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Motion Picture Application

DYE TRACKS

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A TIMELESS INTRODUCTION IN MOTION PICTURE SOUND RECORDING.

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INSIDE...

THE SUMMARY IN BRIEF.

Sound is a 360-degree experience and whether we are attending a concert hall or a motion picture theatre, the full emotional impact of the presentation is the result of a wide variety of sonic vibrations that arrive from every direction.

We are now entering the Third Age of reproduced sound. The monophonic era was the first, which lasted from Edison's invention of the phonograph in 1877 until the 1950s. During that time the goal was simply to reproduce the timbre of the original sound. No attempts were made to reproduce directional properties or spatial realism. Based on inventions from the 1930s, reaching the public in the mid '50s, the stereo era was the Second Age. This stereo sound added two dimensions of space and has provided great listening pleasure for four decades. The introduction of digital multi-channel surround systems was the beginning of the Third Age, offering the public the opportunity to almost "feel" the sound.

These surround systems can provide this involving presence in a way that is robust, reliable and consistent. The only constant throughout the complete history of recorded sound, is the physical way by which the analogue soundtrack is recorded on the filmmedium itself. Up to now silver containing soundtracks are used to produce the necessary density for the reproduction equipment. This technology, as old and well known as it is, is not that straightforward as it should be. In particular, the labs are encountering an increased risk together with an extra cost, not to be neglected.

This third era, can only be a real technological revolution if also the recording methodology of the analogue tracks are adapted to the modern needs. Dye tracks, creating the necessary density without the use of silver and the inherent redevelopment, will be the alternative in the very near future.

This paper explains the real core of this technology, together with the necessary practical data to expose the sound negative and the final motion picture print film.

The paper "DYE TRACKS" can be ordered at AGFA (Tel. +32 3 444 8041) 2000 05 11

Early history of movies with sound.

In the narrowest sense of the term, the first talking movie was probably a test film W.K. Laurie Dickson showed to Thomas Edison as a demonstration of the Kinetophonograph in 1889.

Edison had assigned Dickson to work on this at the same time he started development of the Kinetograph. Amazingly, this bit of sound film still seems to exist. It's basically an Edison employee saying "hello" to Edison from the screen. This system was a sound-on-disc system, essentially a gramophone hooked up to a Kinethograph with presumably some means of synchronisation.

A fire in Edison's labs in 1914 forever ended their experiments with sound films which were never commercially successful.

In 1904, a former Edison employee named Lauste developed a sound-on-film system. It was not practical for use in theatres due to problems with amplification.

Amplification was actually the problem that kept sound out of the theatres for many years, rather than a lack of technology to match some form of sound with images.

Lee De Forest developed the solution in 1923, with the Phonofilm sound-on-film system. There were a number of experiments with this system in the mid-20s, and eventually it was incorporated into the Fox Movietone system.

D.W. Griffith used this system to attach a sound introduction onto one of his films, "Dream Street".

The first major commercial film with synchronized sound was "Don Juan" in 1926. It used the Vitaphone, sound-on-disc system.

"The Jazz Singer", also produced by Warner Brothers (in 1927) had already several musical numbers and a handful of lines recorded by Al Jolson.

By 1930, sound-on-disc was totally abandoned until recently the DTS system appeared. It has the advantage of being cheaper and requires less complicated equipment. It has the disadvantage that one has to ship discs around, as well as film reels.

Sound-on-film systems used one of two competing technologies. One was a variable-area soundtrack, the other a variable density and both used a portion of the film not projected, out towards the sprocket holes.

Variable-area soundtracks filled (and still do) a varying area of the sound track with solid black, encoding sound information. Variable-density fills the entire area with varying shades of grey to encode the information. Both systems existed in the 30s, but variable area eventually prevailed.

The nature of sound waves.

As the human acoustical system can only register pressure variations, sound waves are said to be created by vibrations. Sound can only be transported from the generating source (speaker) to the human receiver (eardrum) by means of a suitable medium such as air.

As sound travels away from its source, the original amount of energy is spread over a rapidly increasing area, and thus the strength of the waves are reduced. This effect follows an inverse square law, meaning that doubling the distance reduces the sound energy to one quarter.

Since the sensitivity of the ear is not linear, meaning that a double sound intensity does not lead to a double sound sensation in the brain (psofometric sensitivity), the sound intensity is expressed on a logarithmic scale. On this scale, a double sound intensity is an increase of 3 dB on the logarithmic scale. In the same system, a signal-to-noise ratio of 50 dB means that the loudest sound a system can produce is 100,000 times louder than the background noise of the system.

As the sound waves pass a fixed point, the air pressure at that point varies between an upper and a lower value. The difference between the highest and the lowest value is a measure of the strength or loudness of the sound, and is called the amplitude of the sound wave.

If the number of vibrations per second is increases or decreases, more or less waves reach the same fixed point. This change in rate is heard as a variation in pitch and is called the frequency of the sound wave, expressed in a number of cycles per second or Hertz (Hz).

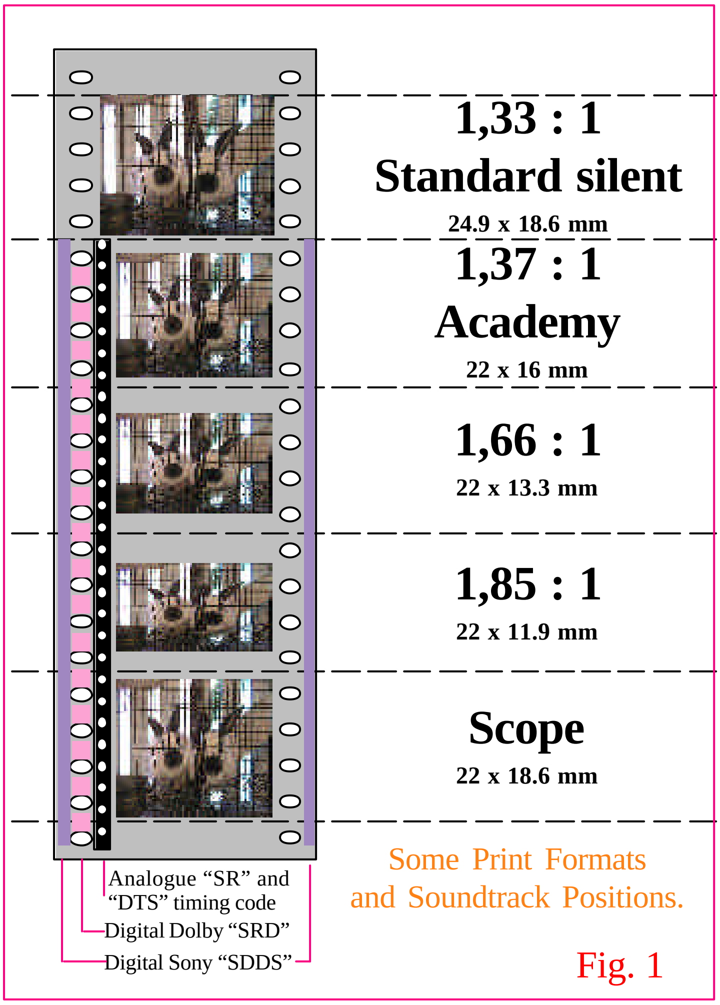
Very few sounds have a single-frequency wave form. Even a single note on a musical instrument consists of a fundamental frequency together with a number of upper harmonics; waves of frequencies exactly a multiple of the fundamental. It is the presence of these harmonics that give each instrument, voice or acoustical effect its characteristic timbre and colour, enabling us to distinguish between ,for example, a piano and a flute.

All these sound/pressure vibrations are received by the human eardrum, transmitted through a number of small bones to the inner ear and sent to the brain after being converted to nerve pulses. At the very beginning of this human "receiver", the eardrum is vibrating at the same frequency as the original sound. That's why young people can hear frequencies between 20Hz and 20000 Hz, while older people (with a thicker and thus stiffer eardrum) tend to have problems hearing frequencies above 12000 Hz.

So sound can only be heard in real time, meaning that a sound wave after it has been generated continuously expands and thus spreads its original energy over an increasing volume of medium (air). This means that the distance and time over which a sound wave can be heard is very limited, and depends upon the original wave properties, e.g. frequency, amplitude and medium.

To store sound for a longer period of time, it has to be recorded on another medium such as a magnetic tape, compact disc or a motion picture film. Only in this way can the original sound be transported together with the stored image and reproduced by the proper means, e.g. film projector and a sound chain.

Sound Recording



Some Print Formats and Soundtrack Positions.

Fig. 1

Any sound recording system involves the conversion of sound waves into a permanent form which may at a later stage, be converted back into the original sound waves. This permanent form can be either analogue or digital. The storage principle however can be either photographic or magnetic on a separately applied set of magnetic sound tracks. The latter is an inherently expensive system and therefore only applied to motion picture films where first there is enough place to put the tracks and second the improved sound quality goes together with an improved image quality e.g. 70 mm releases.
The trend is to release 70 mm prints without magnetic tracks but digital DTS instead.

The analogue soundtrack.

As the stored sound data has to be an exact replica of the original sound, the analogue storage system has to able to store frequencies between 20 Hz and 20000 Hz with an acceptable high signal-to-noise ratio.

The frequency reproduction is directly dependant upon the projection speed which is held very constant at 24 frames* per second. So in reality the waves are "written" directly on the film material, with a wavelength decreasing with higher sound frequencies.The optical analogue sound tracks, which are positioned between the perforations and the image frame, carry an exact replica of the original sound waves. As can be seen in Fig 3, a 20 Hz soundwave takes 23 mm on the film to be stored and reproduced again at the normal projection speed. A high frequency of 20000 Hz has a 23 micron wavelength on the film. In these 23 microns, a full wavelength has to be written and reproduced afterwards with high quality.
Since the practical sound information is a complex composition of different frequencies and amplitudes, the stored waveform has, of course, the same complexity.

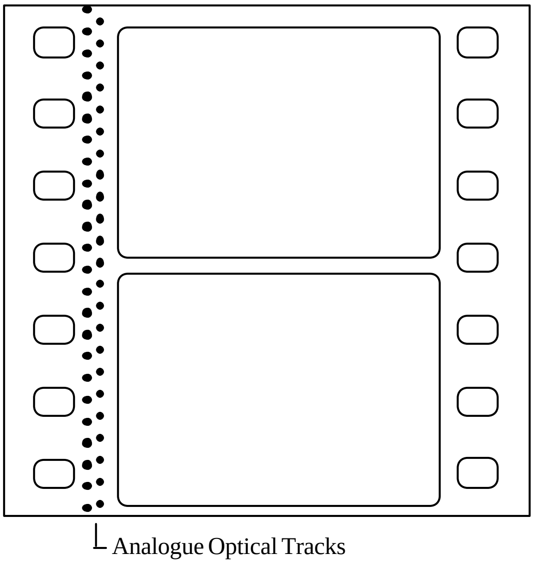


Fig. 2

* The original projection speed in motion picture was one foot / sec or (with a frame height of 19.05 mm) 16 frames/sec. Later, due to sound reproduction problems, the projection speed was increased to 1.5 feet/sec or 24 frames/ sec. Since Telecinema systems are copying motion picture films without any speed correction to 25 frames/sec, a motion picture film broadcasted on TV is projected 4% too fast, and thus 4% shorter in time than the original theatre version while all frequencies are shifted upwards by the same 4%.

Sound Recording

A 9 kHz signal on a 35 mm film, projected at 24 frames/sec needs a photographic resolution of about 80 lines/mm. Photographically this is no problem but image-spread during exposure and development, slippage during printing and chemical fog serve to reduce the resolving power of the system. Therefore, all the different components in the film printing chain need to be extremely accurate and stable. Nevertheless, for this loss some compensation can be made by electronically boosting the high frequencies during transfer. Since the space and thus the size of the sound track is limited, the maximum amplitude which can be stored is also limited. This means that the maximum signal to noise ratio of an analogue optical soundtrack is limited to 55 dB*. Also at this point, compression techniques are applied to improve the reproduced sound quality. Dolby has put a lot of effort in this matter and introduced the modern standard recording system. The Dolby A system allows storage for a full 4-channel stereo sound on 35 mm prints, further improved in the Dolby SR (Spectral Recording) system.

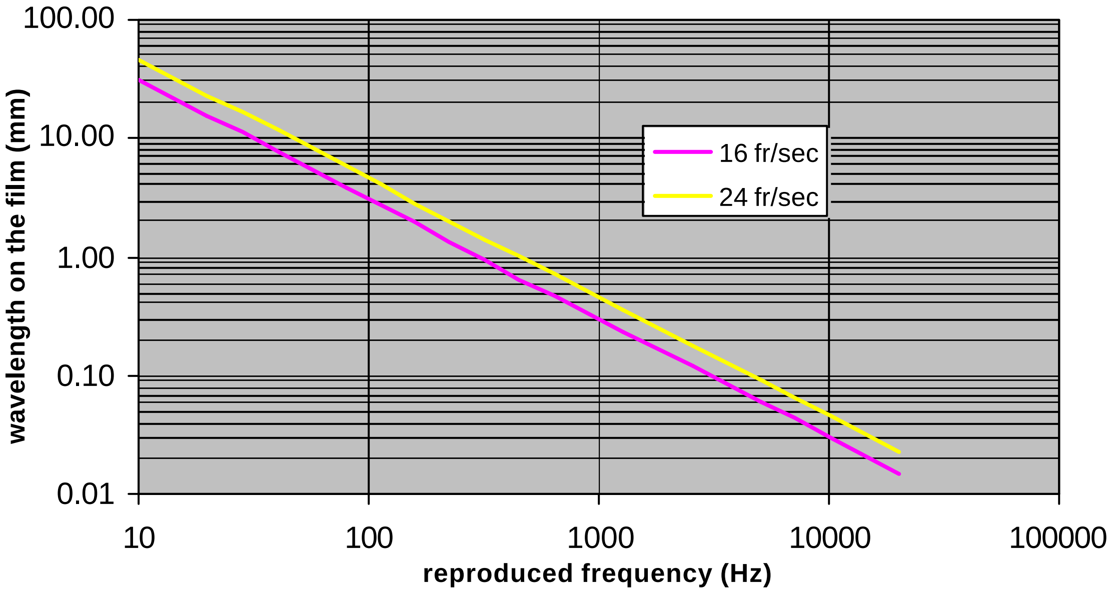


Fig. 3

Taking the above considerations into account, it must be clear now that throughout the sound recording process trying to use the maximum sharpness of the film material is very crucial. Therefore, AGFA sound negatives ST8D and ST9 as well as CP20 colour print film are optimised and produced with utmost care for recording sharpness.

However, since every layer on the film material has a certain thickness and since every kind of emulsion has a certain degree of light scatter, special precautions have to be taken while exposing and copying the film material.

So, exposing a negative material will introduce (due to internal reflections and light scatter) a certain degree of image spread. At the same time, while exposing the print film a certain degree of image choking will appear. Hence producing a soundtrack with the highest quality means adjusting the exposures of both films (sound negative and print film) in such a way that the spread in the negative is compensated by the choke in the positive print.

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* Decibel.

A logarithmic value (named after Alexander Graham Bell), used to express the ratio of two powers.

So 1 dB = 10 * log Ps/Pn where Ps can be the sound power and Pn the environment background noise.

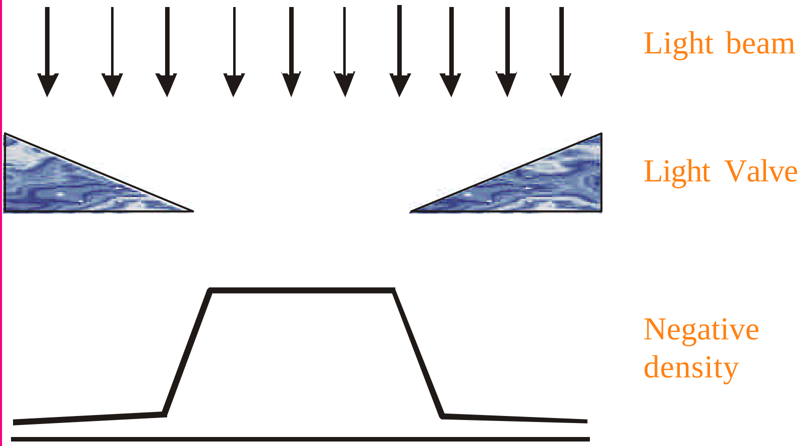
A 50 dB level means, therefore, a power ratio of which the log is 5 or 10^5 = 100000. If these values are weighted with the human audible sensitivity curve, one talks about dBAs (acoustical decibels).

Magnetic tracks can carry signals up to 70 dB louder than the background noise, which explains the use of this (more expensive) recording technique in systems with improved image quality (e.g. 70 mm prints).

The Analogue Sound Track.

Exposing a sound negative (producing the opticals) is commonly done in a dedicated sound camera (Westrex ...). Starting from the sound original on a master tape, disc or cassette, a sound negative material is exposed. Depending upon the installed options the sound camera is able to expose any combination of available soundtracks e.g. analogue, DTS, SR or SDDS.

Since the different sound systems use different light sources, the kind of sound negative needs to be adapted to the sound systems to be exposed.



Exposing the sound negative.

Fig. 4

- Analogue = white light
- DTS = white light
- SRD = green light (570nm)
- SDDS = red light (660nm)

A sound negative, designed to accept all the different sound-systems needs to be sensitive through the entire visible spectrum e.g. panchromatic. The AGFA sound negative, developed for this purpose is the ST9.

An orthochromatic sound negative e.g. AGFA ST8D can be used for exposing the analogue track together with DTS ans SRD DOLBY).

AIM DENSITIES FOR SOUND NEGATIVES ST8D AND ST9: 2.50 - 3.00

Remarks.

- Since we only need density variations, the sound negative is a black and white material.
- Of course the panchromatic ST9 sound negative can be used instead of ST8D but not the other way around !
- ST9 material needs to be handled in complete darkness.

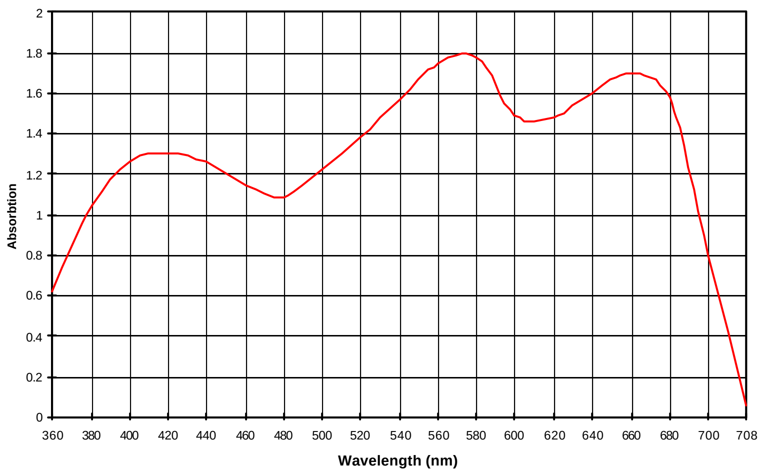


Fig. 5

Spectral sensitivity of panchromatic ST9 sound negative.

Exposing a sound negative.

The Analogue Sound Track.

