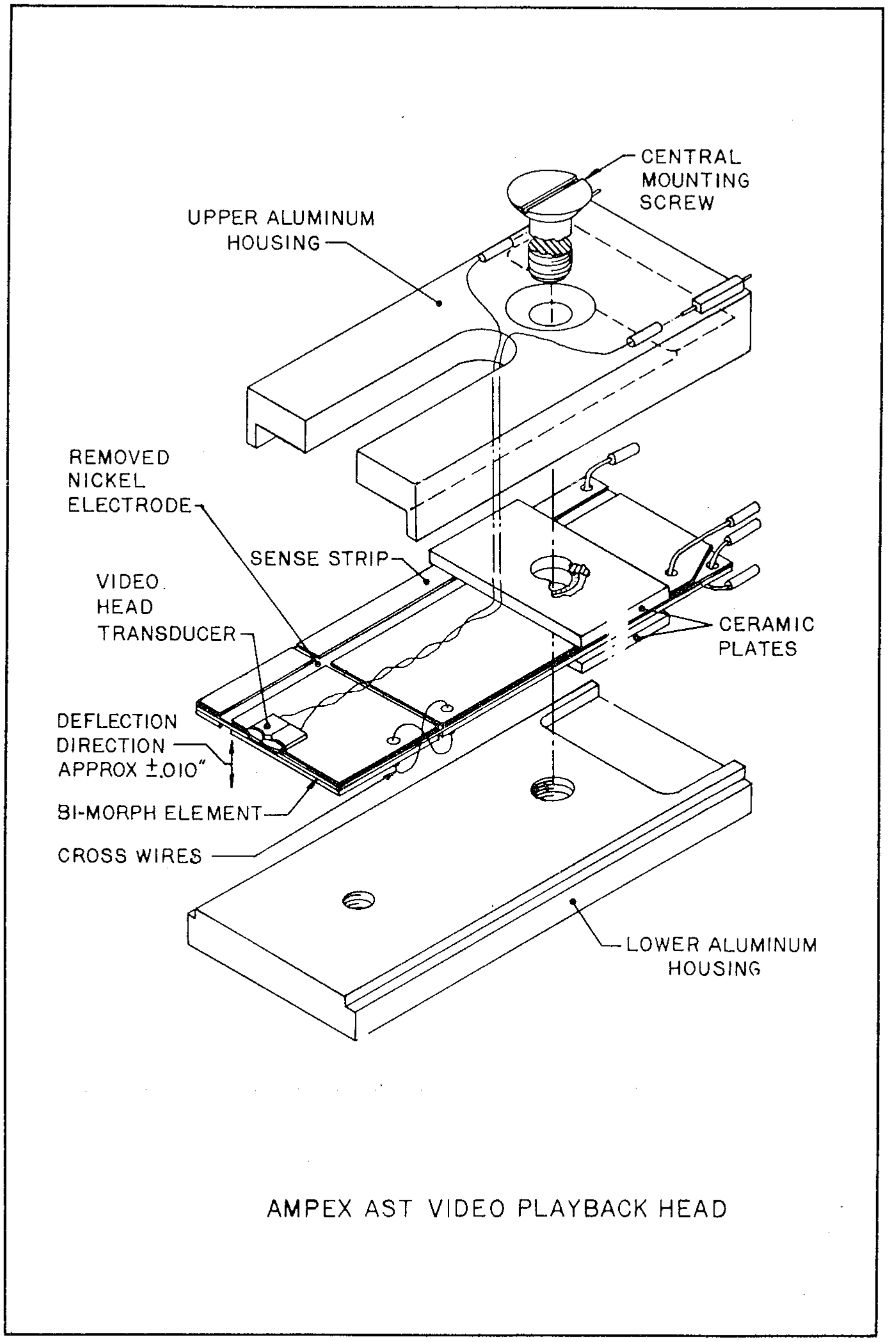


Figure 29 Exploded view of a current AST head.

truly continuous slow motion. Figures 21 through 28 illustrate the device. Figure 29 is an exploded view of the head.

