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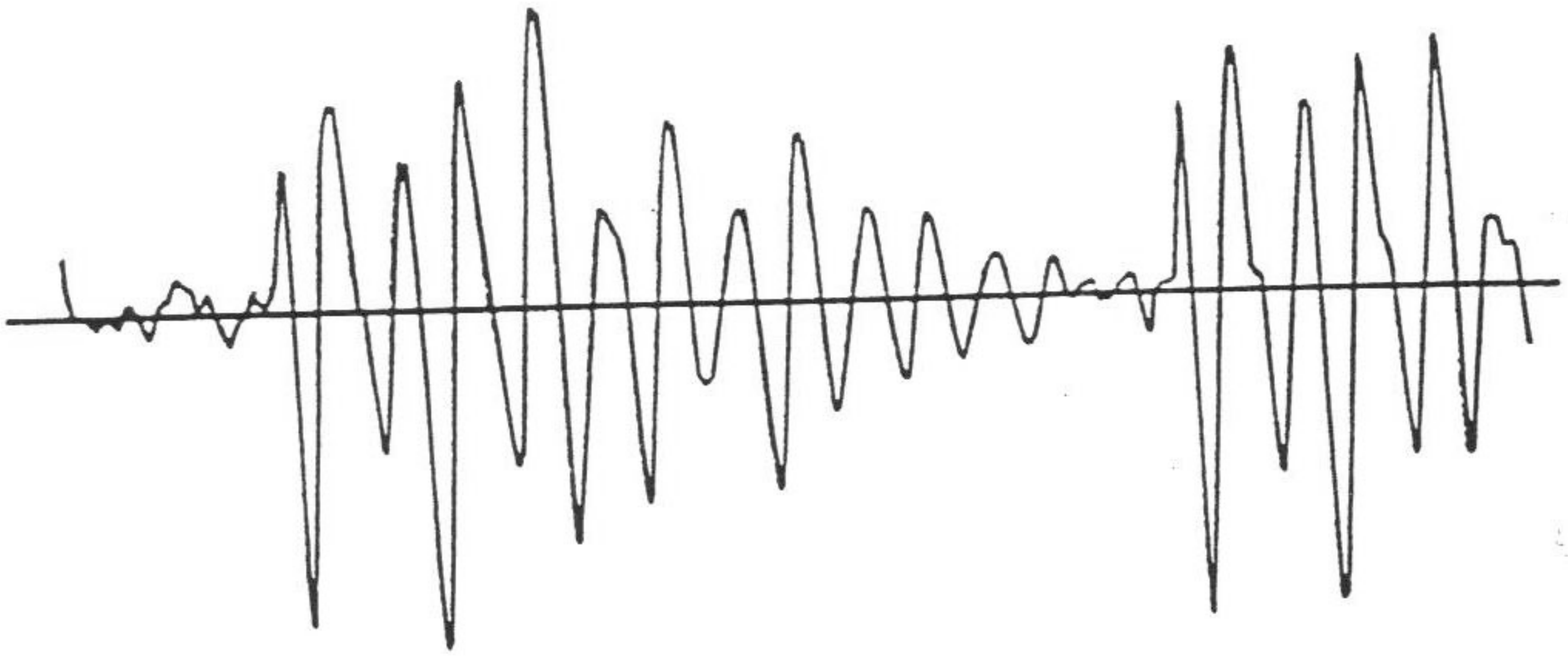
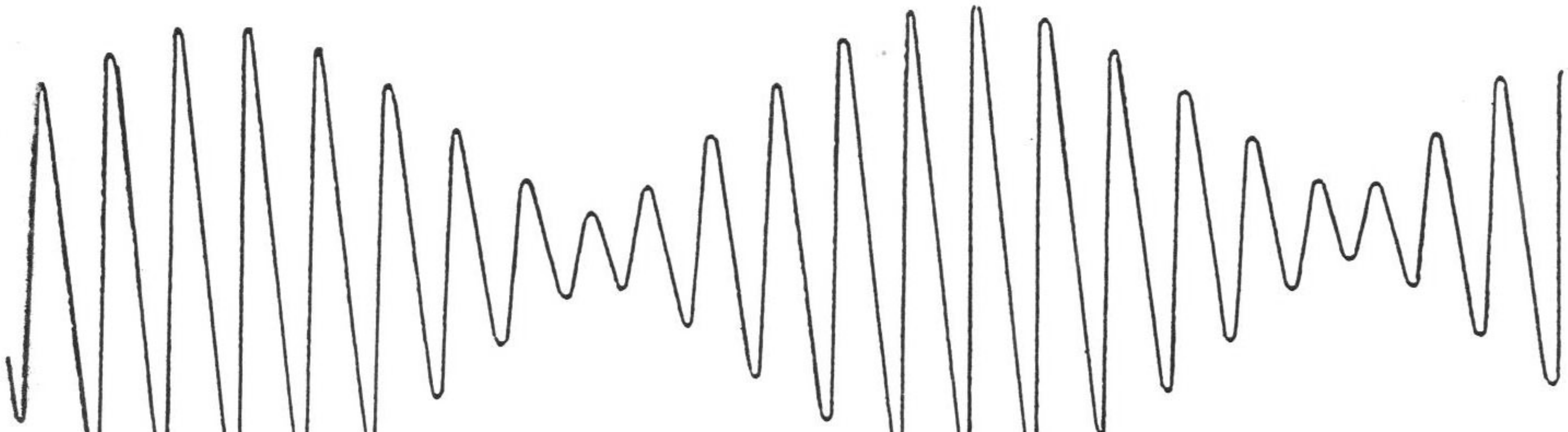
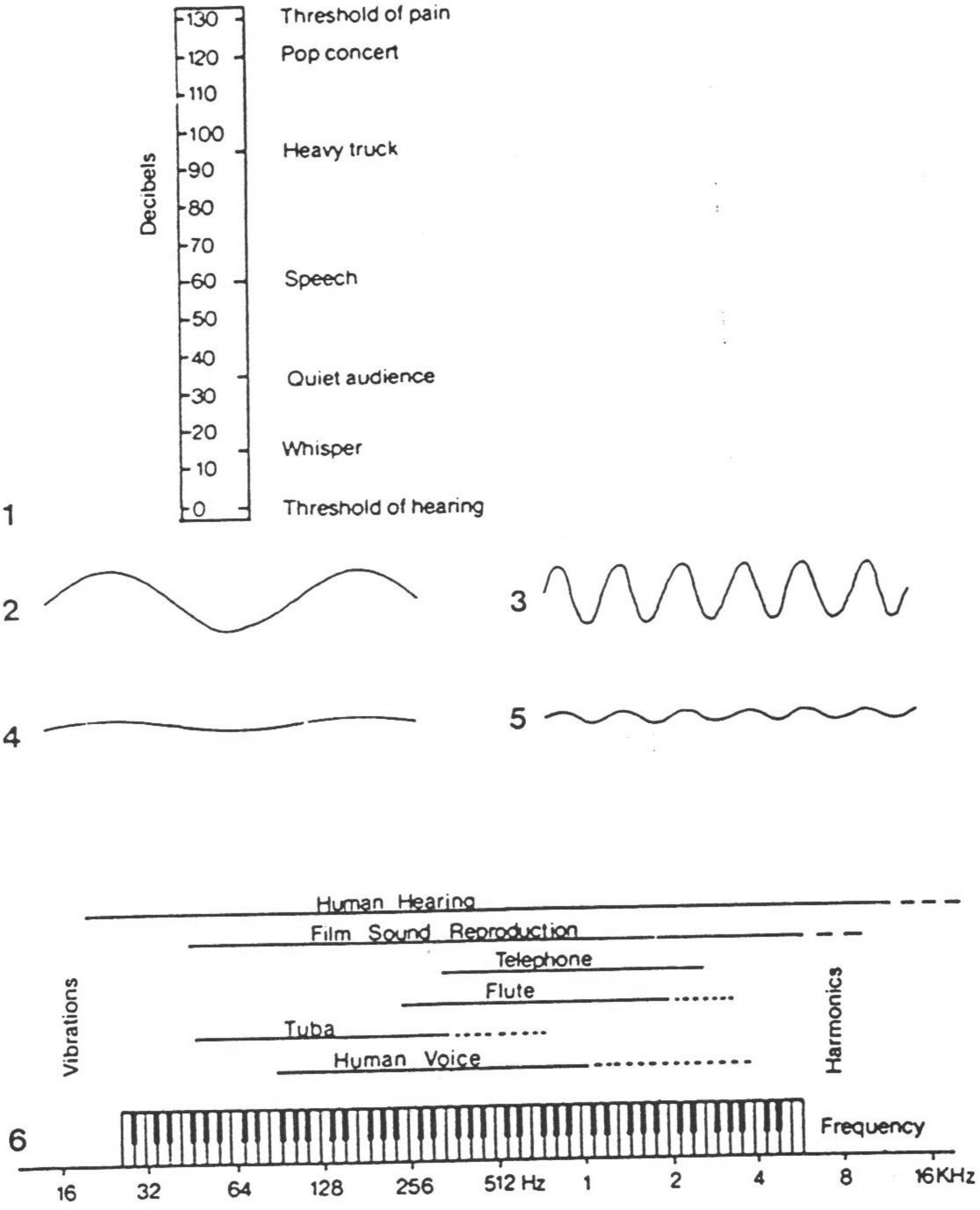
Photographic Sound Technology







Hearing sounds
(1) The ear can receive sounds up to about 130 dB above the threshold (quietest audible sound) without pain. Sound levels fall of with distance: these examples are heard at an average distance of 6 ft.

(2) Low-frequency and (3) high-frequency tones; (4 and 5) the same frequencies at a lesser amplitude. (6) Harmonics extend well above the fundamental frequencies of many sounds.

Sound Waves

Sound waves are created by vibrations. These vibrations can easily be seen if the strings of a guitar are plucked, or felt by placing a hand on the throat when speaking. Sounds are heard when vibrations are transmitted from the object to the ear, through a suitable medium such as air. With each vibration, or beat, of the sounding object, a series of waves or ripples travels outwards in all directions. When these reach the ear, they set up vibrations in the eardrum, which are in turn transmitted through a series of small bones to the cochlea or inner ear. Here, the various vibrations are converted to nerve pulses and set to the brain.