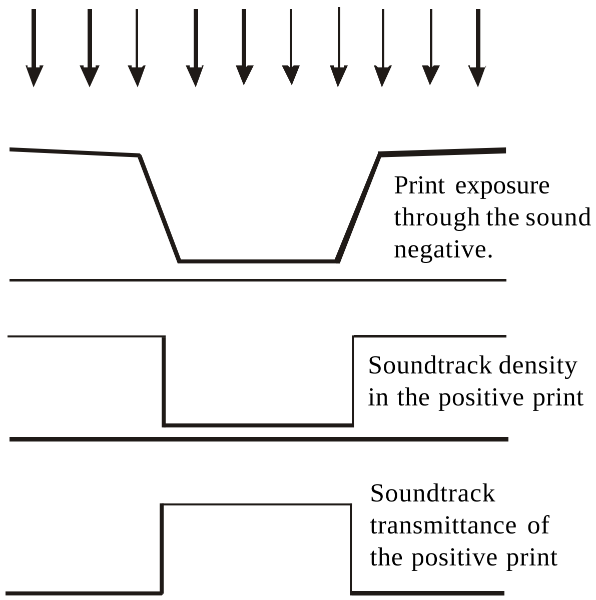


Fig. 6

Exposing the soundtrack means first exposing the sound negative via a sound camera (eg Westrex). This exposure creates (after processing) a certain density and a certain spread of the soundtrack.
This sound negative, together with the action negative, is used to make a positive print (Fig 8).
Since the positive print chokes the soundtrack for a certain amount, both exposures have to be optimized to obtain a perfect symmetrical soundtrack in the final print Fig 7.
The procedure to guide the user to find the optimum densities in both the negative and the positive is called “Cross-modulation Cancellation” or (X-mod).

As a rule of thumb, half the IR density value of the Sound Neg (e.g. ST8D or ST9) can be used for the IR density of the positive soundtrack.

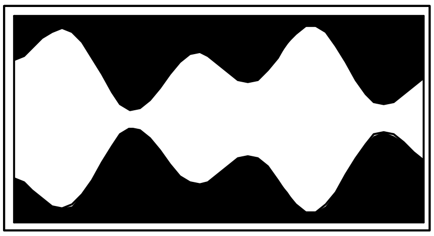


Fig. 7

Exposing a Positive Print by means of an action negative and a sound negative (only analogue track shown).

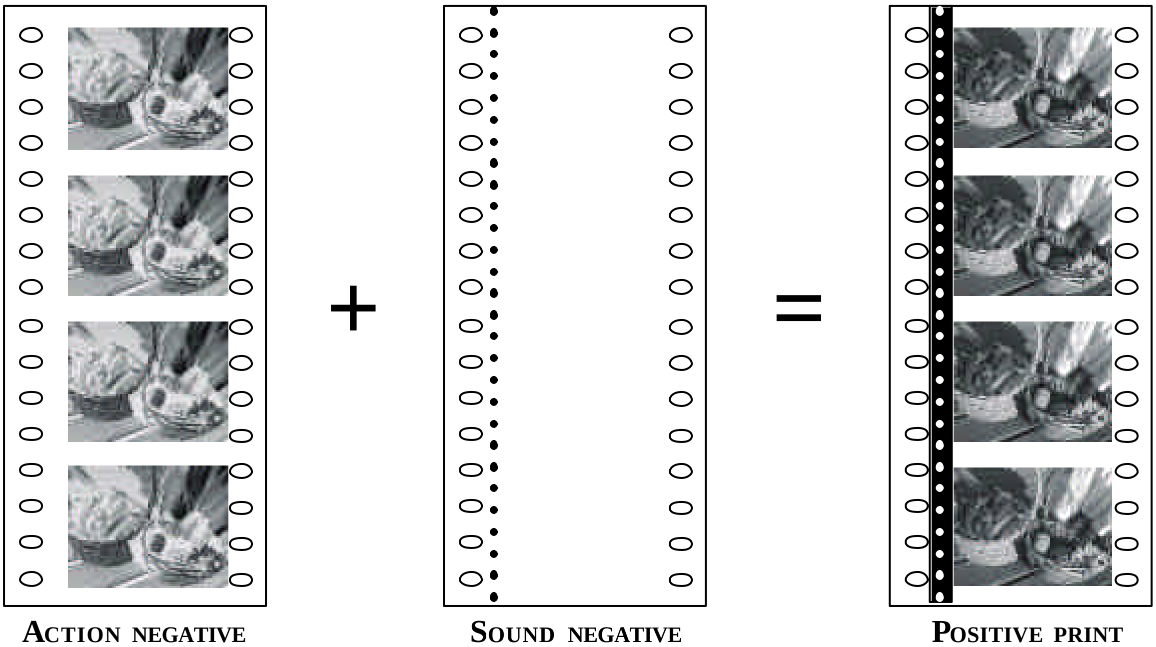


Fig. 8

Exposing a colour print positive.

The Analogue Sound Track.

The normal procedure of a copying process.

As indicated in the following scheme, copying an original starts with exposing a negative. In this negative, the image information is choked due to light scatter and internal reflections during exposure. Also the developing process has a certain influence upon the resulting image.
The latter negative is used in a following step, to expose the final positive copy. For the same reasons however, the image on the positive material is spread this time (because it's a positive material). To reproduce the original information without distortion in the final copy, both spreading and choking should cancel each other out. Since these effects can be influenced mainly by the exposure dose (and thus the resulting density) the result is that for every negative density (exposure level) there must be, theoretically, an exposure level for the positive which could cancel out the negative choking.

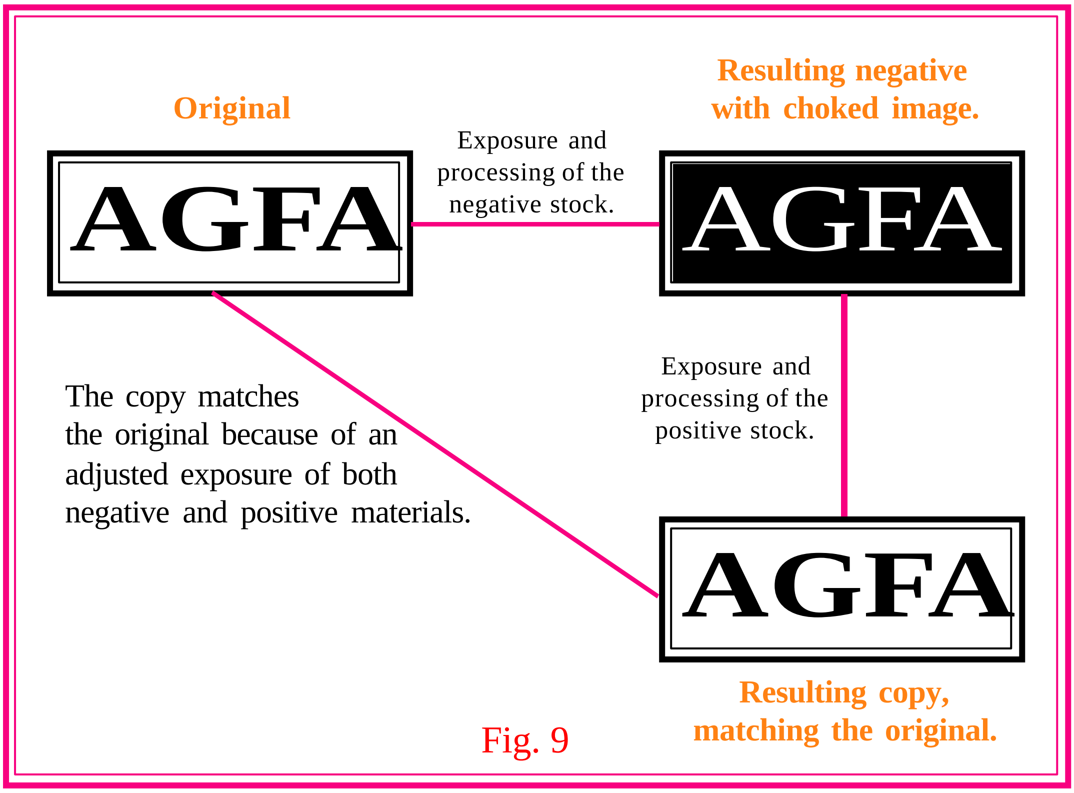
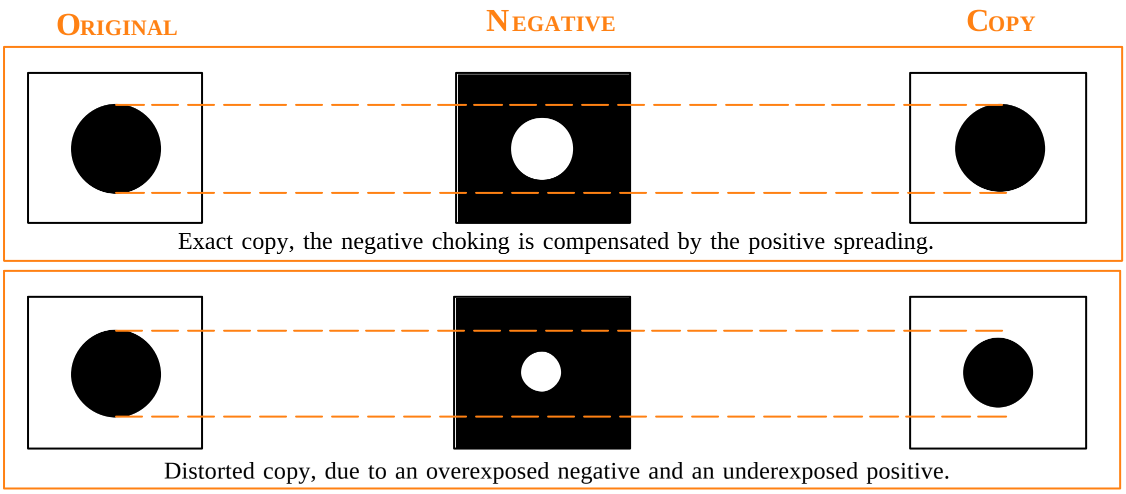


Fig. 9



Exact copy, the negative choking is compensated by the positive spreading.

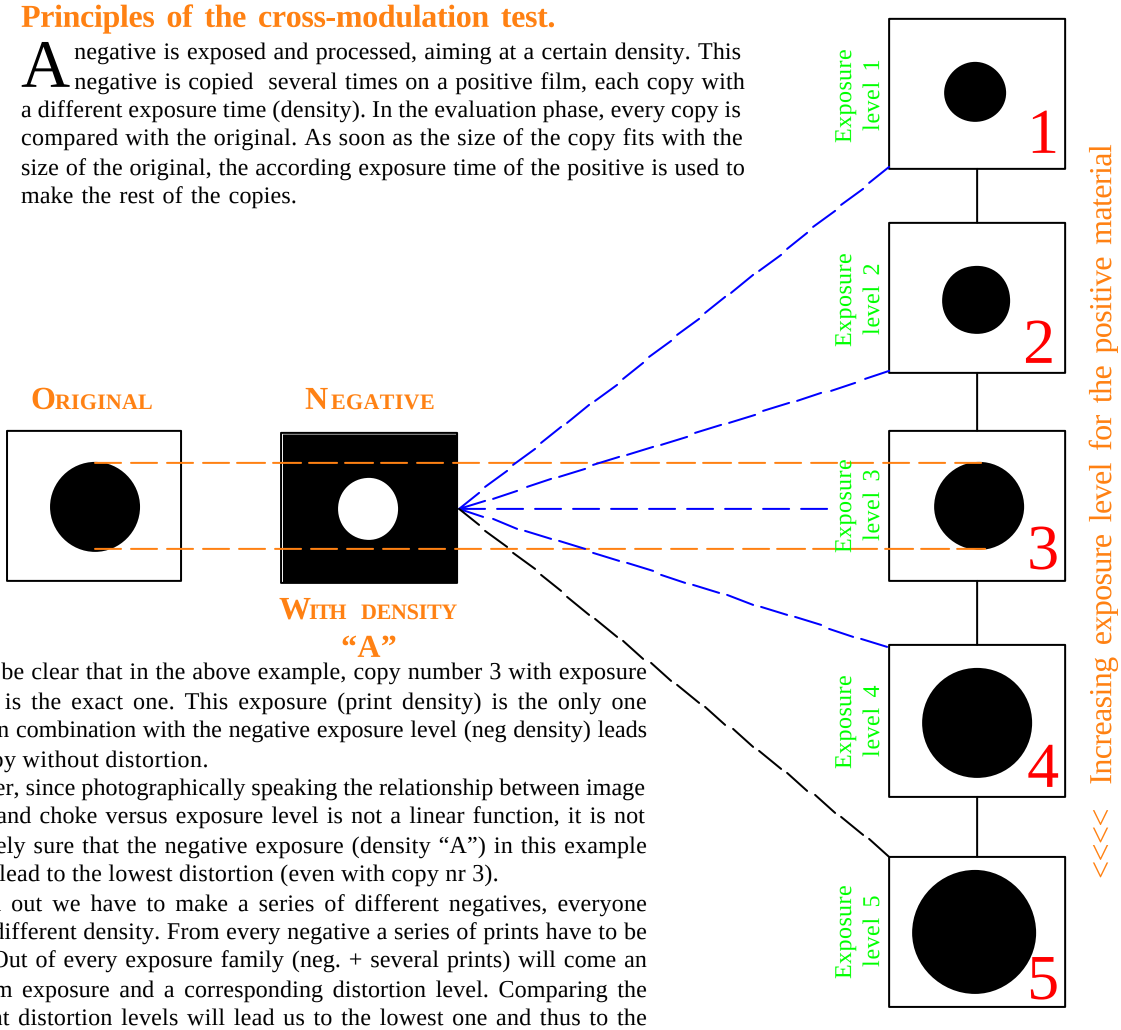
Distorted copy, due to an overexposed negative and an underexposed positive.

Different positive and negative exposure combinations, can lead to either an enlarged or a reduced print. Only matching exposure combinations lead to an exact copy.

Cross-modulation test.

Principles of the cross-modulation test.

A negative is exposed and processed, aiming at a certain density. This negative is copied several times on a positive film, each copy with a different exposure time (density). In the evaluation phase, every copy is compared with the original. As soon as the size of the copy fits with the size of the original, the according exposure time of the positive is used to make the rest of the copies.



It must be clear that in the above example, copy number 3 with exposure level 3 is the exact one. This exposure (print density) is the only one which in combination with the negative exposure level (neg density) leads to a copy without distortion.
However, since photographically speaking the relationship between image spread and choke versus exposure level is not a linear function, it is not absolutely sure that the negative exposure (density "A") in this example will be lead to the lowest distortion (even with copy nr 3).
To find out we have to make a series of different negatives, everyone with a different density. From every negative a series of prints have to be made. Out of every exposure family (neg. + several prints) will come an optimum exposure and a corresponding distortion level. Comparing the different distortion levels will lead us to the lowest one and thus to the corresponding "best" exposure family and density combination.

The cross-mod test itself.

The cross-modulation test (X-mod) is performed in the following way. A continuous tone with a selected frequency (6 or 8 kHz) is modulated in amplitude with a 400 Hz sine wave. This signal is used to expose a sound negative (e.g. ST8D or ST9) aiming at a density between 2.2 and 3.5. With this negative a series of prints is exposed, all with a different density. While running these prints at nominal projection speed through a X-mod analyzer, in the reproduced analogue sound information the 400 Hz signal level is monitored and measured very selectively.
If there's no distortion no signal will be measured, because in the originally recorded test pattern 400 Hz was used to modulate the carrier signal. As long as this symmetrical signal wave is not disturbed, no 400 Hz signal will be measured. On the other hand, the slightest distortion in the form of the recorded signal will disturb the symmetry and end up in a certain measured 400 Hz signal value. Putting these measured (print densities and measured distortions) in a graph, will show very clearly which print density will produce the lowest audio distortion (of course in combination with the used negative density).

Cross-modulation conclusions.

After having produced a complete family of negatives and prints and having analysed all the results, the graph in Fig. 10 can be constructed. It can be seen easily that although there is an optimum cancellation for every negative density and corresponding print density, there is also an optimum between the different families.

In this case the best combination, which will reproduce the analogue sound with the highest quality is found to be a negative with density 2.97 and printed with an aim density of 1.48.

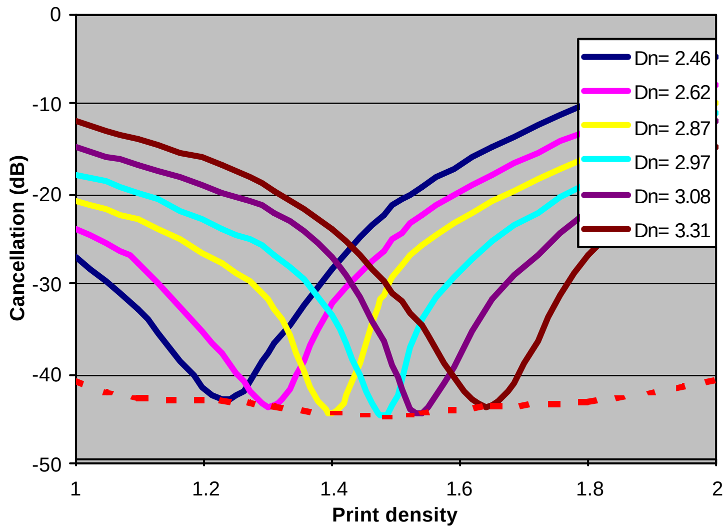


Fig. 10

This cross-modulation test was carried out with AGFA ST8D sound negative, printed on AGFA CP20 colour print film.

Caution.

Although these tests were carried out with the outmost care and precision the results can only be related to the conditions in which they were obtained. Because of small changes in characteristics between different batches of film stock and because of the very important influence of the processing conditions these results can only be used as an indication.

If we use the -30dB as a reference, and take the different density values of the positives and negatives, the graph in Fig. 11 can be constructed. Since for every negative density the -30 dB limit can be reached at two different print densities, two lines will appear (the magenta and dark blue one in Fig. 11).

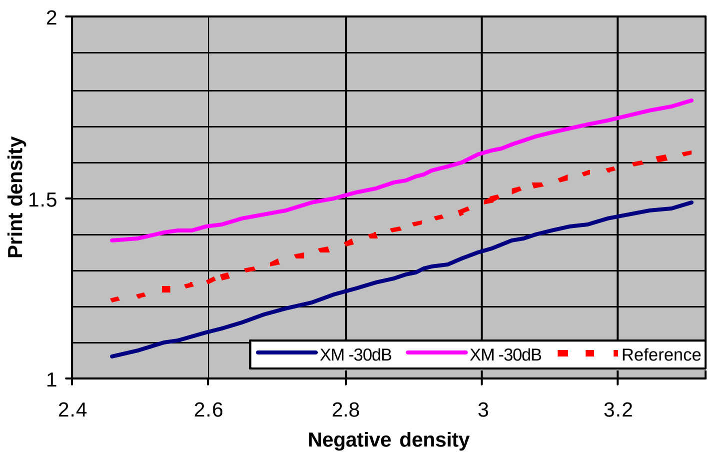


Fig. 11

Drawing another curve as an average of the two previous ones, we obtain a reference line with all the optimum density combinations. Of course there will be a limit to the densities themselves:

- the lowest useful density will be determined by the ground noise limit.
- the highest density will be limited by the needed value of the high frequency response.

