BASF

FOR THE BEST RECORDINGS YOU'LL EVER MAKE

The Inventor's Notebook

TECHNICAL BULLETIN #4

EQ

By Terence O'Kelly

During a lecture in 1819, Hans Christian Oersted discovered to his surprise that electrical current running through a wire made the wire act like a magnet. In October, 1831, Michael Faraday discovered the reverse effect: that moving a magnet in and out of a coil of wire produced electric current in the coil; and the faster the magnet moved, the more current was produced. These two discoveries led to the development of electricity as a medium of energy. Today we generate electricity by using water or steam pressure to turn shafts with huge magnets attached to them. The shafts and magnets are surrounded by coils of wire so that, as the shaft turns, the moving magnets produce electric current in the coils. If an electric motor is plugged into the current, the electricity flows into the motor's coils and turns the magnets on the motor's shaft: the drill drills, the turntable turns.

Faraday's discovery also applies to tape recording and playback. A tape head is actually an electromagnet with coils of wire inside. When music is translated into electrical current, the current is sent to the head to act as a magnet putting magnetic print patterns on the tape.

When recorded tape runs past the playback head, the magnetic prints on the tape create a current in the head which is amplified in the chain of audio components and is finally fed to the speakers. The current induced in the head (its output), however, does not depend directly on the magnetic signal on the tape; the current depends on the rate of change in the flux level, or, in other words, on how fast the magnetic prints move past the head, just as in Faraday's coil. Recorded tape not moving past the head generates no signal in the head at all. Since high frequencies have more prints than low frequencies (cf. FIG. 3, Notebook #3), they have a greater rate of change (they seem to be "moving faster") and, consequently, they have more output. In terms of voltage, the output increases at a rate of 6dB per octave — twice as much output every time the frequency is doubled. To compensate for this increasing output (FIG. 1A), the playback section of a tape recorder has a decreasing slope built into its curcuitry (FIG. 1B) so that the increase plus the decrease is "equalized" for a flat response (FIG. 1C). Equalization makes up for the differences in output by making them equal. However, as frequencies increase and the distances between prints (wavelengths) grow shorter, high frequency losses due to such factors as slow tape speed, wide playback gaps, and limitations in the tape cause the 6dB/octave output increase to level off and begin to drop. To solve this problem, the effect of the decreasing slope (B) is removed at a particular frequency point so that the natural high frequency output increase makes up for the treble losses.

The first ferric oxide tapes made for cassette recorders began to lose their 6dB/octave increase at a relatively low frequency because the cassette tape moved much more slowly than open-reel recorders. The output increase dropped 3dB at a transition point of 1326.3 Hz, so the "equalization" decrease (B) was removed at this frequency. In electronic engineering terms, this transition point was achieved with "a time constant of 120 microseconds" (µs, one millionth of a second).

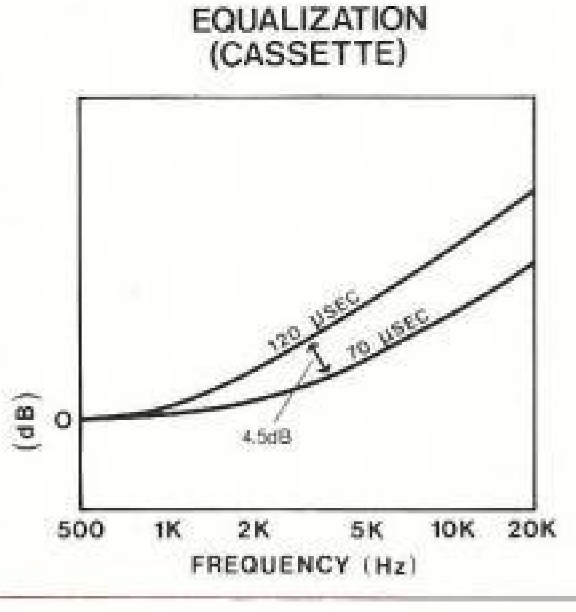
The invention of chromium dioxide tapes significantly improved cassette high frequency response with a totally new kind of tape oxide that was more efficient at short wavelengths than ferric oxide formulas. Because of this efficiency, the transition point of CRO_2 moved to a higher frequency of 2,273.6 Hz, or 70-µs EQ. The time constant of 70-µs is advantageous because it allows the 6dB/octave

FIG. 1

slope (B) to continue longer and, in effect, "boosts" fewer high frequencies (FIG. 2); and less high frequency boost means less tape hiss gets boosted at the same time. The major audible difference between cassette tapes is not in high or normal bias, but in 70 or 120-μs equalization: the 70-μs EQ will always provide about 4.5 dB less tape hiss. Chromium dioxide, chrome-equivalent, ferrichrome, and metal particle tapes all use 70-μs playback EQ.