The AST system in the Ampex VPR-2 is now in use by all major US networks and many others worldwide for both sports and production applications.

The system yields broadcast quality slow motion, still framing, automatic tracking and video confidence (simultaneous full quality playback with record). These capabilities not only add new dimensions to televised sports, but capture the artistic editing ease of film while retaining the advantages of videotape.

The AST technology is now being applied to computer discs and consumer VTRs and represent a major innovation to these disciplines as well. □

Footnote—*The two key engineers in the development of AST were Dick Hathaway and Ray Ravizza, senior staff engineers at Ampex Corp., working under the direction of Don MacLeod, engineering section manager at the time. In addition to the recent Emmy from the Academy of Television Arts and Sciences, Hathaway received the Alexander M. Poniatoff Award, Ampex's highest technical honor, in 1976. The project team was also awarded the prestigious Royal Television Society's Geoffry Parr Award earlier this year.*

FAX 12/8/93
To: Peter Hammar
From Hal Layer
Subject Layer Magnetic Recording Collection

The following items are not at Ampex:

Brush Soundmirror BK-401 Tape Recorder	Gd.	1946
FBI Spy minirecorder, spec. cart., stereo	Ex.	c.1970
Brush Office Mag. Disc. recorder	Gd	1947
Mohawk Message Repeater loop rec.	Gd.	1956
Magnecord PT-6A recorder	VG	1948
Magnecord Amps. PT6-J & PT6-J	VG	1948

The following items are at Ampex:

CAT	DESCRIPTION (MAKER, MODEL, ETC)	Cd	AGE
DR	Masco audio vinyl disc recorder, Model RK-6	Ex	1948
TR	Amer. Videonetics prototype tape transport	Ex	1970
	Amplicorp "Magnemite" wind-up rec., Model 610B, #5566	VG	1955
	Broad. Equip. Spec., "Tapak Duplex" wind-up portable	Ex	1955
	DeJur Grundig, Model "Versatile III", #460583, w/cart.	Ex	1965
	Edison, Model "Ediphone" cyl. shaver, Serial 110-S-38969	Ex	1925
	Ficord pocket rec., Model 101-S, Serial 23178, w/spools	Ex	1965
	IBM, Model 224, pocket dictation rec., (magnetic belt)	Ex	1970
	MGM mag-film rec/preamp in 2 wooden cases, #2, #4229	Ex	1953
	Miles, Model "Walkie-Recordall", (plastic belt recorder)	VG	1956
	Minifon, audiotape rec, Serial #230310, (no reels)	Ex	1955
	MMM (3M), audio cart-loop rec., Model 94AG, #002970A	Ex	1970
	Mohawk, Model "Message Repeater", Ser. #4749, w/2 cart.	Gd	1956
	Mohawk, Model 400 "Migetape Chief", Ser. 21211 w/cart.	Ex	1965
	Muntz 4/8-track auto rec., Model M60-69, Ser. 224588	Gd	1965
	Norelco, Model "Carrycorder", #321286, w/orig. cassettes	Ex	1965
	Presto, Model R-27, Ser. #104, (transport only in case)	Gd	1955
	RCA spec. audio cart. rec., Model 1YB-11, #017850	Ex	1960
	Sony audiotape recorder (early imported model)	Ex	1963
	Webster-Chicago audio mag. disc rec., #2-3003, w/disc	VG	1947
	Westinghouse pocket rec., Model H29R1, #361578, w/cart	Ex	1968
VCR	Ampex VCR, VR-1000 chassis, Serial #50146-1	Ex	1956
	Ampex VCR, VR-1000 chassis, Serial #50151-1	Ex	1956
	MVR mag. disc rec., Model VDR-210CF-1, #194, w/disc	Ex	1965
	Panasonic b&w portable rec., Model NV-3080, Ser. A1324	Ex	1968
	Roberts Akai 1/4" b&w, Model 1000, Serial E7037-0088	Ex	1972
	Sony b&w, Model CV-2000D, Serial #10771	Ex	1970
	Sony b&w, Model VO-1000, Serial #22924	Ex	1965
	Sony b&w portable, Model DV-2400, Ser. #8189, w/case	Ex	1968
WR	Air King, Model IC/VRW (US Navy) w/spools, Serial #116	Gd	1950
	Armour, Model 50 w/spools & microphone, Serial #628	Ex	1943
	Brush, KS-12009, Serial #333 (magazine w/spools only)	Gd	1943
	Brush, Model BK-303, w/spools (prototype in alum. case)	Fr	1946
	Crescent, Model R-24 "Recordit", Serial #2121	Ex	1952
	Crescent, Model R-25 "Steno", Serial #8542, w/spool	Ex	1950
	Dailygraph transport w/magazine, #627933, Ser.#1591	Ex	1928
	Dicta-Wire, Model A, Serial #428, w/cassette	Ex	1947
	Electronic Secretary, w/spools	Ex	1951
	Farnsworth, Model P-601 X-1, w/spools (=BK-201), #321	Fr	1947
WR	Frederick Hart, RD-11B/GNQ-1, w/mag., Ser. #C363	Ex	1944
	Frederick Hart, RD-15A/ANQ-1A w/mag & control, #A378	Ex	1944
	General Electric, Model 50, w/spools, no case, Serial 52	Ex	1943
	Magnecorder, Model SD-1F2, Serial 194	Ex	1946
	MCA, Model "Dictascriber", Ser # 5030, w/4 spools, mike	Gd	1947
	Minifon, (original model), #18306, w/spools, mike, phone	Ex	1953
	[illegible]	Ex	1955