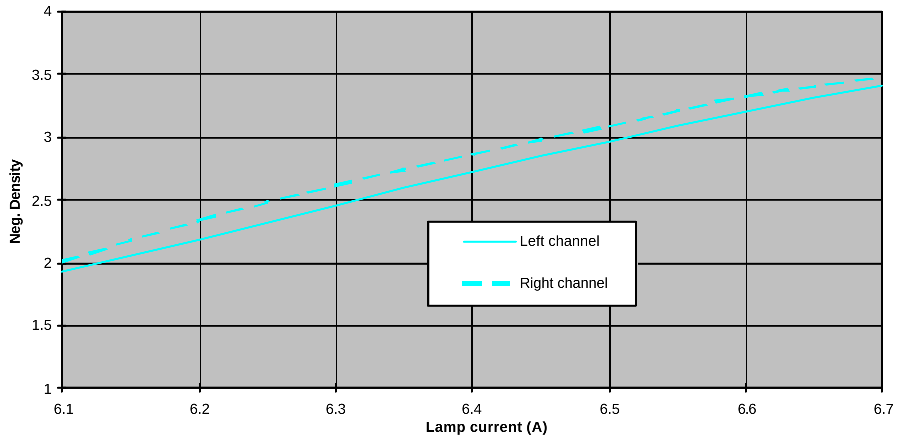
The Analogue Sound Track.

Some additional information.

Combining the negative densities with the corresponding lamp currents used to expose the film in a Westrex camera, leaves us with the next graph. Knowing that in most cases the optimum print density is situated around D=1.25 with a negative density of about D=2.5 shows a corresponding lamp current of 6.3 Amps.
Since most (Westrex) camera's are equipped with a 12 Volts 100 Watt quartz incandescent lamp, the nominal current of this lamp is 8.3 Amps.
This means that shooting the mentioned negative densities will increase the lamp life tremendously.
A technical paper:

"The exposure of photographic material by means of a dimmed quartz halogen lamp."

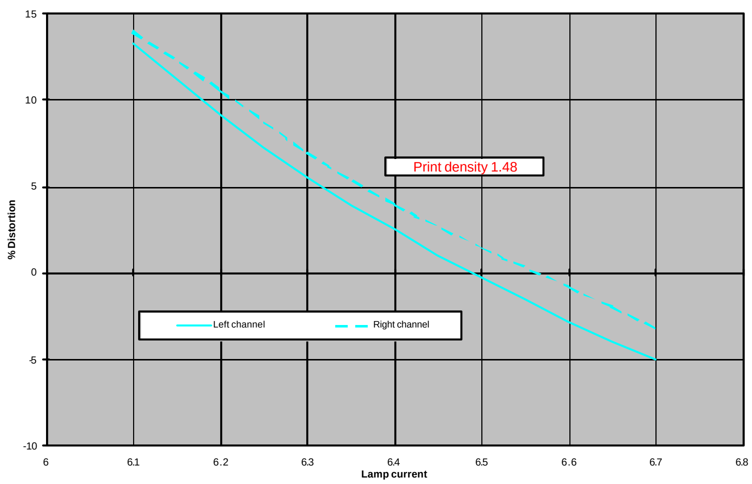
is also available, explaining the symbiosis between halogen lamps and photographic material.



The same correlation can be made between lamp current and final distortion in the printed sound track. This relationship shows us (next graph) that a change in lampcurrent of about 3% leads to an increase in distortion of 5% !

Conclusion.

During exposure of the sound negative, the lamp current (e.g. light output) needs to be stabilized very carefully in order to maintain a constant, low distortion level.



Cross-modulation test.

The Analogue Sound Track.

The specifications for the reproduction of analogue registered sound information can be described by:

Noise - Frequency Response - Distortion - Amplitude

Factors contributing to the noise level:

- graininess of the transparent areas.
- "unclean" edges of the black areas.
- "pinholes" in the black areas.
- dirt, friction, scratches

Factors contributing to the frequency response:

- construction of the sound camera (optics / focusing)
- MTF (sharpness) characteristics of the film stock.
- good contact between sound negative and positive during printing.
- construction of the sound reproducer (optics / focusing)

Factors contributing to the distortion:

- recording of inappropriate sound volume.
- image spread during exposure and processing.

Amplitude:

- determined by the difference in minimum and maximum density of the printed soundtrack.

Before discussing the item of exposing the final colourprint, it's necessary to introduce a clear idea about how the colour process really works. That's why in the next pages the principles of colour mixing and print film composition is explained.

Quality considerations.

Colour Mixing Processes

To understand the process of coloured image and sound reproduction, be it a real photographic image or an image containing sound information e.g. dye tracks, it is necessary to have some knowledge about the colour forming process itself.
It was Sir Isaac Newton who confirmed the composite nature of white light by combining the rays of the spectrum through an inverted second prism and thus reversing the dispersion of the coloured rays to reform the white light. This experiment demonstrates that white light can be produced by mixing or adding together all the coloured lights of the spectrum. By using the six principal coloured bands in the spectrum*, this can be summarized as:

W = R + O + Y + G + B + V

Because of the seemingly triple nature of colour vision however, the sensation of whiteness can be obtained by combining only three monochromatic light rays of selected wavelengths, one in the red region of the spectrum, another in the green and the third in the blue. So:

W = R + G + B

Additive colour mixing.

Colours are produced additively by artificial means when two or more individual beams of coloured light are brought together. The simplest way of doing this is to project different beams of light on the same screen. Indeed, we can mix a blue beam with a pure yellow light of 570 nm and again produce the sensation of white. In this case we note:

W = Y + B

Since Y = R + G (= complement of blue), we are back to:

W = R + G + B

In fact, the integration of red, green and blue beams of light, gives not only the sensation of white, but by making the appropriate variations between one, two or all three beams and their intensities, the whole range of colour sensations can be obtained. For this reason lights of these three colours provide the basis of all additive methods of colour reproduction and are conveniently referred to as the ***primary light colours*** or the ***additive primaries***.
Following our notation therefore:
W = R + G + B so that

W - R = G + B

signifying that white light minus or without red light produces green-blue, such a colour being named cyan.

Similarly,

W - G = R + B

meaning that white light minus green gives purple or magenta, and

W - B = R + G

which is, of course, yellow.

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* Colour bands

Red	620 - 700 nm	Orange	590 - 620 nm	Yellow	570 - 590 nm	Green	500 - 570 nm
Blue	450 - 500 nm	Violet	400 - 450 nm				

So yellow can be described as white light minus blue.
Because it's difficult (and expensive) to generate pure monochromatic light, and because the cones in the eye are sensitive for a rather broad part of the corresponding spectrum (Fig.12), monochromatic light beams would have no real advantage in colour reproduction processes. If a beam of light is projected through a blue transparent filter, this filter will absorb red orange and yellow. The apparent blue beam will contain green, blue and violet and may be represented by G + B + V.
Likewise if a second beam is projected on the same screen through a yellow filter which absorbs only blue and violet light, this beam will look yellow but will contain red, orange, yellow and green and may be represented as R + O + Y + G.

The resulting mixture on the screen is therefore:

Yellow beam	= R + O + Y + G
Blue beam	= G + B + V
Mixture	= R + O + Y + 2G + B + V

This mixture contains all the ingredients of white light with excess green light and will appear to be bright, pale green to the eye.

Sensitivity of the eye.

As can be seen in Fig.12, the scotopic (colour) vision of the human being is limited to 3 overlapping parts of the spectrum. Between these cone sensitivities, is the blue vision (S-cone) the least sensitive and the green vision (M-cone) the most sensitive.

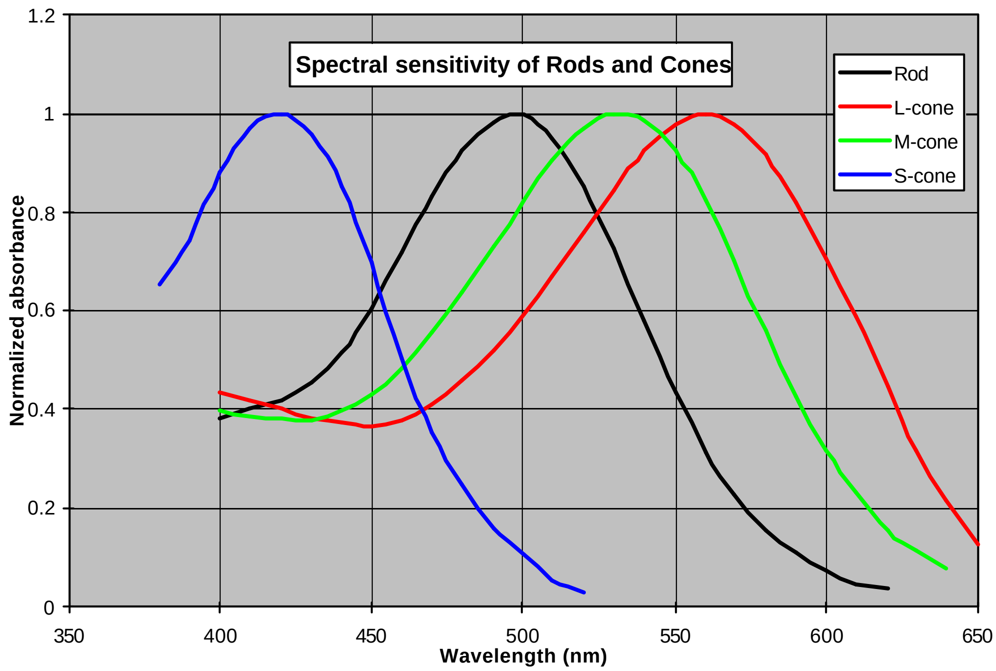
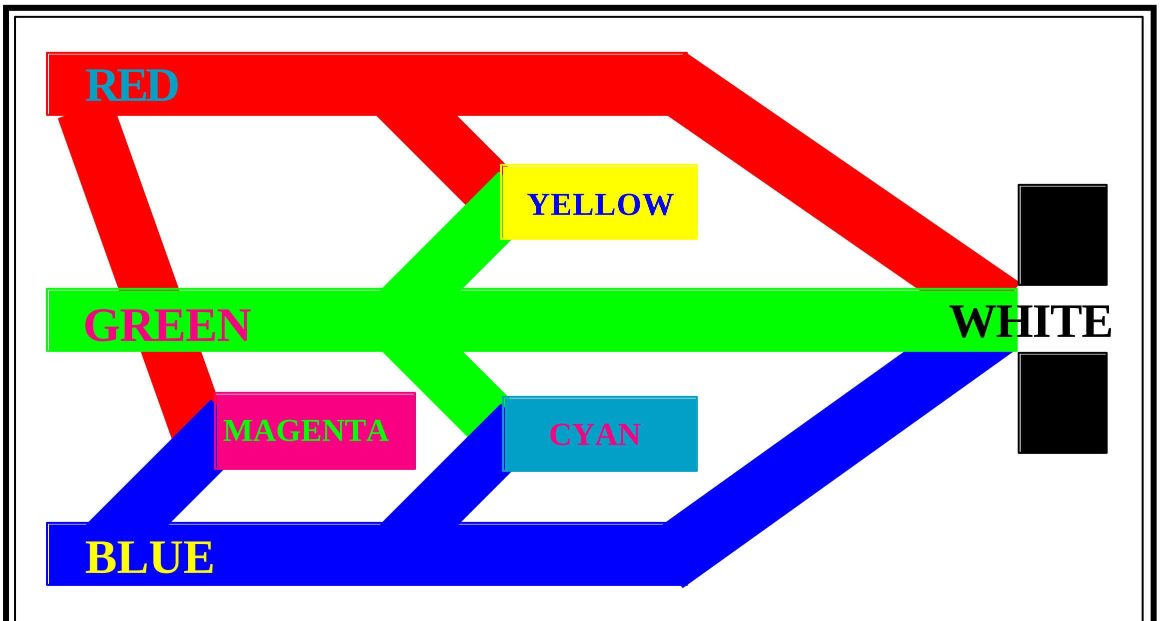


Fig. 12

The rods on the other hand are far more sensitive than the cones, but only able to produce grey information. The difference in sensitivity is such that for decreasing light levels, the colour perception changes gradually from normal over normal minus blue to normal minus red and finally grey.

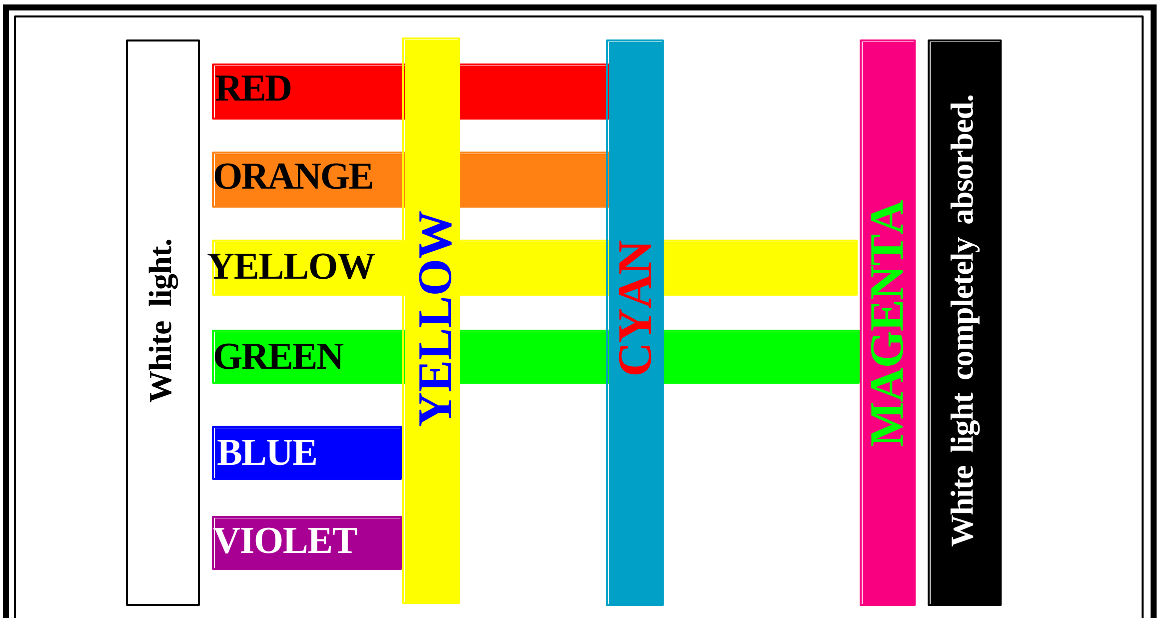
Is it not so that all cats are grey in the dark ?

Colour Mixing Processes



ADDITIVE COLOUR PROCESS

Fig. 4



SUBTRACTIVE COLOUR PROCESS

Fig. 12

Additive and subtractive colour mixing.

Subtractive colour mixing.

Whereas additive processes are based on the projection and blending by suitable means of coloured lights, subtractive methods involve the mixing or superimposition of coloured materials usually in the form of paints, inks or dyes. The name ‘subtractive’ is used because the effects are obtained by combinations of material substances which always absorb or ‘substract’ light in various ways.
Strictly, subtractive mixture takes place only with nonscattering media such as dyes.
Again, by using the simple notation of initial letters

W = R + O + Y + G + B + V

we can put X in the proper position to indicate the absorption of light of a certain colour. Suppose we have a yellow painted wall, meaning that blue and violet is absorbed and the rest of the spectrum reflected.
If we paint this wall a second time with cyan paint, absorbing red, orange and yellow the result can be calculated as follows:

yellow paint	= R + O + Y + G + X + X	
+		
cyan paint	= X + X + X + G + B + V	
mixture	= X + X + X + G + X + X	that is green
+		
red paint	= R + O + X + X + X + X	
mixture	= X + X + X+ X + X + X	that is black

As we can see after painting yellow and cyan, the result is green. After putting a third layer (red), the result is black.
It is well known, at least by artists, that the careful blending in various proportions of yellow, cyan and magenta paints, used alone and two or three together, will produce effects of all possible colours except white. Normally, people believe that the primary colours in painting are red, yellow and blue. But, as shown above, the “red” primary must be purplish-red properly named magenta, and the ‘blue’ must be a greenish-blue, that is, cyan. Because white cannot be obtained from the subtractive primaries, they have to be placed on a white base such as paper, or, provided they are transparent, viewed against white light. If, therefore, three transparent glass filters having the yellow, magenta and cyan colours of the subtractive primaries are placed one behind the other in the path of a beam of white light, each will absorb one third of the components of white light and the end effect will be black..
Because the subtractive method is, in general, easier to apply, it is more widely used than the additive method. It must be clear now that the artist painter makes use of the subtractive method and on a much greater scale it is employed in colour photography, cinematography and in all branches of the printing industry.
The principle of the method, using transparent materials (as in motion picture) is illustrated in Fig. 14 on page 15.

Colour Print Film

Colour print films consists mainly of three different and important layers (Fig.15 on page 18). On top of the package we start with the orthochromatic sensitive layer, sensitised for the green part of the spectrum and forming magenta dye. The second layer is sensitised for red light, forming cyan dye and finally the blue sensitive layer, forming yellow dye. The order in which the different layers are stacked is determined by the eye sensitivity. It has to be understood that, due to light scattering, the sharpness of the exposed image decreases with the depth of the layer itself. Because the eye is most sensitive to green light, and since the first layer is the sharpest, the green sensitive layer is put on top of the stack, forming magenta dye.
As indicated in Fig. 16 (page 19), the print film can, of course be exposed with a combination of light, producing all the colours necessary for the reproduction of a coloured image.
Once the print film is exposed and processed, the image can be projected using the subtractive colour mixing procedure as indicated in Fig.19 (page 22).
Every scene can be colour corrected changing the exposure level in every discrete colour. This is done in the printer by changing the RGB filter densities in the optical path.