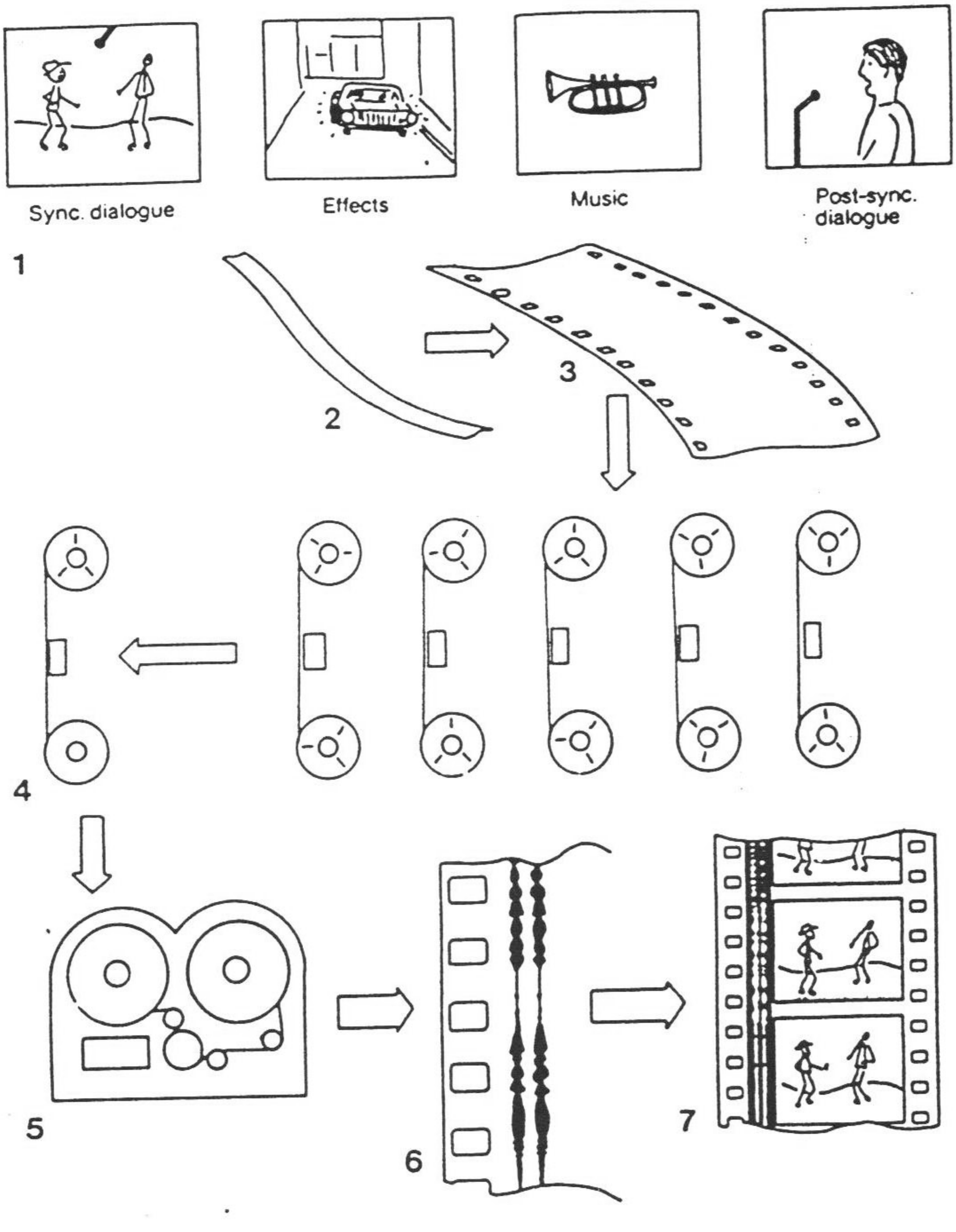
As sound travels away from its source, the energy is spread over a rapidly-increasing area, and thus the strength of the waves is reduced. This follows an inverse square law, so that every time the distance is doubled, the loudness is reduced to one quarter, and so on. The relative loudness of two sounds is expressed in decibels: these form a logarithmic scale, so that every time a sound is doubled in strength, it becomes 3 dB louder. On this scale, for example, a signal-to-noise ratio of 50 dB means that the loudest sound a system can produce is 50 dB (or 100 000 times) louder than the background noise of the system.

Frequency and amplitude

As each wave passes any fixed point, the air pressure at that point rises and falls. The variation between highest and lowest pressures represents the strength or loudness of the sound, and is termed the *amplitude* of the soundwave. Now a more rapid vibration will result in more waves arriving per second. This factor is termed the *frequency* of the sound, and is heard as a variation in pitch. A flute, for example, produces higher frequencies than a tuba. Frequency is measured in cycles (complete waves) per second, or Hertz (Hz).

Very few sounds have a single-frequency wave-form. Sounds of speech, traffic noise, or machinery, for example, are a complex mixture of waves of different frequencies and varying amplitudes. Even a single note on a musical instrument consists of a fundamental frequency together with upper harmonics; waves of frequencies exactly two, three or four multiples of the fundamental. It is the presence of these harmonics which gives each instrument its characteristic timbre, and enables us to distinguish, for example, a trumpet from a violin.

Normally, a young person can hear frequencies between 20 Hz and 20 000 Hz. However, in older people, the eardrum tends to thicken and become stiffer, so that the frequencies above 12 000 Hz become increasingly difficult to hear.



Film sound production
(1) Sound is recorded from various sources onto ¼-in tape, (2), and then transferred onto magnetic film, (3), for editing. After editing, the sound is mixed from many tracks onto one master 'final mix' (4), from which a signal is fed into the sound camera (5), to expose the sound negative, (6). This is printed alongside the image to produce a composite print, (7).

① MAG [illegible]
② MAG 35 mm
③ EDITING 35 mm
④ ST8
⑤ CP1

. . . . and how we save them for later.

Sound Recording

Photographic sound

Any system of recording sound involves converting transient sound waves into a permanent form which may, at a later stage, be converted back into sound waves. Microphones use various principles to produce an electrical signal – that is, a rapidly varying current or voltage – in direct relationship to a sound wave. As early as 1900, experimenters used this signal to vary the intensity of light falling on a strip of film, and by moving the film steadily past the light beam, obtained a record of the sound. After developing the film, playback was achieved by projecting a beam of light through the moving film onto a photocell, and using the varying electrical output from this device to produce sound in a telephone ear-piece. This, in principle, is the photographic sound system used today, except that modern practice is to pre-record all the sounds required onto magnetic tape, which is then used as the source for the photographic system.

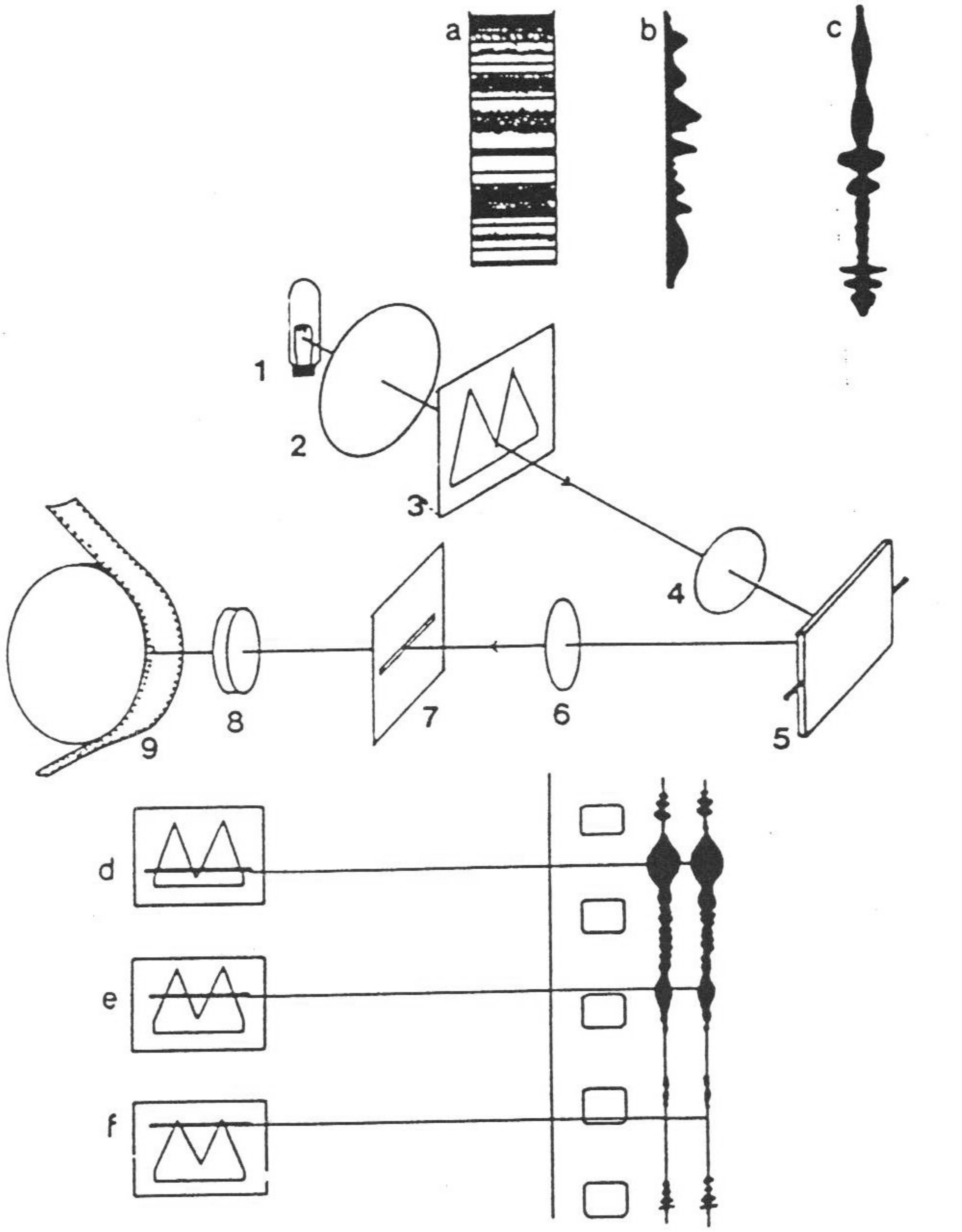
Magnetic sound

Magnetic recording tape consists of an emulsion of ferric oxide (recently other materials have been used with some success) coated onto a thin flexible support. During coating, a magnetic field ensures that all the particles of oxide are aligned parallel to the length of the tape. In recording, the electrical output from a microphone is used to produce a small, varying magnetic field in the recording head. As tape is passed over the head, each oxide particle becomes a miniature bar magnet, and the signal is recorded as a variation in the degree of magnetization of each particle. In playback, the tape is passed at the same speed over a similar head, and the rapidly-changing magnetic field induces an electrical signal which may be used to drive an amplifier and loudspeaker system, or input to another recorder.

Comparison of magnetic and photographic sound

Magnetic sound recording is more convenient than direct recording onto film, as tapes are available for immediate playback, and may be re-used many times, whereas film requires processing and printing before it can be played, and may be used only once. Furthermore, magnetic recording produces a much better signal-to-noise ratio than film, so that a wider range of amplitudes can be recorded without background noise becoming obtrusive.

Magnetic tape can also record higher frequencies than can film. For these reasons, magnetic recording is used in most stages of film production, and frequently as the final track of prints for television. However, for bulk release printing, it is far cheaper and more convenient to incorporate a photographic track, printed and processed at the same time as the image, and this basic format of sound on film has remained essentially unchanged over the last half-century.