There is another cassette playback time constant in addition to 120 μs and 70 μs that is not as widely known: 3180 μs (50 Hz transition point). Instead of boosting the lowest bass frequencies so much that there may be problems with hum or low frequency noise, those frequencies below 50 Hz are rolled off slightly on playback. To make up for this rolloff, the record EQ gives those frequencies a boost during recording equal to the playback rolloff. Some manufacturers, however, are abandoning the 3180-μs time constant standard because they feel that new head designs for better low frequency response are restricted by this time constant. A tape recorded on a machine with the 3180-μs EQ and played back on a deck without it will have too much bass unless a tone control can reduce it to a degree.

FIG. 2



Playback equalization is standardized so that any tape recorded on any one machine will sound the same on all machines when it is played back because all machines should have exactly the same playback EQ. Since the types of heads, circuitry, and tape formulations do differ, any adjustments are made to *recording* equalization or "preemphasis" in a particular recorder using a particular tape. The adjustments are made to *record EQ* so that the frequency response on playback is flat according to the *standard playback EQ* which all decks follow (FIG. 3). All decks use some amount of record EQ to give the high frequencies a boost before recording because the high frequency losses cannot be compensated enough simply by removing the decreasing slope with playback EQ. Boosting the high frequencies *before* recording also avoids increasing the tape hiss that accompanies playback EQ, but the record EQ must not be so great that it boosts the highs to distortion or saturation caused by overloading the tape. So, while playback EQ is standard on all machines, each machine has an adjustable record EQ which is used to insure flat frequency response at the standard playback equalizations.

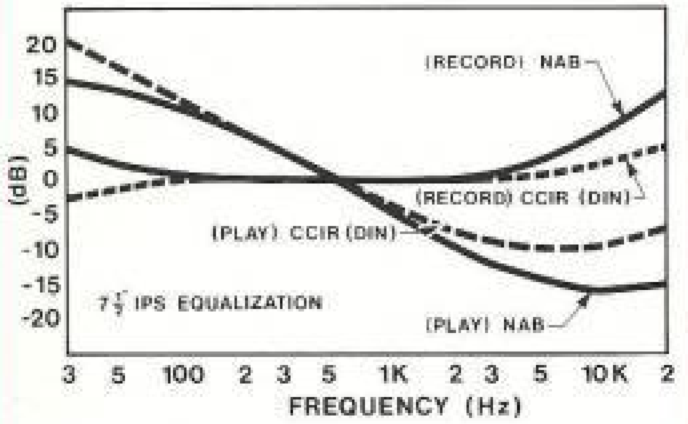
FIG. 3

Open reel tapes also use equalization, and the faster speeds available mean less drastic frequency alteration. Complications arise, however, because of a variety of speeds and because of different standards—NAB, DIN, IEC, and CCIR. Most American and Japanese open-reel decks conform to NAB standards somewhat similar to those used in cassette decks. The chief difference between the NAB and the other, European, standards is that the NAB allows the 6dB/octave slope in playback to continue to a higher transition frequency to reduce more tape hiss, and the bass does not receive as much playback boost in order to avoid hum problems and low frequency noise. NAB standards call for a 3180-μs EQ rolloff for the bass for 3¾, 7½, and 15 inches per second (ips); the high frequency time constant is 90 μs (1768 Hz) for 3¾ and 50 μs (3183 Hz) for both 7½ and 15 ips. At 30 ips there is no bass attenuation; 17.5 μs (9095 Hz) is the high frequency EQ.

European standards, known as DIN (German), IEC (international), or CCIR (French) use different time constants (FIG. 4). The 3¾ ips speed uses the same as those of the NAB, but other speeds have no bass rolloff at all. High frequency time constants are 70µs (2274 Hz) for 7½ ips and 35 µs (4547 Hz) for 15 ips.

FIG. 4

EQUALIZATION (OPEN REEL)



Some professional machines are designed so that a choice of NAB or IEC playback EQ is available. An open-reel recorder using NAB EQ uses a bass boost on record equalization to make up for the 3180-µs rolloff on playback. NAB time constants also call for more record preemphasis of the high frequencies than the IEC time constants because the high frequency turnover or transition point occurs at higher frequencies to avoid more hiss (compare the 4.5 dB less noise of a cassette time constant of 70 µs compared to 120 µs). The drawback is that the extra preemphasis pushes the high frequencies closer to the point of distortion or saturation because of the boost. A 14,000 Hz tone will be boosted about 6-8 dB higher than a tone of 333 Hz at 7½ ips; 10-12 dB at 3¾ ips; and as much as 16-20 dB at cassette speeds. What musical content exists at such a high frequency generally has about 40 dB less energy than musical content in the midrange, but live music and high quality discs can contain much greater high frequency energy. When that greater high frequency energy gets an extra 16-20 dB boost, it can easily saturate the tape.