Exposing colour print film

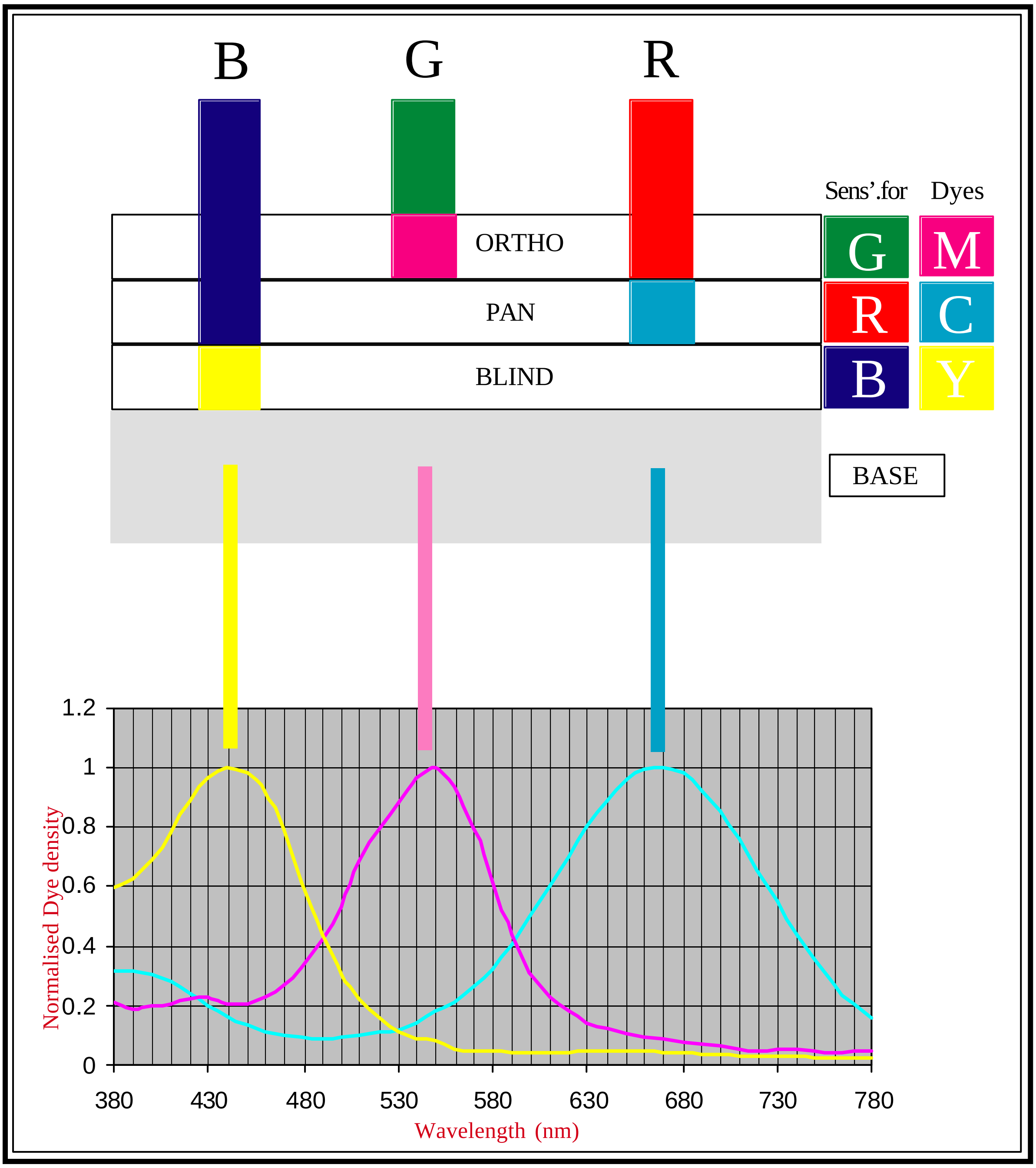


Fig. 15

Exposing colour print film

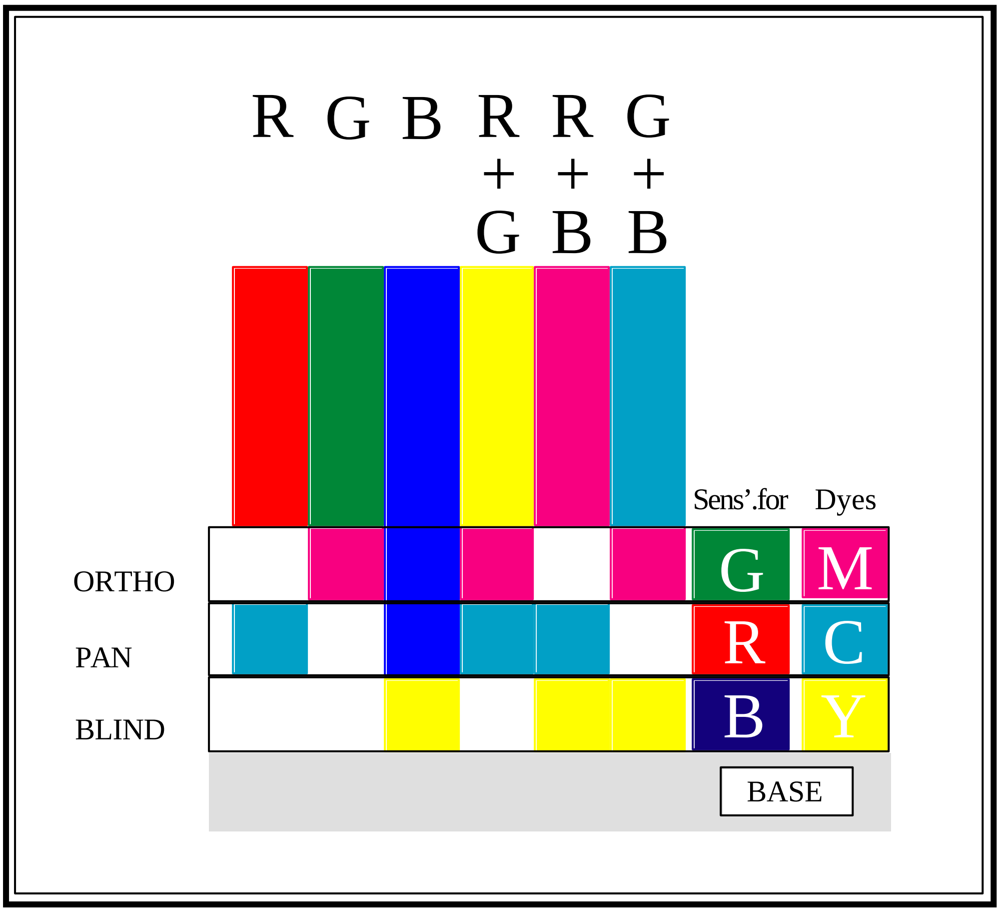


Fig. 16

As can be seen in the above drawing, if the film is exposed with one of the primary additive colours (RGB), only the corresponding layer reacts and forms the complementary dye. However, if the material is exposed with a primary subtractive colour (YMC), two layers are activated and two dyes are formed, also leading to the complementary colour of the exposing colour.
Of course, exposing the film with white light, every layer will be activated, forming the three complementary subtractive dyes. During projection (see Fig.19) the result on the screen will be black because all the light will be absorbed in the corresponding place in the coloured layers on the film.

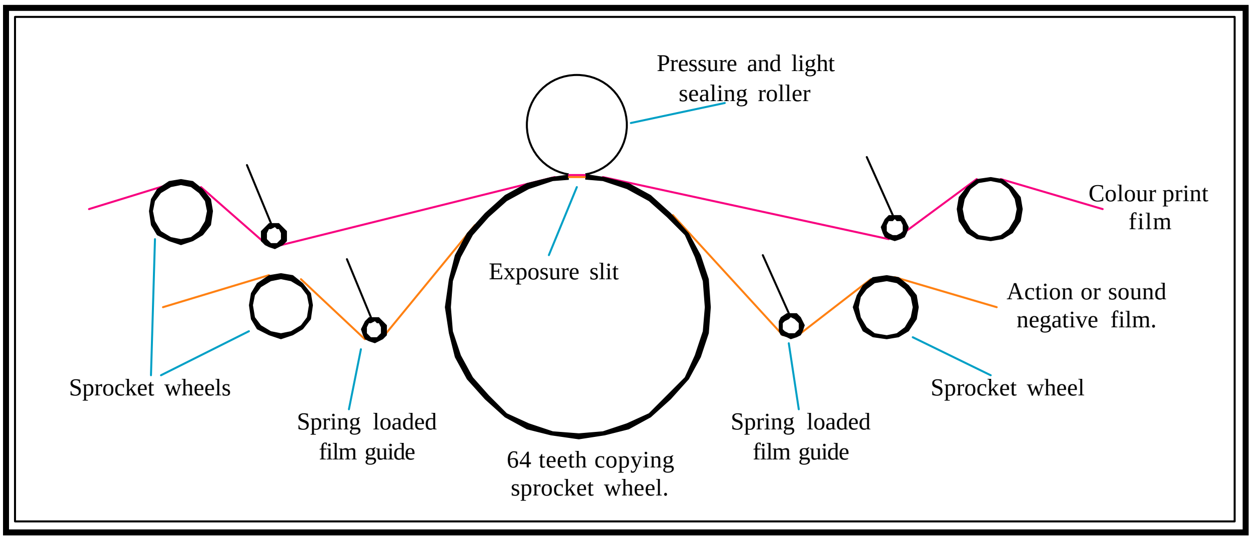
Exposing the print film with different colours.

Some additional information.

Exposing a colour print film is in practice almost always done by means of a film “printing” device. This printing device, in theory, consists of a means to transport the unexposed colour positive film, the action negative and finally the sound negative. Depending upon the printing direction, the raw film stock is exposed through the action negative and in a following but completely independent step the sound tracks are exposed by means of the sound negative.

Both the exposure sequences are done by transporting the raw film stock in contact with the corresponding negative over a standardised copying sprocket wheel. The image copying wheel is equipped with an exposure slit as wide as the image area, while the sound copying wheel is equipped with dedicated light sources to expose the different sound systems (SR, SRD, DTS and SDDS).

The next drawing shows a common practical set up of a copying station on a printing device.



The diameter (and thus the number of teeth) on the copying wheel is standardised because of the difference in perforation pitch between the negative and positive material. Since the negative material is closer to the center of the copying wheel, the pitch of the latter material will be smaller compared to the pitch of the positive material.

Since:

- the number of perforations on the copying wheel = 64
- the positive pitch = 4.75 mm

  the circumference of this wheel is 64 x 2.75 = 30.4 (1 foot !)

Therefore the pitch of the negative material needs to be 0.01 mm less or 4.74 mm.

Practical printing speeds are (for panel printers): 120, 180, 240, 480 and 960 ft./min.

THE OPTICAL PATH WITHIN THE PRINTING HEAD.

Because the film sandwich (positive and negative) is transported and positioned on the printing wheel (page 20 and Fig 17), the light falling through the printing slit must be adjustable, both in spectral power and intensity. To provide this light energy, the light emitted by an incandescent lamp (e.g. 1200 Watt) is split by means of dichroic filters into 3 main colours Red Green and Blue (Fig 18). The amount of light can be controlled by means of light valves, separate for every colour. Finally, the resulting light beam is projected through the printing aperture or exposure slit on to the continuously moving film. Depending upon the original film (negative or internega-tive) colour correc-tions have to be made for every different scene or only once at the beginning of the copying pro-cess. In this case, the negative used is already corrected for every scene. The advantages are that first of all no marks are nec-essary on the original negative, and second because no correction changes are necessary, printing speed can be higher.

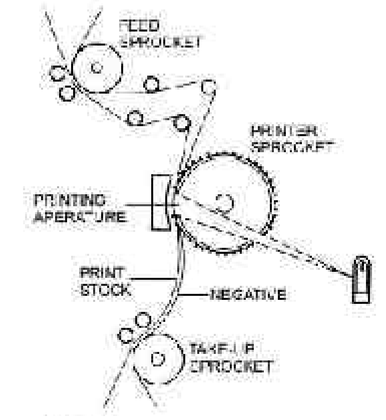
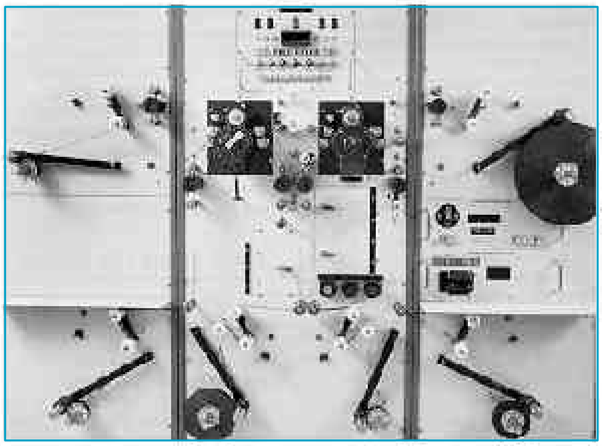
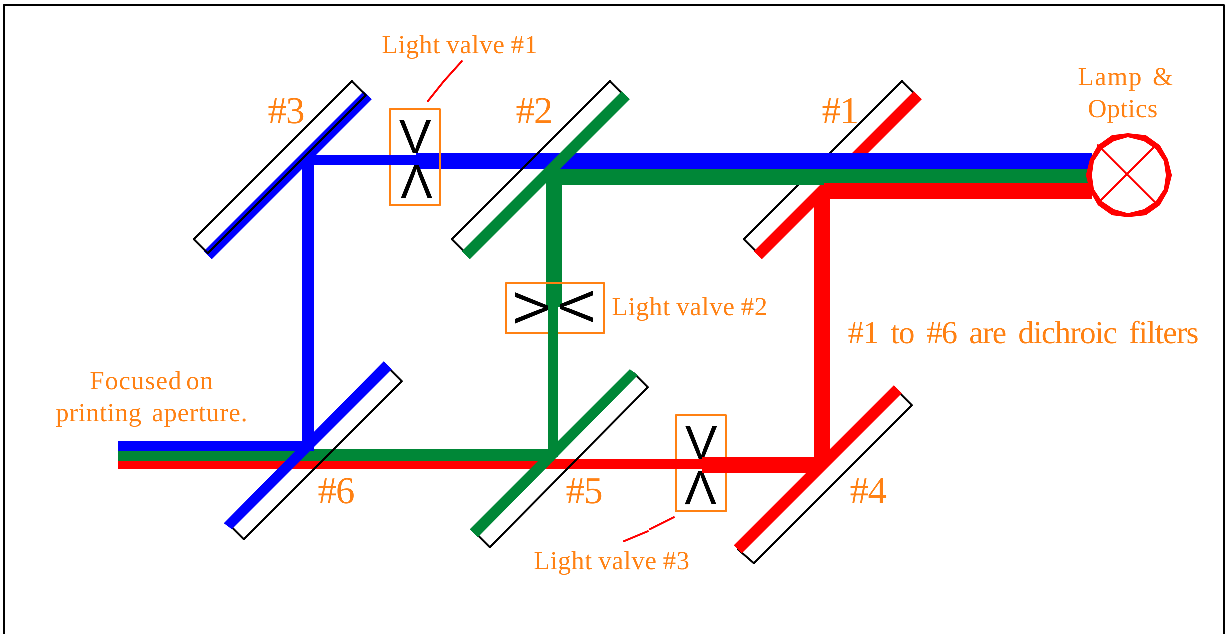


Fig. 17



A continuous contact panel printer.



MIRROR AND FILTER ARRANGEMENT IN THE LAMPHOUSE OF A STANDARD PANEL PRINTER.

Fig. 18

Exposing a colour print film.

Colour Print Film

Projector, equipped with a white light emitting lamp (Xenon). This light passes through a colour print film with selectively exposed colour layers. The remaining light is projected and focussed on a white screen.

The light falling on and reflected by the screen forms the final image for the viewer.

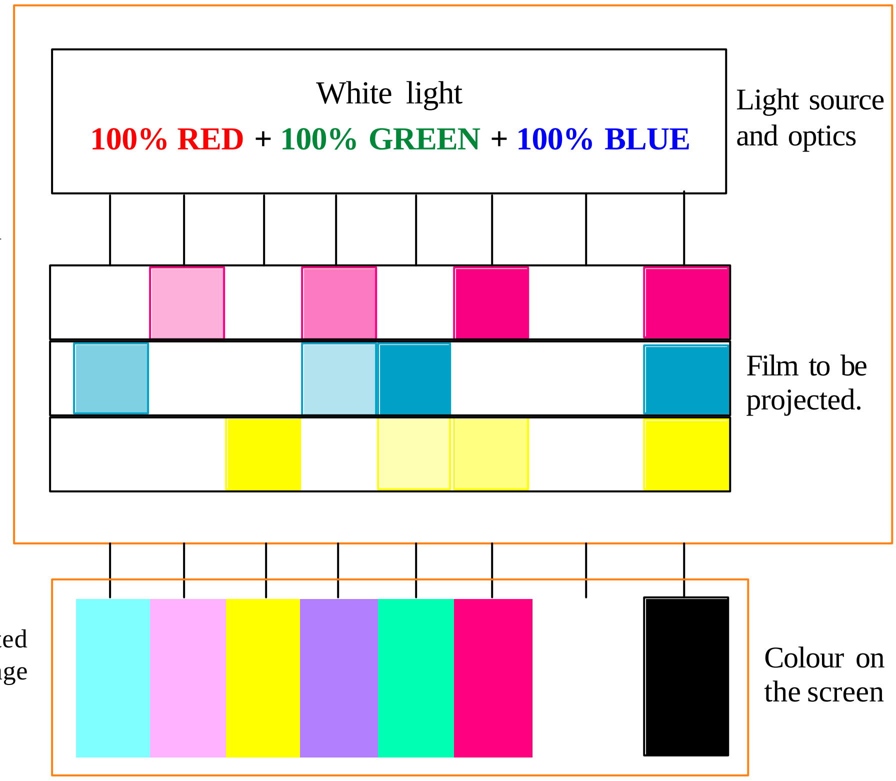


Fig. 19

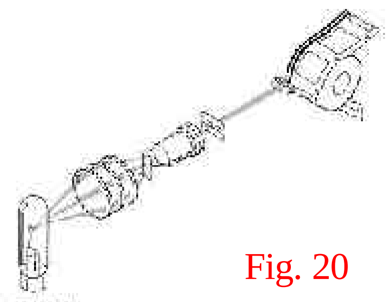


Fig. 20

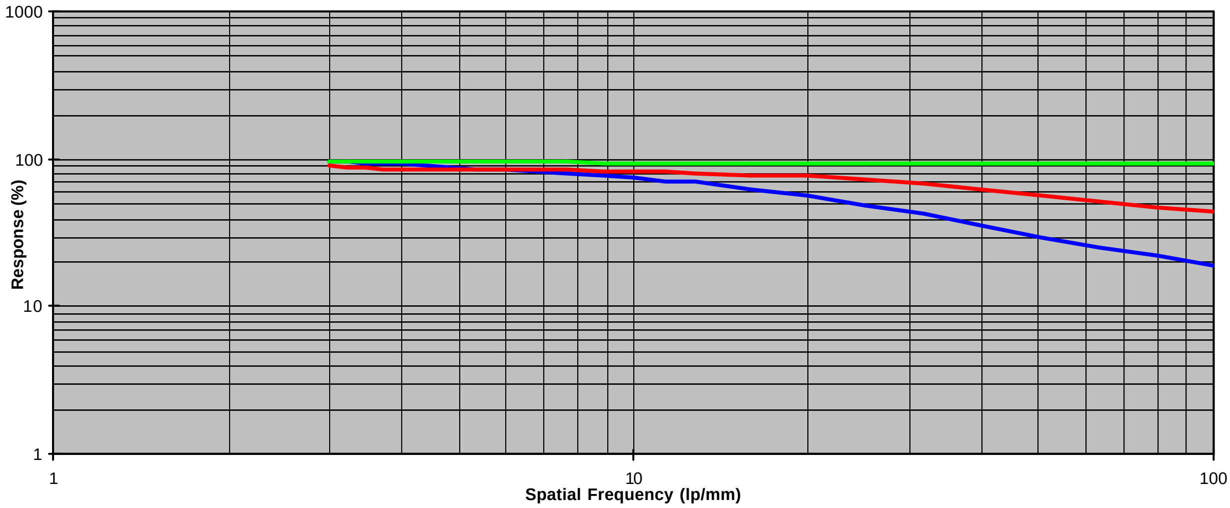
Reproduction of the recorded analogue sound is accomplished by projecting a light beam (incandescent or red LED) onto the analogue sound track. The light passing through the film is modulated by the varying density of the sound track, page 7, and projected on a light sensitive detector. Finally the resulting signal is processed and fed into the theatre sound amplification system.

Since every layer in the print film can be exposed selectively, and since the density of the corresponding dyes is a function of the exposure level itself, in theory every possible colour can be formed.
If such an exposed and processed colour print film is fed through a motion picture projector, and thus exposed by means of white light, the subtractive colour process of the film makes it possible to reconstruct whatever colour is wanted on the screen.