The photographic soundtrack
(a) Variable-density track; (b) early (unilateral) variable area track; (c) modern bilateral variable-area soundtrack.

The galvanometer sound camera. (1) Light from the lamp is collected, (2), and passes through a W-shaped mask, (3). Lenses (4) and (6) image the mask onto slit aperture (7), but the mirror galvanometer at (5) oscillates with the sound signal, this moving the image up and down and resulting in a varying-width slit beam which is focused by lens (8) onto the moving sound-recording stock (9). Varying positions of the image on the slit result in a wide, medium or narrow (d, e and f) beam of light on the film.

An image of the sound wave.

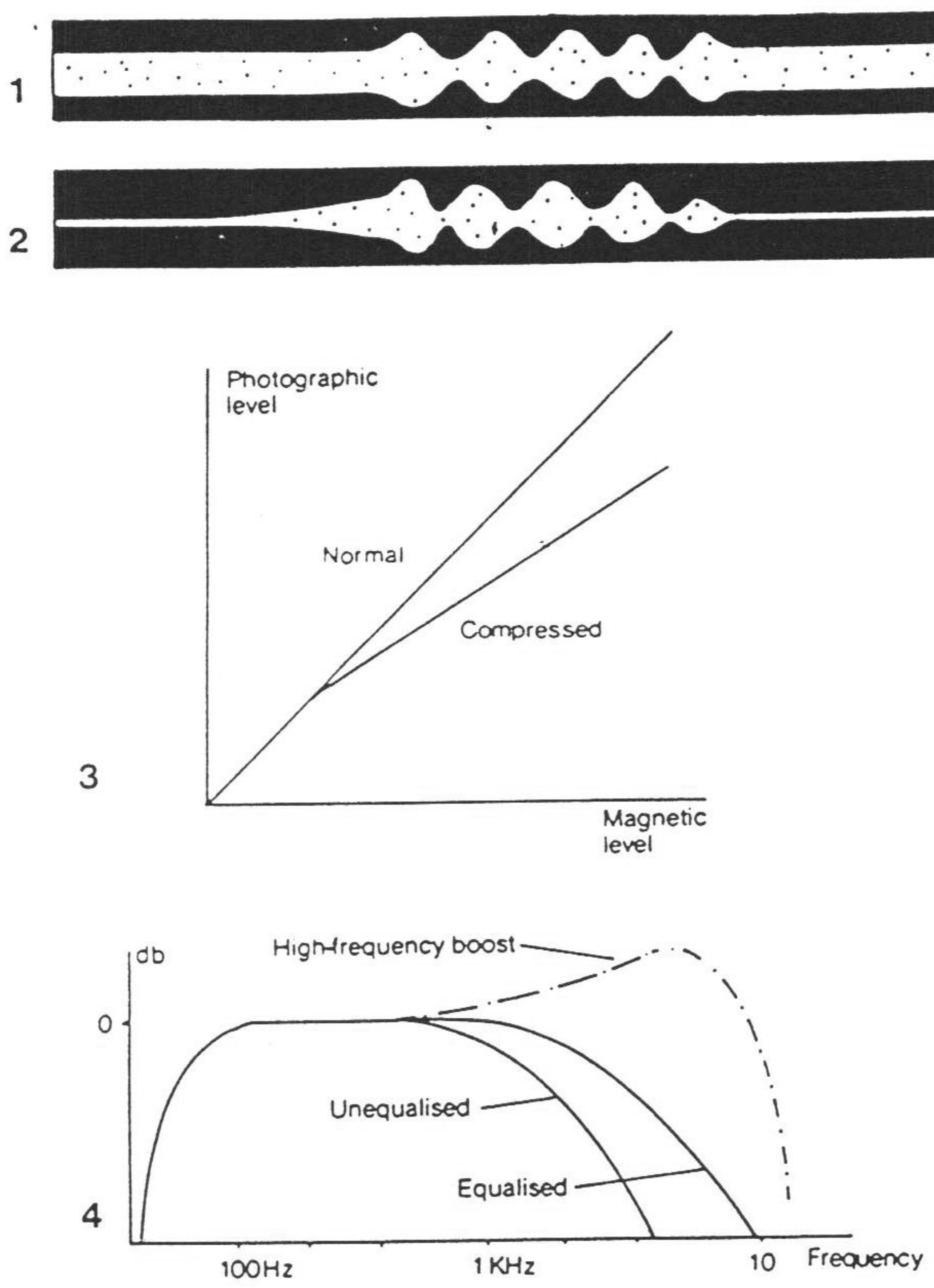
The Sound Camera

Early sound cameras used the incoming electrical sound signal to vary the brightness of a helium-filled glow-lamp, whose light then passed through a narrow slit and onto the moving sound negative. This was superseded by two systems that used a constant light source.

The principle of the mirror galvanometer camera is the same as that of a voltmeter or ammeter; if a current is passed through a coil of wire suspended in a magnetic field, then it experiences a twisting force that is proportional to the current. A small mirror is attached to the coil, and a fine beam of light is directed at it, so that the reflected light beam will oscillate from side to side in exact proportion to the electrical signal.

In the early RCA Photophone system this beam of light was allowed to fall onto a slit, and as the edge of the beam moved back and forth it traced out a waveform on the film passing behind the slit. In the modern system, the light passes through a triangular mask and is then reflected by the galvanometer mirror onto the slit. As the mirror moves with the electrical signal, so the triangular image moves up and down, lighting a broader or narrower portion of the slit. By using an appropriately-angled triangle it is possible to produce a wide variation in track width with only a small movement of the mirror. An optically-reduced image of the slit is projected onto the film as it passes at uniform speed, leaving a continuous trace of the signal. Since it varies on both sides of the light beam, this is termed a *bilateral variable area track*. A further modification replaces the triangular aperture with a W-shaped one, producing two lines, known as a *double bilateral track*.

In the Western Electric light-valve system, the electrical signal is passed through two spring-loaded metallic ribbons in opposite directions. As the current varies, electromagnetic forces either draw the ribbons together or force them apart, allowing more or less light from a constant source to pass between them and fall on the film. Like the glow-lamp system this produced a variable-density soundtrack in which the sound waves are represented by bars or striations of darker or lighter area on the film. In the modern Westrex light valve, the ribbon assembly has been turned through 90 degrees so that the ribbons are parallel to the length of the film, and the beam of light is brought into sharp focus on a slit so that it is lit over a varying width, as in the galvanometer system.



Improving sound reproduction
(1) Without ground-noise reduction: (2) with ground-noise reduction: the track adjusts in width to accommodate the signal, remaining as narrow as possible at all times to minimize grain noise in the print. (3) Compression reduces the level of loud signals compared with quiet ones, to accommodate a wider range. (4) Equalization boosts the otherwise deficient high frequencies to obtain an extended overall response.

The audio signal is processed to prevent distortion. . . .

The Sound-recording Channel

Ground-noise reduction

When clear film is run through the sound head of a projector, the grain in the emulsion produces a hiss. With a loud soundtrack this may go unnoticed; however, during quiet passages it becomes objectionable. Hiss of this sort is known as *ground noise*; it can be kept to a minimum by ensuring that the exposed area of the sound negative (and therefore the clear area of the positive soundtrack) is kept as narrow as possible.

The normal rest position of the galvanometer mirror would give an exposed line of half the available width, allowing the maximum oscillation in both directions. During quiet passages, however, only a small movement is necessary, and the average position may be offset so that the width of the exposed track is reduced. This is done by applying a direct-current signal, or bias current, to the galvanometer. This current is adjusted so that during silent passages the exposed area of the negative is about two thou (0.05 mm) wide. In louder passages the bias current is reduced in proportion to the signal strength so that the track is always just wide enough to accommodate extremes of movement of the mirror.

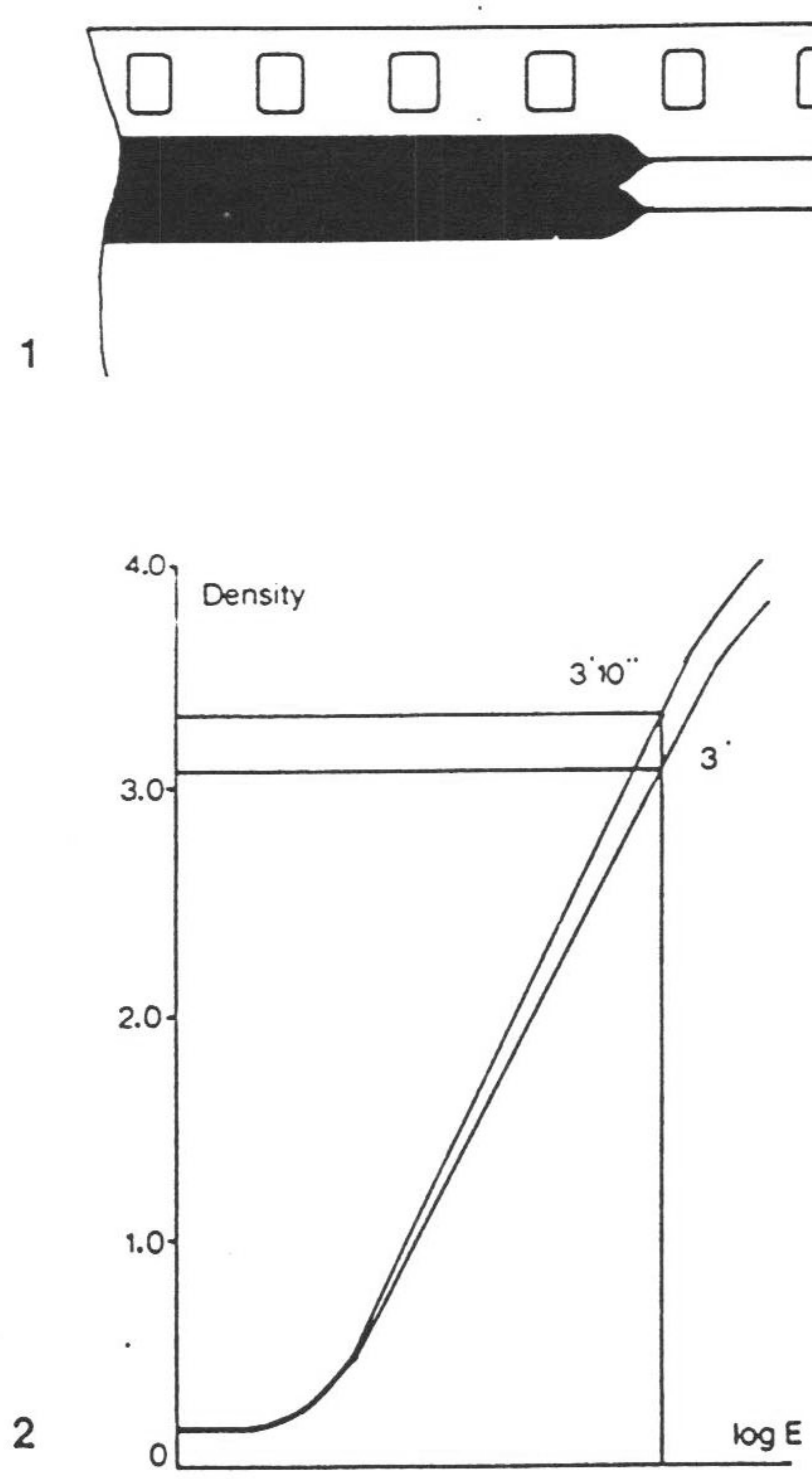
The bias current must not vary too rapidly as this would introduce an audible but unwanted signal on the track. In practice the bias line can open up for loud signals in about 15 to 30 milliseconds (ms), and is allowed to close down much more gradually – about 250 ms. To prevent distortion in the first few milliseconds of a sudden loud signal, a delay is built into the main audio signal line so that the noise reduction system 'anticipates' the signal.