The change in the 6dB/octave slope to a less steep curve is determined by an electronic resistor-capacitor network built into a tape deck. The turnover frequency is determined by the formula:

$$\text{Frequency} = \frac{1}{2\pi T} = \frac{159{,}155}{\text{Time Constant Value}}$$

where T is the time constant in microseconds, and the Time Constant Value is an integral number such as 70 or 120. The time constant itself is determined by the values of the resistance multiplied by the capacitance in the R-C network. For example, a 10,000 ohm resistor X a 0.007 microfarad capacitor will provide a time constant of:

$$10{,}000 \text{ ohms} \times (7 \times 10^{-9} \text{ farads}) = 70 \times 10^{-6} \text{ seconds} = 70\,\mu\text{s}$$

The *seconds* in *microseconds* refers to time. Resistance multiplied by capacitance results in units of time:

$$R = \text{ohm} = \frac{\text{Mass} \times \text{Length}^2}{\text{Time} \times \text{Charge}^2}$$

$$C = \text{Farad} = \frac{\text{Time}^2 \times \text{Charge}^2}{\text{Mass} \times \text{Length}^2}$$

$$R \times C = \text{Time}_{\text{seconds}}$$

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TECHNICAL BULLETIN #6

The Cassette Housing

By Terence D. O'Kelly

Magnetic recording tape has grown immensely popular because of the development of plastic cartridges and cassettes. Until tape was stored safely in a plastic case[1] which could easily be inserted into a recorder or playback unit, magnetic tape was only used by those confident enough in their manual dexterity to handle delicate ribbons of coated plastic film and to thread them around a maze of guides, lifters, and capstans. Cartridges and cassettes made it easy: the tape came threaded around guides built into the plastic housing. Although ease of handling was an obvious benefit of the new tape formats, a disadvantage was that the tape alignment and guidance formerly entrusted to hardened steel parts on open-reel machines was now left to the somewhat suspect plastic parts of the tape housings.

The development of the unisette, elcaset, and domestic video cassettes provides some evidence that engineers did not put full confidence in plastic housings. In these formats the recording machine itself provides the tape alignment and guidance after it draws the tape from the shells and places it on the transport system of the deck. The audio cassette, however, has constantly been improved by refinements of the shell. New materials, new designs, and new manufacturing techniques have all contributed to making the internal guiding of the tape more exact, more uniform, and more reliable.

The basic parts which constitute a precision cassette are:

2 shell halves plus their windows
2 lubricated foil sheets, often called "slip sheets"
2 hubs, each with an interlocking piece to attach the tape leader
2 roller guides on lubricated stainless steel axle pins
1 metal shield
1 pressure pad
tape and 2 leaders (or a "leader" and "trailer") attached to the hubs

The halves are joined either by four or five stainless steel screws or by sonic welding. Either method can give a good seal. Five screws provide a more rigid fit than four screws, and sonic welding is even better in terms of rigid construction. The five-screw construction, however, is more popular because there is no risk of heat distortion due to welding and because it allows the user to take apart and reassemble the cassette with relative ease.

Poor quality cassettes reveal themselves by missing parts or poorly formed parts, not by the method of sealing. Roller guides are usually the first parts to be eliminated in cheap cassettes. The roller guides are replaced by little plastic posts around which the tape is dragged but not guided. Sometimes the roller guide will be there, but the axle pin will be an ordinary steel pin. When this pin oxidizes and expands, the roller guide revolves irregularly and finally locks, becoming a *big* plastic post. The rusted pin and the sticking roller cannot guide the tape properly and will not give the smooth, flutter-free movement of a well designed guide. Cheap cassettes often eliminate the slip sheets, also. These sheets, made of a variety of plastic films with teflon, silicone, or graphite lubrication, act as bearing surfaces for the hubs and as gentle guides for the tape packs. Without them a cassette housing cannot provide uniform tape travel and cannot reduce tape edge damage.

Each part of the cassette is designed for a particular function. In order for it to perform properly, each part must be designed and manufactured properly. Sloppy parts assure sloppy performance. The function of the individual parts and important parameters are discussed below (cf. Fig. 1):

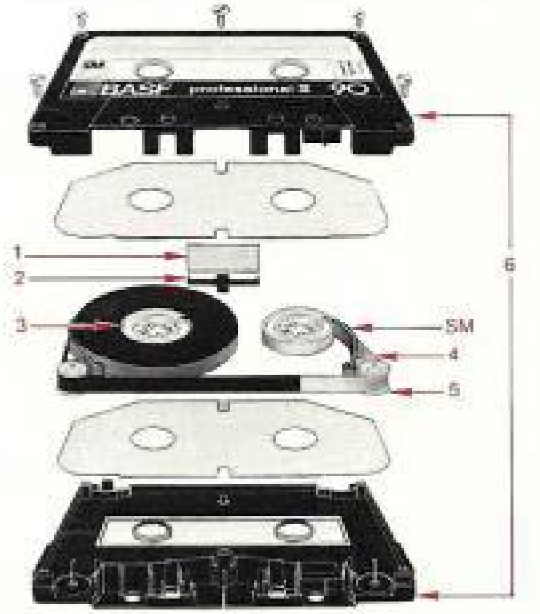

Fig. 1: Cassette Parts

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[1] "Cassette" is diminutive form of case, which is a derivative of the Latin casa, or "house"; a cassette is a "little house."