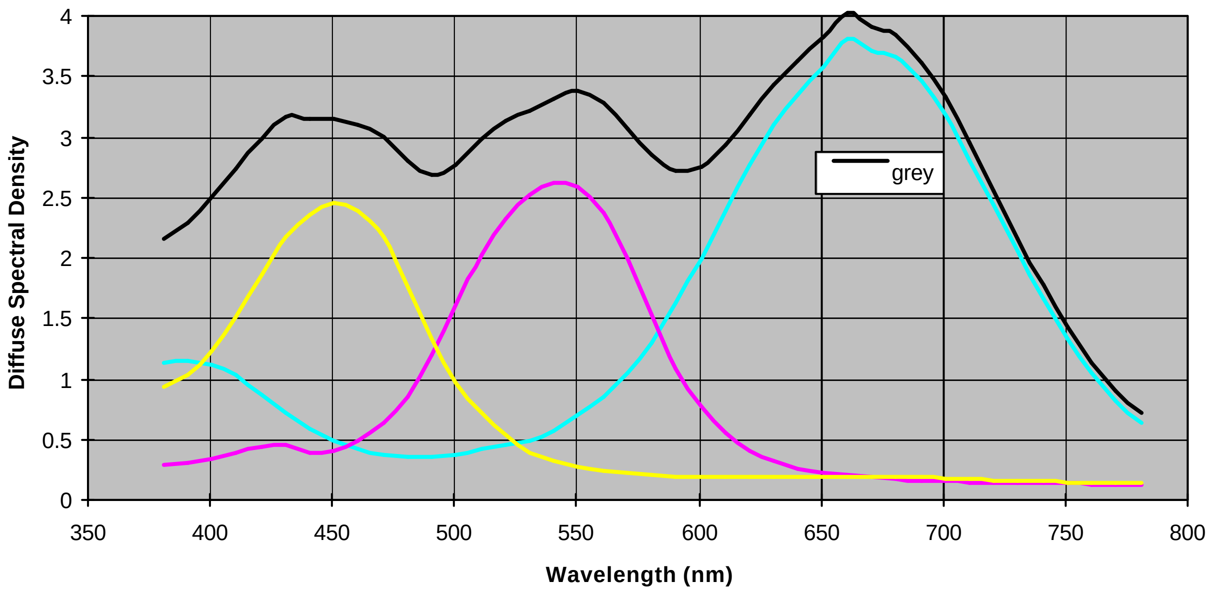
Projecting a colour print film.

CP20 Colour Print Film Characteristics

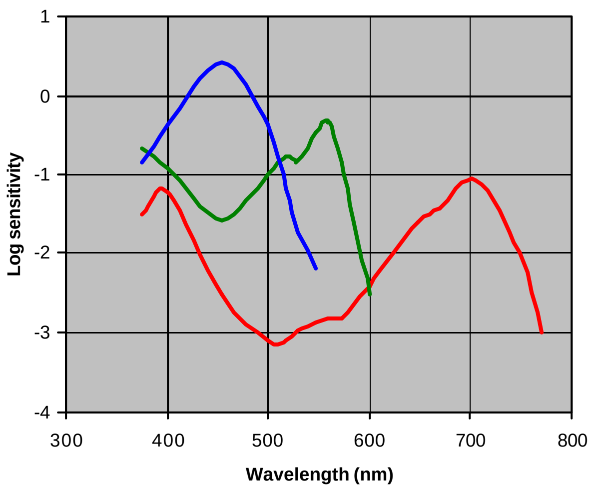
Sharpness of the different layers.



Dye densities for a neutral grey with density D3.



CP20 spectral sensitivity.



Colour Print Film Sound Track Exposure

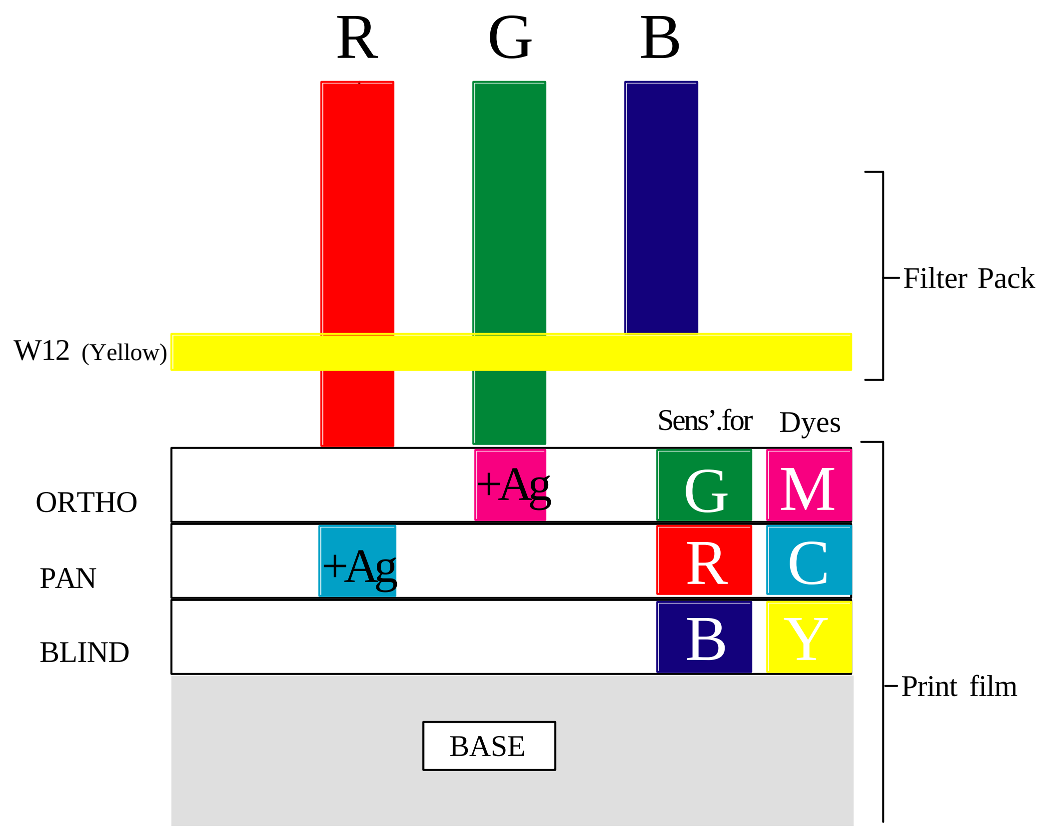
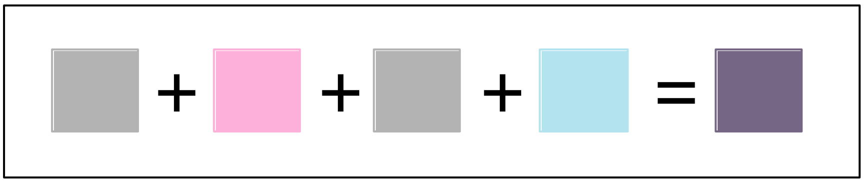


Fig. 21

Because of the relatively low sharpness of the yellow dye, blue light is blocked by means of a yellow filter during exposure of the analogue sound track on the print film. This means that only magenta and cyan dyes are used to build up the necessary track density. Through the application of a paste (e.g. redevelopment of the analogue soundtrack), the total track density is increased with the density of the redeveloped silver in both layers (ORTHO and PAN). The result of this operation is an analogue track with a total density of;

$$\mathbf{Ag^{*}_{ortho} + D_{magenta} + Ag_{pan} + D_{cyan}}$$

or



Of course the total density needs to be determined by means of the explained cross-modulation method. Aim values of these densities are summarised the addendum on page 44.

* Ag being the chemical symbol of silver.

Exposure of the redeveloped analogue sound track

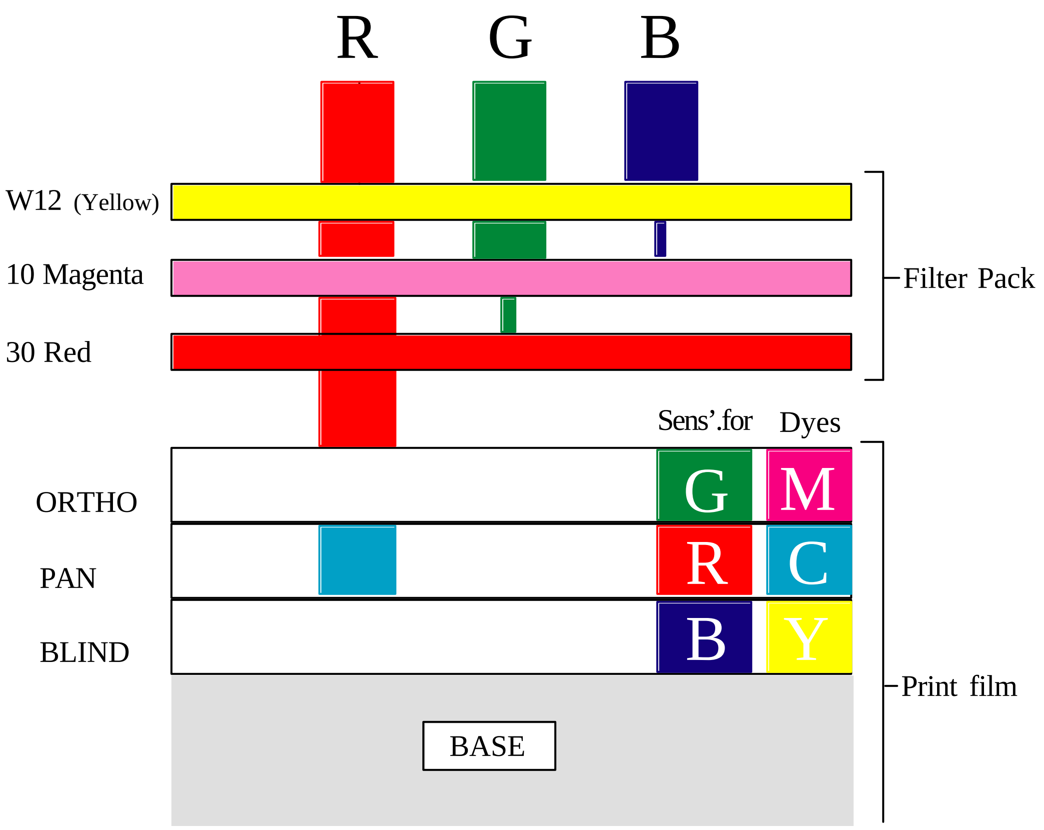
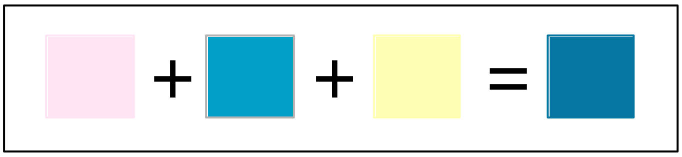


Fig. 22

Both the SDDS and SRD readers in a cinema projector are equipped with red LEDs, therefore, the according digital track needs a high density within the sensitivity spectrum of these LED's (660 nm). Blocking the green (magenta dye) and blue (yellow dye) will be necessary, and is normally done by means of a **YELLOW - MAGENTA - RED** filter pack combination (see the above figure). If printing speeds are too high, because of the relatively high filter pack densities, the available amount of light to expose the remaining layer can become critical. In this case it's advisable to use only a 29 RED Wratten or glass filter (see page 32).
The resulting colour of these digital soundtracks is;

$$\text{some}^{*}\, D_{magenta} + D_{cyan} + \text{some}^{*}\, D_{yellow}$$

or:



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* "some" in this case means that since the used filters are not perfect and since the spectral absorption of the dyes is rather wide, some unwanted density is created in the corresponding layers and dyes. However since there's no redevelopment of this digital track and hence no remaining silver, the resulting density is created by the different dyes.

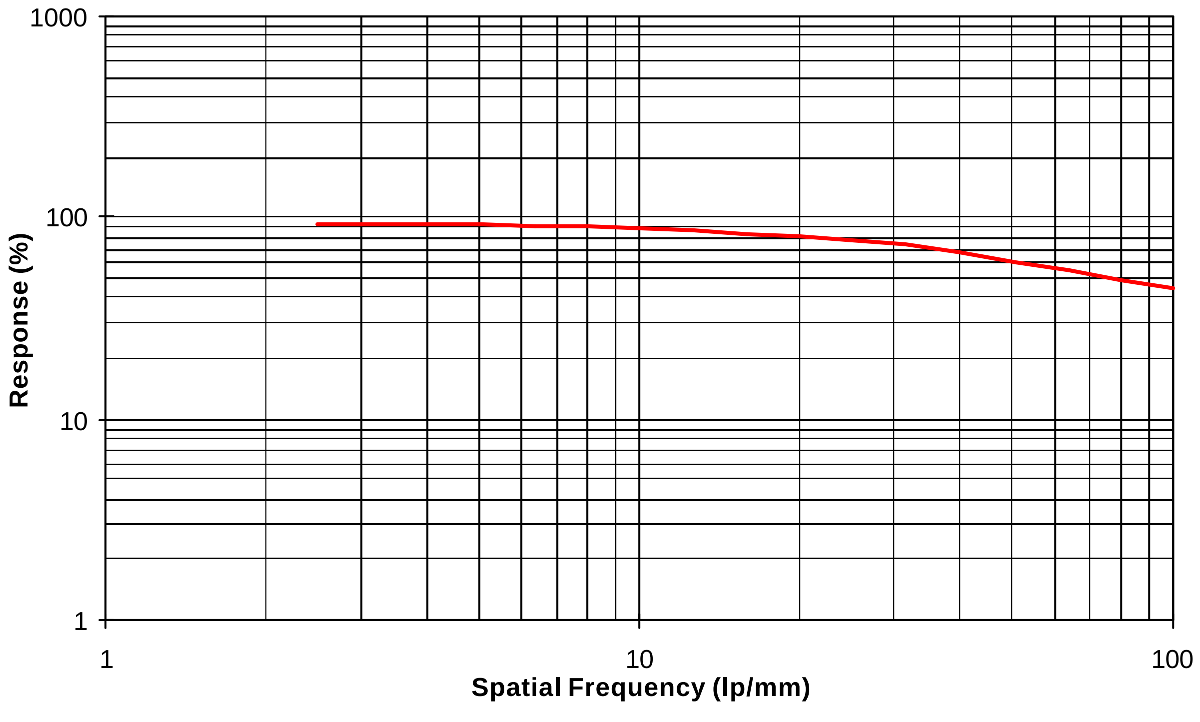
SDDS (SONY) & SRD (DOLBY) exposure.

AGFA panchromatic black and white film ST9 is specially designed for recording all present types of sound tracks. From the conventional variable area analogue sound track exposed with a tungsten light source, up to the modern high performance digital tracks, exposed with a red or green light source, can be recorded on this high contrast film.
ST9 performs with excellent results when exposed and processed to print sound tracks on AGFA colour print film CP20. And of course it can be used with the same results on all competitive print films.

Characteristics.

Sharpness.

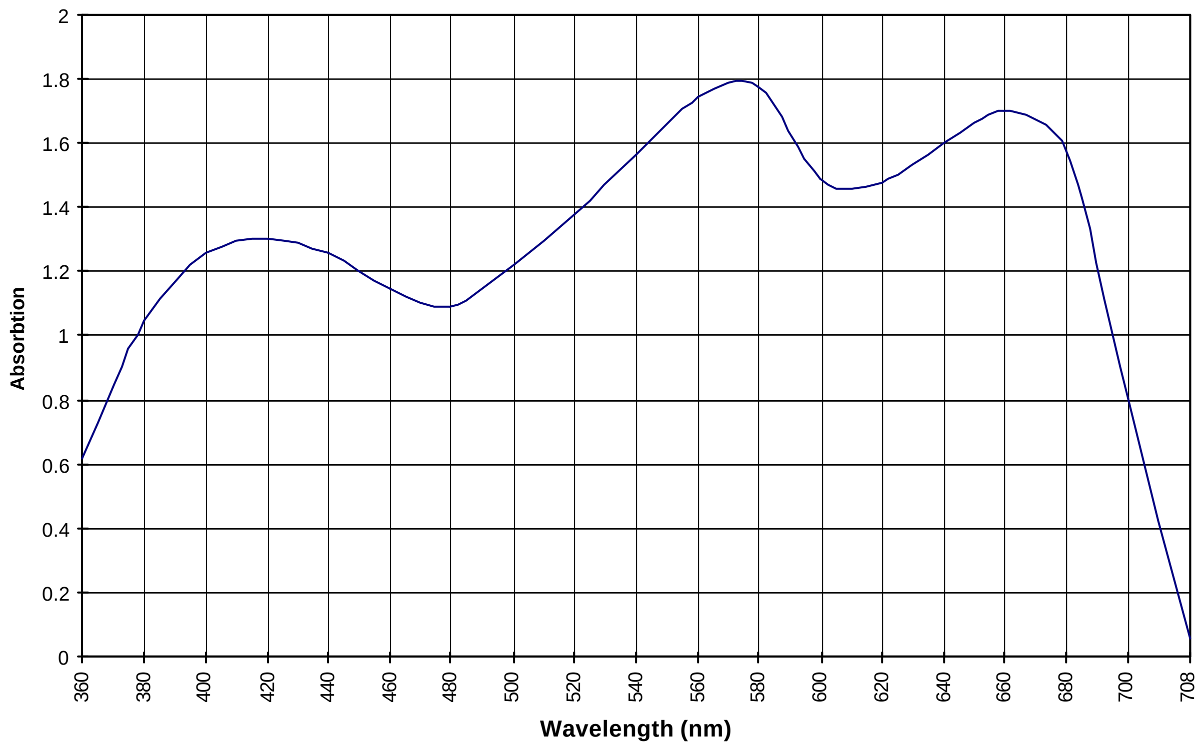
Since the final sharpness of any film depends upon every step in the exposure and processing chain (sound cameras, film printers, processing, projector lenses etc.) only the intrinsic and specific sharpness of the ST9 can be measured and charted as a reference. In the following graph, the *Spatial Frequency* refers to the number of line pairs (sine wave cycles) that can be reproduced per millimetre film length. The *Response* indicates the percentage of reproduced line pairs. Of course the flatter the curve and the higher the number of reproduced line pairs, the sharper the film.



SHARPNESS OF SOUND NEGATIVE ST9.

Spectral Sensitivity.

Since ST9 is developed for all round sound recording, it needs to be panchromatic. Moreover, this film has been optimised for the recording of SONY's SDDS (at 655 nm) as well as for the recording of DOLBY's SRD (at 580 nm).



SPECTRAL SENSITIVITY OF SOUND NEGATIVE ST9.

Because of the panchromatic sensitivity, it's obvious that the unprocessed film needs to be handled in total darkness. The use of a safelight must be avoided while the slightest amount of edge fogging can damage the SDDS track.

Base.

ST9 panchromatic emulsion is coated on a polyester base with a thickness of 125 microns. The excellent size-holding characteristic of the polyester base improves the wow and flutter response as well as the high frequency response of the analogue track, while a higher dimensional stability is always an advantage for the high precision recording of the digital tracks.

Storage.

Store unexposed film always at 13^{0}C (55°F) for lower. However, for a long period, store at -18^{o}C (0°F). Exposed film needs to be processed promptly.

Processing.