Compression

Magnetic recordings can carry signals up to 70 dB louder than the background tape noise, whereas a photographic track can accept a maximum of 55 dB. A 'flat' transfer would result in quiet sounds being lost in the hiss, and loud sounds being distorted, just as photographing an excessively contrasty scene results in blocked-in shadows and burnt-out highlights. Photographic sound channels therefore include a compression stage in which low-level signals are boosted, and high levels reduced. This raises the average level of a soundtrack but at the expense of losing the impact of very quiet or very loud passages.

Film loss equalizer

Photographic soundtracks invariably lose signal level at high frequencies. In part this is because accurate reproduction of a 9 kHz signal on 35-mm film requires photographic resolution of the order of 80 lines per mm, and image-spread during exposure and development, slippage during printing, and chemical fog all serve to reduce the resolving power of the system. Some compensation can be made for this by electronically boosting the high frequencies of a recording during transfer.



Process control
(1) Sound negative density is read on a full-width flood track. (2) High-contrast sound negative is very sensitive to slight processing changes.

.... but development must be carefully controlled.

Processing the Sound Negative

A good variable area sound negative must have exposed areas that are effectively opaque, unexposed areas free from fog, and the border between them as sharp as possible. Sound negative stocks are therefore black-and-white emulsions of a very high contrast, fine grain, and high resolving power, with sufficient sensitivity to react to the extremely short exposure times in a sound camera (approx 1/80 000 sec). The emulsion is usually orthochromatic (blue- and green-sensitive) and the base incorporates a grey dye (density approx 0.25) to reduce internal reflection and halation.

Processing is normally in a high contrast, metol/hydroquinone-type bath such as D97, although many laboratories make their own modifications to this formula to increase contrast and reduce fog level.

Sound negatives are usually exposed and developed to a density between 2.50 and 3.30. This results in significant image spread which increases with density, and must be balanced exactly with opposite image spread in the positive print so that distortion is kept to a minimum. Negative density control is therefore very important.

Unfortunately the high contrast of the process makes this particularly difficult. A very small change in lamp current (say, 0.1 amp) may alter the negative density by as much as 0.20, and so in some cameras lamp brightness is monitored directly by a small photocell inside the lamp housing. in any case it is normal practice to expose a few feet of *flood track* – that is, a full-width bias line – on the end of every roll of sound negative. A section of this is broken off and developed first, so that the correct developing time for the rest of the roll may be determined.

A minor processing change has little effect on the gamma of the stock: but larger corrections would change the fog level, gamma, and grain structure sufficiently to have considerable effect on the quality of sound reproduction. It is therefore important that the process chemistry be maintained accurately. Normal control procedures are carried out using sensitometric strips exposed on the type of stock used in the sound camera. Note that while sensitometer exposures are usually at least 1/100 sec, soundtrack exposures are approximately 1/80 000 sec, and there is a considerable degree of reciprocity failure between these two times. Sensitometric strips cannot therefore be relied upon for accurate stock comparisons, and exposure tests must be carried out in the sound camera. For routine control purposes, however, sensitometric strips are quite adequate.

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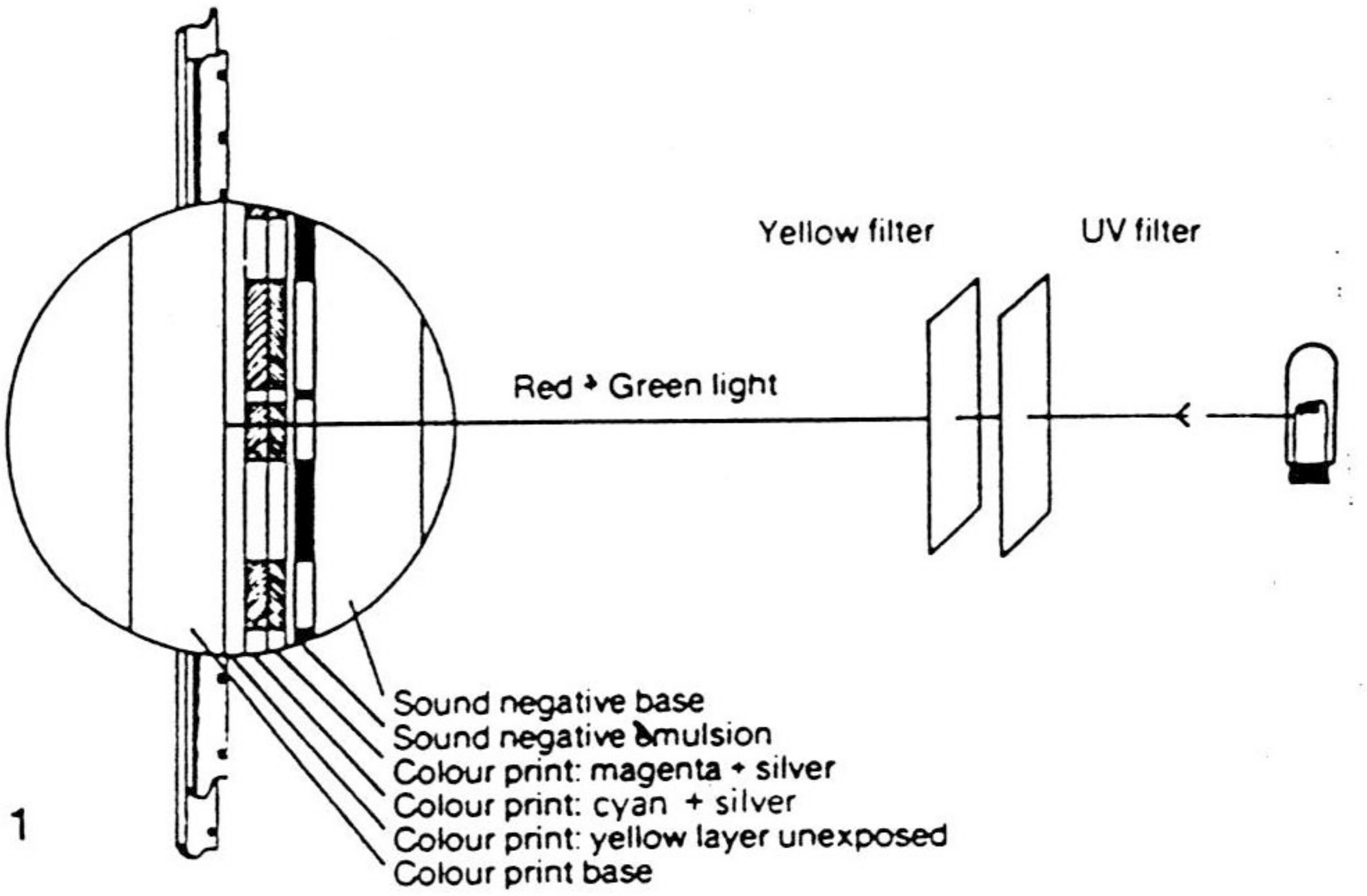

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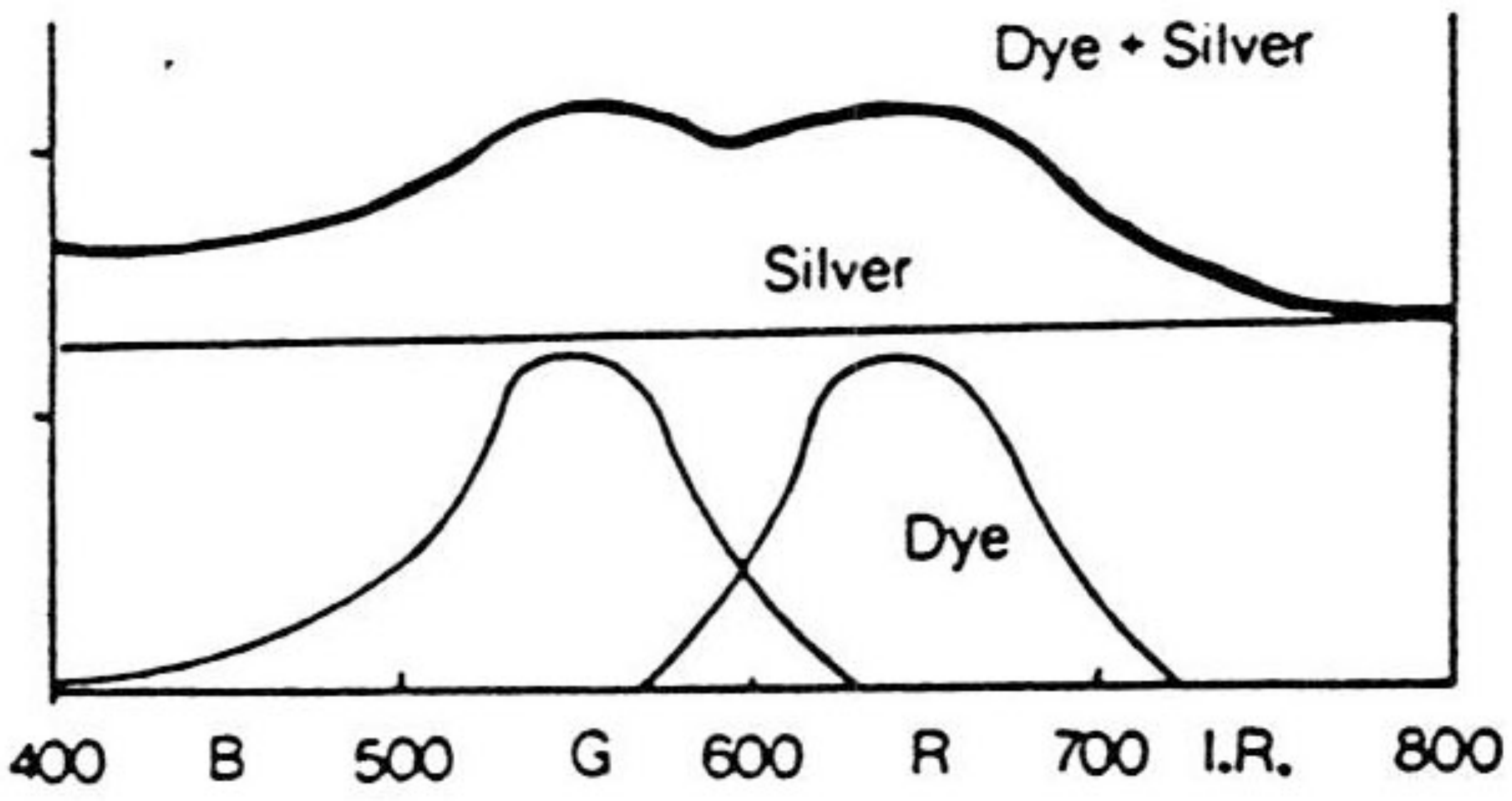


Sound printing
(1) Printing through a yellow filter exposes the two top layers of colour-positive stock. (2) Only silver provides density in the near infra-red region just above 700 mm, where the projector photocell is sensitive.