1. **Metal shield.**
The metal shield is a remnant of the early days of the cassette when players and recorders used high impedance heads and were likely to pick up noises from stray electromagnetic fields. Modern heads have lower impedances and are relatively immune to stray fields, but the shield is maintained in order to be compatible with old cassette machines. The material should be non-magnetic with good permeability to draw fields away from the head.

2. **Pressure Pad.**
The pressure pad pushes the tape against the head in order to achieve good tape/head contact which is essential for high frequency response at slow cassette speeds. Pressure pads can be mounted on foam supports or on metal springs, which are less likely to lose their elasticity under different environmental conditions. The pad must be positioned accurately so that it contacts the wide variety of head shapes in use today; for example, discrete heads, combination heads, and sandwiched record and playback heads. The fiber nap of the pad must be very tight so that loose fibers do not work their way between the head and the tape to cause dropouts of the audio signal. The pressure exerted by the pad must be within specified limits; too little pressure prevents good contact and too much deforms the tape.

3. **Hubs.**
The hubs are usually a low-friction, Delrin® -type plastic. Concentricity is essential to provide smooth tape movement. Concentricity must also be maintained at the point of the attachment of the leader to the hub. Much has been made of special C-clamp attachments whose shape matches that of the hub, but the C-clamp is merely a rounded version of a very old style of clamp. A newer, safer method is to use a staking pin designed to fit inside the perimeter of the hub. Both clamps are just as effective as long as neither clamp interferes with the roundness of the tape pack by protruding from the hub or by leaving too large a gap in its fitting. The thick leader ribbon which forms the first wrap around the hub defines the effective concentricity, not the style of the clamp. The hubs have a certain amount of play in the shell because they adapt to the feed and takeup shafts of the machines in which they are placed. Bearing surfaces in contact with the shell halves must be free of burrs and surface imperfections to insure smooth and wobble-free movement.

4. **Leader.**
The leader is a polyester film which is thicker than that used as backing for the tape in order for the leader to withstand the shock of sudden tension when the tape runs to the hub attachment in fast wind modes. Some leaders are designed as "non-abrasive head cleaners" which work by using their roughened surface to scrape debris off the head. This method is "non-abrasive" only in the sense that it is mercifully short. Head cleaning leader also happens to work in the wrong direction. Debris should be wiped out of the head gap, not scraped into it. The proper way to clean a head is use a cleaning solvent designed for heads[2] and to apply it to the head with a swab in a motion *parallel* to the tape gaps, not in the direction of tape movement.

5. **Roller Guides.**
The guides are very critical for proper alignment, especially in double-capstan drive systems. Their axle pins must be wobble-free and aligned 90° to the plane of tape travel in order to avoid shifting the tape across the heads (Fig. 2). The guide itself should be perfectly concentric. Its shaft should have a slight bulge to it with the widest part exactly in the middle of the tape path. The molding technique must be such that no seam or burr exists anywhere on the guide. The ends of the guide have flanges with very sharp delineation for the best tape contact. The roller is usually low-friction Delrin® -type plastic.

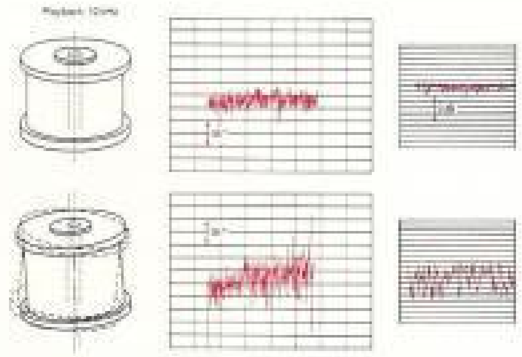
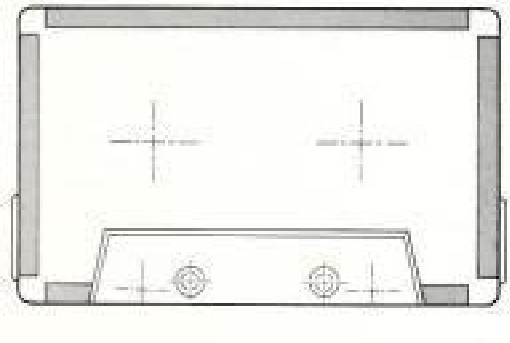


Fig. 2: Influence of various types of rollers on constancy of phases and level of output.

6. **Shell Halves.**
The shell halves are the most visible parts of the cassette, but many of their important design points are within the housing and not obvious. The plastic molding should have good definition and few flow marks for reasons of cosmetics; the individual parts should be aligned with extreme precision for reasons of performance. Critical points are: the faces and edges of the cassette which are the support points used by various cassette machines for holding the cassette (Fig. 3); the hub support area; the fittings for



(DIN 45 516; IEC 94)
Fig. 3: Support surfaces of compact cassette

The physical relationship between the cassette and the recorder/player is critical for good performance. The darkened support surfaces above are used by the machine to align the housing and, therefore, the angle of tape/head contact. There are three holding points for the cassette: either two points on the top support surface and one reference hole, or one upper support point and both reference holes. (Only three points are chosen for the same reason that a three-legged stool is more stable on varying surfaces than a four-legged chair would be.)

