Good Picture – 2007. ***The Imaging Chain***.
An RPS Teaching Symposium. University of Westminster. Regent Street, London.
18 December 2007.
Presentation by Ray Knight: ***The Final Link in the Imaging Chain.***

The Final Link in the Imaging Chain

This master document has been made available as a PDF download from the RPS website. The presentation will be based upon this document. Any one who has not made detailed notes at the presentation should be able to read over this document, re-living any questions, and hopefully find an answer.

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THE FINAL LINK IN THE IMAGING CHAIN

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Definitions p. 45, and Glossary pp. 46-53.

Show Desktop Grey Scale as opening shot

The above test picture is essentially a low key image, and it will induce the eye into setting black level to an appropriately dark value suitable for low key pictures. The background is a dark grey, not black.

Monitor Black Level, Flesh Colour & Picture Matching

Setting the black and white levels of a picture monitor, or projector, is extremely important for properly judging the displayed image quality of stills or television pictures *etc.* Our subject includes *picture matching* and *flesh colour*, which has engaged the creative minds of the film industry, television broadcasting, graphics arts for design and print, and photography.

Our eyes are much more sensitive to tonal changes among dark greys as compared to the lighter greys. Darkly pigmented areas of an oil painting that have dried dull are greatly enlivened with re-touching varnish, to a far greater degree than the light areas. If you adjust the brightness control of your television set or computer monitor (black level), the change in the dark greys is very easy to see, even critical, yet a similar change that is occurring in the lighter areas goes quite unnoticed. We now refer to the work of Wilhelm Eduard Weber (1804-1891) and Gustav Theodor Fechner (1801-1887).

The Weber-Fechner fraction specifies Brightness Discrimination as the fraction $\Delta B/B$*, where* ΔB *is the increment of brightness which can just be detected at the brightness level B.* The Greek character delta, Δ, is used to mean *a small change of.* As the brightness gets lower, into the dark greys, the increment of brightness change that we can see also gets smaller, essentially remaining at the same fraction that $\Delta B/B$ promises. This explains why we are so sensitive to, and critical of, the setting of CRT or monitor black level, much more than the setting of the lighter greys and white level. We use a $\Delta B/B$ fraction of 1%.

The critical aspect of setting black level is at the heart of this discussion, both setting the monitor black level and the black level of the picture signal. To some degree a picture monitor that is *sat down* – a phrase meaning that black level is set a little too dark – will induce the colorist (the operator responsible for adjusting image quality) to sit or *lift the picture up* – this time the meaning is to lighten black level a small amount – the overall effect being to establish a good looking picture. The foregoing scenario has followed a well known principle, namely, *that we look at a picture monitor and adjust the picture signal to make the picture look good, on that picture monitor*. There are certain limits to this self compensating way of working. One of them being when the picture signals from these two separate locations are editorially brought together we find they do not picture match. The picture monitors at the two remote locations were dissimilar in their black level set up and the visual compensation practised at each site produced an acceptable result *at that site*, but not a pair of matching pictures for editorial use. An instance of “It looks OK leaving me”.

We *are* speaking about small changes here, and while we are all able to see such changes especially when they are brought to our attention, most viewers will pass them bye. For this reason we aim to operate in visual surroundings that stabilise the response of our eyes. (See 9, Viewing Conditions & Monitor Calibration on page 32).

Picture Matching

Picture matching is the art of making two, or more images such as we see in a moving sequence, look alike in all aspects of their image quality, appropriate to the story, production scene and atmosphere being portrayed. This can be broken down into certain elements over which we have direct control such as *black level,* exposure and colour balance. While some aspects of colour balance can be quite accurately defined, such as the colour temperature of a white point, *etc*. the sense of black level, exposure and colour balance within picture matching is a subjective assessment made with respect to the adaptation of the colorists eye, and until a sequence of shots are presented to the eye we do not know exactly how the eye is going to react. It is as important as ever for a digital image to be colour balanced as well as being adjusted to look right in the colour managed sense of shot-to-shot picture matching. This requires operators and designers *etc.* who are sensitive to these matters, to be able to make and contribute to image balance adjustments aimed at improving or maintaining the appearance of a good workflow, as seen on TV and in print. Such colour and picture matching requires access to a good viewing environment that enables these fine adjustments to be seen and made. It is quite surprising how careless some operatives can be over this fundamental requirement.

The Personality of Flesh Colour

As the sound of an orchestra can be traced back to many pure sounds, as for instance the BBC time signal – which is a pure 1000 cycles per second, 1000 Hertz (Hz) – so our recognition of faces includes the perception of the characteristic colour of skin. Skin colour is found to be particularly constant within ethnic groups and it is quite surprising how the constituents of blood leave their signature as a constant factor that determines complexion colour. The hemaglobin products are outstanding in the degree to which they shape the basic spectral reflectance of skin with their sharp rise in reflectance at about 580 nm.

The constancy of skin colour, abstracted from our visual personality, is one factor among many that contribute to the appearance of our physiognomy. The colour specification of some make up products is accurately synonymous with skin colour which, seen in the three dimensional totality of the head (and elsewhere), or its reproduction, provides us with the rich variety of individuality augmented by the details of shape and texture as influenced, for example by lighting and perspiration.

The Aim of a Flesh Colour Test

To speak of flesh colour only is to isolate Hue, Value and Saturation from the personality of flesh colour – from all the other details that add to the visual description of the three dimensional head, hand or other anatomical feature. These subtle aspects of shape, ageing and general character are often conveyed as three dimensional information enhanced with directional lighting, such as the sagging of otherwise firm flesh and muscle, the wrinkling of smooth skin and the lines beside the eyes, neck and elsewhere. If these character aspects are removed from consideration we are able to find a basic colour that is quite representative of large groups of people within society, found by looking at such relatively flat areas as the forehead, cheek, back of hand and palm of the hand, plus other areas according to the state of undress. As soon as you see an abstracted skin colour it is clearly not real, however that misses the point. This process of isolation is a concept with nothing to do with the reproduction of colour in a prescriptive sense. It has everything to do with setting up colour reproduction systems with a test colour, whose colour specification is placed somewhere in the colour space of the reproducing system, and is a test that is accurately representative of skin colour, in order that that system may then reproduce real object colours, close to and including skin colour with some fidelity, when asked to do so. Imagine a scene in which two actors are performing, one black and the other white. When both are in shot the camera is in need of a state of set-up that will enable both to look good. They can only be treated separately in single shots and that may well lead to some picture miss-matching on items other than the performers themselves.

This test is like the tube of flesh colour paint, thought by some to be a useless artistic anathema, probably voted onto the colour card by the non-creative member of the board of directors that actually looks very much like a cake of make up, an abstracted flesh colour that comes alive when applied to the real shapes and contours of a three dimensional face. For a technical set-up test to be representative of real object colours we need to look closely at those objects we wish to see accurately or pleasingly reproduced, especially if they have an oddly shaped spectral reflectance curve, in this instance skin colour. In fact make-up manufacturers have already done this. Reproduced flesh colour is sometimes seen to vary greatly on broadcast television between programmes, presenters and commercials. The displayed variety of flesh colour is the sum of natural character variations (which we wish to retain) and imposed colour errors of reproduction (which we wish to remove or minimise). It is not our intention to bring all flesh colour reproduction to one standard colour although the means of colour control and analysis may make use of a standard sample representative of flesh colour. Control is exercised over the basic colour reproduction characteristics of colour film and camera equipment such that an original colour or colours are given acceptable reproduction. The intention is that a variety of object colours in front of camera are treated the same from different sources and are given the opportunity of individual colour reproduction as appropriate, especially if seen in the same shot or adjacent sequential shots.

Even though great variety in the complexion colour of paintings can be seen, *they all look credible*. We do not see groups painted with heads, or a head, looking different to a degree beyond its character part such that it does not sit happily in that group. Life magazine for April 1987 was a special movie issue. Sixty-two artists loyal to Paramount Studios attended a celebration group photo call, a double spread on pages 130/131, which together with the cover shot, is an example of how make-up in the film industry has, at least in the past, been able to impart a similar theatrical or professional look to all artists – but the natural character of each artist was not compromised. On the other hand the 1905 portrait paintings by Henri Matisse and Andre Derain of each other are not wrong, but intensely expressive. See **Leymarie,** Jean. *Fauvism*. SKIRA (1959). Pages 78 and 79. For the colour reproduction of complexions, flesh, and blood, for use in remote medical diagnosis we would need to see a screen image in a proper viewing environment that looked real, divorced from creative license or the hand of made-up uniformity. Kolor Rite fluorescent tubes were made to provide good quality illumination in hospital situations where complexion colour matters, where the phrase "you do not look well" carries a good deal of medical information. There is in *normal* reproduction – and such a phrase as normal does exist within the requirements of picture matching – a spread of flesh colour that will be close to some central colour or aim point that can be used for technical purposes. See **Stimson,** Allen., and **Fee,** Edward. *Color and Reflectance of Human Flesh* Journal of the Society of Motion Picture and Television Engineers, Vol 60. May (1953) pp. 553-558.