The soundtrack is printed alongside the image.

The Photographic Sound Print

By their very nature, sound prints must be made in a continuous (rotary) contact printer. As with picture negative, sound negative stock is manufactured with a short pitch in order to fit perfectly inside the curved path around the printing sprocket wheel. The back-up roller in the printing gate must be adjusted accurately: if set too tight, it is liable to 'massage' the stock and produce intermittent slippage. In order to minimize the effect of any slippage (which results in loss of high-frequency-signal level), exposure times in the printer are kept as short as possible by making an extremely narrow printing aperture.

In colour prints, only the top two layers of the emulsion (magenta and cyan) are exposed. This provides sufficient density, and results in a sharper track image than if all three layers were used, with correspondingly better high-frequency response. A Wratten 12 yellow filter is inserted in front of the light source to remove blue light, together with a 2B filter to eliminate ultra-violet radiation. This filter pack must be removed for black-and-white printing, in order to expose the blue-sensitive positive stock.

Processing

In colour positive processing, magenta and cyan dye track images are produced together with corresponding silver images in these two layers. The silver gives the soundtrack its characteristic dark purple-blue appearance; a track that contains no silver (having missed redeveloper application) appears a saturated bright blue, whereas an under-exposed but correctly developed track is a lighter, greyish blue in colour.

Track density

Any deviation from the optimum track density, normally set at around 1.40, will result in noticeable distortion due to mismatched image spread. Positive track densities are measured using an infra-red-passing filter in the densitometer, to correspond with the sensitivity of the S1 projector photocell, peaking at around 800 nm.

Direct recording

On occasions it is not practical or economical to make a sound negative, and the soundtrack is exposed directly onto the print stock in the sound camera. The normal W-shaped mask in the galvanometer system is replaced by an opposite form, so that normally-exposed areas are left clear, and *vice versa*. In the conventional negative-positive system the effects of image spread in each stage tend to cancel each other out; with only a single stage this is not possible; and exposures and densities are kept very low in order to retain sufficient sharpness. The resultant soundtrack is lacking in level, particularly at high frequencies, and has a noticeable background hiss. Such prints are mainly used for mechanical tests, or where only a working copy of a soundtrack is required.

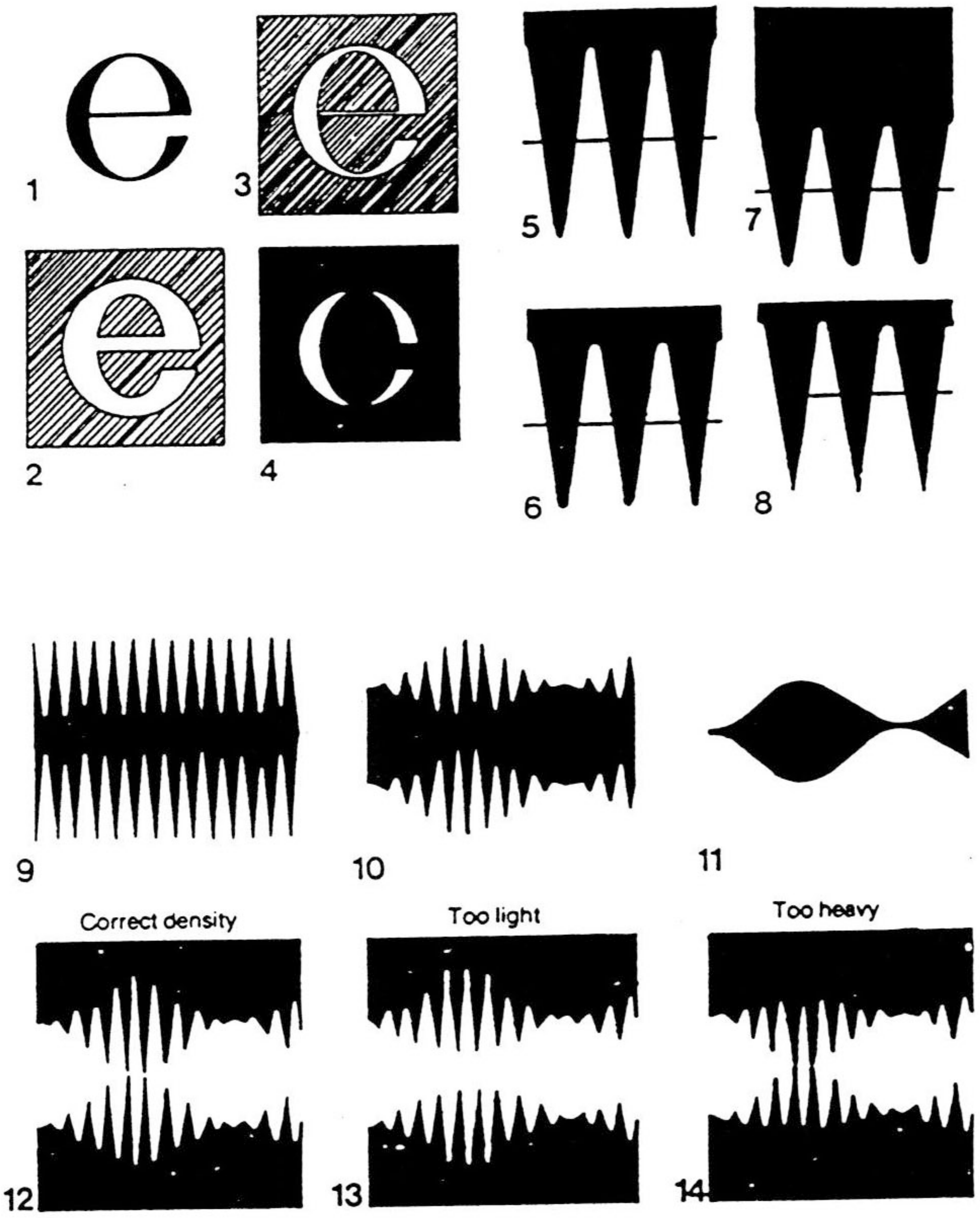


Image spread
(1) Original pattern; (2) under-exposed negative; (3) correctly-exposed negative; (4) over-exposed negative in which fine detail is lost. (5 and 6) Ideal wave form; (7) over-exposed waveform with filled-in valleys; (8) under-exposed waveforms with feathered peaks.

Cross-mod tests: (9) High-frequency tone; (10) cross-mod signal (a modulated high-frequency tone); (11) low-frequency reference tone. (12) Well-exposed print; constant average width of track, and no low-frequency signal. (13) Underexposed print with feathering of peaks and variation in average width causing a spurious low-frequency signal. (14) Over-exposed print with filled-in valleys, and again, a spurious low-frequency variation.

A system for controlling distortion. . . .

Cross-modulation Tests

Image spread

The image formed in a sound negative is inevitably slightly more diffused than the light beam generating it. There is a further slight loss of sharpness when a positive print is made from the negative. This unsharpness arises both from light scatter within the emulsion during exposure, and from chemical diffusion during processing. The resultant image spread causes dark areas of the track to expand. Fortunately, in the positive print, the shift is in the opposite direction, and so the two effects may cancel each other out. The extent to which this is successful is measured by the cross-modulation test.

Cross-modulation tests

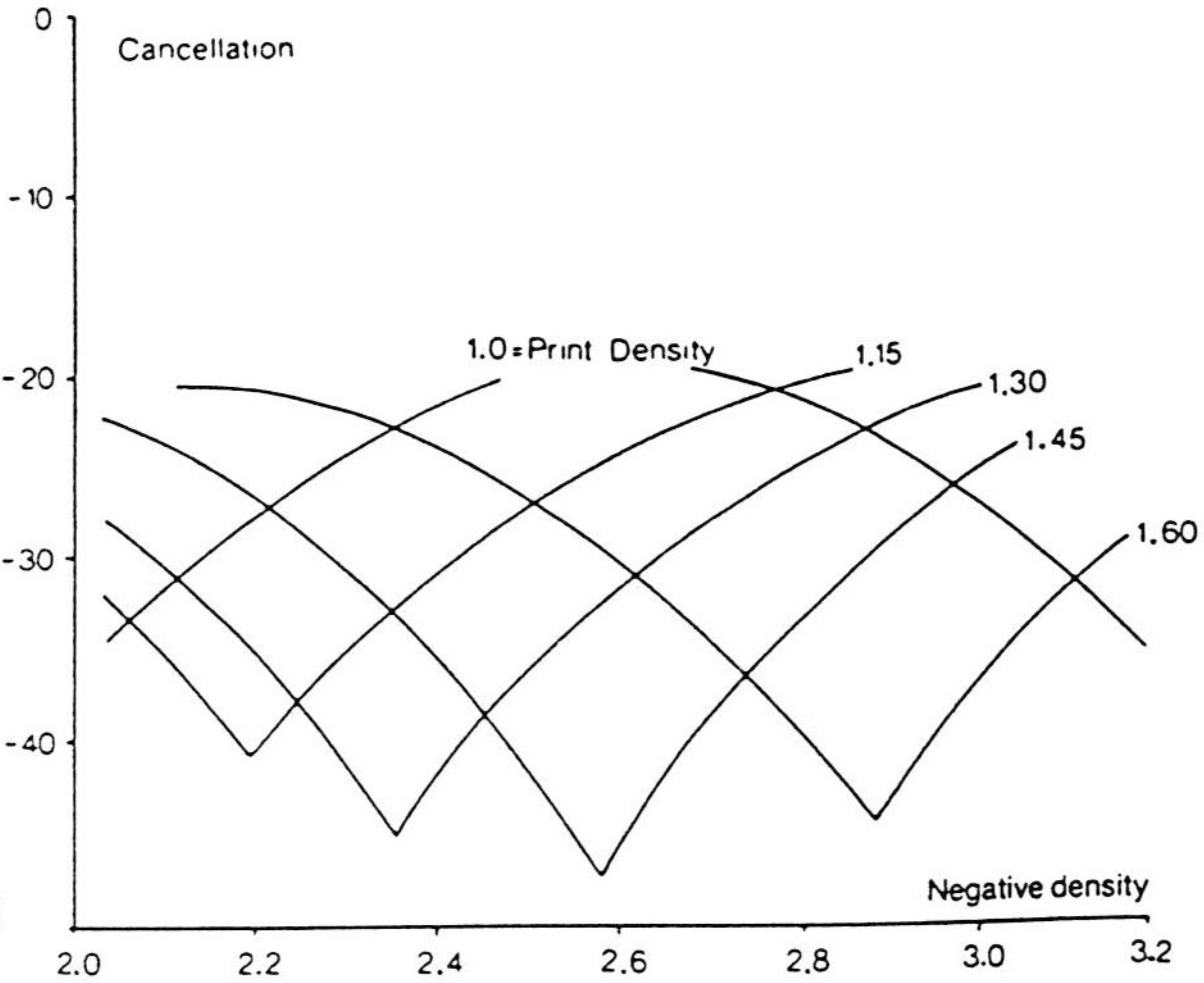
High-frequency signals – waves with narrow peaks and valleys – are more affected by image spread than low-frequency waves, much as a thick coat of paint will fill in very fine scratches on a surface but follow the contours of wider marks. In an over-exposed negative track with excessive image spread, not only is the difference between high-frequency peaks and valleys reduced (painting over the scratches) but the average width of the track over a complete wave is increased much more where there *is* a high-frequency wave than where there *is not*.