CAT	DESCRIPTION (MAKER, MODEL, ETC)	Cd	AGE
DR	Masco audio vinyl disc recorder, Model RK-6	Ex	1948
TR	Amer. Videonetics prototype tape transport	Ex	1970
	Amplicorp "Magnemite" wind-up rec., Model 610B, #5566	VG	1955
	Broad. Equip. Spec., "Tapak Duplex" wind-up portable	Ex	1955
	DeJur Grundig, Model "Versatile III", #460583, w/cart.	Ex	1965
	Edison, Model "Ediphone" cyl. shaver, Serial 110-S-38969	Ex	1925
	Ficord pocket rec., Model 101-S, Serial 23178, w/spools	Ex	1965
	IBM, Model 224, pocket dictation rec., (magnetic belt)	Ex	1970
	MGM mag-film rec/preamp in 2 wooden cases, #2, #4229	Ex	1953
	Miles, Model "Walkie-Recordall", (plastic belt recorder)	VG	1956
	Minifon, audiotape rec, Serial #230310, (no reels)	Ex	1955
	MMM (3M), audio cart-loop rec., Model 94AG, #002970A	Ex	1970
	Mohawk, Model "Message Repeater", Ser. #4749, w/2 cart.	Gd	1956
	Mohawk, Model 400 "Migetape Chief", Ser. 21211 w/cart.	Ex	1965
	Muntz 4/8-track auto rec., Model M60-69, Ser. 224588	Gd	1965
	Norelco, Model "Carrycorder", #321286, w/orig. cassettes	Ex	1965
	Presto, Model R-27, Ser. #104, (transport only in case)	Gd	1955
	RCA spec. audio cart. rec., Model 1YB-11, #017850	Ex	1960
	Sony audiotape recorder (early imported model)	Ex	1963
	Webster-Chicago audio mag. disc rec., #2-3003, w/disc	VG	1947
	Westinghouse pocket rec., Model H29R1, #361578, w/cart	Ex	1968
VCR	Ampex VCR, VR-1000 chassis, Serial #50146-1	Ex	1956
	Ampex VCR, VR-1000 chassis, Serial #50151-1	Ex	1956
	MVR mag. disc rec., Model VDR-210CF-1, #194, w/disc	Ex	1965
	Panasonic b&w portable rec., Model NV-3080, Ser. A1324	Ex	1968
	Roberts Akai 1/4" b&w, Model 1000, Serial E7037-0088	Ex	1972
	Sony b&w, Model CV-2000D, Serial #10771	Ex	1970
	Sony b&w, Model VO-1000, Serial #22924	Ex	1965
	Sony b&w portable, Model DV-2400, Ser. #8189, w/case	Ex	1968
WR	Air King, Model IC/VRW (US Navy) w/spools, Serial #116	Gd	1950
	Armour, Model 50 w/spools & microphone, Serial #628	Ex	1943
	Brush, KS-12009, Serial #333 (magazine w/spools only)	Gd	1943
	Brush, Model BK-303, w/spools (prototype in alum. case)	Fr	1946
	Crescent, Model R-24 "Recordit", Serial #2121	Ex	1952
	Crescent, Model R-25 "Steno", Serial #8542, w/spool	Ex	1950
	Dailygraph transport w/magazine, #627933, Ser.#1591	Ex	1928