Logarithmic Graphs and Setting Black Level

The CRT characteristic curve is generally presented as a logarithmic graph conveniently made by using logarithmic graph paper to plot the basic linear voltage input / light output values obtained from measurements. A feature of logarithmic graphs is that a power law is represented as a straight line, and zero (or nothing) is not represented on a logarithmic axis, which enables a very wide range of values to be clearly represented. Starting from 100% or 1, numbering reduces in the sequence 100, 10, 1·0, 0·1 and 0·01 and so on, getting smaller and smaller *but never reaching zero*. Setting the brightness control of a picture monitor to cut-off, by observing the condition of zero emitted light; just prior to making practical measurements of the very small amounts of light emitted at the bottom end of the CRT curve is very critical indeed. These measurements are made in darkness with the operator's eyes partly dark adapted, after about 5-10 minutes in complete darkness – full dark adaptation takes a lot longer, in the order of hours. After one hours dark adaptation in a dark room the threshold stimulus for a normal eye diminishes to one-hundred-thousandth of its initial value. The brightness control (black level) is set as near as possible to the condition of *no emitted light for zero signal input*, not below that setting or above it, if possible. The characteristic curve we then arrive at is the true *static* curve of the CRT less the effect of any ambient room light, which is usually present in a practical operational or viewing situation. The difficulty in accurately setting this black level accounts in part for the variation in reported values of measured static CRT gamma. While this setting is never used in practice – we do not view pictures in total darkness – this static figure is required to support further dynamic calculations. It must be said in passing that whenever room lighting is reduced to a minimum, in much the same way as movie film is viewed in darkened or dimmed auditoriums, the reproduction seen on a picture monitor is greatly enhanced.

Seeing Black

There are two modes of seeing black. Dark adapted and light adapted.

DARK ADAPTED. The first is with the dark adapted eye, where you sit in a dark blacked-out room for a while, say 10 minutes. This imposed darkness allows the eye to become very sensitive, in which state it can detect extremely small brightness values – or dark greys. If room lights are inadvertently switched on we are quite dazzled, like going outdoors into full sunshine.

LIGHT ADAPTED. If we do go outdoors (leaving the room lights on) we wince and shade our eyes 'till they become accustomed to the sunlight at which point our eyes are light adapted to a very high ambient level. If we turn round and look back into the room we have just stepped from it will look very dark, perhaps black.

We have illustrated two extreme states of adaptation. Dark adapted and light adapted, which are, broadly, the two modes of seeing black. The many states of intermediate adaptation are illustrated in ***Fig. 14*** *The Overall Adaptation of the Eye from Moonlight to Sunlight, and* ***Fig. 15*** *Local Adaptation as for Viewing a Print and its Surround.*

We conclude that our perception of black is less to do with the actual brightness or luminance of the object we look at, but more with our state of visual brightness adaptation at the time, and the relative brightness of the black object in relation to the visual field it is within. It is therefore important to control the average brightness of any test signal used to visually set black level. As indicated in ***Fig. 17*** *Details of the Desktop Greyscale.* A design intended for low key images. In fact it is the same requirement for standardising viewing conditions for general picture viewing.

A Case For Adaptation

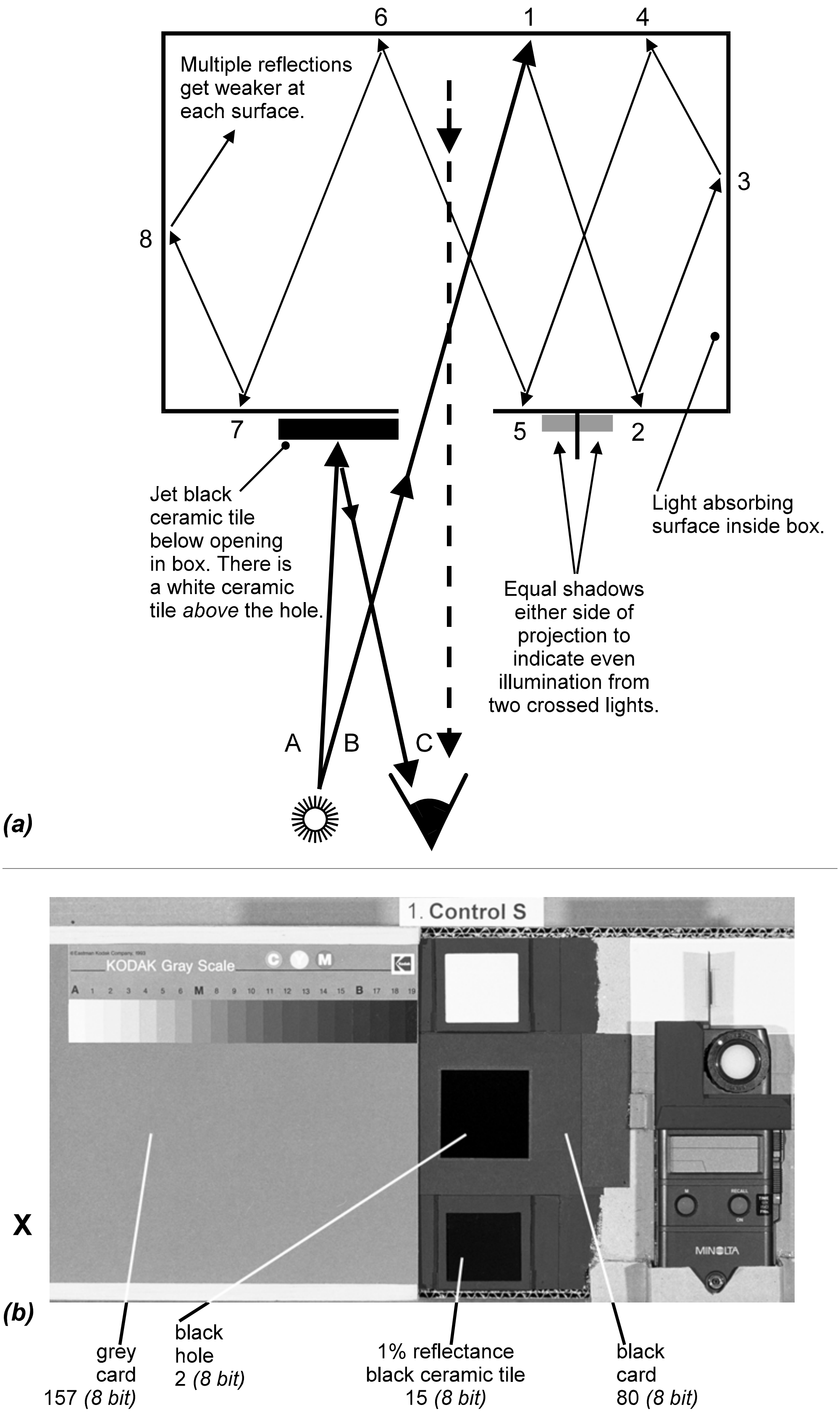
Light can continue to diminish after we have perceived black, the quantity simply gets smaller, a figure below our threshold of sight. But then, what is it that we see? for we have to see something for sight to have a perception for us to consider. Our perception of a rich, velvety, jet black remains, even of the classic black cavity that represents absolute black by absorbing (nearly) all radiation (light). If black is correlated with a non-stimulated condition then it has a parallel with silence in hearing. I have heard silence, while sat amongst desert rocks – nothing could be heard. A contradiction in terms, may be,

but such a memorable experience. Black may also be the sensation attached to the resting stage of the cortical process – reference lost.

How Black is Black?

Black is a relative figure of reflectance, where about 1% reflectance in a scene will have the appearance of a good black. Now look at your television set switched off and note the brightness of the CRT screen. This is the luminance starting point for picture blacks on the CRT, which is anything but black, its actual brightness being the result of prevailing ambient light reflected off the glass screen and phosphor arrangement. The appearance of good blacks in an image whose CRT is actually a dark grey is due to our visual adaptation to the general image and its surrounding brightness. This general process of brightness adaptation accounts for our normal perception of black in normal scenes. Similarly, the projection of images onto a white screen as with motion picture film and slides, allows the perception of black *on the white screen* from adaptation to the average scene brightness. Although the auditorium is in near darkness there is sufficient flare to light up the white screen, but we read it as black in the places that need to look black – in those image areas that have a high density in a colour transparency or, those image areas in a digital file with pixel values close to zero.

A shiny black ceramic tile with a measured reflectance of 1% casually looks very black. But seen against an area designed to reflect a minimum of light – much less than 1% – the shiny black tile is clearly lighter than black, and this order of black differentiation can be seen, photographed and is easily visible on screen via a scanned film image. See ***Fig. 1*** *Generating Kirchoff's Absolute Black.* In the tonal structure of scenes we note that black, as a reflective element, is a relative term, there is always the possibility that a yet darker area will make an accepted black appear grey. It gets darker and darker but never an absolute black – or zero light. *That would compete with an astronomical black hole!*



The above values were measured from a colour negative scan with above-black level and below-white level values adjusted to ensure there was no clipping.

Fig. 1 Generating Kirchoff's Absolute Black

1. WE HAVE A CAMERA TO USE ... CAMERA DYNAMIC EXPOSURE RANGE ANALOGUE VS DIGITAL IMAGING THE JUST NOTICEABLE DIFFERENCE OR JND THE SCENE BRIGHTNESS RANGE & LIGHTING CONTRAST THE BRIGHTNESS RANGE OF A PRINT BRIGHTNESS ADAPTATION OF THE EYE COLOUR ADAPTATION OF THE EYE & WHITE BALANCE VIEWING CONDITIONS & MONITOR CALIBRATION ADOBE RGB & sRGB COLOUR SPACES COLOUR SEPARATION & BLACK GENERATION PRINT PROFILE GENERATION DOT GAIN *... & A PRINT TO MAKE*

We Have A Camera To Use

The previous presentation by Mike Tooms has outlined the colorimetric basis of our digital camera for it to produce good results. We assume that the manufacturers have taken note of this technology. We make this assumption because so much technology of today is considered to be proprietary information, even though it originated in 1931 and was then, and still is, openly available. However, recent developments in computing, photography and printing have seen an incredible leap forward in quality and manufacturing facility, with the computer industry standard Photoshop keeping sentinel watch with the latest in colorimetric requirements. In order to facilitate the interchange of colour images, we are now familiar with, or are offered the opportunity to become familiar, with the idea of a three dimensional colour space – simply referred to as a colour space – in which each and every colour can have a measured location. This is graphically illustrated in the MAC Colour Sync facility.