A cross-mod test signal consists of a high-frequency tone (6 kHz for 35 mm, 4 kHz for 16 mm) modulated by a low-frequency variation (400 Hz). In an ideal waveform, the high-frequency signal varies in amplitude between 10 per cent and 90 per cent of maximum output 400 times a second, but because the average light transmission at any part of the waveform remains constant, there is no audible signal at 400 Hz.

If the positive print is over-exposed, then the dark areas surrounding the clear track spread into the peaks and valleys of the high-frequency signal, lowering the average transmission where the high-frequency signal is strongest, but having little effect at the weaker phases of the signal. Thus, average transmission varies with the modulation of the signal, and a 400 Hz sound can be detected.

Similarly, in an under-exposed positive print, the dark areas surrounding the clear track do not spread sufficiently to counteract the spread of the negative image, and the track area is spread wider in areas of strong high frequency, once again producing a signal at the modulation frequency of 400 Hz.

The cross-modulation signal is purely a test device designed to produce a measurable effect when image spread is not cancelled effectively. In a normal soundtrack the effect is most noticeable when any high-frequency signal changes rapidly, and a spurious wave is introduced. In speech, sibilant sound such as 's' sound 'spitty', while musical instruments such as cymbals lose their clarity and sound muddy.



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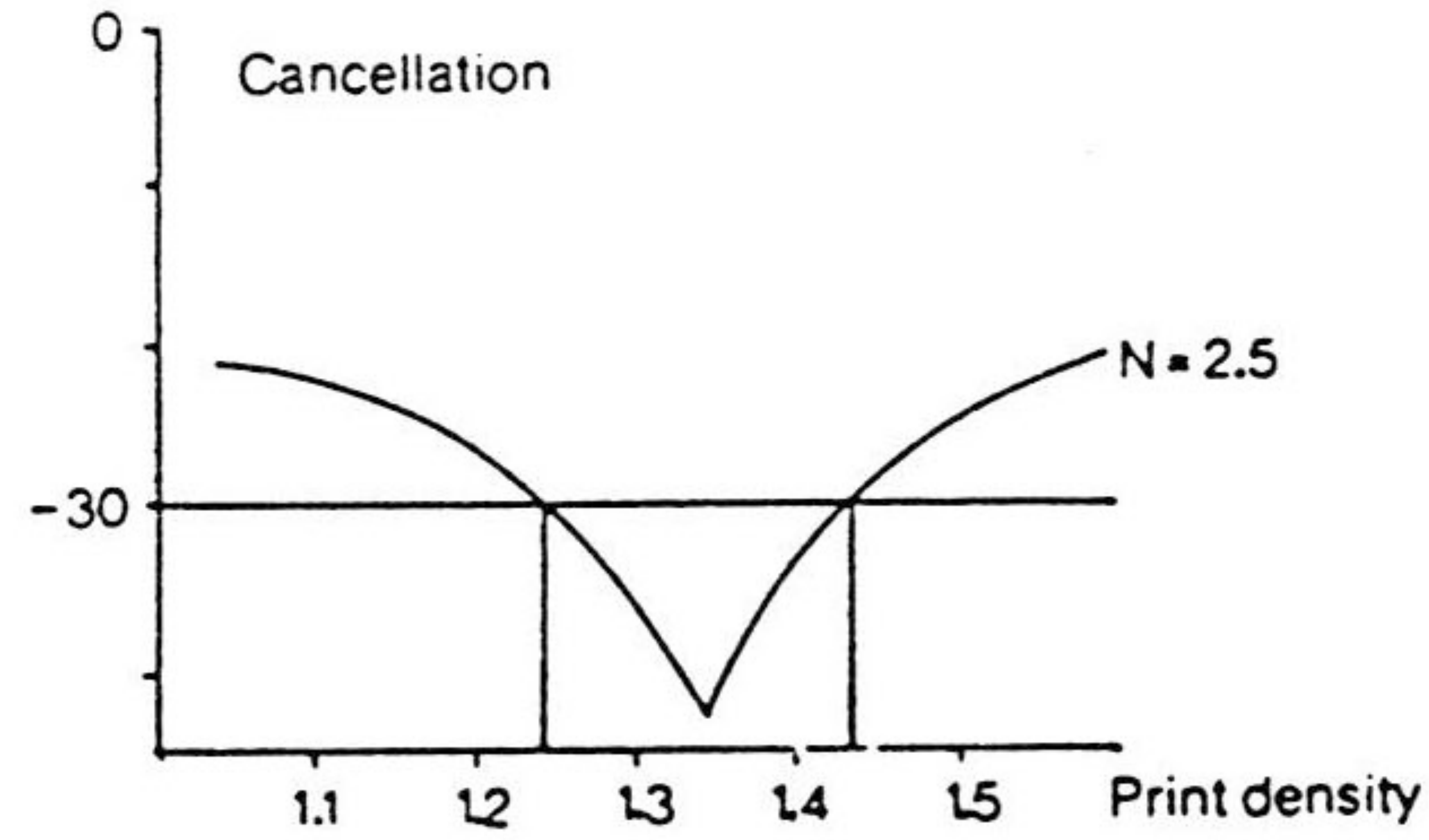

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The cross-mod family
(1) Each curve represents results from a set of negatives at a single print density (P). The value at the V of each curve indicates the ideal negative density for that print.
(2) Control tolerances may be estimated by plotting a series of print results from a single negative. The V width at 30 dB (the normally accepted minimum cancellation result) indicates the upper and lower limits for print density. A minimum of 35 dB is suggested for stereo soundtracks.

. . . . requires tests to establish the correct aim densities.

Cross-modulation Tests in Practice

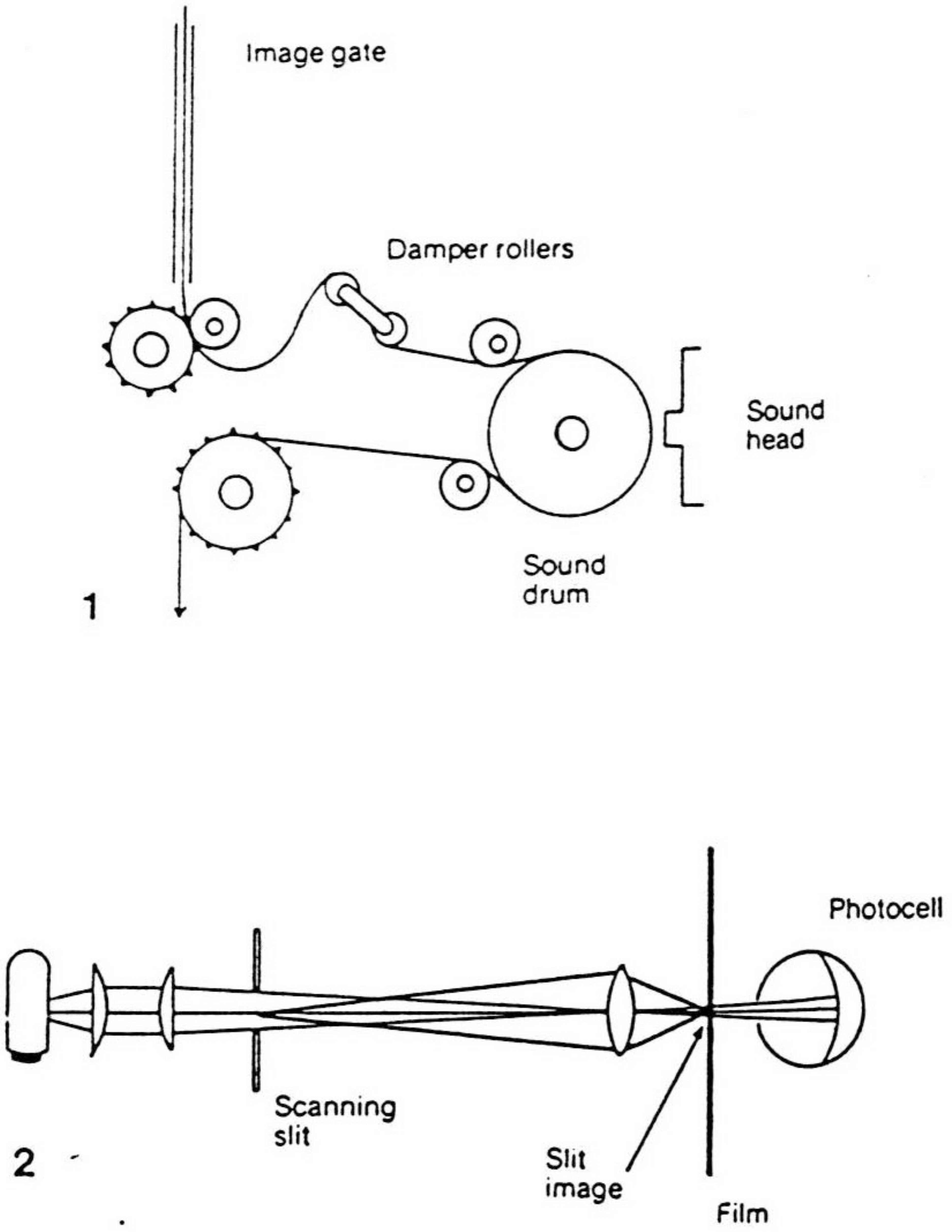
A complete family of cross-mod tests must be produced to find the negative and positive densities that will give best results. A set comprising reference tone (400 Hz), cross-modulation signal (6 kHz for 35 mm, 4 kHz for 16 mm, modulated at 400 Hz) and high-frequency signal, together with a flood track (full-width bias line) density test, is exposed at a range of lamp currents in the sound camera, and developed. This full series is then printed onto the appropriate positive stock at a range of printer-lamp settings. Since the dark areas of the positive print correspond to clear film on the negative, and *vice versa*, a given printer exposure will result in the same positive density regardless of the exposed density of the negative.