	Dicta-Wire, Model A, Serial #428, w/cassette	Ex	1947
	Electronic Secretary, w/spools	Ex	1951
	Farnsworth, Model P-601 X-1, w/spools (=BK-201), #321	Fr	1947
WR	Frederick Hart, RD-11B/GNQ-1, w/mag., Ser. #C363	Ex	1944
	Frederick Hart, RD-15A/ANQ-1A w/mag. & control,#A378	Ex	1944
	General Electric, Model 50, w/spools, no case, Serial 52	Ex	1943
	Magnecorder, Model SD-1F2, Serial 194	Ex	1946
	MCA, Model "Dictascriber", Ser. # 5030, w/4 spools, mike	Gd	1947
	Minifon, (original model), #18306, w/spools, mike, phone	Ex	1953
	Minifon, Model "Special", Serial #185027, w/spools	Ex	1955
	Minifon, Model P-55, w/spools, mike, phone	Ex	1955
	Peirce, Model 260, Serial 10122, w/cartridge, mike	Vg	1950
	Peirce, Model 55B, Serial #2004, w/spools	Vg	1946
	Peirce, Model RD107/GNQ-14, Serial #93, w/cartridge	Ex	1950
	Pentron, Model 748 "Astrosonic", Ser. #7240, w/spools	Ex	1949
	Radio-Technic, Model 13-A-3C, Ser. #494	Ex	1945
	Radio-Technic, Model 13-A-3C, Serial #494	Ex	1950
	Radio-Technic, Model 20-N-DS	Gd	1945
	RCA, Model 12775, (Black plastic case), (no cartridge)	Ex	1947
	Record-O-Phone telegraphone, #680 w/spools, wood case	Ex	1923
	Silvertone, Model 101.773.1 w/timer clock	Ex	1947
	Silvertone, Model 8085, w/spools & mike, Ser. #446152	VG	1947
	Telemaster, w/spools & small 78rpm message record	Ex	1950
	Webster-Chicago, Model 180-1, Ser. #134858, w/spools	Ex	1949
	Webster-Chicago, Model 181-1R, w/spools, brown case	Ex	1950
	Webster-Chicago, Model 228-1 w/mike, Serial #0418471	Gd	1951
	Webster-Chicago, Model 228-1, Serial #844, w/spools	VG	1951
	Webster-Chicago, Model 78-1, w/spools, grey case	Ex	1947
	Webster-Chicago, Model 80-1, w/spools, Serial #39899	Ex	1947
WRA	AS&W large spool of recording wire	Ex	1949
	Shure, Model 812, mag wire head in original box	Ex	1949
XRA	Cartivision "Auto Racing" videotape in printed box	Ex	1970
	Fidelipac "Chamber Bros." 4-track tape cartridge	VG	1965
	Frederick Hart, RD magazine, MX303A/ANQ-1	Ex	1944
	Frederick Hart, RD magazine, MX303A/ANQ-1, Serial 1881	Ex	1944
	Frederick Hart, RD magazine, MX303A/ANQ-1, Serial A378	Ex	1944
	Frederick Hart, RD magazine, MX303A/ANQ-1, Serial 833	Ex	1944
	Protone-Minifon large tape cartridge in case	Ex	1965