Nearly all digital camera techniques have a foothold in the history of silver film and its processing. This is most certainly true for the older photographer amongst us. For young students this can change with a modern educational process that takes its cue from a fast moving industry composed of elements from computing, optics, physics, electronics and miniaturisation. At the end of all the steps in whatever chain of events is ***an image,*** and this receives serious attention so that at least a thread from the best of yesterday can be woven into today's fabric. And similarly for speech (theatre), reading (typography and graphic design and music (performance).

While the basic camera design is fixed we do have a number of buttons to push and the following *links in the chain* are offered in explanation and encouragement. The latter because not everybody is weaned off wet film to favour digital techniques: a process hastened by the disappearance of film equipment. We eventually adopt the position of the last link in the chain, as the viewer of the print. But first a look at the camera IMAGE SENSOR, shown in the following block diagram, ***Fig. 2 (and Fig. 3).*** If you think Figure 2 looks complicated this is because we have tried put, onto one A4 page, all the individual electronic processes that comprise our initial capture to eventual print. Such blocked flow diagrams were the stuff of television development, which preceded the digital photo revolution. Figure 2 is revived here in the face of industrial and commercial secrecy, because it acts as a visual analogue of the processes we wish to understand and recall.

In contrast, the overall wet film printing process could be seen (in dim safe lighting) as a row of shelved chemicals waiting to be decanted and a line of dishes each the size of the finished print – and more of them if you were processing to archival standards. The process was extremely tactile, clear to see and easy to remember. We look for the same clarity in our computers, electronic cameras and peripherals and to promote this we have Figure 2, a diagram prepared, as a metaphor for complex thinking, that hopefully reduces the problem to a simple analogy or a number of small analogies that are easy to comprehend individually, enabling their relationship to the complicated whole to become evident, permitting a complexity of thoughts to be built up and conveyed between minds.

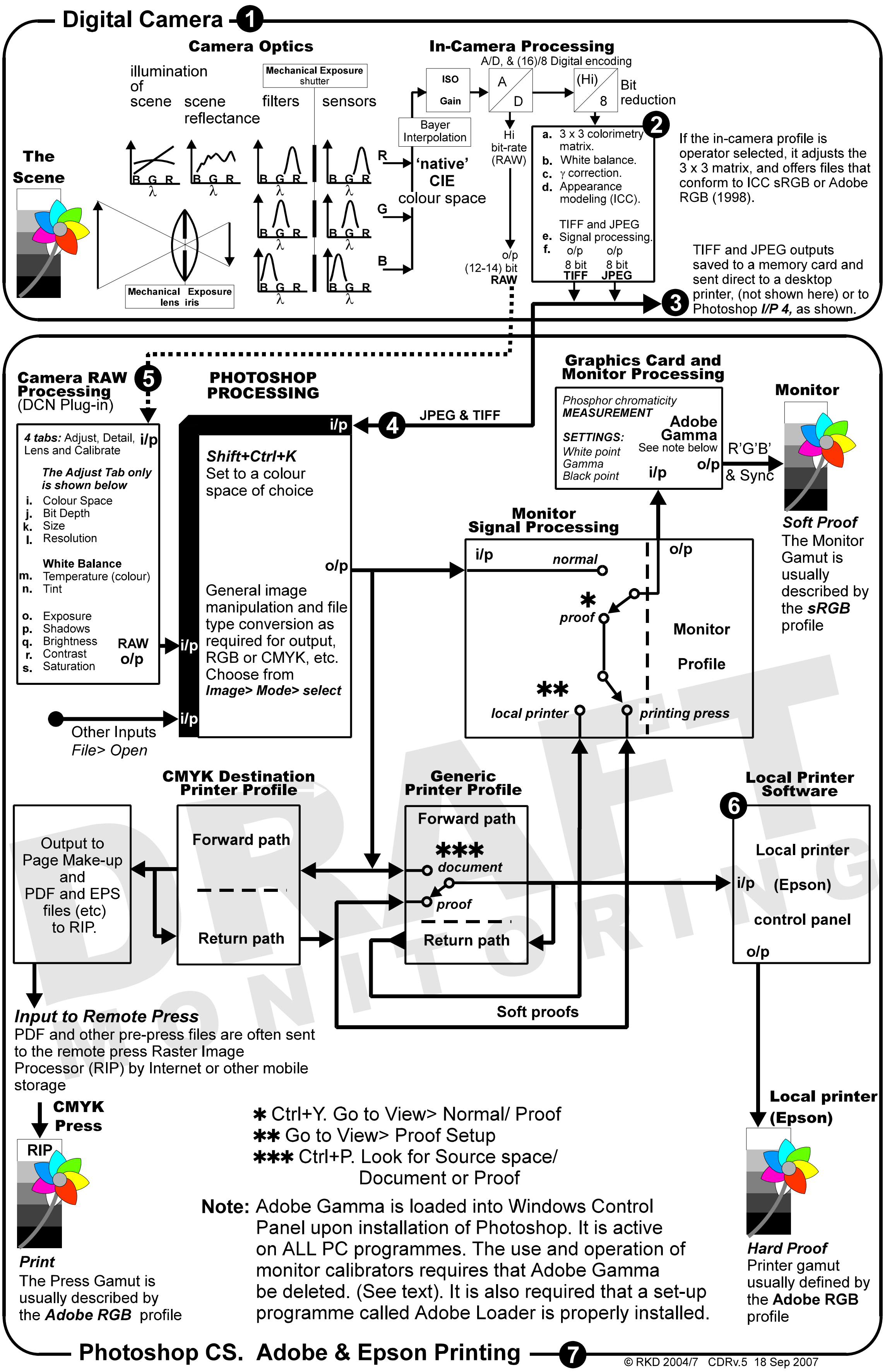


Fig. 2 Flow Diagram of Camera – Photoshop – Printer

WE HAVE A CAMERA TO USE …

2. CAMERA DYNAMIC EXPOSURE RANGE

ANALOGUE VS DIGITAL IMAGING
THE JUST NOTICEABLE DIFFERENCE OR JND
THE SCENE BRIGHTNESS RANGE & LIGHTING CONTRAST
THE BRIGHTNESS RANGE OF A PRINT
BRIGHTNESS ADAPTATION OF THE EYE
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DOT GAIN

… & A PRINT TO MAKE

Dynamic Range and Dynamic Exposure Range

The first word in the above phrase – **Dynamic** – refers to the indeterminate nature of the range of *values* referred to because they are dependant upon a previous function, such as scene illumination being Sunny or Cloudy Dull. These *values* are variable, moving or subject to change, converting static signals to dynamic ones.

The second word of the phrase – **Range** – refers principally to the limit of a sequence of values which, in image work, might be the extreme limits of black and white, including all intermediate values (greys). In numbers this might be expressed in analogue exposure figures presented to an imaging device such as film or an electronic sensor (*'f'* stops). In output terms this relates to film density (D Log E) or a voltage output from an electronic sensor (OETF, Opto Electronic Transfer Function). Both D Log E and OETF plot the shape of what has become known as a transfer characteristic, the function that describes the passage of data through a device as being either (1) linear, with no distortion, or (2) non linear, implying a form of distortion or image enhancement (Photoshop curves).

So far we have only considered analogue values. At some stage the output of the image sensor within a modern digital film scanner, or digital camera, will be passed to an A to D (Analogue to Digital) converter for conversion to a digital signal. It now becomes convenient to understanding to refer sensor data to its input, or output. Exposure data is clearly input referred (or scene referred) and the signal output is output referred.

Whatever these signals are called, and wherever they are measured, they relate to the original input exposure data. It is the range of exposure values (greys), derived from the operation of lens aperture and shutter speed that the sensor is capable of differentiating between the limits of black and white. It is the nature of these ever changing exposure values to call for the description Dynamic, the limiting Range of which is determined by the sensor and given in exposure terms, hence the explicit phrase **Dynamic Exposure Range.**

The image sensor places range limits on the levels we name as black and white. At **black level** it is the device (sensor) noise that obscures any smaller signals being seen from smaller exposures (less light), sometimes called a noise floor. At **white level** it is the **Sensor Saturation** that prevents a higher signal output from greater exposures (more light). Between these limits the sensor is assumed to have a linear transfer characteristic, or OETF.

The voltage output from the sensor, and the A to D converter, follows the sensor input exposure variations and as such has a similar Dynamic Range, measured in terms of repeating a halving of exposure at white level until the noise floor is reached (similar to the doubling of ISO speed rating). Dynamic Range is often given as so many lens stops, from white level down to the noise floor. (One stop being a halving of exposure).

The digital values given to the sensor output, via the A to D converter after digitisation, will depend upon the chosen bit depth. For 8 bits this is the ubiquitous 256. Raw files are of higher bit depth, in the order of 12 to 14 bits, depending upon the manufacturer. Higher bit depths result in greater numbers, such as a 12 bit RAW file with 4096 levels: these levels are set to operate between the limits of black (level zero) and white (level 256 or 4096, as discussed here), and increase the numerical number of signal levels between the fundamental limits of black and white. A RAW 12 bit file is numerically more accurate than the 8 bit standard file but, with the same characteristics that the sensor offers to all A to D conversions by way of the its **Dynamic Exposure Range.**

Exposure

Exposure is the integration of light intensity and time (lens aperture and shutter speed), and at this stage (at the sensor input) it includes the secondary effects of depth of field (lens aperture) and the stopping / or blurring of image motion (shutter speed). This only happens once per image, at the initial image capture – when you go click. Subsequent adjustment of quasi exposure in software is possible due to the similarity of effect between a linear sensor and a linear adjustment of circuit gain following to the sensor output.