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[2] Freon TF or cleaners with a flourocarbon base (trichlorotriflourothane blended with 1,1,1 trichloroethane for a tongue twisting example) are safe and effective. Pure isopropyl alcohol is a little less effective but also less expensive. Rubbing alcohol is often isopropyl alcohol with such additives as lanolin to prevent dried skin and may leave the additives on the heads as residue.

the roller guide axles; and the plastic "bridges" and pins in the open area where the head and capstan/pinch roller penetrate (Figs. 4 & 5). These last parts are extremely important because the head pushes the tape against them after they have left the roller guide; if they are not properly aligned vertically, they can tilt the tape slightly in one direction or the other and cause errors in azimuth alignment (Fig. 6). Neither accurate roller guides nor dual-capstan control can make up for this kind of azimuth error because neither can isolate the tape from an off-center tilt.

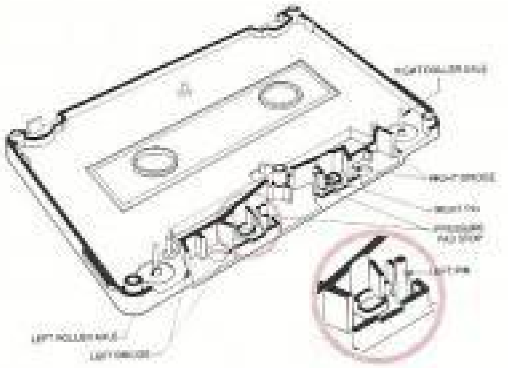


Fig. 4: The important elements influencing the tape alignment in the cassette (the base of the asymmetric shell)

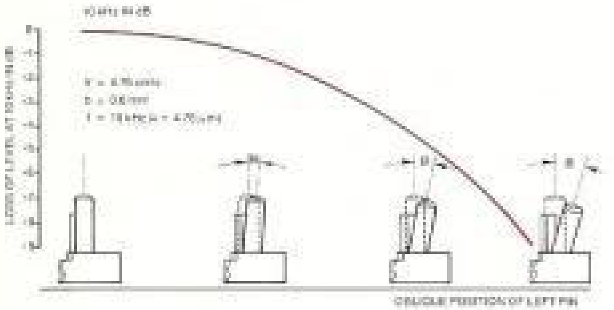


Fig. 5: Relationship between the deviation of the left pin from the vertical (angle of the error: approx. 10 times exaggerated) and the loss of level at 10 kHz in dB

The cassette housing has three rectangular openings meant for the erase head to the left, the playback head in the center, and the pinch roller to the right. Two circular holes on the face allow the capstan(s) to fit behind the tape; the two other, square-like holes are "reference holes" meant for pins on machines to hold the cassette in position. Plastic tabs on the top edge of the housing can be broken off in order to prevent recording over or accidentally erasing recorded material. The left tab prevents erasure of the side facing the viewer. Chromium dioxide and other high bias tapes have square notches next to the tabs so that recorders can distinguish between these tapes and normal tapes if the recorders automatically select the proper bias and equalization. Housings for metal particle tapes have two additional square notches in the center of the top edge to distinguish them from chromium dioxide tapes.

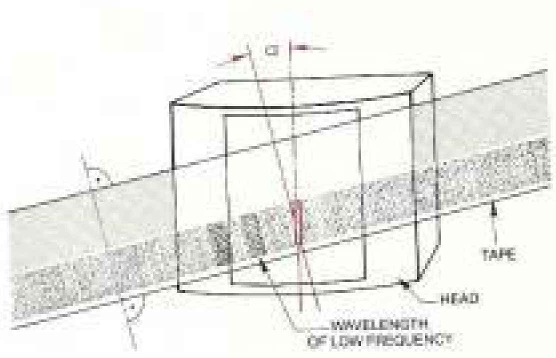


Fig. 6: Angle of azimuth error caused by misaligned tape

A small degree of azimuth error will reduce high frequency output without an apparent reduction of mid-range and low frequency output because of the differences in the width of the magnetic prints: the higher the frequency the shorter the wavelength and the narrower the magnetic print. If a very narrow magnetic print crosses the gap at an angle (such as α above) and is not perfectly parallel to the gap, the gap cannot "read" the entire print at a single moment. One end of the print will have crossed the gap before the other end reaches it. The partial reading of the print will reduce the output which would have been generated had the entire print been read. An error of ⅕°, for example, will reduce the output of 10 kHz by 3dB. A lower frequency with a wider print will not suffer the same amount of reduction in output because its print is significantly wider than the gap, and the gap will miss a smaller percentage of the print.

Cassette housings and hardware transport systems have improved considerably from the early days of constant jamming and wrinkled tapes. Research continues to develop further refinements to make performance even better. A new, long window housing introduced by BASF incorporates many of the latest refinements to eliminate one of the last and most persistant flaws inherent in cassette housings — tape skewing. Tape skew introduces azimuth errors as the tape moves out of alignment with the head gaps. The audible result is both a loss of high frequencies and a loss of stereo imagery if the error is great enough.