LAYER COMPUTER & COMPUTER/RELATED COLLECTION __rev.10/1/93

computers

1956 Heath Electronic Analog Computer kit (front panel only), (Heath)($945)
1964 EAI analog computer, Model TR-20 (EAI) ($10,000)
1971 Compumedic analog computer, (Compumedic)
1972 GRI Minicomputer, Model 99/IIB (GRI) ($5000)
1973 Intel Intellec-8 microcomputer, CPU: 8008, (Intel) ($2398)
1974 Intel Intellec-4-40 microcomputer, CPU: 4040, (Intel) ($2398)
1974 Scelbi-8H Mini-Computer, CPU: 8008, (Scelbi) (kit: $580)
1974 IMP-16P. microcomputer (front panel only), CPU: IMP-16, (Natl Semiconductor)
1975 HP 3000, Series II, minicomputer (front panel only), (Hewett Packard)
1975 IBM 5100 Portable Computer , CPU: IBM IC module, (IBM)($20,000)
1975 Altair 8800 microcomputer, CPU: 8080, (MITS)(kit: $439; assembled: $621)
1975 Sphere-1 microcomputer, CPU: 6800, (Sphere)(kit: $860; assembled: $1400)
1976 Altair 680b microcomputer, CPU: 6800, (MITS)(kit: $425; assb: $610)
1976 IMSAI 8080 microcomputer, CPU: 8080A, (IMS Assoc.) ($931)
1976 Sol Terminal Computer--20, CPU: 8080A, (Processor Tech) ($1850)
1976 SC/MP Development Sys., singleboard, CPU: SC/MP, (Natl Semicond.) ($499)
1976 Intel 80/10 singleboard microcomputer, CPU: 8080, (Intel) ($295)
1976 Intercept, Jr. singleboard microcomputer, CPU: IM6100, (Intersil) ($250)
c.1976 Z-80 Starter Kit singlebrd microcomp, CPU: Z80, (SD Sys, Micro Design) ($365)
1977 Byt-8 microcomputer (front panel only,, CPU: 8080A, (Byte Inc.) ($539)
1977 Byte 8080 microcomputer, CPU: 8080A, (Byte Inc.) ($539)
1977 COSMAC VIP singleboard microcomputer, CPU: 1802, (RCA) ($250)
1977 E&L MMD-1 singlebrd microcomp, CPU: 8080, with BUG Books, (E&L) ($500)
1977 Apple II, Model "0," with "Language Card", CPU: 6502, (Apple)($1600)
1977 Home-brew one-bit microcomputer, CPU: MC-14500B
c.1978 Am-2900 Microcomputer (singleboard), CPU: 2901, (Adv. Micro Devices) ($975?)
c.1978 Microcomputer-in-a-Suitcase Trainer, CPU: NEC8255, (Integrated Comp. Sys.)
c.1978 IASIS Computer-in-a-Book, (singleboard), CPU: 8080, (IASIS)($530)
1978 SPARK-16 microcomputer w/cassette recorder, CPU: 9440, (Fairchild)
1978 Instructor-50 microcomputer, CPU: 2850 (Signetics) ($350)
1978 SYM-1 microcomputer, (singleboard), CPU: 6502, (Synertek) ($239)
c.1979 Microcomputer/Terminal (?), Model ESAT-200B, CPU:1802 (ElectroLabs)
1980 Sinclair Z80 microcomputer, CPU: Z80, (Sinclair) ($200)
1981 Osborne Model 1 portable microcomputer, CPU: Z80A, (Osborne)($1795)
1981 Z8 Basic/Micro Computer (single-board), CPU: Z8, (Micro Mint)($195)
1982 Timex Model 1000 microcomputer (Sinclair ZX81 design) ($200)
1983 TRS-80, Model 100, portable microcomputer, CPU: 80C85, (Tandy) ($799)
1983 Sinclair 1500 microcomputer, CPU: Z80A, (Sinclair) ($200?)
1984 Apple IIC microcomputer, CPU: 65C02, (Apple) ($1295)