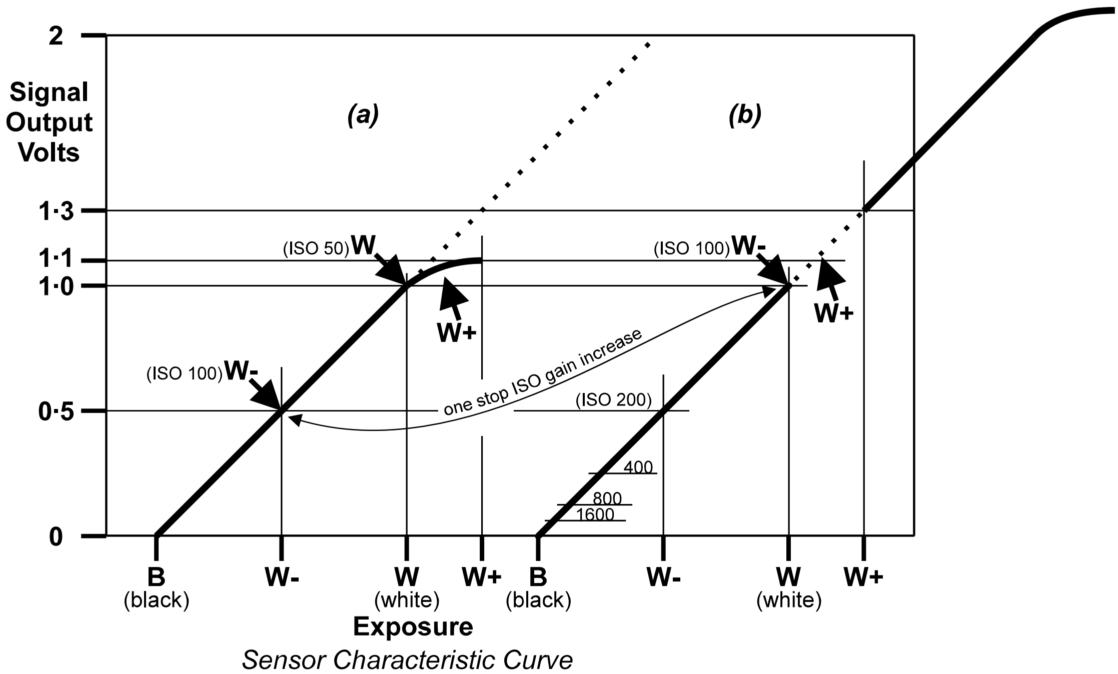
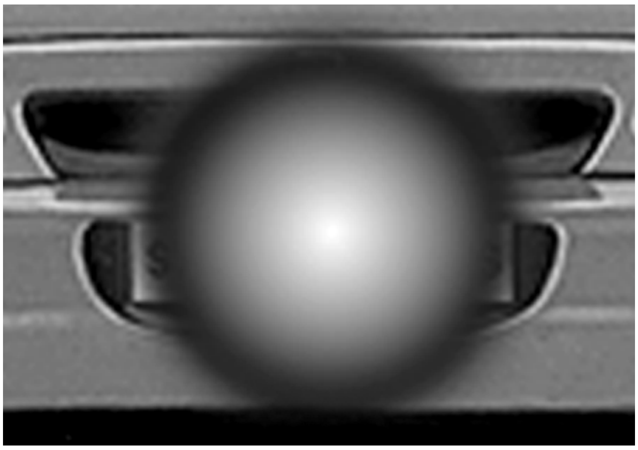


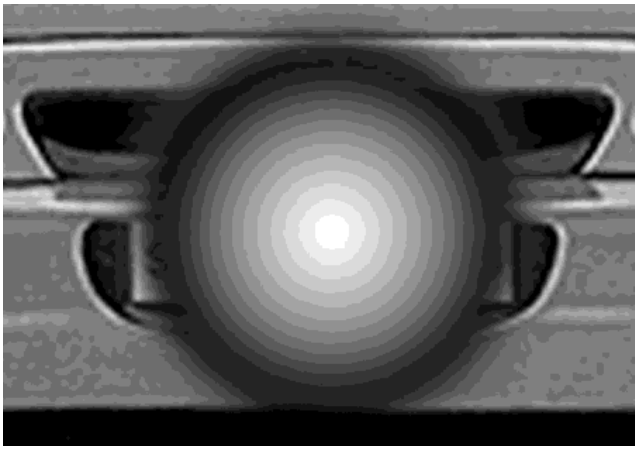
Fig. 3 The Sensor Characteristic and ISO Speed Rating

Referring to ***Fig. 3*** *The Sensor Characteristic and ISO Speed Rating.* The transfer characteristic of an image sensor has a linear response. As exposure increases the sensor output increases to a point where no further output results. This point of limiting is at or near to white level and we measure grey steps down to black from this white point. We call this *working from white downwards*. This range from white to black level is the dynamic signal range of the sensor in question. It is also the dynamic signal range of the sensor at the cameras lowest ISO speed rating. Higher speed ratings are obtained by appropriate increases of circuit gain. A limit to the number of steps discernible from white occurs near black level due to the presence of noise, (and the physics of the sensor). High circuit gain, associated with high ISO speed rating, increases the visibility of this noise, not unlike the worsening of film grain as film and its processing could be adjusted to produce higher film speeds.

The principle pictorial difference between 8 bit and 16 bit image processing is a freedom from layering, after image manipulation. The tonal steps of 8 bit encoding are chosen to be subliminal, as ***Fig. 4*** *Tonal Layering* attempts to show.



(a)



(b)

Fig. 4 Tonal Layering

The tonal reproduction of the top image ***(a)*** is quite smooth with a minimum of layering (some can be seen near black level), using about 256 greys. The lower image at ***(b)*** is reproduced with only 15 greys, and clearly suffers from insufficient grey levels, the effect called layering is clearly illustrated.

The layering at black level in ***(a)*** is the likely result of image manipulation that can result in the loss of some code levels, seen as tonal layers. This is why care has to be taken if you only have 256 initial levels to deal with. Tonal resolution greater than 8 bit, or 256 levels, is called for in very high quality work.

Layering generally degrades an image. It is also printed from a laser printer of limited tonal resolution.

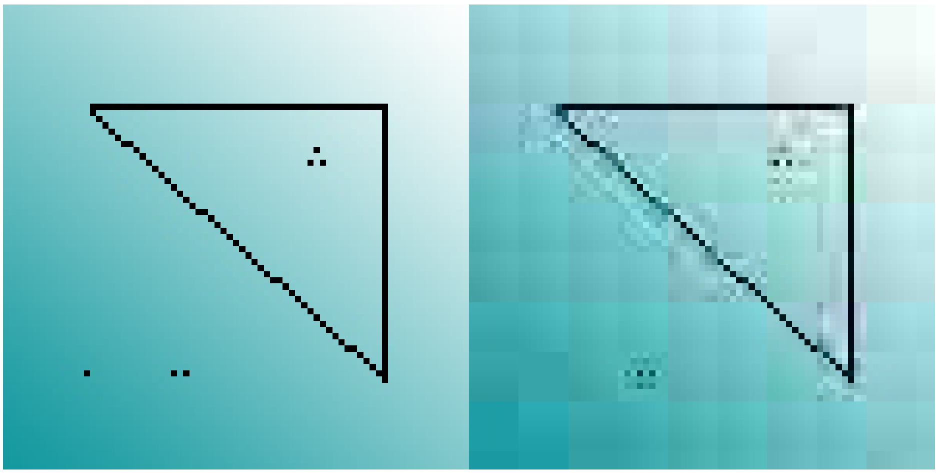


Fig. 5 JPEG Compression Artefacts (See p. 13)

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DOT GAIN
… & A PRINT TO MAKE

Analogue vs. Digital Imaging
This is included as a reminder of how analogue film compares to digital imaging. We bear in mind the vast number of photographers practising a hobby as a craft, and the enthusiasts of many principles and persuasions that populate all the photo Clubs and Societies. All that photo craft, acquired over time, is now being supplanted and so quickly.

Some essential and significant differences between analogue and digital photo imaging are:

(1) The continuous nature of analogue signals (film) is broken up into a fixed number of digital levels. The popular number for 8 bit encoding is 256, or 2 to the power of 8. $2^8 = 256$. When some of these levels get lost, or replaced, an effect called laying may be seen. See ***Figure 3, Tonal Layering.***

(2) The pixelated nature of the image, as a digital file. These pixels can sometimes become visible.

(3) The possible introduction of unwanted artefacts due to file compression.

It is required that all these unwanted effects are kept to subliminal levels. By subliminal we mean *below the threshold of sensation*: we cannot see them, at any time. By allowing their occasional visibility certain financial gains may be made. When subliminal levels are maintained the digital print can give its silver counterpart a good run for its money! We note that some Photographic Societies do not differentiate between wet silver and digital work at exhibition time.

We hear cautions to stay away from JPEG compression because it can bring with it some nasty artefacts. ***Fig. 5*** *JPEG Compression Artefacts*, reveals the structure of JPEG artefacts.

An image size of 75 pixels square shows how the JPEG artefacts are collected into squares of 8 x 8 pixels each, counting from the top left corner of the picture. The original file was a smooth gradation from a bluish hue to white, with a black line triangle 1 pixel wide and one or two single stand-alone black pixels. This file was given maximum compression in Photoshop, shown on the right.