After positive processing, the prints are run through a sound playback head. For each test, the cross-modulation output at 400 Hz is measured and compared with the reference tone. This result indicates the effective cancellation of negative and positive image spread. Similarly, the high-frequency signal output is compared with the reference tone as an indication of overall track sharpness.

Graphs are now plotted of cancellation against negative density, with one line connecting the series of points for each print. Each line should appear V-shaped, curving steeply down to a minimum value and then rising equally rapidly, as negative density is varied. The lowest point of each V indicates the best possible negative density, at which cross-mod distortion is least, for the print density in question. A light print works best from a light negative, while a heavy print favours a heavy negative.

Other criteria are also of importance: a density below about 1.20 will be more subject to noise from unwanted light transmitted through the dark areas of the print, while unduly heavy negatives and prints will result in greater high-frequency loss. Once a final combination has been decided upon for any combination of stock and printer it is normal for a laboratory to set the print density as a standard so that negatives, once made, can be printed at any time in the future at a standard setting. Sound negatives on different batches of negative stock, or from different sound cameras, should be made to a density that will suit this established print density.

Although this somewhat lengthy test procedure should be carried out regularly, and certainly after any stock or equipment changes, routine control on individual negatives and prints may be carried out using standard sensitometric methods, aiming for the densities indicated by cross-mod testing.



The projector sound head
(1) The intermittent movement of the film through the image gate is smoothed out to a perfectly steady movement around the heavily-damped sound drum. (2) A reduced image of the scanning slit is formed on the film soundtrack.

Sound completes the picture.

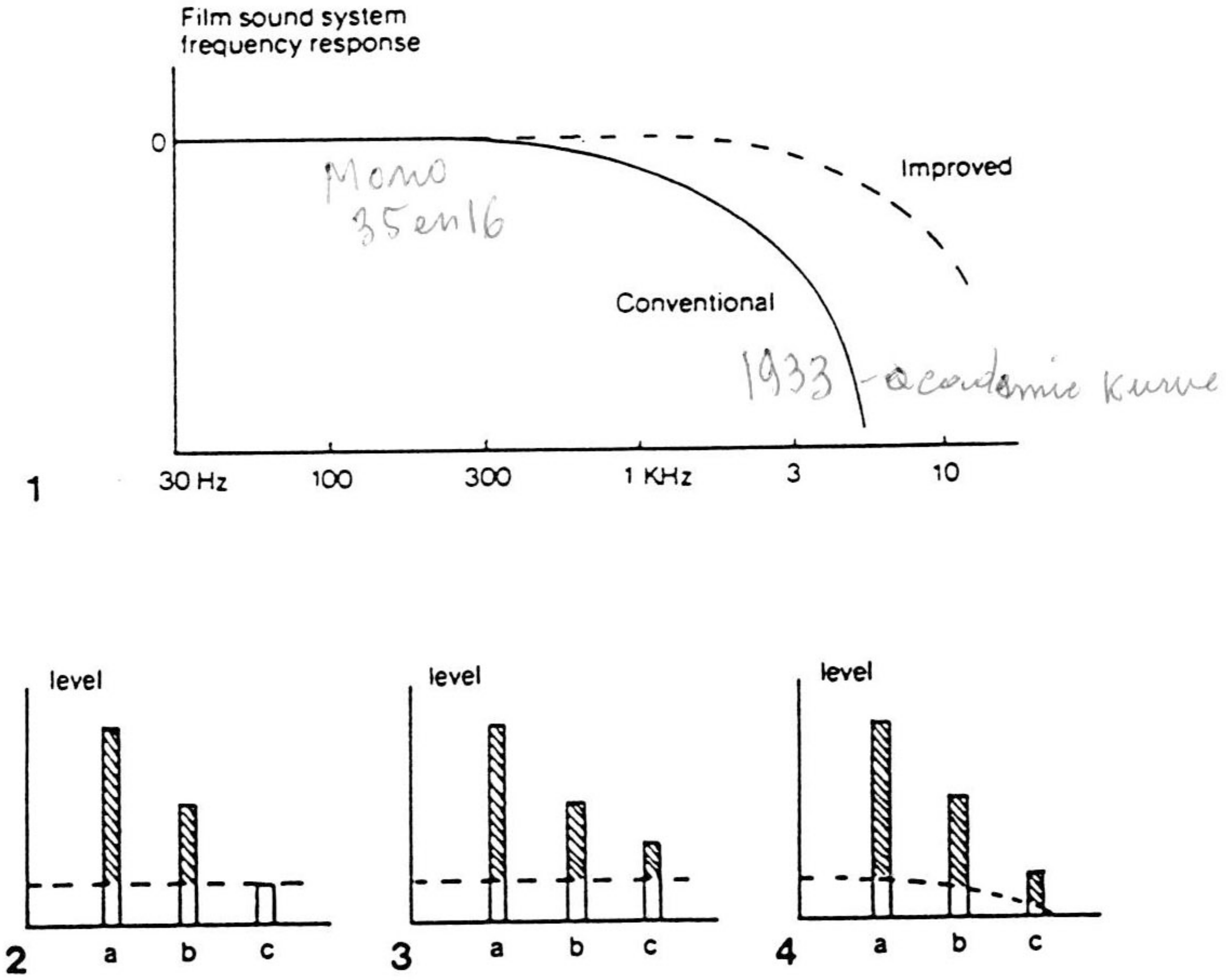
Theatrical Sound Reproduction

Unlike the intermittent movement of image projection, soundtrack reproduction requires an absolutely uniform motion: even a one per cent speed variation would cause enough variation in pitch (wow) to be readily noticeable to the average listener. This constant speed is provided by separating the projector sound head from the picture head and providing for a slack loop of film in the lace-up between the two. In the sound head the film is driven round a relatively heavy flywheel which may in addition be electrically or mechanically damped to elimination any trace of vibration still transmitted by the film.

The projector sound head operates in a complementary manner to the sound camera. Light passing through a narrow slit is focused onto the soundtrack, where a varying proportion is transmitted depending upon the width of the track (variable area) or its density (in the earlier variable-density system). This light is collected by a photocell which produces a small electrical signal proportional in strength to the light received. Once amplified, this signal is fed to the theatre's loudspeaker system where it produces audible sound. As in the sound camera, the width of the slit is of great significance. Too wide a slit results in high-frequency loss: if it is too narrow there is an overall loss of output since not enough light can be transmitted. The most efficient width has been found to be 0.0013 thou (0.033 mm). In practice, the slit itself is many times wider than this, and a system of lenses focuses an optically-reduced slit image of the correct width onto the film.

16-mm prints may be either A-type or B-type: the emulsion may be on either front or back surface of the film as it is projected. In most projectors the slit is focused on the front surface and so best high frequency response is obtained from B-type prints. Non-standard (A-type) prints may be played but a slight loss of sharpness in the sound reproduction will be noticed unless the soundhead is of a type that can be refocused.

Photocells in 35-mm and 16-mm projectors are sensitive predominantly to infra-red radiation, peaking at around 800 nm. This standard was established when black-and-white prints were the norm. Unfortunately, the dyes used in colour prints have a very low density to infra-red, so it is necessary during processing to restore the original silver image in the soundtrack area by means of redevelopment. Super-8 projectors use a newer type of photocell which is responsive to visible light, and a simple dye track is adequate in this format.



Improvements in sound reproduction
(1) Extended high-frequency response, resulting in crisper soundtracks. (2) Noise reduction: high-level (a) and mid-level (b) sounds only can be heard above the noise level of a conventional soundtrack. (3) Noise reduction applied during recording boosts low-level signals, (c). (4) On playback, the correct relationship is restored, thereby cutting noise level in the quiet passages.

Recent improvements to sound reproduction.

Dolby Stereo Soundtracks

Noise reduction

Noise-reduction systems work by boosting low-level signals at the time of recording, and then cutting them back on playback. The proper relationship between loud and quiet signals in the soundtrack is maintained; but the hiss from the recording system is reduced in the quiet passages. In the Dolby system, separate channels of noise reduction operate at different frequency ranges, with significantly improved results.

Academy curve

Early film-sound systems suffered more from high-frequency loss and distortion than today's tracks do, and in 1938 a standard known as the *Academy Curve* was introduced to restrict high frequencies in the film-sound chain. Signal levels started to be cut at around 2 kHz, and were as much as 10 dB down at 9 kHz, resulting in the dull, flat sound of conventional film soundtracks. However, improvements in film stocks and photographic sound equipment, as well as the Dolby noise reduction system, mean that soundtracks can now be reproduced faithfully with frequencies of up to about 14 kHz.

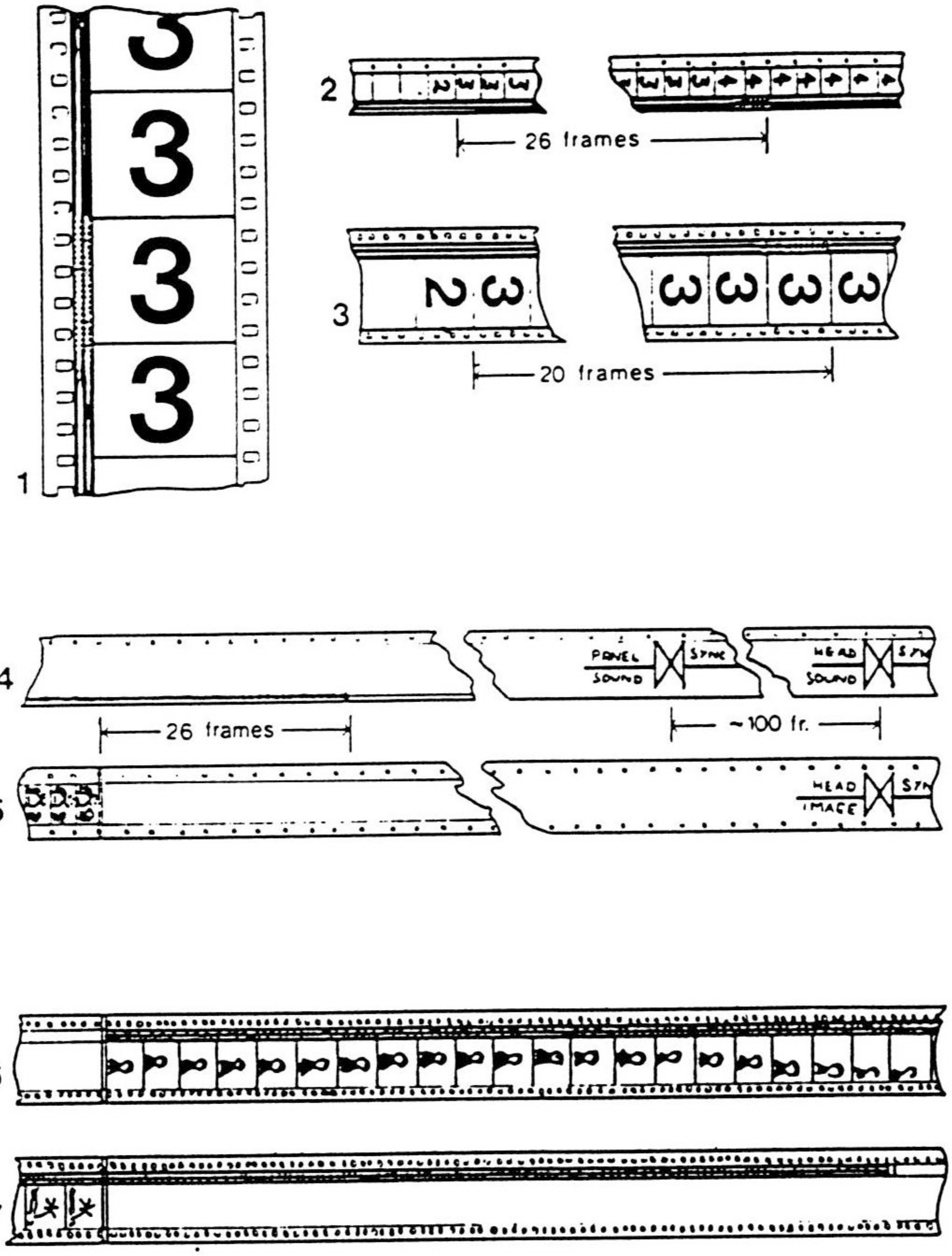
Dolby noise-reduction yields a signal-to-noise ratio of about 55 dB (the difference between maximum volume and background noise), enabling tracks to range louder, but without the distraction of noise in quiet passages. Stock and equipment improvements lead further to an extended frequency response giving a brighter, more realistic sound, particularly in music.

