# Recording Media

## *History*

The technology of magnetic recording dates back to 1878, when Oberlin Smith proposed the idea of recording telephone signals onto a length of steel piano wire.

In 1889, Danish inventor Valdemar Poulsen developed principle of magnetic recording

In 1903 produced practical sound records using steel wire wound helically on a cylinder rotating under an electromagnet. It was described as a device to record telephone messages in the absence of the called party. Fidelity was low, just usable for voice.

Poulsen's first demo of the *Telegraphone* was in Paris in 1900. It is described as superior to the phonograph and a great advance in physics as well.

First phonographs used a steel needle in a diaphragm amplified by a horn. All mechanical, no electronics at all. Needle applied about a pound of pressure. The disks actually wore the needles out. Steve had a 1929 Victrola. May have used bakelite for the cylinders or disks.

During WW2, machines in BBC used to send messages to French underground. US Army and Navy employed them similarly.

Wire recorders recorded onto spools of steel wire. The wire rusted so had to be careful about the media. Wire had to be clean (no oil). Run wire through a magnetic coil to magnetize parts of the wire. Problem with cross-magnetic fields.

Wire recorders popular from 1947 to 1952. First audio recorder in homes.

Advent of oxide based magnetic tapes many benefits over steel wire. Mainly ability to record and play back in stereo. Ended wire recording era. Rusted steel magnetized on tape. That's why magnetic tape is brown (videotape, cassette tapes, floppy disks).

Audio tapes have gone through several formats over years. Original format steel wire. German engineers in 1930's perfected first tape recorders using oxide tapes. Originally appeared in reel-to-reel format.

Compact cassette patented in 1964 and eventually beat out 8-track tapes and reel-to-reel to become the dominant tape format in the audio industry.

## *Longevity / Stability*

Signals recorded on steel wire records held up well over the years. Bandwidth was 200 – 7 KHz. This is somewhat better than telephone's 300-3000 Hz. OK for voice recording but limited fidelity for music.

No other magnetic recording media to date come close to a wire recording's longevity.

(played a wire recording over the Internet).

As an info storage medium, magnetic tape is not as stable as film or paper or wire. Can record sound onto film. Film and non-acidic paper can last for centuries, whereas magnetic tape will only last a few decades.

Use of mag material for storage is further confounded by the prevalence of several formats (U-matic, VHS, S-VHS, 8mm, BetaCam, quad, IVC, D2, D1, D4, D5, D6, D9, et cetera).

Multiple media types: iron oxide, chromium dioxide, barium ferrite, metal particulate, metal evaporated. Different amount of energy needed to be applied to the tape in order to get a particular media type to perform properly.

Books maintained same format for centuries, have almost exclusively used ink on paper as the info storage medium, and require no special technology to access the recorded info.

Likewise, newer microfilm, microfiche, and movie film are known for their stability when kept in proper environments, and viewing formats have not changed significantly over the years (stuck with formats once they were established).

Access to info on a tape can be lost because the format has become obsolete and/or a working recorder cannot be located.

## *Tape Composition*

Diagram 1 of tape terms.

Magnetic tape consists of a thin layer capable of recording a magnetic signal supported by a thicker film backing. More than just rust, as Ralph said. The magnetic layer or **topcoat** consists of a magnetic pigment suspended within a polymer binder.

Hands around a piece of recording tape from 2" quad. The shiny side is the recording side.

The binder holds the magnetic particles together and to the tape backing. The structure of the top coat is similar to the structure of Jell-O that contains fruit – the pigment (fruit) suspended in and held together by binder (Jell-O). The top coat, or magnetic layer, is responsible for recording and storing the magnetic signals written to it.

Binder also provides a smooth surface to transport the tape through the recording system. It'd be like sandpaper with the wrong binder. Other components added to binder to help transport the tape and facilitate info playback. Other components added to binder to reduce friction, which reduces the tension needed to transport the tape through the recorder and reduces tape wear. Lubricant in the back and the front on the 2" quad tape.

A head cleaning agent is added to the binder to reduce the occurrence of head clogs that result in dropouts. On the quad, the heads spun at 9000 rpm. Had to have some way to keep heads clean. Generates static, which attracts dust.