This is a fearful demonstration of JPEG artefacts, made so to be quite explicit. The whole montage – as seen here – was then saved as a JPEG file of *maximum quality*. **N.B.** There are no artefacts to be seen on the left hand side of this image: that is a measure of how sensible JPEG compression can be, at Photoshop level 12. They *are* there but at a subliminal level.

I emphasise this point because I was recently told, on good authority (shown, even!) that JPEG has some undesirable qualities as compared to an original RAW file. I believe that JPEG compression at quality level 12 (highest quality in Photoshop) produces an image that is virtually indistinguishable from its original at all normal viewing. Those changes that can be measured are of the order of 1 in

255, and are probably due to computational rounding errors. In picture matching terms they were subliminal and consequently could not be seen.

The image I used is shown below at ***Fig. 6*** *High Quality JPEG Illustration* and the processing workflow was as follows:

The cleanest image I could find for this test was from an early Kodak Photo CD sampler. I downloaded image 15 as an RGB file, 2048 x 30762 pixels, 16 bits per channel, and converted this to 8 bits per channel. In order to be able to measure any image changes I imported the test chart TC-2 to provide unambiguous flat areas for measurement. This 8 bit TIFF file then measured 26 mB. After JPEG compression at level 12 its file size was reduced to 4 mB. Two A4 prints were made which were indistinguishable apart after an appropriate drying time. The two files measured as follows:

The Subliminal Nature of Level 12 JPEG		
	TIFF	JPEG (12)
	26 mB	4 mB
Patch %		
99	3	3
98	5	5
97	8	8
96	9	9
95	13	13
90	25	25
Black		
1	252	252
2	250	250
3	247	247
4	245	245
5	242	242
10	229	229
white		
R	255/0/0	0/255/0
G	0/255/0	***0/255/1***
B	0/0/255	***0/0/254***
C	0/255/255	1/255/255
M	255/0/255	255/0/255
Y	255/255/0	***255/255/1***

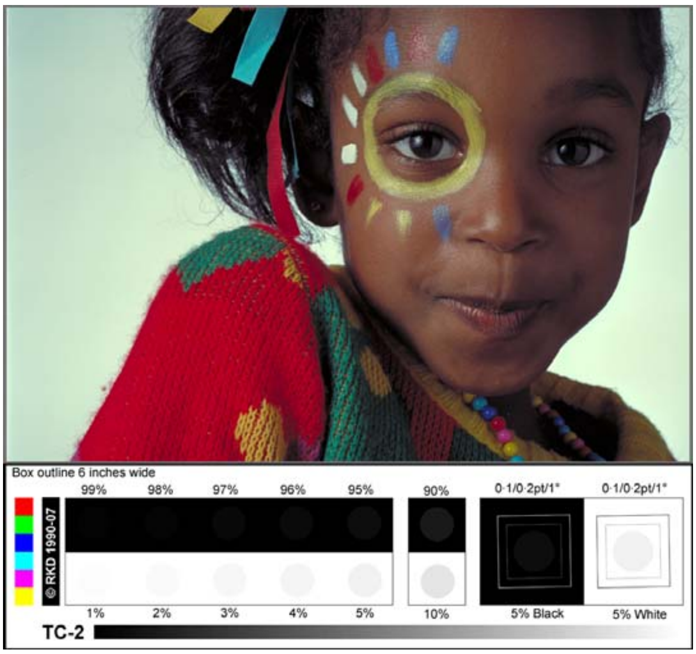

Fig. 6 High Quality JPEG Illustration

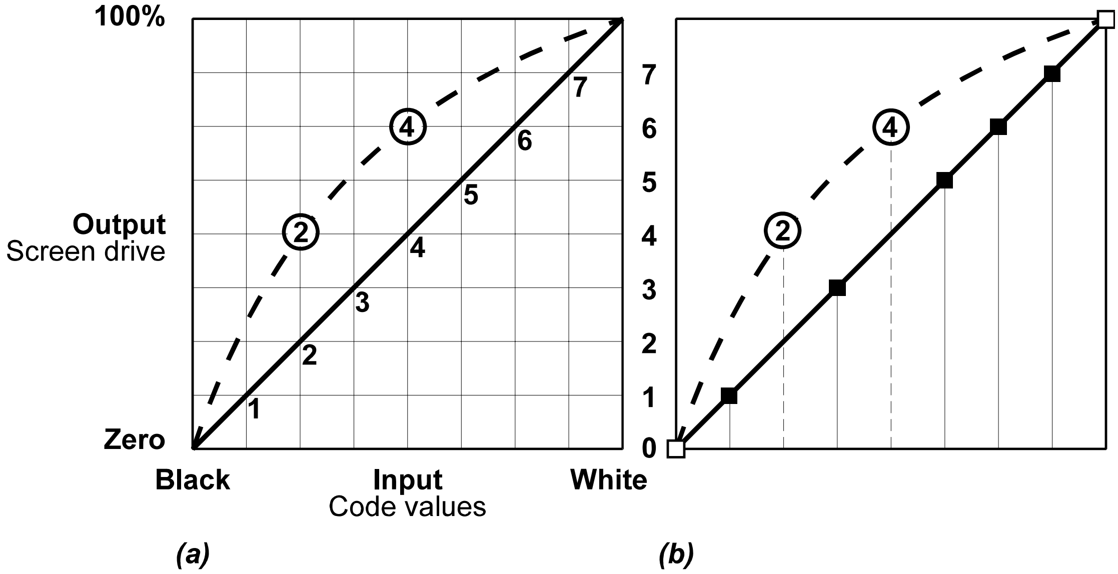

Fig. 7 The Destructive Nature of Image Manipulation

Digital File Structure

We refer to ***Fig. 7*** *The Destructive Nature of Image Manipulation.* The solid linear graph at ***(a)*** represents a digital file with all code values undisturbed and present between black and white, reduced in this illustration to 7 greys. Each value occupies an intersection, numbered from 1 to 7. There are no other values available, in this representation. If a Photoshop curves adjustment is applied to this set of values, as indicated by the dotted line, then the adjusted image occupies new code values from amongst this existing set. Greys 2 and 4 (circled) look for and find new values, as shown on the right hand graph at ***(b).*** All the remaining greys shown as solid black squares are deleted, allowing any code value gaps to become potential tonal gaps: hence tonal layering. Such image manipulation is said to be destructive of parts of the file structure

If this illustration was to mimic an 8 bit depth file then we would have 255 greys to deal with. Should we use 16 bit depth then the number of code values rises to approximately 65,000. The chances of layering then occurring are much reduced.

The number of code values for some bit depths are: 8 bit – 256; 12 bit – 4096; 14 bit – 16,384; 16 bit – 65,536.

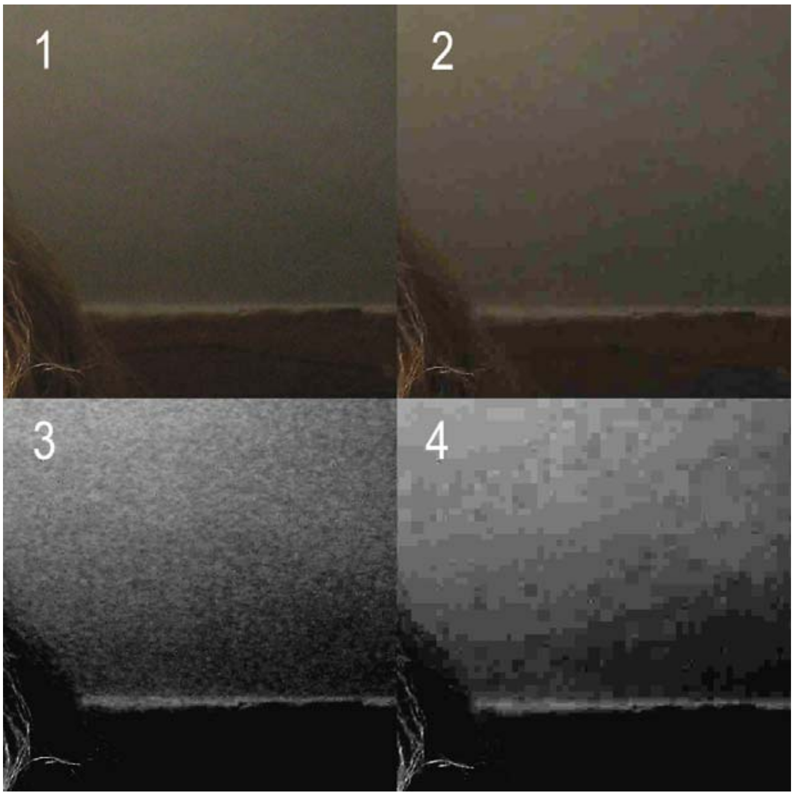

Fig. 8 reveals layering from a JPEG camera file (Canon IXUS 850)

Quadrant 2 is a detail of an original IXUS 850 JPEG image, 3072 x 2304 pixels compressed to approximately 3 MHz.. This is converted to native Photoshop PSD format at 1. To make the layering more apparent at 3 and 4 I have reduced chroma to zero and increased contrast. This image does not make a good laser print.