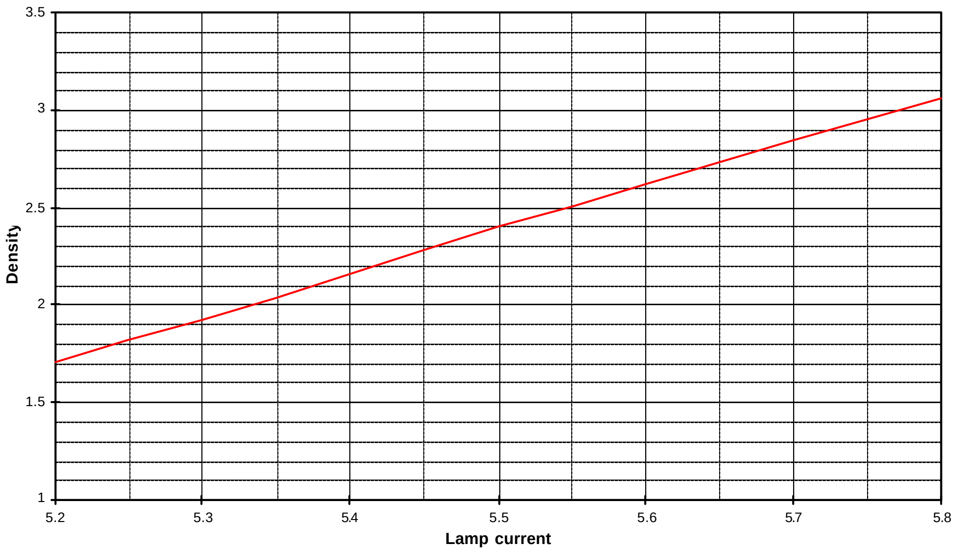
ST9 must be processed according to the standard D-97 black-and-white process recommendations. For a particular processing machine, the processing times may require modification.

Processing step	Temperature	Time
Developer	23°C +/- 0.2	05:00
Fixer (G308)	20°C +/- 1	06:10
Rinsing	18°C +/-2	03:40
Drying	32°C +/- 1	15:00

Exposure.

Analogue soundtrack.

ST9 can be exposed to tungsten illumination to produce an analogue soundtrack with a visual negative density between 2.3 and 3.5 (including base density). Of course the optimum negative density can (must) be determined by means of a crossmod test. However, the aim density in the positive print is 1.25. As a rule of thumb (without X-mod test) the negative density is twice the print density. For a typical Westrex sound camera (with an 18 mil slit) the next graph shows the relationship between the *Lamp current* setting and the produced *Density* on ST9.



SAMPLE LAMP CURRENT FOR RECORDING THE ANALOGUE TRACK ON ST9.

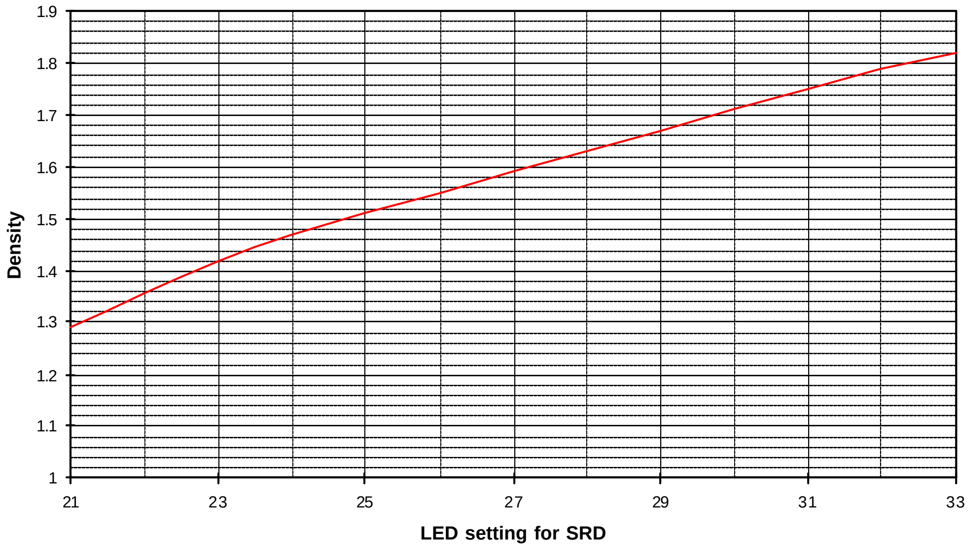
Example: To shoot a negative density of 2.4 the lamp current has to be 5.5 amps.

Sound Negative Film

SRD.

As with analogue tracks, the optimum negative density is determined by recording a series of densities, printing them and evaluating them through playback on the Quality Control system being used by DOLBY or SONY. However, good results have been obtained with a negative density of 1.6.

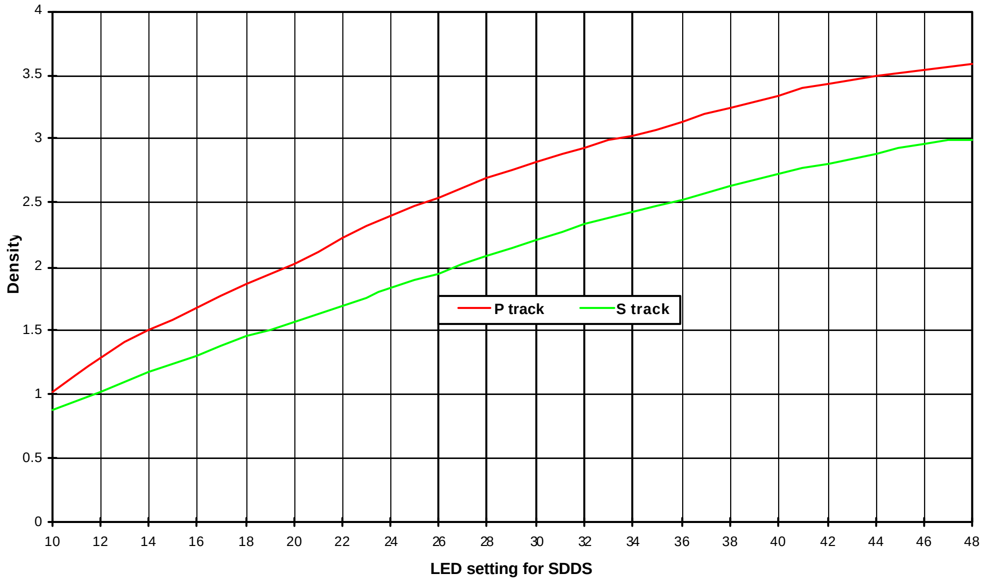
The next graph shows the negative density as a function of the LED setting on the DOLBY recording equipment.



Example: To obtain a negative density of 1.6 the LED setting has to be 27.

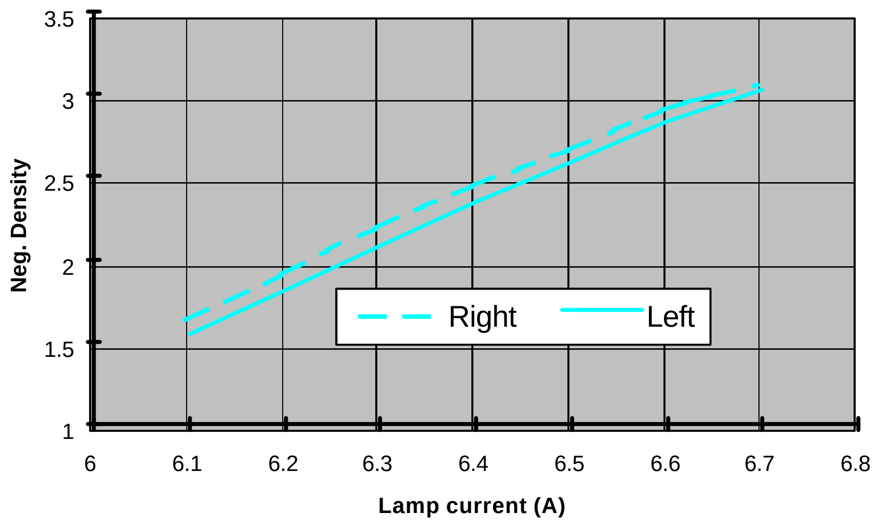
SDDS.

Determination of an optimal negative density for printing SDDS follows exactly the same procedure as for exposing SRD. Shoot a family of densities, and after printing and processing run them through the QC software. In this case however, AGFA advise a negative density of 2.5, which according to the following graph recommends an LED setting of 26 for the P track and 36 for the S track.

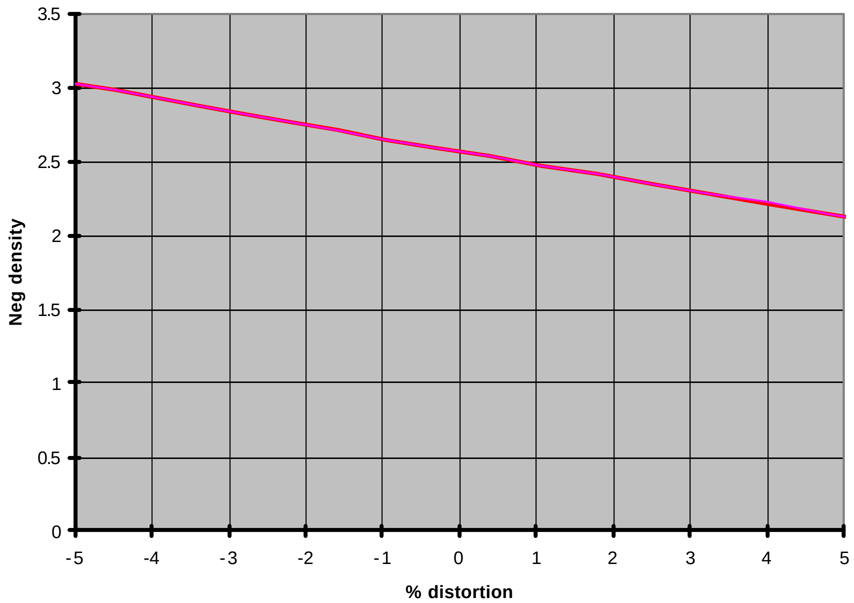


Sound Negative Film

This orthochromatic black and white film is designed for recording the conventional analogue sound track, exposed with a tungsten light source, as well as the DOLBY SRD digital track exposed with a green LED light source (580 nm).
Since ST8.D is the predecessor of ST9 panchromatic, all the other ST8.D characteristics are comparable with the latter film stock.
Since also the aim densities for exposing the analogue track are within the range 2.3 and 3.0, sample settings are as follows:



SAMPLE LAMP CURRENT FOR RECORDING THE ANALOGUE TRACK ON ST8D.



DISTORTION AS A FUNCTION OF NEG DENSITY.

The above graph shows a zero distortion at a negative density of about 2.5, corresponding as a rule of thumb with a print density of almost half (1.25).

In general, photographic filters are used to block, pass, enhance or lower the energy in a certain region of the visual (actinic) part of the electromagnetic spectrum. Most of the filters used in the motion picture printing process are either **Colour Compensating Filters** or **Wratten* filters.**
In both series a rather wide choice of filters is available.

Colour Compensating Filters.

This kind of filters is mainly being used to change the colour balance of pictures recorded on colour film or colourpaper. Therefore this kind of optical filters control the colour balance by attenuating the red, blue or green part of the spectrum. These filters can be combined, but one should always try to use single filters rather than combining them.
The reason for this is:

- the fact that combined filters often create a colour, different from that of a single filter,
- and even more important, combined filters introduce a higher overall density than a single filter.

As an example, let's consider a set of magenta filters, adjusting the complementary colour green. The next figure (Fig. 23) shows a family of these filters namely 10M, 30M and 50M. Every filter has it's own characteristic density at the dominant wavelength of 550nm and they all have (practically) the same transmittance (or density) for the blue and red part of the spectrum.

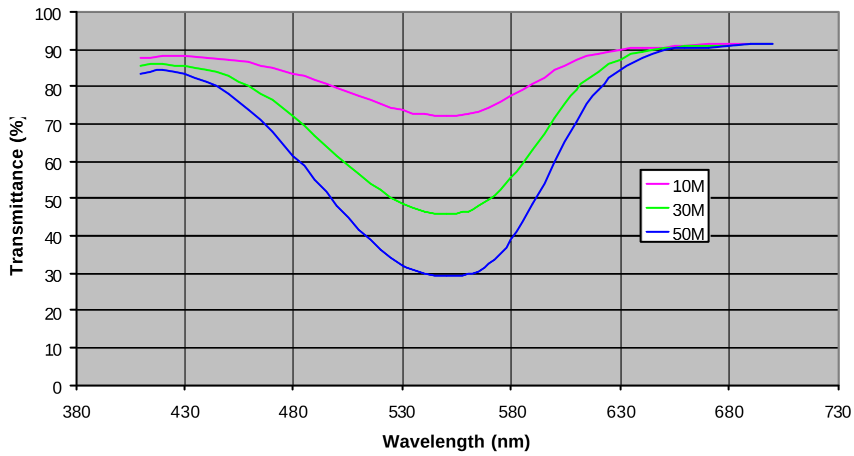


Fig. 23

Let's suppose we need a 50M filter to correct a certain exposure. We can do this by using a single 50M filter or it's possible to combine two 10M plus one 30M. The result is shown in Fig.24 on the next page. It is important to see that the filter sandwich produces a certain spectral difference compared to the single 50M. However, the biggest difference can be seen outside the green part of the spectrum, in this case blue and red. An extra attenuation of about 17% is introduced in the red part of the spectrum, in a part where we can use all the available light for ultimately exposing the film. So if the available amount of light is critical (due to, for instance, high speed printing) one should avoid using a filter sandwich in the optical path.

* Named after Frederick Charles Luther Wratten (1840 - 1926) an English manufacturer of collodion glass plates. He was also a famous manufacturer of photographic filters. The KODAK photographic filters still bear his name.

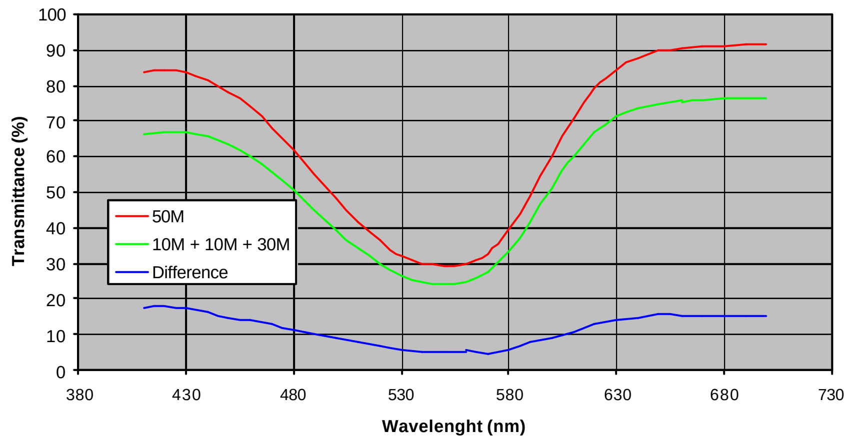


Fig. 24

Wratten filters.

These filters are a collection of standardised photographic filters, which can be used for several exposure purposes. Some of these filters can be a very good alternative for the proposed filter sandwiches in exposing sound tracks.
In the next graph (Fig. 25) the commonly used filter sandwich for exposing SDDS is drawn against the alternative of a single Wratten (W29) filter. The most important difference is to be found in the useful part of the spectrum, e.g. at 700 nm where the panchromatic layer has the highest sensitivity (see page 23 for the sensitivity curves of CP20 print film).
In this part of the spectrum, the difference in transmittance of both alternatives is almost 15% !

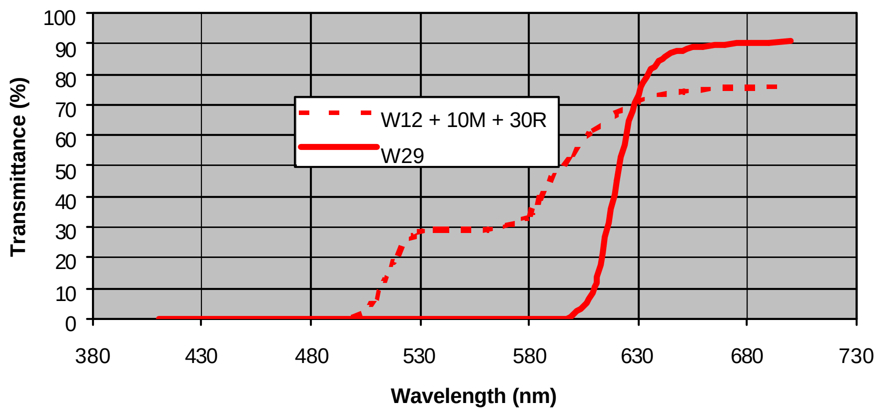


Fig. 25

Another important argument for using a single filter instead of a combination of several filters is the fact that in this case the W29 RED filter defines a much sharper cut off ratio. This means that unwanted exposure of other layers in the target (print) film will be reduced significantly.
On the next page this item is explained by means of the graph in figure 26.

Combining filters

Photographic Filters

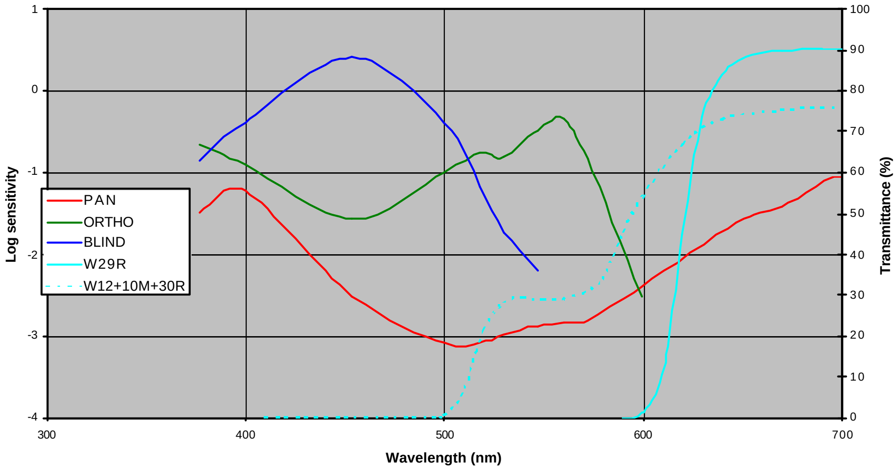


Fig. 26

With respect to the sensitivity curves of CP20 film stock, it can be seen clearly that the W29R filter cuts off the spectrum rather sharply. On the other hand, using a filter sandwich (W12+10M+30R) means a certain exposure of the BLIND and also the ORTHOchromatic sensitive layers, leading to a higher track density but also resulting in a reduced sharpness.

Just for the record, the figures 27 and 28 are showing the performance of the W12 (Yellow) and W29 (Red) filters.