What's a dropout? A loss of information (lose a whole line in some older recorders). Piece of dust gets on head, can't get off head, separates the tape from the head, so the tape doesn't get recorded at that point where the dust was. Have these problems on video tape, hard drives, streaming tape.

Carbon black is also added to reduce static charges which attract debris to the tape.

Diagram 2 of magnetic tape. As tape gets old, loses these lubricant reservoirs and gets dry.

All three tape components: magnetic particle, binder, backing) are potential sources of failure.

Shelf life of tape under normal conditions controlled by binder rather than the mag particles.

Life of binder independent of whether or not we use the tape.

## *Binder Degradation*

Binder responsible for holding magnetic particles on tape.

If binder loses integrity, through softening, embrittlement, loss of cohesiveness, or loss of lubrication, the tape may become unplayable

**Sticky tape** or **sticky shed** are commonly used terms to describe the phenomenon associated with deterioration of the magnetic tape binder. Put these in black book.

Binder polymers subject to chemical process called **hydrolysis**. In this process, long molecules broken apart by a reaction with water to produce shorter molecules that don't impart same degree of integrity to the binder system.

Steve had a tape that got locked onto a scanner due to hydrolysis and had to have Joe remove the tape using alcohol.

Compare this to a wool sweater, if enough individual yarns are cut, the sweater will eventually fall apart.

The polyester linkages in the binder systems that are broken by water molecules. Water must be present, and the more water present the more likely the polymer chains will be broken. The binder polymer will absorb water from the air and will absorb more water in high humidity environment than a low humidity environment. Compare this process for open bags of crackers, potato chips, and cereals; they will lose their crunch as they absorb moisture from the air. In the winter, indoor humidities generally can be lower and less moisture is absorbed from the air.

Binder hydrolysis can lead to a **sticky tape** phenomenon characterized by a softer than normal binder coating, higher friction, and/or gummy tape surface residues. Sticky tape can exhibit sticky shed, produce head clogs, result in stick slip playback, and in some cases, seize and stop in the tape transport. Won't play back at a constant speed anymore. Tape binder debris resulting from binder deterioration will result in head clogs that will produce dropouts on tape when played back.

What's the physics of a head clog? Diagram 3. Head clog clogs the gap with magnetic debris, making this a dead short. Battery voltage is zero across a dead short, no voltage across transducer that converts magnetic energy to electrical energy.

Sticky tape syndrome results in squealing of audio tapes as the tape very rapidly sticks to and releases from the playback head. On a cassette or R2R tape.

Procedures such as tape baking can temporarily improve binder integrity, allowing sticky tapes to be played and data recovered. Takes out moisture. A temporary fix. 122F / 50C for three days will sufficiently firm up the binder coating so that the tape can be played. A last-ditch effort. Temporary effect, should transcribe within one or two weeks. Tape baking should not be considered a cure-all for the treatment of sticky tapes. May actually cause more damage (like if it melts the tape).

Not supposed to touch tape. Have to do this on R2R to thread it. Oils ruining the tape.

If tape gets really bad, can pull the binder off the tape.

## *Lubricant Loss*

Lubricants normally added to binder to reduce friction of topcoat layer. Facilitates tape transport through recorder and reduces tape wear. In a video recorder, where tape wrapped around rapidly recording head, low friction prevents overheating of the tape. Head will get hot also.

Surface of magnetic tape is porous. In some tapes, liquid lubricant added to binder and will reside in these pores. When tape passed over a head or tape guide, lubricant squeezed out onto tape surface. Excess lubricant on tape surface absorbed back into tape surface (not all of it though).

Phenomenon similar to that observed when surface of wet sponge gently pressed and released – water exuded to surface and reabsorbed.

Over time, lubricant level in tape decreases. Partially consumed every time tape is played. This is all part of job as lubricants – consumed/worn down sacrificially to protect tape. Also will migrate to heads and guide pins every play.