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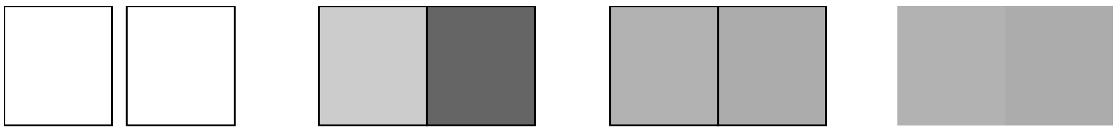
The Just Noticeable Difference or JND
In order to talk about subliminal values (signal levels) we introduce the term Just Noticeable Difference, or JND. Anything less than a JND will not be seen. The 256 8 bit levels, in a clean and completed file, are close enough together to not be individually discernible, together they can look like a smooth continuous grey scale because each step is visually less than one JND from its neighbour. However, if we adjust the tonal scale of the image to make it lighter or darker, then some signal levels are likely to become unused, possibly increasing the contrast between certain adjacent levels, which may then be seen as layering. Had this image adjustment been made on a 16 bit file then the above mentioned increase in contrast may not have been seen because many more 16 bit levels equate to an 8 bit JND.



(a) ***(b)*** ***(c)*** ***(d)***

Fig. 9 Illustrating the Idea of a Just Noticeable Difference (JND)

Tonal Layering
There is a fixed 8-bit file structure to accommodate all values from zero to 255 and a precise 16-bit structure from zero to 65,535, and so on for other bit depths. These structures can only accommodate a signal at their fixed locations: not a little lower or higher but at that prescribed value only. If any image manipulation takes place, causing some values to move elsewhere – perhaps to make the image look lighter or darker, we may then find some values vacated or unoccupied which means there may be tonal gaps in the file structure, *coarse enough for us to see*, an artefact called layering, as in ***Fig. 4*** *Tonal Layering*. 8-bit is only smooth to look at when all values are present. There is then a possible general loss of grey code values as image manipulation takes place, which is why it is recommended that 16-bit is used (if available) for initial image processing before conversion to its final 8-bit form. A new image grey due to manipulation, or an image import, cannot find a place in between any two adjacent code values from zero to 255 in an 8 bit system.

If the number of printed pixels per length are kept above a certain figure, say of 300 ppi (pixels per inch) they will not be seen. They are subliminal. The demonstration folder (available to view) compares prints from a 300 dpi Photoshop file and the same file compressed to JPEG 8. The relative file sizes were 9.6 MB to 785 KB.

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The Scene Brightness Range & Lighting Contrast

The dynamic exposure range of a camera is what you have to make pictures of your chosen composition with. Later you may wish to consider certain software processing tricks to handle large brightness ranges. High figures of brightness range come to mind including all highlight's, specula's and cast shadows: to a simple scene of plain reflectance only that might be in the region of 100:1. We need figures for some discussions but very soon *we are concerned with the appearance, or absence, of print shadow or highlight detail.* We are back to the principles enunciated by Ansel Adams, of adjusting exposure and processing with print values in mind, embodied in his Zone System.

The brightness range of your scene is the basic reflectance of items within the composition (object contrast), for a dull day or with the sun from behind the camera casting very little shadow for the camera to see. Since light travels in straight lines we may be quite precise about the formation of shadows.

If the sun is positioned to one side and you are shooting, as we say, the shadow side then the basic scene contrast (object contrast) is increased by the cast shadows. Outdoor lighting contrast is the ratio of the sun shining from a partly clouded, or a clear sky, known as Key + Fill, to Fill, lighting ratio. This lighting ratio increases the basic object contrast to become the scene brightness ratio. The two sides of a three dimensional object, as seen by the camera, are illuminated by the sun and the sky (Key + Fill) on one side, and on the other by the sky alone (Fill). For completeness we should mention the totally overcast situation of flat, shadow-less and potentially uninteresting lighting.

Leonardo da Vinci supported the continuous gradation of shadows as a primary way of describing form, of bringing three dimensional objects alive on the two dimensional painting surface. He would appreciate the smoothness of today's 8-bit files of 256 grey levels. *"… still it appears to me that these gradations are infinite upon a continuous surface which is in itself infinitely divisible."*[1]

We illustrate lighting contrast with Figure 12, a Fence Repair photo.

Fig. 10 The Anatomy of a Shadow.
Fig. 11 The Quality of Shadow Depending on the Relative Geometry of Distance and Size.
Fig. 12. Fence Repair. (1) In overcast skylight and (2) In Sunlight.

1. **Gage,** John. *Colour and Culture*, T&H (1993), chapter 7, page 135.

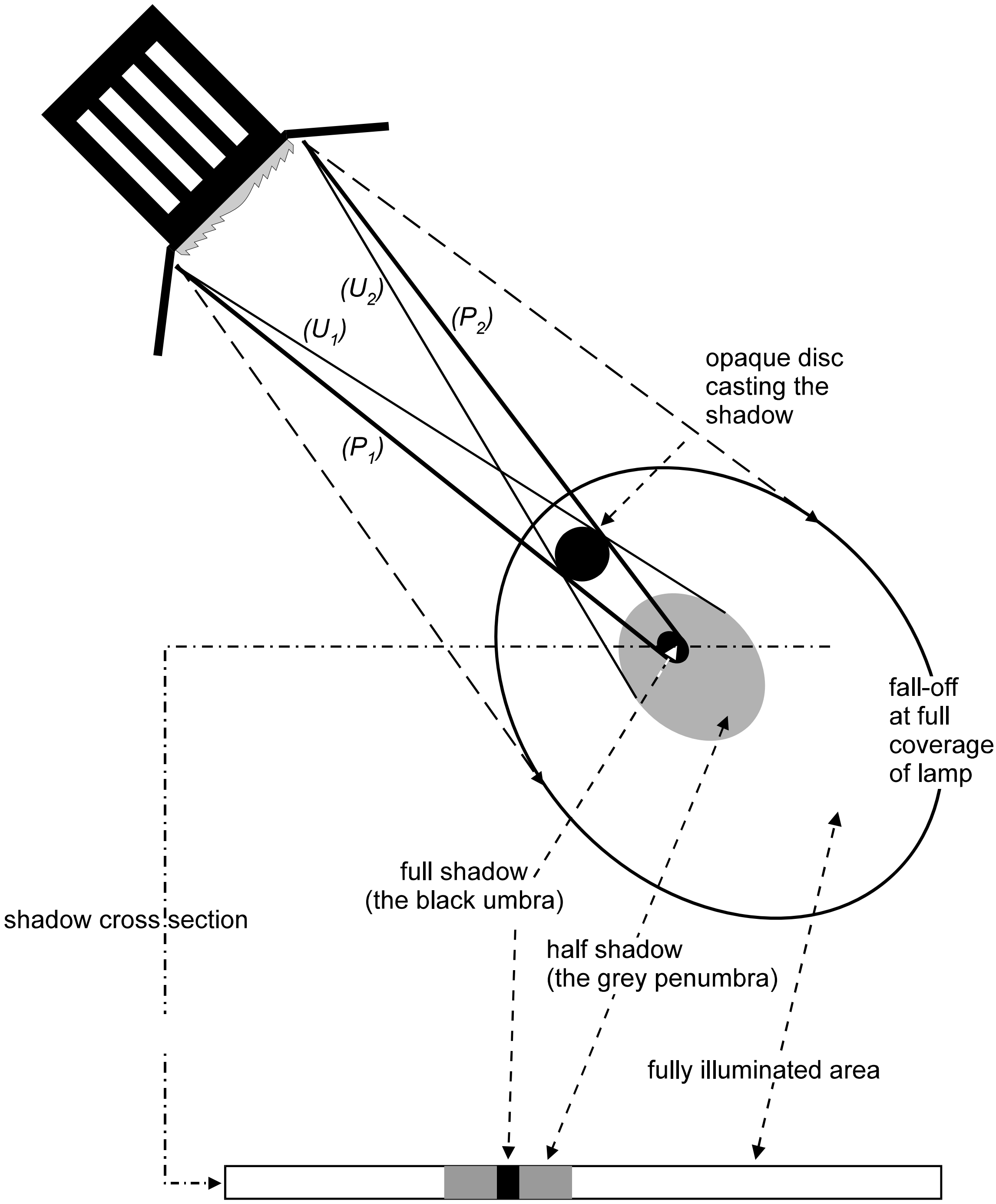

Fig. 10 The Anatomy of a Shadow

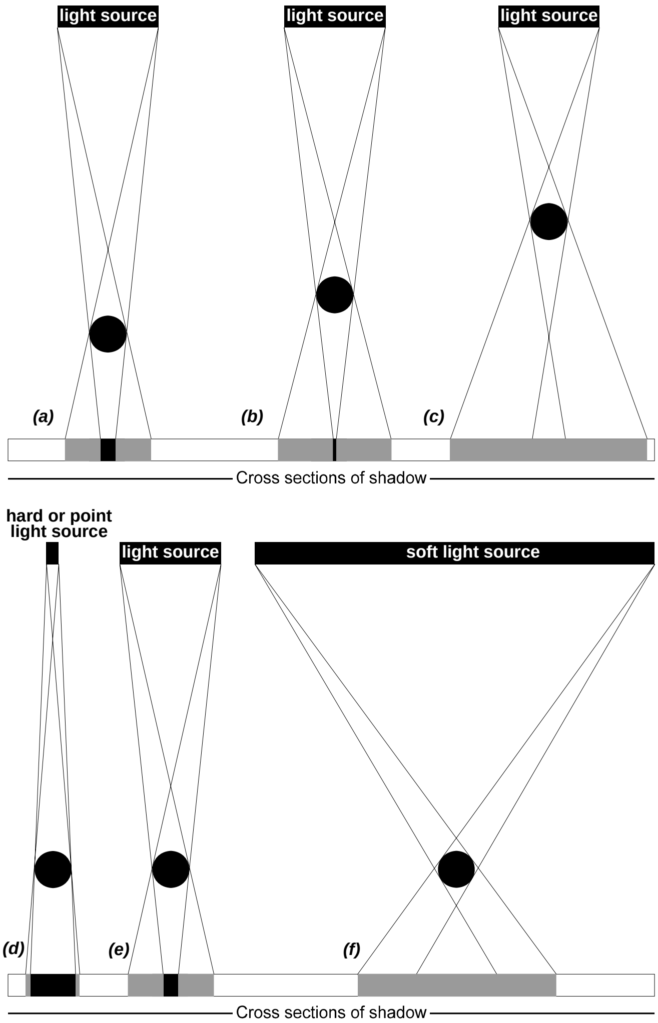

Fig. 11 The Quality of Shadow Depends on the Relative Geometry of Distance and Size

Fig. 12 Fence Repair (1) Overcast sky, (2) Sunlight.