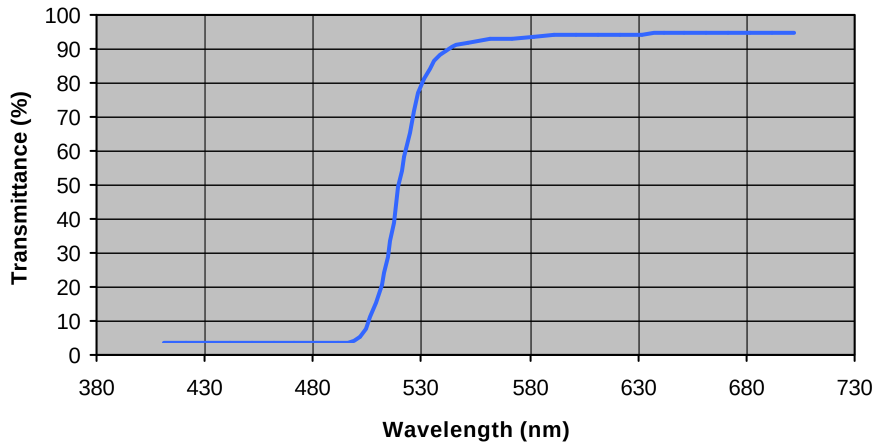


Fig. 27

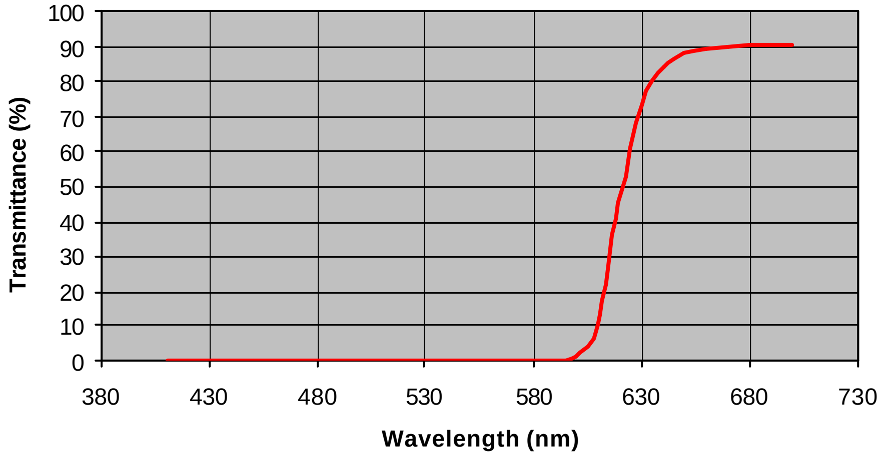


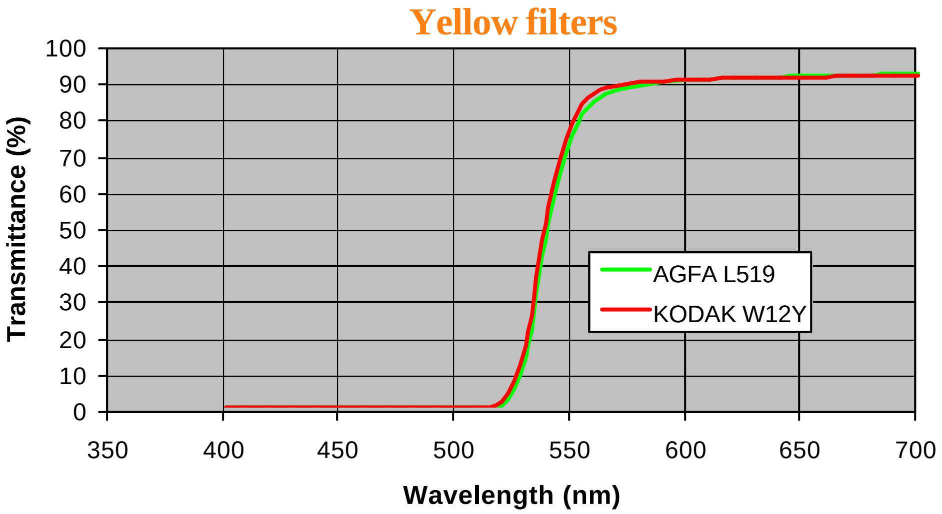
Fig. 28

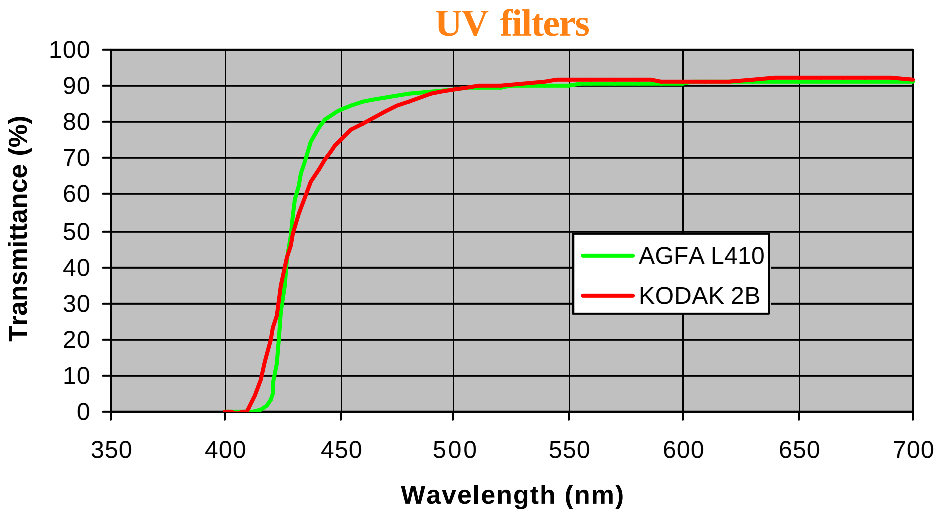
Combining filters

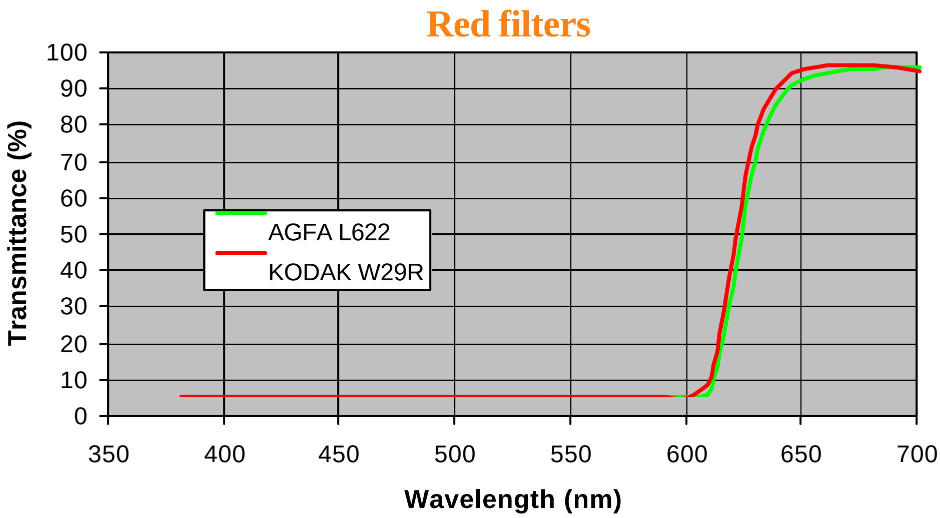
Photographic Filters

Mainly used filters.

The following filters are commonly used in the sound track printing process. AGFA filters can be ordered through your AGFA representative.





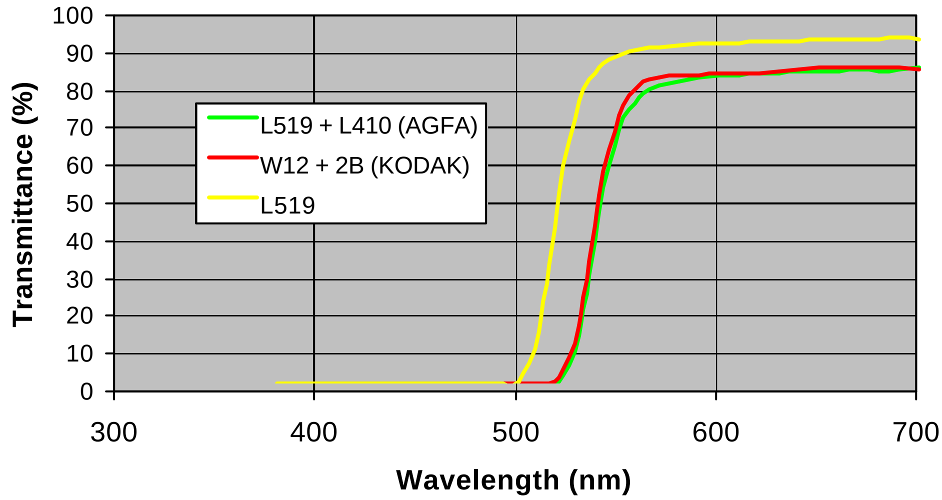


Filter characteristics

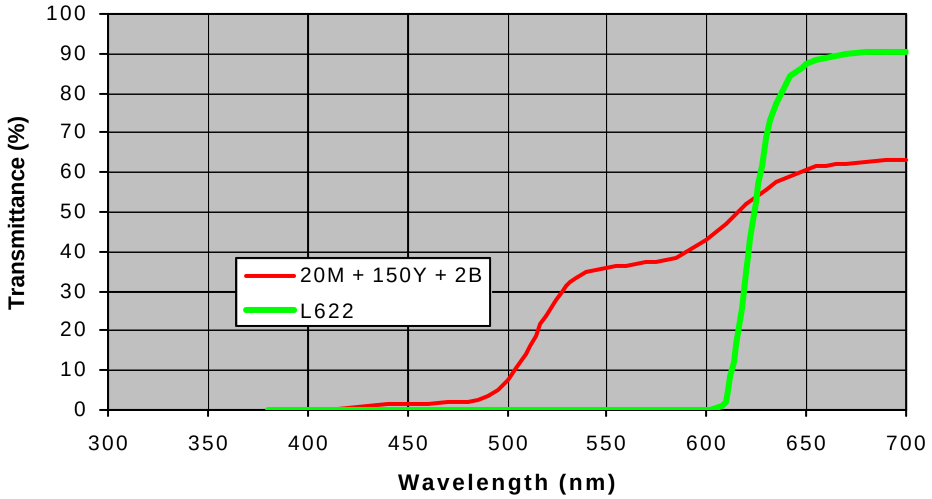
Photographic Filters

Analogue track and DTS.

Since both these tracks are printed at the same time, they use the same filter pack in the copying cylinder of the printer. The widely used filter sandwich consists mainly of a yellow filter (L514 or W12Y) to block the blue light in order not to build up yellow dye density. Because these yellow filters "leak" a little around 320 nm (density 1.8 at 320nm) and because all the layers of print film are still sensitive at this wavelength a UV filter (2B or L410) is used to close this gap.
However, if there's a lack of light (e.g. due to high printing speed) a printing test can be considered without the use of the UV blocking filter (the yellow curve in the next graph), giving about 10% more light with some unsharpness as a consequence.



For both the digital tracks (SRD and SDDS) the filter pack 20M + 150Y + 2B is commonly used.
Also, a lot of light (27% !)can be gained by using a single L622 filter.
The practical results are summarised in addendum A.



Recommended filters

Dye Tracks

What are dye tracks ?

As we have seen on page 24, the conventionally exposed and redeveloped analogue soundtrack builds up opacity by means of the density of the redeveloped silver in both the ORTHO and the PAN layer together with the corresponding dye densities of these layers.

Since building up silver density can only be accomplished through redeveloping the remaining silver in the soundtrack, a redeveloping stage is necessary while the colour print is processed.

Generally speaking, dye tracks are analogue soundtracks without any silver density, meaning that the necessary opacity is obtained only through the density of the dyes in the ORTHO and PAN layers. A little bit misleading perhaps because the two digital tracks SRD and SDDS are registered from the beginning by means of dye densities only.

What's the advantage of dye tracks ?

Because of the very important advantages for both the labs and the theatre owner, dye tracks will be introduced in the very near future.

For the lab on one hand the advantages are clear, no more redevelopment does not mean only a reduction in cost. The most important improvement is the significant reduction in production loss, due to bad redevelopment, splashes of development agent, introduced scratches and so on.

For the theatre owner on the other hand, the replacement of the incandescent lamp leads to a higher frequency response of the sound system and a much longer lifetime (typical 10.000 hours instead of 3.000) of the reader itself. Since the light output of an LED degrades graduately, it can be replaced before any problem occurs.

Are there really no disadvantages ?

Sure there are disadvantages, and as a matter of fact a rather important one. Knowing that today there are a little over 55.000 LAMP-to-LED convertions made on a total of almost 120.000 cinema screens worldwide, there's still a long way to go.

The problem is, that switching over from redeveloped tracks to dye tracks today means that 65000 screens will start reproducing the analogue sound with a lower quality. There's no way to obtain the same cross-mod cancellation with one and the same release print on a conventional incandescent lamp reader and at the same time on a red LED reader, without increasing the magenta dye density in the ORTHOchromatic layer.

That's how the High Magenta concept was born.

Some figures and facts (1999).

\# ***cinema screens***

Europe	28.372
Asia Pacific	35.154
Latin America	7.827
Middle East/Africa	5.500
North America	33.241
Canada	1.924

# ***digital Dolby installations***	>23.000
# ***Sony SDDS systems***	> 8.000
# ***Red LED analogue sound readers***	>55.000 (incl.20.000 in North America)

Introducing dye tracks

High Magenta.

Bearing in mind that the new installed Red LED readers have an exciter light source operating at a wavelength of 655 nm (+/- 5nm) and looking at the absorption curves of the dyes in today's print films (Figure 29) we can see very clearly that only the cyan dye forms a significant opacity at the reader's wavelength.

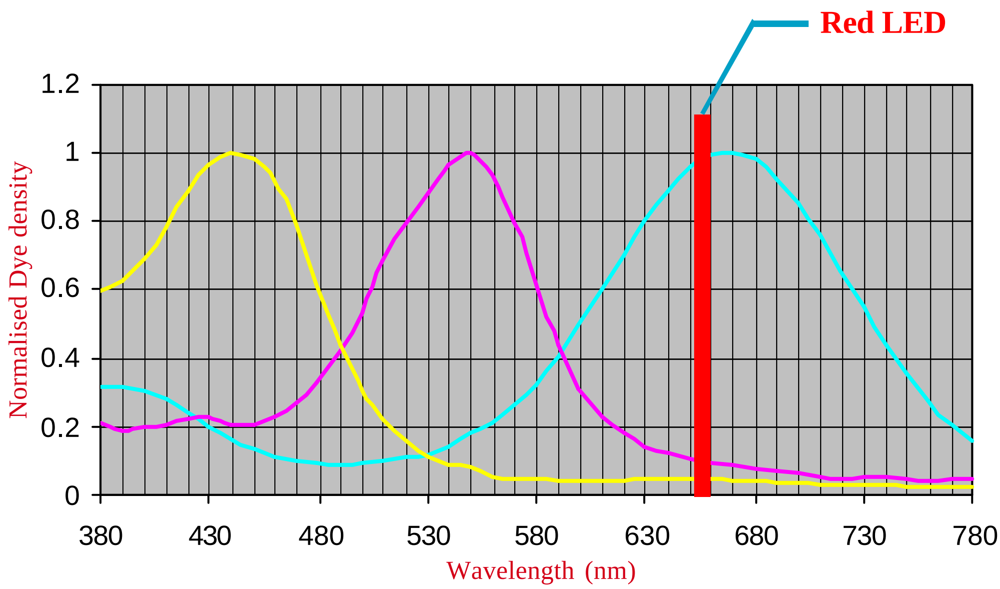


Fig. 29

So at the end, when all projectors are converted to these red LED readers, a high cyan density will be the final solution and a good alternative to avoid sound track redevelopment.

In the meantime, however, the majority of cinema projectors are still reproducing the analogue sound by means of an incandescent lamp reader system. This means that today's feature films will be projected by either a system equipped with a red LED or a system still equipped with the conventional incandescent lamp reader. In both cases however, the sound quality needs to be maximum.

It has been found that a higher than usual negative density and an increased magenta density in the positive print produces the same crossmod cancellation for both reader systems, nevertheless with a difference in signal to noise ratio of about 10dB.

Therefore this system with increased green (magenta) density, referred to as a High Magenta print, is seen as the perfect intermediate step between the conventional redeveloped sound track and the final cyan dye track.

However it must be clear now, that this intermediate solution called High Magenta still needs redevelopment of the silver content in the analogue track. The only difference is a change in colour balance in the print and a higher density in the green sensitive layer of the sound negative.

Important !

Both sound negative film materials ST8.D and ST9 as well as the AGFA colour positive CP20 are perfectly matched to be used in either the conventional way (with redevelopment) or in the alternative way (High Magenta with redevelopment or even High Cyan without redevelopment).

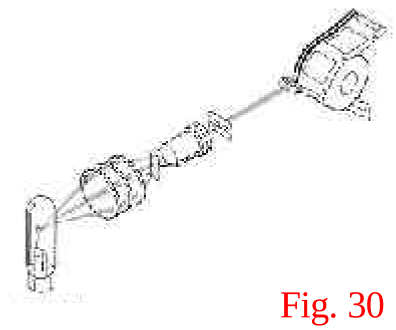


Fig. 30

Having a close look at the reader system in a common motion picture projector (Fig. 30) we find three main parts.
First of all the kind of exciter lamp which is used to illuminate the analogue sound track. This lamp can either be an incandescent lamp or a red LED.
Then, in between the exciter lamp and the detector, we have the release print. The analogue soundtrack on this print can have a different colour balance, depending upon the system used (conventional, High Magenta or High Cyan).
And finally we encounter the detector, which is the same in the different set ups. All these items have their own spectral characteristics, and thus the reader system's performance depends upon these characteristics.
Let us first consider the exciter lamps. If an incandescent lamp is used (Fig. 31), a rather broad energy spectrum is available to illuminate the soundtrack.

Emitted power spectrum of a 6 Watt sound reader exciter lamp.

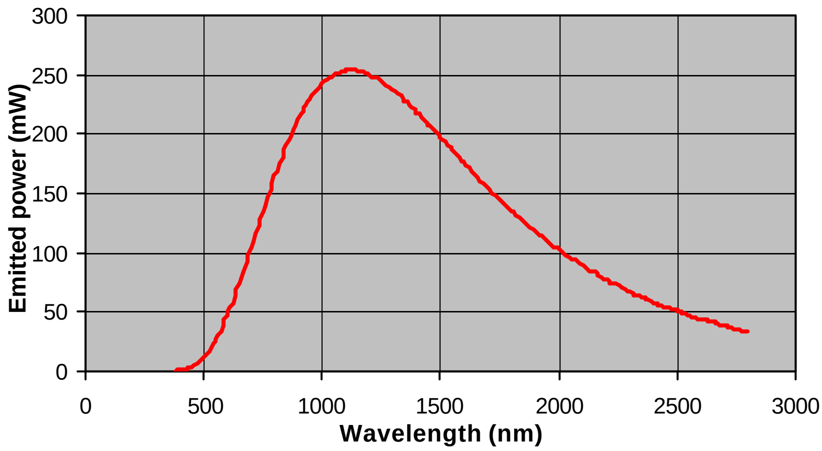


Fig. 31

It's clear that this kind of lamp has a maximum energy output in the far infrared region. The interesting part of this spectrum, where the print film dyes are situated is therefore much narrower and smaller (Fig. 32).

Used part of the incandescent lamp power spectrum.