Lubricant levels decrease over time in un-played archived tape due to evaporation and degradation. Lubes in some tapes are oily liquids that are volatile and evaporate over time. Some lubricants can degrade by hydrolysis and oxidation.

Info on severely degraded mag tapes can be recovered, in some instances, after re-lubrication of the tapes.

Prior to relubrication, the tape may have seized in the tape transport as a result of high friction, or the mag coating may have been readily torn off the tape backing by a high speed tape head. Tape head actually protrudes into the tape on a VTR. If lubricants are gone, may be tearing the tape.

Relubrication must be done by experienced individuals. If over-lubricated, excess will act as debris and increase head-to-tape spacing, causing signal losses and dropouts.

## *Magnetic Particle Instabilities*

Magnetic particle, or **pigment**, (the term is a carryover from paint technology), is responsible for storing recorded information magnetically as changes in the direction of the magnetism of local particles.

Particles aren't physically moving, it's just the direction of the magnetic field (the north and south poles of the particles).

If any change in magnetic properties of pigment, recorded signals can be lost. Magnetic **remanence** characterizes pigment's ability to retain a magnetic field. Remanance is the remaining magnetic field left after reversing the magnetizing current to zero.

Refers to amount of signal remaining after recording process. Strength of signal recorded on a tape magnetically is directly related to magnetic remanence of the pigment. Thus, a decrease in magnetic remanance of pigment over time can result in lowered output signal and potential info loss.

**Coercivity** characterizes the pigment's ability to resist demagnetization. It's the strength of the magnetic field that must be applied to a magnetic particle in order to coerce it to change the direction of its magnetic field.

Demagnetization of a tape can result from an externally applied field. A magnetic tape with a lower coercivity is more susceptible to demagnetization and signal loss.

Pigments differ in their stability. Iron oxide and cobalt-modified iron oxide pigments are the most stable pigment types of those used in audio and video tapes. These pigments are generally used in the lower grade audio and low to high grade video tape formulations.

Metal particulate (MP) and chromium oxide ($CrO_2$) provide higher output.

A decrease in signal output of two dB may be observed over the lifetime of metal particle and chromium dioxide based tapes. Even with losses, output signal still better than a comparable iron oxide based tape.

Loss of signal manifests as reduction in clarity/volume of sound recording and in reduction in saturation of a video recording.

Not much to do to prevent magnetic deterioration in metal particle and $CrO_2$ pigment types. Rate slowed by storing in cooler temps. Air condition takes humidity out of air (through cooling). By products of binder deterioration can accelerate the rate of pigment deterioration, so lower humidity would be preferred to minimize magnetic pigment degradation.

Metal evaporated (ME) video tapes require no binder polymer, as the entire magnetic layer consists of a single, homogeneous metal alloy layer that is evaporated onto the tape substrate. Magnetic coating on ME tape much thinner than the corresponding layer on an MP tape, so they are generally not as durable and do not hold up well in repeated play of freeze-frame video applications.

### *Substrate Deformation*

The tape backing or **substrate**, supports the magnetic layer for transportation through the recorder. Since the early 1960's, audio tapes and video tapes have used an oriented polyester film as a tape substrate material. Polyester shown to be chemically stable and are highly resistant to oxidation and hydrolysis. Problem is excessive tape pack stresses, aging, and poor wind (wined) quality can result in distortions and subsequent mistracking when the tapes are played.

Best way to reduce degree of tape backing distortion is to store mag media in constant temp/humidity environment. Each time temp/humidity changes, tape pack expands and contracts. Can increase the stresses in the tape pack that can cause permanent distortion of the tape backing. Can show up as mistracking.

## Review of what we've covered

How is pigment described? Like fruit in Jell-O. The fruit is the pigment (magnetic particles) and the Jell-O is the polymer. Avoid problems by controlling temperature and humidity.

Hands around pro reel. Pro reel has very sturdy flanges and a well-made hub. Tape edges are very very critical.

Tape is made in huge webs (sheets) that are very wide. Four feet across.

What's different between video and audio tape? Video is recorded in a slant, so orient the particles in a slant on video tape.

## Lab

We are tired of sitting down at lecture. We will go into maintenance lab.