The high frequencies are lost because the very narrow and short magnetic prints of high frequencies cannot be resolved by a playback gap if they cross the gap at an angle rather than straight on. The stereo image is affected by a change of synchronization as one track runs across its gap slightly ahead of or behind the second track. A signal intended to fit "in between" two speakers should be recorded on two tracks and played back at the same level. If its magnetic prints do not cross the gaps simultaneously, the image will shift to the speaker receiving the earlier signal.

The causes of tape misalignment not due to the tape are due to imprecisely formed points of tape contact in the housing or the points of housing/recorder contact. If the housing itself is physically distorted, it will not lie at the correct angle facing the heads. In order to prevent misshapen cassette housings, BASF uses a highly condensed polystyrol plastic capable of withstanding a temperature of 85°C. (185°F.) for a 24 hour period without warping. This endurance trial, known as the Ford test, is seldom passed by competitive housings. The long window, molded at the same thickness as the shell wall, provides additional reinforcement for the halves.

All BASF cassettes incorporate a patented tape guide called the SM or Security Mechanism guide. This guide, of Delrin® plastic, has flanged edges which work somewhat like packing arms in aligning the tape from or onto the hubs rather than relying solely on slip sheets which contact the tape edges. All cassettes suffer some degree of tape edge damage after repeated passes, especially at fast winding speeds, because of the edge/shell contact. The SM guide is designed to control and guide the tape even in cases of serious damage so that the tape does not ride over the tape pack and get caught in the hub spindle area. The most rugged use a cassette is likely to undergo is that in car stereo systems. An endurance test conducted by a noted car stereo manufacturer showed fewer failures in cassettes using SM guides (BASF cassettes and others) than in those without them.

Molding techniques for the new long window design have been given the utmost care in the areas of tape/shell contact. The roller axles, the bridges, the plastic guide pins, and the pressure pad stops are molded at extremely precise angles to maintain correct tape travel without causing the tape to skew. The most significant feature, however, is the shell half design. Manufacturers' attempts to make mirror-image halves in order to achieve perfect tape alignment have not taken into account the fact that all internal parts involved in tape guidance, such as the roller guides and roller axles, would also have to be mirrored by an exact opposite. If one roller guide faces downward, the other would have to face upward. In addition, each tape contact point would have to be mirrored by its exact opposite, exact in every dimension, angle, and surface characteristic. Tape travel on side 1 of a mirror-image design cannot match that of side 2 if there is any difference at all between halves. The slightest difference between halves will cause the tape to track differently on both sides

BASF has developed a different design which totally avoids any mirror-image mismatch: all the tape contact points are on side 1 as a base, and side 2 provides the cover. The cover fits tightly on the base with an off-center joint at the area of tape travel so that the tape touches no parts of the seam. Any mismatch between halves, no matter how slight, will not affect the tape travel since that depends on one solid piece, not two. The angle of travel from side 1 is much more likely to match that of side 2 if the elements of error have been cut in half.

The improvement in tape guidance is significant. Cassette tape has seen major improvements in increasing high frequency output; but unless that output is maintained in a stable manner, the increase will be of little practical value. The long window design of the new BASF housing is an important step in tape guidance and in freeing the cassette from what was once called an inherent limitation.

BASF

FOR THE BEST RECORDINGS YOU'LL EVER MAKE

8/82

Pins and Stays in the Cassette

Remember that, if there is a high frequency loss, the pins in the cassette which guide the tape could be the cause. The main point is that they must be made so precisely that they cause no tape deflexion and stand in perfect verticality. But what does "perfect" mean, considering the "order of magnitude" to which this applies?

In order to discover and, at the same time, to measure the influence of different recorder transport systems, BASF technicians built an extremely accurate cassette for measurement purposes (Fig. 24). It is completely functional (obviously only on one side) because the pins and stays are arranged as in any cassette but are constructed of adjustable steel pins. In order to be able to measure any desired slanting in the area of thousandths of a millimeter, a special "slant measurement tool" was built (Fig. 25). With this tool the pins and stays of the mass produced cassettes are also being measured.