calculators

1890 Burroughs Adding and Listing Machine ($300)
c.1900 Britannic calculator No. 2120 (Guy's Calc. Machine)
c.1910 Felts & Tarrant Comptometer
c.1920 "The Calc. Corp.-Michigan," (The Calculator Corporation)
c.1920 Addometer (Reliable Type Co.)
c.1930 Ve-Po-Ad pocket adding machine
c.1938 Addititor Arithma
c.1940 Gem Adding Machine
c.1948 Michigan (The Calculator Company)
1950 Monroe LA-5 High-Speed Adding Calculator
1951 Facit NTK calculator
1964 Friden 132 Electronic Calculator ($1950)
1965 Monroe IQ-213 Comptometer ($1085)
c.1965 Micro-Tally (Technidyne)
c.1965 Speedee Add-A-Matic
1968 Wang Calculator System ($3800)
c.1969 Olivetti Divisumma-18
1972 Hewlett-Packard HP-35 handheld calculator ($395)
1972 Sanyo ICC-82D Handheld calculator ($350)
c.1972 Pocketsize microchip calculator kit, board marked: "GDM CT 5005" (unknown mfg.)
c.1973 Casio Root-8
c.1973 Interton VIP-10 pocket calculator
c.1973 Summit KO8 calculator
1973 Electronic Slide Rule, SR-10 (Texas Instruments)
1973 Electronic Slide Rule, SR-11 (Texas Instruments) ($120)
1973 Royal Digit III calculator
c.1974 Royal Digit IV calculator
c.1974 Commodore "Rechargable Electronic Calculator," Model GL-986R
1975 Hewlett-Packard 9815A desktop calculator ($2900)
c.1975 Novus 842 pocket calculator (Nat'l. Semiconductor)
c.1980 Sharp PC-1250 pocket computer/calculator
1982 Sharp PC-1500 pocket computer

video game systems & computer-related toys

1960 Think-A-Tron "Electronic Q&A Computer" toy with punched cards (Hasbro)
1972 Odyssey [first home video game] (Magnavox) ($150)
1975 Pong video game, Model C-100 (Atari)
1975 Odyssey 100 video game (Magnavox) ($60)
1975 Odyssey 200 video game (Magnavox) ($80)
1975 TV Tennis toy [mechanical version of Pong game], (Marx)
1976 Adversary 370 (Natl. Semiconductor) ($99)
1976 Ricochet video game (Microelectric Systems) ($120)
1976 DIGITEK 2001 (Digitek Electronics)
1976 Tournament-2000 TV game (Unisonic) ($120)
1976 Channel F Video Entertainment Sysem, CPU: F8 (Fairchild) ($170)
1976 Super Pong 8000 (Visulex) ($168)
1976 Wonder Wizard 7702 (General Home)
1977 APF "M1000 Microprocessor" ($125)
1977 Atari PONG video game ($99)
1977 Atari VIDEO PINBALL video game ($80)
1977 Brain Game, Model C-700 [prototype of VCS model?] (Atari)
1977 Video Pinball C-380 (Atari) ($80)
1977 Bally Professional Arcade Computer System, CPU: Z80 ($300)
1977 Telstar Ranger, Model 6046 (Coleco) ($50)
1977 Telecourt TV game (Hometronics)
1977 Studio II Home TV Programmer game/console, CPU: 1802 (RCA) ($150)
1977 Sands 2200 game
1978 Atari VCS cartridge video game, Model CX2600 (Atari) ($200)
1978 Imagination Mach. [game/comp w/keybrd, disk & cas.] CPU: 6800 (APF) ($599)
1978 HIT AND MISSILE game (Tomy) ($20)
1978 BLIP-the Digital Game, [all mechanical] (Tomy) ($12)
c.1978 Tomy Computer toy, [all mechanical "computer terminal" w/keyboard]
c.1978 RAMI, The Binary Teacher toy
1979 Intellivision cartridge video game (Mattel) ($250)
1979 Merlin, The Electronic Wizard ($30)
1983 Vectrex vector-scan videogame, with Vectrex cartridges & 3-D helmet ($200)