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The Brightness Range of a Print

Ink jet prints on a paper base will offer a similar brightness range as their wet darkroom predecessors, measured from white to black, which means they can look as good. We loosely speak of paper white as being of 100% reflectance and solid black being 1% reflectance, or density 2. This amounts to a brightness range of 100:1 which is very convenient for discussions and plotting graphs. In actual fact neutral looking white paper is never 100% reflectance, except for one special case, called a Hi-white or Whiter-than-white – which is strictly not a neutral white. This can be caused by adding a fluorescent dye to the paper and illuminating it with a little UV light. ***Fig. 13*** *Paper Reflectance Showing the Blue Peak due to Fluorescence,* was measured at Westminster University lab at Harrow and shows a modest blue increase to 100%. The ICC White Paper #14. 2005, reports a blue increase to 120%. Such techniques lead to papers called Hi White, or whiter than white. Upon becoming familiar with such Hi-white papers a neutral sample will, by comparison, look darker and possibly less attractive.

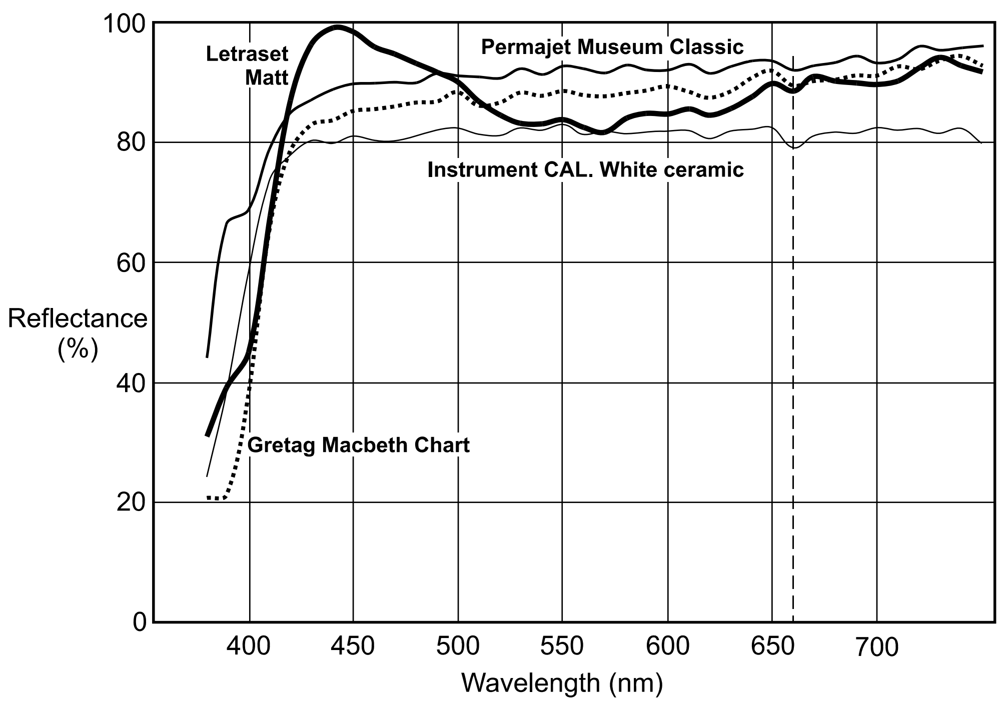

Fig. 13 Paper Reflectance Showing the Blue Peak due to Fluorescence
Westminster University, Harrow.

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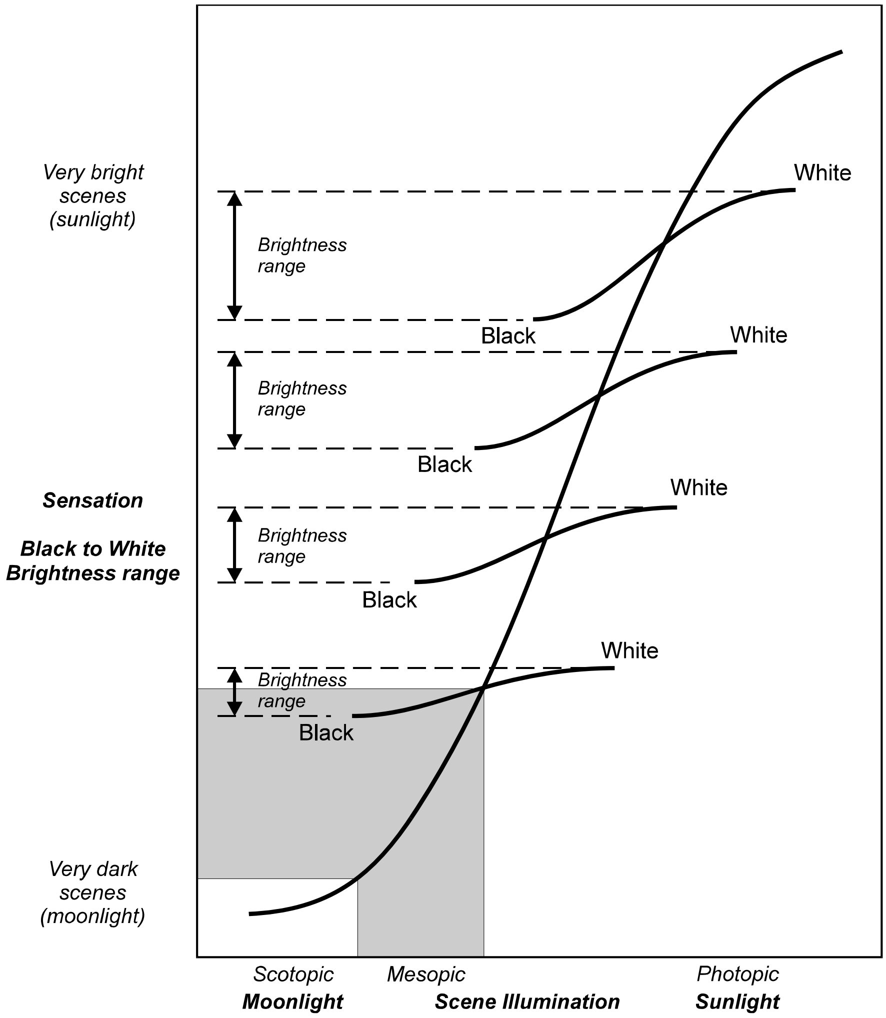


The Scene Illumination axis is marked from moonlight to sunlight, together with three states of adaptation for the eye ie., *scotopic, mesopic* and *photopic.*

Adaptation of the eye to a wide range of scene illumination is shown, indicating the relatively small range of percieved black and white sensation that occurs at every level of adaptation.

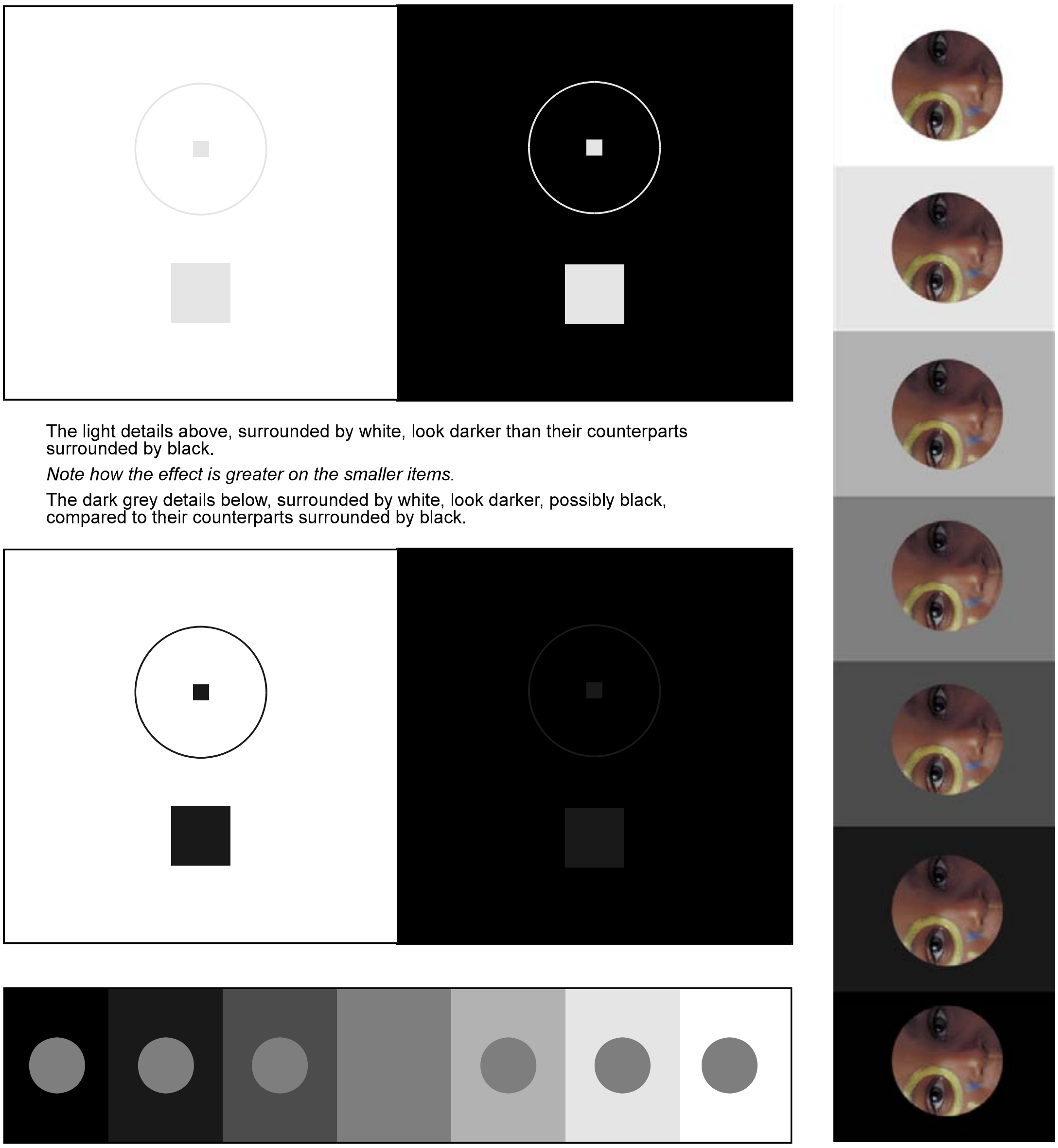
I have added the three ranges of eye adaptation corresponding to full colour vision, *photopic*: no colour vision, *scotopic* and the intermediate range of *mesopic* vision (shaded above) where both rods and cones operate to produce the Purkinje effect. *After Marshall & Talbot.*.