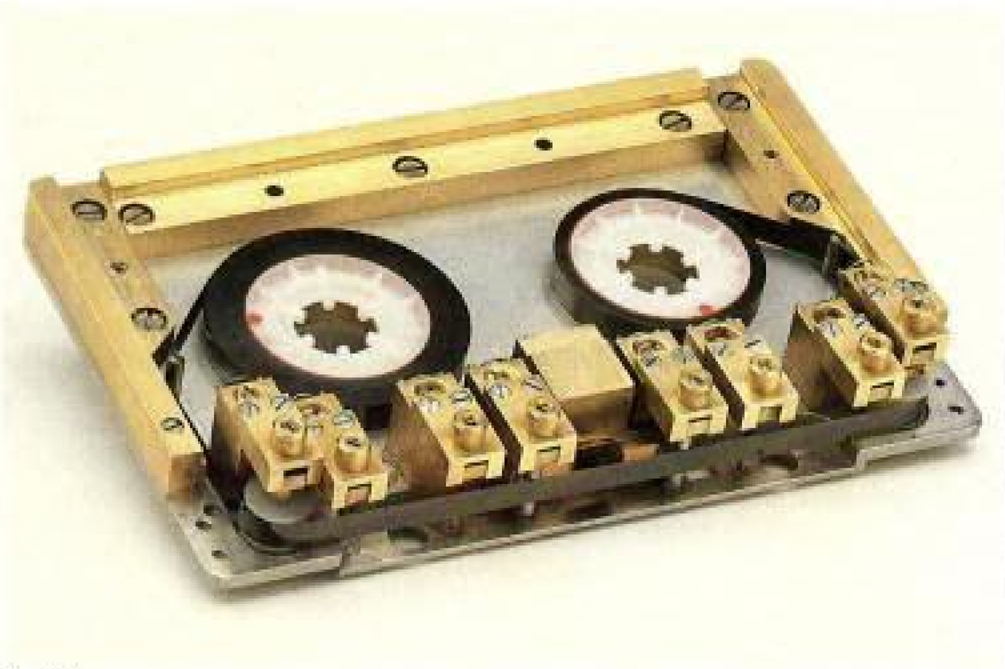
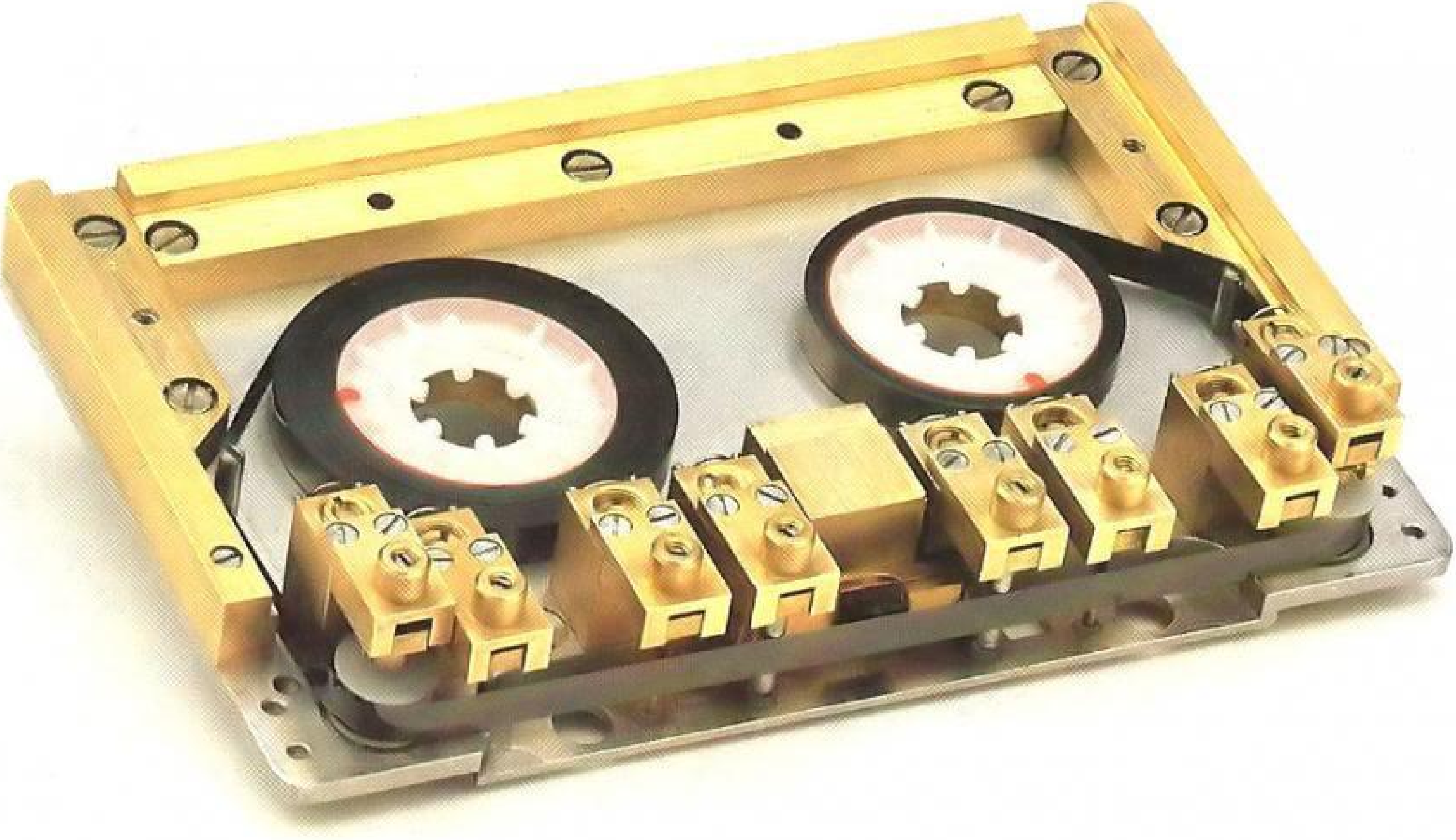


Fig. 24
The pins and stays of the BASF mechanical reference cassette are precisely adjustable in thousandths of a millimeter. Only with such a precision tool (specially manufactured!) can the allowable tolerances of the pins and stays be determined for mass produced cassettes.