mscl

1948-90 Library of computer literature, manuals, pamphlets, etc.
1966 Lockheed mechanical digital timer (USAF)
c.1970 Dektak Inspection/Scriber machine [with microscope for IC Wafers]
1970 Comp-U-Kit 10 (Sci. Measure., Skokie, IL) ($57)
1971 Pulsar LED digital watch (Hamilton) ($900)
1972 Desk-top IBM card reader, Model D-150 (Documentation, Inc.)
1973 Pop Electronics Digital Logic Microlab (SWTPC)
1974 CPU board with 4004 (Pro-Log Co.)
c.1975 Intel System Interface & Control Module MCB 8-10
1975 Microsoft black paper-tape programs, BASIC, etc.
c.1976 Processor Technology paper-tape programs, games, etc.
1975 Paper-tape readers, mscl.
c.1978 Intel keyboard, Model MDS-CRT
c.1978 Pro-Log 80 (tester of 8080 CPUs)

Written By Peter May/June 1982

Remembering Harold Lindsay

Ampex is indebted to audio pioneer Harold Lindsay.

It was Lindsay's work as project engineer and chief designer of Ampex's Model 200 magnetic audio tape recorder, the first professionally acceptable machine of its genre, that helped establish Ampex as a high technology company. And it was Lindsay's inimitable personal style and dedication to a variety of interests that brought the company further acclaim as an associated participant in the communities Lindsay served.

Harold Lindsay — doer, believer, inventor extraordinaire — died April 1 in his Los Altos Hills, California, home. He was 72.

The memorial service held April 3 in his honor did more than offer eulogies. It also illustrated yet another of Lindsay's living legacies.

Through the church's sound system specially designed and installed by Lindsay himself, company employees Fred Pfost and Don Ososke and Ampex museum curator Peter Hammar respectively recited a poem, sang a prayer and reminisced about Lindsay the man. The Menlo Park (California) Presbyterian Church's fine acoustics were simply one more testimony to a lifetime of achievements.

When Lindsay became a full-time company employee in December 1946, he played a major role in turning Ampex, then a small subcontractor of electric motors, into a major high technology company.

He was lured to the firm by Alexander M. Poniatoff, the founder of Ampex, to help develop a professional audio recorder. Lindsay

HAROLD W. LINDSAY
1909-1982

became project engineer and chief designer of the Ampex Model 200, the first professionally acceptable magnetic tape recorder ever produced.

The Model 200 was demonstrated in October 1947. The ABC Radio Network's subsequent purchase of the first 20 production units marked the beginning of the regular use of tape by U.S. radio networks. By April 1948, the recorder was being used nationally to broadcast the Bing Crosby show.

The Model 200 established Ampex as the leader in audio recording technology. While the firm is best known for its development of the first videotape recorder, Ampex has continued to be a leading producer of audio recorders for the radio, television and recording industries.

Following the success of the Model 200, Lindsay directed the development of later generations of Ampex audio recorders, and set-up the first quality control and industrial design departments at Ampex. During his involvement in the latter project, Lindsay developed the industrial design for the VR-1000, the first videotape recorder introduced by Ampex in 1956.

Lindsay then spent 5½ years as technical assistant to Alexander Poniatoff, and later became corporate consultant on audio technology in the advanced research and technology department.

He was named manager of the audio engineering department in 1965, and left that post in 1969 to become a corporate consultant.

After a 30-year association with the company, Lindsay retired from Ampex in 1977, but he continued to consult for the company on various audio and magnetic tape projects. He also served as a guest speaker for employee orientations and most recently assisted in the design of the new Ampex Museum of Magnetic Recording.

A native of San Diego, Lindsay studied at the University of California at Berkeley and held engineering positions at Shell Development Company, Litton Engineering Laboratories, and Dalmo Victor before joining Ampex.

Also, during World War II, he was employed at the University of California, where he worked on the Manhattan Project and helped design the special control equipment employed in atomic research. For another Berkeley project, he helped develop an automatic barometric release to open parachutes.