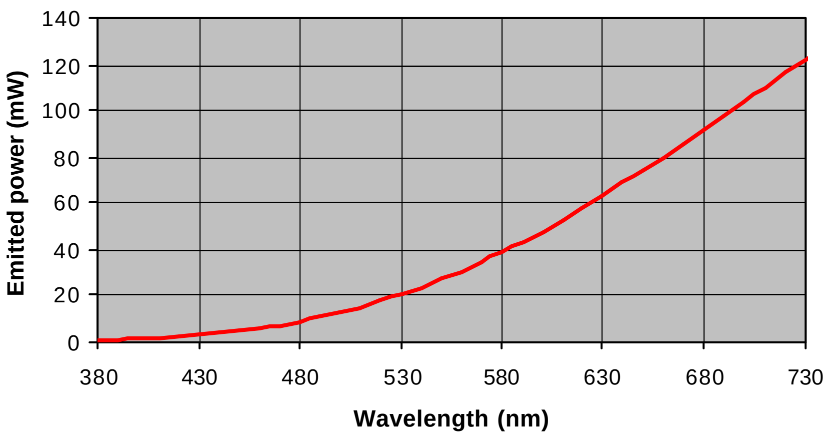


Fig. 32

On the other hand a solid state reader, equipped with a red LED shows a very narrow energy spectrum.

Energy spectrum of a red LED emitting at 655 nm

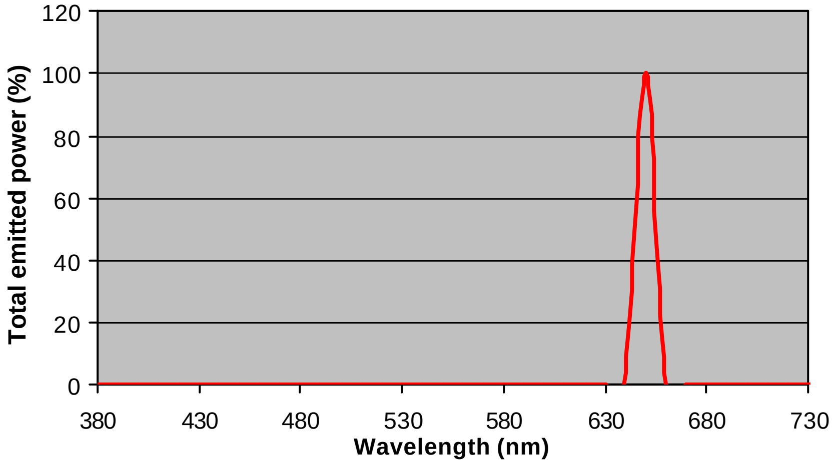


Fig. 33

The common element in all readers is the detector device, a solar cell with a sensitivity spectrum as shown in fig 34.

Relevant part of the sensitivity spectrum of the detector cell.

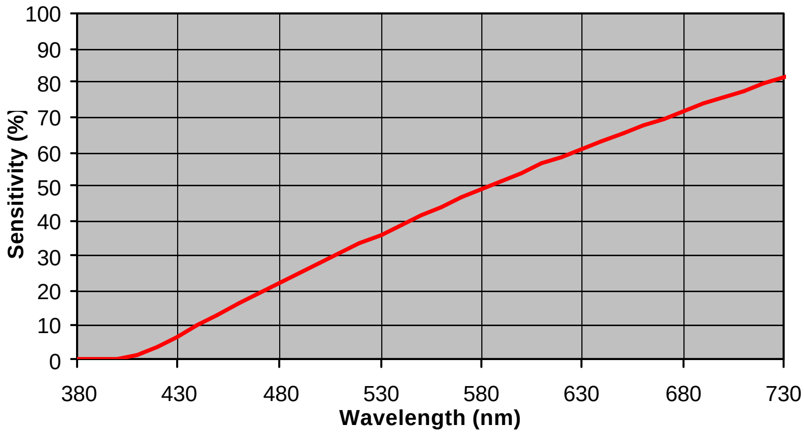


Fig. 34

If we now compose a linear absorption spectrum for print film, and multiply the spectral emitted energy with the film absorption and the detector sensitivity, we obtain the system response.
Let us now consider three different systems:

- a conventional system with incandescent lamp reader
- a red LED reader on a High Magenta print
- a red LED reader on a silverless High Cyan print,

and compare the conventional system with the two others.

Dye Tracks

If we compose a positive exposure with realistic values, aimed at an increased magenta density in order to provide a feature print for red LED readers and incandescent lamp readers as well, we obtain the following spectral absorption (Figure 35).
The density values measured in status A are in this case:

Red density (cyan dye):	2.00
Green density (magenta dye):	3.48
Blue density (yellow dye):	1.52
IR density (silver):	1.10

Overall spectral density of a High Magenta positive print.

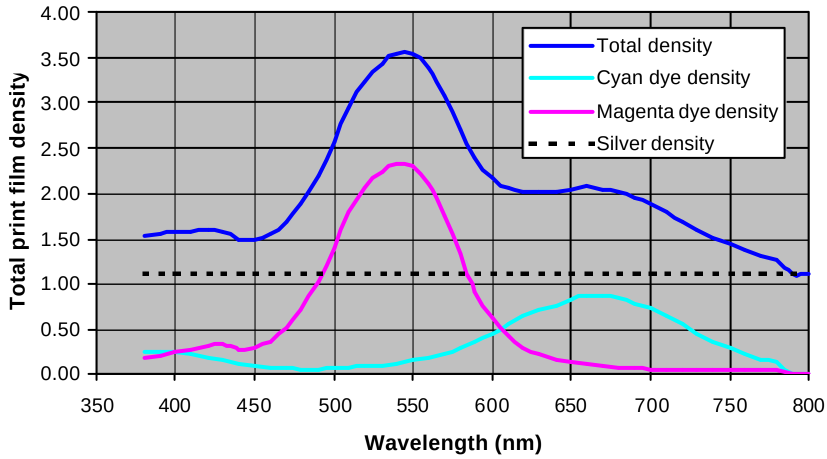


Fig. 35

If this “High Magenta” print is read by the two different reader systems, we obtain the following results:

Spectral power response of a High Magenta system.

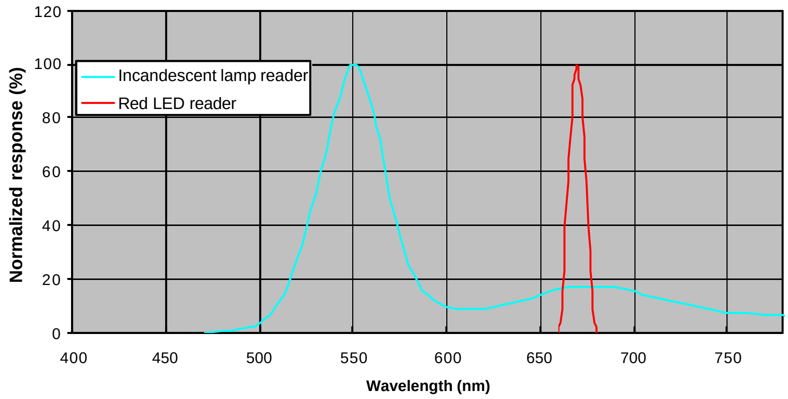


Fig. 36

Since the surface covered by the curves is a direct measure of the detected energy, the ratio between the two surfaces (incandescent lamp - LED) is an indication of the difference in signal performance.
If we calculate this ratio we obtain a value of 8.27 dB, meaning that High Magenta in this case offers the same cross mod cancellation at both reader systems, but introduces a reduction in Signal to Noise ratio of about 8,3 dB.

How it works

Dye Tracks

If we do the same exercise for a High Cyan (silverless) print, and we aim for practical densities of:

Red density (cyan dye):	2.00
Green density (magenta dye):	0.40
Blue density (yellow dye):	0.40
Silver density:	not relevant,

we obtain a spectral density curve as shown in figure 37.

Overall spectral density of a High Cyan positive print.

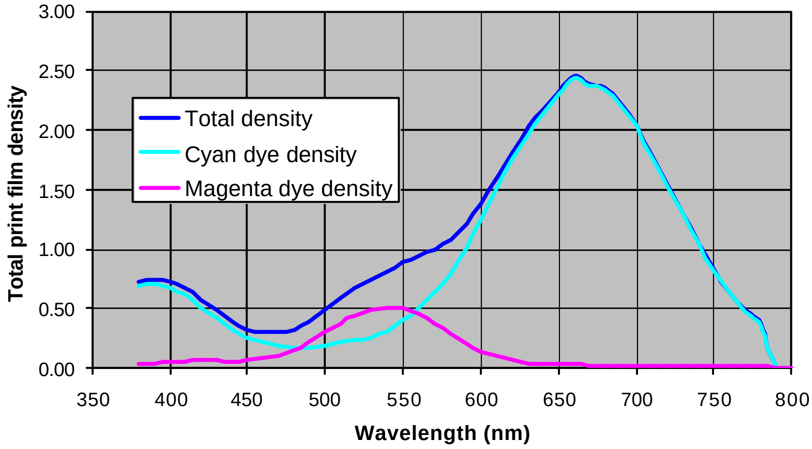


Fig. 37

Again, if this "High Cyan" print is read by the two different reader systems, we obtain the following results:

Spectral power response of a High Cyan Dye Track system.

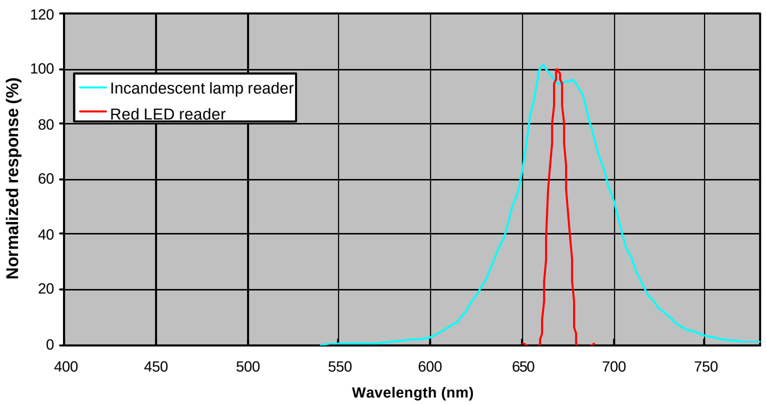


Fig. 38

Also in this situation, an analogue sound track without silver density, we find a reduction in signal to noise ratio of about 8.24 dB.
Finally, if we do the same exercise for a family of different dye densities (cyan and magenta) we obtain figure 39.

How it works

Dye Tracks

Difference in signal to noise ratio between dye track and conventional systems.

It has to be clear that these results only apply for comparing the signal to noise ratio of both systems. In every case a cross mod test is necessary to determine the optimum densities in order to obtain a minimum distortion of the final reproduced sound signal.

Difference in S/N ratio for a High Magenta soundtrack with a 1.1 silver density.

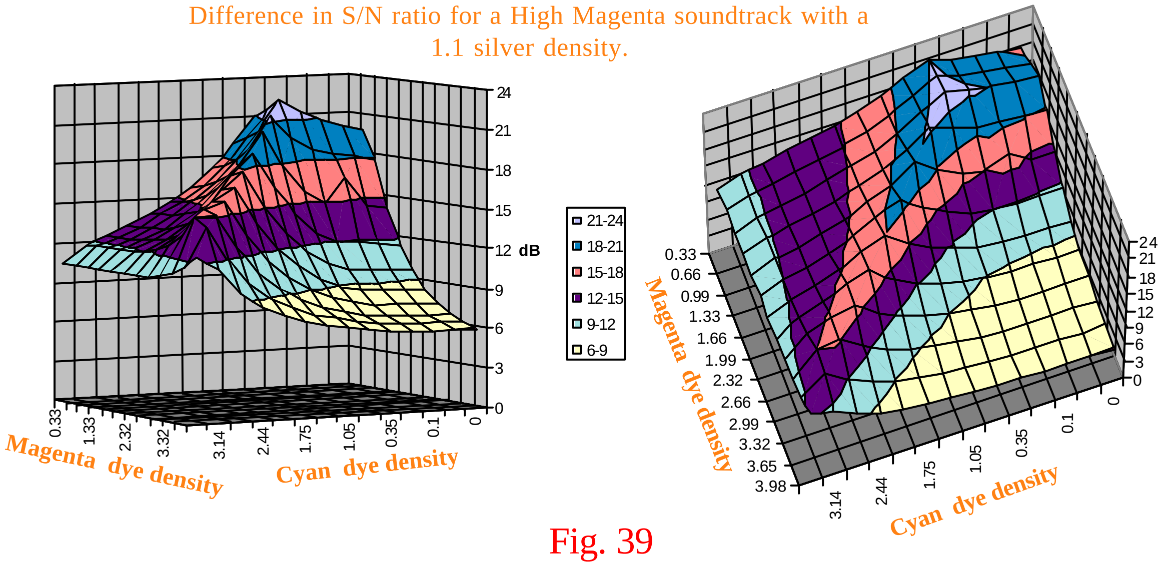
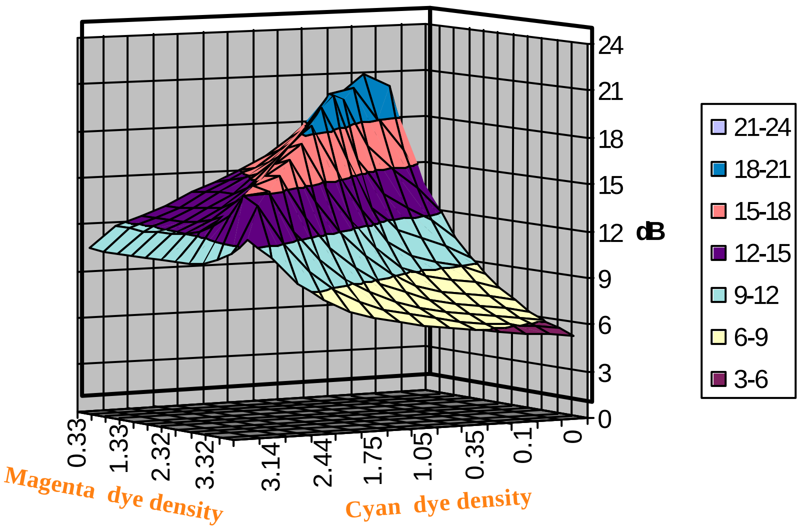


Fig. 39



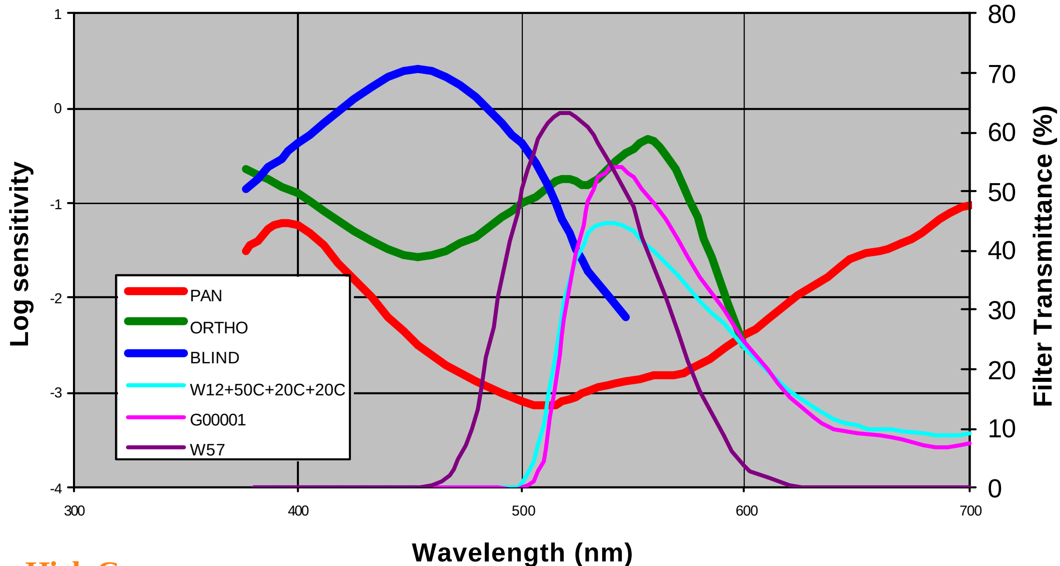
How it works

Dye Tracks

For printing dye tracks, the following filter packages are proposed.

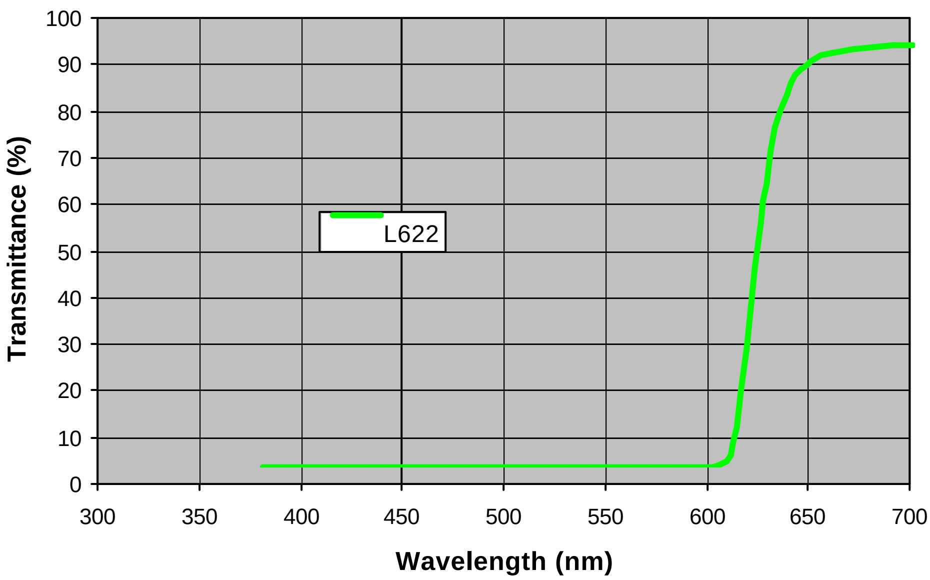
Printing High Magenta.

To expose the orthochromatic sensitive layer and thus creating magenta dye density after processing, either a filter combination (W12+120C) or a single filter can be used. The latter one leaves more light available but creates more density in the blue sensitive layer, introducing more unsharpness. An AGFA filter specially coated for this purpose, know as the G00001 filter, performs much better. As the next set of curves shows, with respect to the W57 the G00001 is shifted towards the optimum of the green sensitive layer and nevertheless having a much lower base density then the combination W12+120C.



Printing High Cyan.

To expose for a higher cyan density, the energy in the red part of the actinic spectrum must be increased. This can be done by using a single L622 (AGFA) or a W29R (KODAK) filter.
Both have a high efficiency (>90%) in the actinic part of the spectrum



Both filters (L622 and G00001) can be found in the backpage of this booklet.

Filter package

Addendum

Recommended aim densities and filter packs for sound negatives and colour prints.

	Neg.density	Print density	Filter pack
Analogue	2.5 - 3.0	1.25 - 1.5	#12 Yellow #2B (UV blocker)
SRD	1.2 - 1.5	1.3	#170 Yellow #20 Magenta #2B (UV blocker)
SDDS	2.0 - 2.5	R = 1.2 - 1.4 G = <= 1 B = <= 0.35	#29 Red or #L622 AGFA
HighMagenta	3 - 3.3	R = 2 - 2.3 G = 3.8 - 4 IR = 1 - 1.1	#12 Yellow #90 Cyan or AGFA G00001
High Cyan	to be determined	te be determined	#29 Red or #L622 AGFA