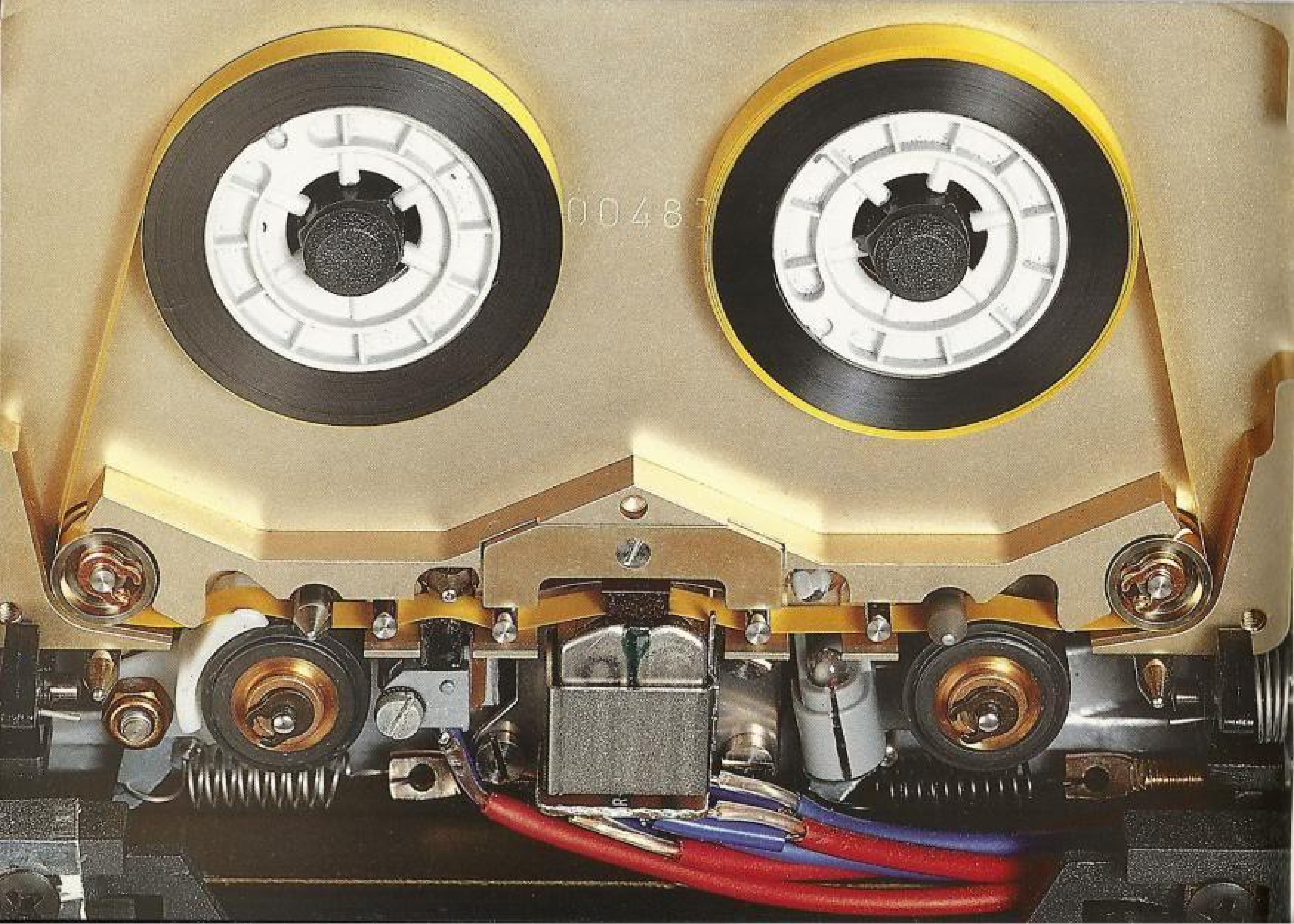
Fig. 25
With this slant measurement tool – BASF's own unique construction, as is the mechanical reference cassette – the accuracy of the pins and stays is measured.

Extensive, time-consuming research with the mechanical reference cassette has shown what degree of slanting is still tolerable, that is, has no audible influence on the playback of music.

These measurements determined the degree of precision required of the injection molding equipment. Here, too, it is a matter of a few thousandths of a millimeter. That sounds good, but it requires a great deal of work in the building of the injection molds and continuous, rigorous control in manufacturing the housing. This is the only way the precision of the modern BASF compact cassettes is achieved and maintained. Here, naturally, BASF's long experience in injection molding technology and plastics is an advantage.




BASF
CALIBRATION MECHANISM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