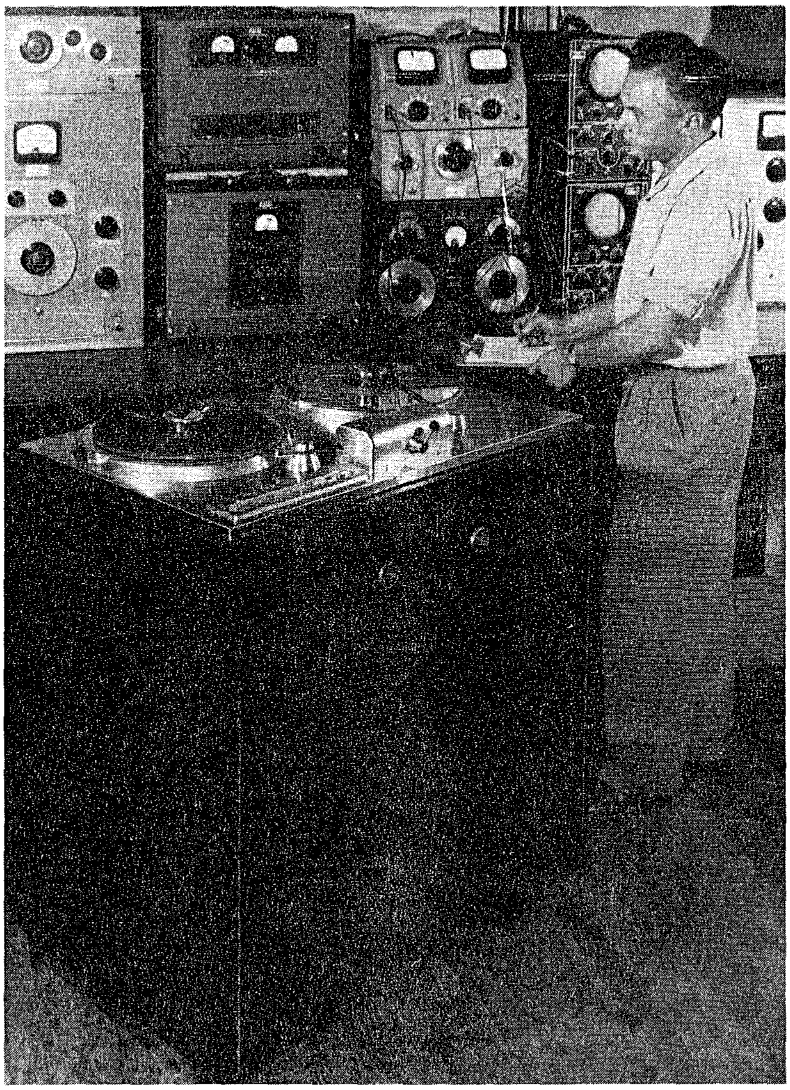
For many years Lindsay was active in the development and use of audio recording and amplification techniques in Northern California.

He designed and operated the sound system at the first Monterey Jazz Festival in 1958, and did similar work for the pageant staged by Walt Disney to open the 1960 Winter Olympic Games at Squaw Valley.

Another interest, working with architects on the acoustical design of buildings, led to numerous projects in the construction of schools, theatres, and churches, including the church where Lindsay's memorial service was held. His work on the First Baptist Church of San Jose, which attracted international attention, required more than five miles of electrical wiring, 300 jacks and 123 amplifiers.

Harold Lindsay always laughed at the idea of sitting for even an hour on a porch rocking chair. In a 1977 newspaper interview, he described his approaching retirement time as the "prime of his life." He also said he could not understand people who didn't know what to do with their spare time.

Ever curious, undeniably inventive, Harold Lindsay was often dubbed the "gentleman genius" for his alert, yet soft-spoken ways. He was one who made the most of his time, first, last and always.



THE AMPEX MODEL 200, the magnetic tape recorder developed by Harold Lindsay in the late 1940s, revolutionized the recording industry.