Stereo sound

Domestic stereo systems have two tracks (left and right) and require the listener to sit roughly equally between the two speakers. In the cinema this requirement is impossible to meet for the entire audience, and so film stereo uses four channels: left, right, centre and surround.

Normally, music makes full use of left and right channels, but dialogue is placed in the centre channel as in mono tracks. (A stereo dialogue track would make cross-cutting of the image very confusing, as characters would appear to change position with every camera angle.) The surround channel feeds speakers along both sides of the auditorium, and is used for atmospheric tracks and occasionally to bring sounds 'right out of the screen' such as spaceships flying overhead.

A stereo sound camera produces a double bilateral track from two galvanometers, each reflecting a single beam and producing one of the two bias lines. An encoding device mixes the four separate channels of sound into two signals in such a manner that they can be analyzed into the original four signals during replay. Left and right channels correspond to the left and right bias lines, and the combined signal in both lines produces the centre channel. Surround sound is recorded in both lines, but with a phase shift to distinguish it from the centre channel.



Picture and sound synchronization
(1) The sync pip may be easily recognized in a photographic soundtrack. (2 and 3) The pip appears a set number of frames ahead of the '2' where it is heard. (4) Sync marks are placed in the sound negative leader so that it may be laced up on the printer correctly with the image negative, (5). The image negative sync mark also serves as a starting point for frame-count cueing (FCC). (6) Sound from the start of reel 2 is printed alongside the end of reel 1 so that nothing is lost when the head leader of reel 2, (7), is cut off in positive assembly.

. . . . and people should talk when their lips move.

Picture and Sound Synchronization

During sound editing, a short 'pip' is placed in the soundtrack leader, to be heard a specified number of frames before the picture starts. One convention is that this pip should sound at the frame marked '2' on a standard 'clock' leader – that is, exactly two seconds before the picture starts.

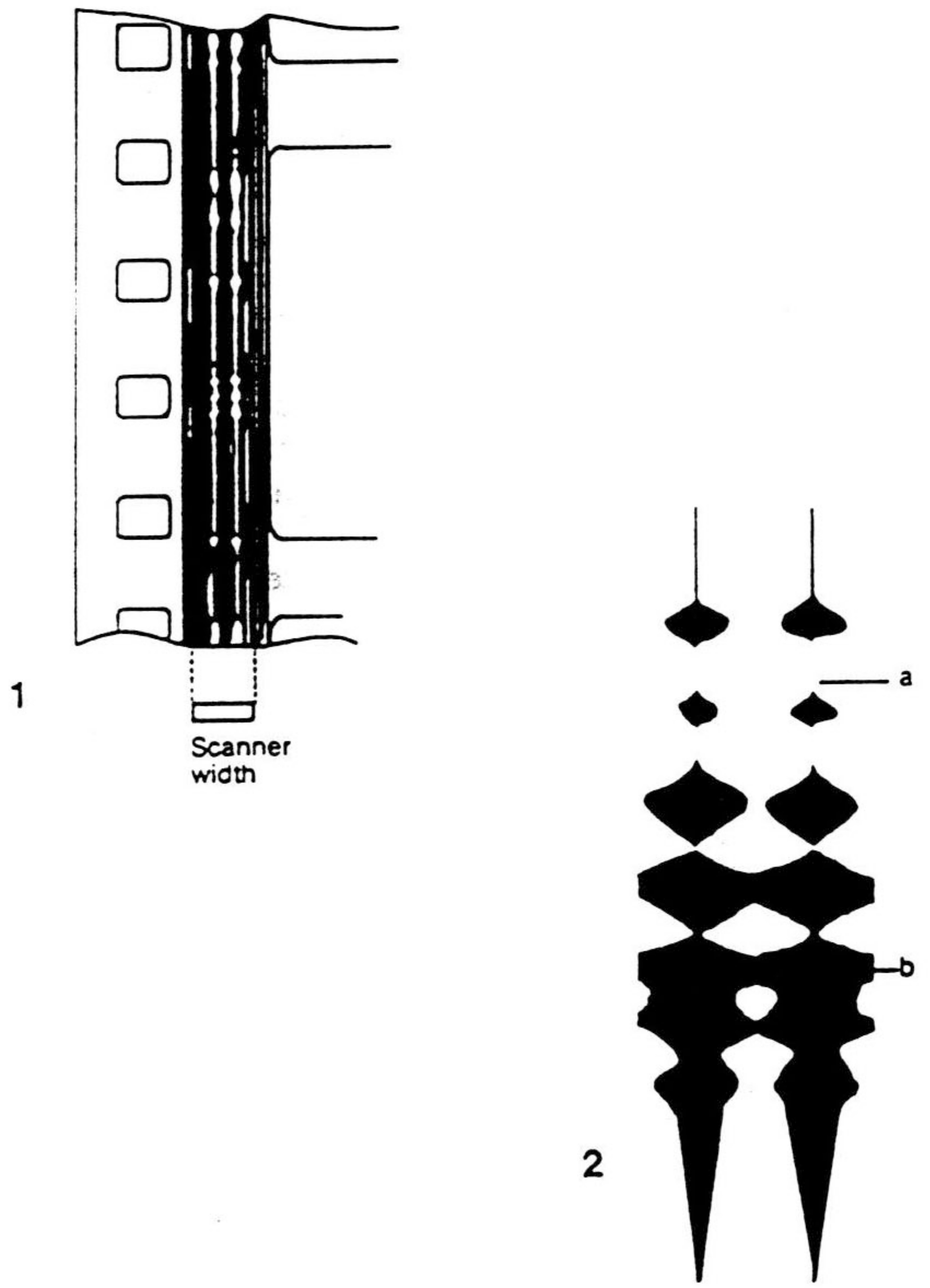
When a print is projected, any given frame of film passes through the sound head some time after it has appeared in the picture gate: in 35-mm projectors this gap is 20 frames, in 16-mm it is 26 frames. The photographic soundtrack must therefore be advanced by this amount so that it plays in synchronization with the image. The sync pip should therefore appear on the print level with a particular frame ahead of the '2'. In 35-mm this is the fourth '3', and in 16 mm the last but one '4'.

In order that the printer may be laced up correctly, a *sync mark* consisting of a cross with a hole punched in the centre is placed in corresponding positions in the thread-up leaders of the picture and sound negatives. When the printer is laced up with these sync marks in their respective gates, image and sound will be printed in the correct synchronization. Practice on Model-C-type printers is to punch a hole in the raw stock corresponding to the picture sync mark, advance the printer until this punch hole is in the sound gate, and align the sound negative sync mark with it. This is not practicable on panel printers, and a separate sync mark is placed on the sound leader allowing for the separation between picture and sound gates on the printer. Different positions will be required for different types of printer.

The degree of tolerance to an 'out-of-sync' track is hard to assess accurately. Since sounds from distant events are normally heard late, a retarded sound track is often less disturbing than one that is advanced. An average audience is not disturbed by sound that is one frame too early, or two frames too late. It must be remembered, however, that successive errors in post-synchronized track editing, and in sound printing, may add up to a detectable error, even though each individual operation is frame accurate.

Sound overlays

Since soundtracks are printed some frames ahead of the image, the last few frames of any reel would normally have no sound printed alongside them. If two reels are to be spliced together for projection, the first second or so of the following reel's track must be recorded at the end of the previous reel so that picture and sound are both uninterrupted.



Sound distortion
(1) In a poorly-applicated track, the edge of the redeveloped stripe is scanned in the sound reproducer, causing a variable rumble or hiss. (2) Over-modulation because of poorly set ground-noise reduction (a) or an excessively strong signal (b) results in squared-off, rough-sounding waveforms.

Recognizing sound problems and solving them.

Sound Defects

Crackles

Fine particles of dirt, scratches or cinches in the negative, all result in showers of white spots on the print. These are heard as a background of clicks and crackles. Since white spots affect only the dark areas of the track, this noise is most noticeable during quiet passages where the bias line is narrowest. Noise during loud passages originates in the clear areas of the print. Loose dirt or scratches on the print, or an excessive and smeary application of lubricating wax to the print, are likely causes.

Pops

Low-frequency pops or thuds are caused by relatively large holes or spots in the positive soundtrack. Often these occur when bubbles form in the redeveloper bead during application, leaving spots in the soundtrack without silver, and light blue in appearance.

Hiss

Hiss results from a random, unwanted signal being reproduced. In an optical soundtrack this may come from a grainy or slightly fogged track area, or from scanning beyond the edge of the soundtrack.

Low volume

This may arise from a print that has not been redeveloped, or an excessively light print. Moderate variations in print density, however, have little effect on sound level, and volume errors are most likely to be the result of an incorrect recording level during mixing or transfer.

Sibilance

Incorrect negative or positive densities result in cross-modulation distortion, heard as spitting 's's, and 'muddy' orchestral sounds.

Clipping

A 'ragged' edge to loud sounds, but acceptable quality at low levels. This may be caused by an incorrectly-positioned scanner slit in the projector, or overloading during sound transfer.

Wow and flutter

A gradual (wow) or rapid (flutter) variation in pitch is caused by an uneven playing speed at some stage of sound reproduction. This cannot be caused during printing, however, since negative and rawstock must inevitably run through the printer at the same speed.

High-frequency loss

Some high-frequency loss is inevitable in a photographic system, but is normally corrected by film loss equalization. A frequent cause of excessive high-frequency loss (producing a woolly, muffled sound) is poor printer contact or slippage resulting in a visibly-blurred track.