Fig. 14 The Overall Adaptation of the Eye from Moonlight to Sunlight

Brightness Adaptation of the Eye
The performance of the viewers eye is critical to this whole process, of looking at the scene to photograph and eventually viewing a print. This process is about making something for the eye to see, and in some instances for that eye to make a meaningful comparison to the original, even if that cannot be seen at the time of print viewing. Our print assessment may well then be coloured by memory.

Fig. 14 *The Overall Adaptation of the Eye from Moonlight to Sunlight.* We note the eye's ability to make any scene comfortable to view. It always makes an adjustment to cause the brightest part of the scene to be easy to see. It is never the blacks that receive viewing attention: they are the result after a white adaptation has taken place.

Fig. 15 *Local Adaptation as for Viewing a Print and its Surround*, is the classic picture of some grey patches, all of the same tone, looking different according to the background they are seen against. This does not occur as dramatically in colour as indicated by the inserted face, on the right, even when chroma is removed (not shown here).



The light details above, surrounded by white, look darker than their counterparts surrounded by black.

Note how the effect is greater on the smaller items.

The dark grey details below, surrounded by white, look darker, possibly black, compared to their counterparts surrounded by black.

The grey series above is after Hering (1834-1918). All the grey circles have the same value. A similar effect may be seen to the right, using flesh colour.

Fig. 15 Local Adaptation as for Viewing a Print and its Surround

Lastly, there is the adaptation that occurs within an image. For this we turn to ***Fig. 16*** *Relative Brightness Adaptation Among Print Details.* The steps of this small grey scale will each appear slightly shaded by adaptation to their adjacent step. In fact we can conclude that the appearance of black within any image is due to the presence of other brighter details in the image. That is how we see a black on an otherwise white projection screen, accepting the effects of flare.

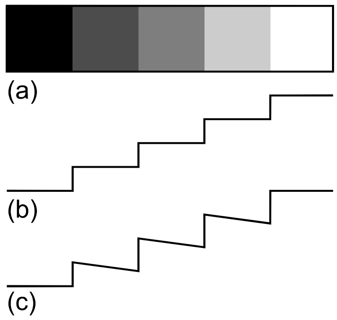
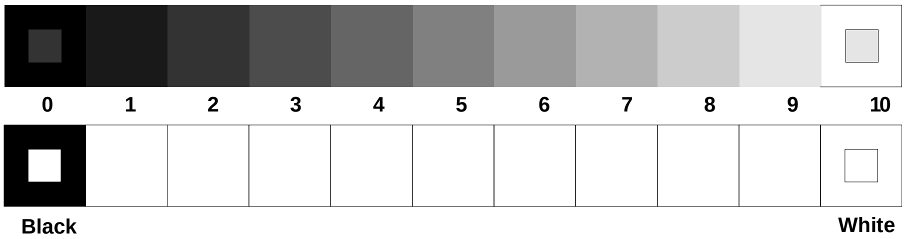


Fig. 16 Relative Brightness Adaptation Among Print Details

The grey scale above at (a) has steps formed as shown in (b), which shows level flat step distribution. A visual study of the individual grey scale steps reveals an apparent brightness distribution more in line with that shown at (c).

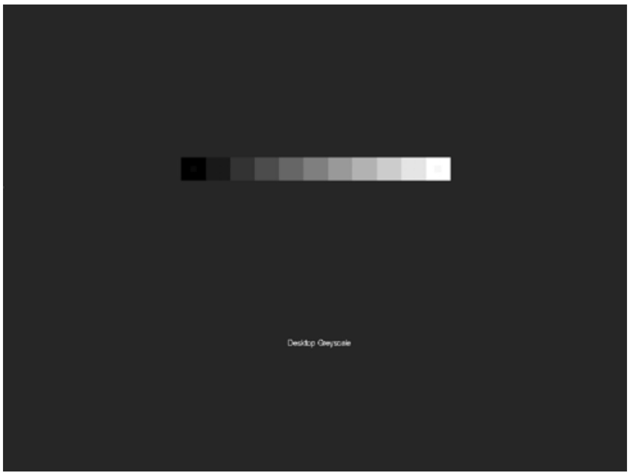


Grey scale Step	Pixel values 0-100 (rounded)	Pixel values 0-255 (rounded)
0	0	0
spot in black	***(3)***	***(8)***
1	10	25
background	(***15)***	***(38)***
2	20	51
3	30	77
4	40	102
5	50	127
6	60	153
7	70	179
8	80	204
9	90	230
10	100	255
spot in white	***(97)***	***(247)***

See Tabled data at end of text for converting between values 0-100 and 0-255.

Background tone surrounding the greyscale, to fill the desktop. Its tonal value is between steps one and two, at about 15% of white level, NOT to match any grey scale step.

File resolution to size the grey scale to about 2/3 of monitor width, as below.



Desktop Greyscale for Monitor Set-up

Fig. 17 Details of the Desktop Greyscale

This greyscale for *desktop set up* has a dark background intended to simulate a low key image. I found an 18% average figure too bright and I have settled for something darker. 38 on the 0-255 scale. Clearly, the setting of screen black level is significant for critical on-screen assessment of images: *hence the care we take about what your eye may be adapted to when making this very important adjustment.*

If you use a screen calibration device it is as well to have a known test image at hand to check out the devices auto settings.

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Colour Adaptation of the Eye
The eyes ability to adapt to the colour of daylight outdoors at sunrise and sunset, compared to a midday value of colour are of interest here, and speak for all the other instances of colour adaptation we meet. We can, of course, make use of Automatic White Balance (AWB) or the nominated and fixed white balances of Daylight, Cloudy, Tungsten, Fluorescent, Fluorescent H and Custom, to name those available in my wee Cannon IXUS 850, and other digital cameras. But the only “organic auto” facility we have with which to view a print, or DTP screen are our eyes. ***This auto facility cannot be switched off,*** but we can pre-set it with external data to calibrate it, as it were.

Colour Temperature
At the heart of this is the subject of colour temperature, measured in degrees Kelvin looking at a heated black body: that is a measurement made in a laboratory. A black body is a definition – made practical – that radiates light but does not reflect any. The work of a blacksmith comes to mind as a practical example, of heating metal for *Forging*, *Hardening* and *Annealing.*

Fig. 18 *The Spectral Distribution of Colour Temperature* shows how increasing temperature increases the total emission of radiation. As the peak of radiation increases, and moves towards the Ultra Violet wavelengths (to the left), the section of visible wavelengths tilt from being rich in red to rich in blue. The lower diagram emphasises this relative red / blue composition of a few colour temperatures by aligning their values at 560 nm to 100 in each case.

Each visible colour temperature can be plotted on a chromaticity diagram as in ***Fig. 20*** *The Planckian Locus plotted on the u’.v’ Chromaticity Diagram.* The plotted curve is called the Planckian Locus. These are strictly correct colour temperatures (CT), derived from a black body, as outlined above. Colours that are near to the Planckian Locus, and look similar, are called Correlated Colour Temperature (CCT). Note that D65 is such a Correlated Colour Temperature, and that its point sits on the green side of the Planckian Locus.

For artists, designers and all creative’s who wish to speak of just “temperature” and “cool” and “warm” colours, the phrase Aesthetic Colour Temperature permits the wildest imagination without flouting the formal rules of Colour Temperature.

It is instructive to see the colours represented by the Planckian Locus, the Colour Temperature colours, and is shown in ***Fig. 19*** *The Colour Temperature Colours as Seen Along the Planckian Locus.* A colour cast will start at (say) red and pass through a well balanced white point, on to blue, not having passed through green. This occurs because at the white point Green is balanced out in the R=G=B triple.

Adaptation
With the foregoing red / blue tilt of the colour temperature curves in mind, and the fact that our eyes are able to adapt to the red rich light of sunrise and sunset (within *n* hours of each event) and at another time to the blue rich light of midday, so making these scenes all look similar, we need to do

something to make our camera exposures look similar too. Otherwise we shall record the various colour temperatures that the eye has become accustomed to, as colour casts.

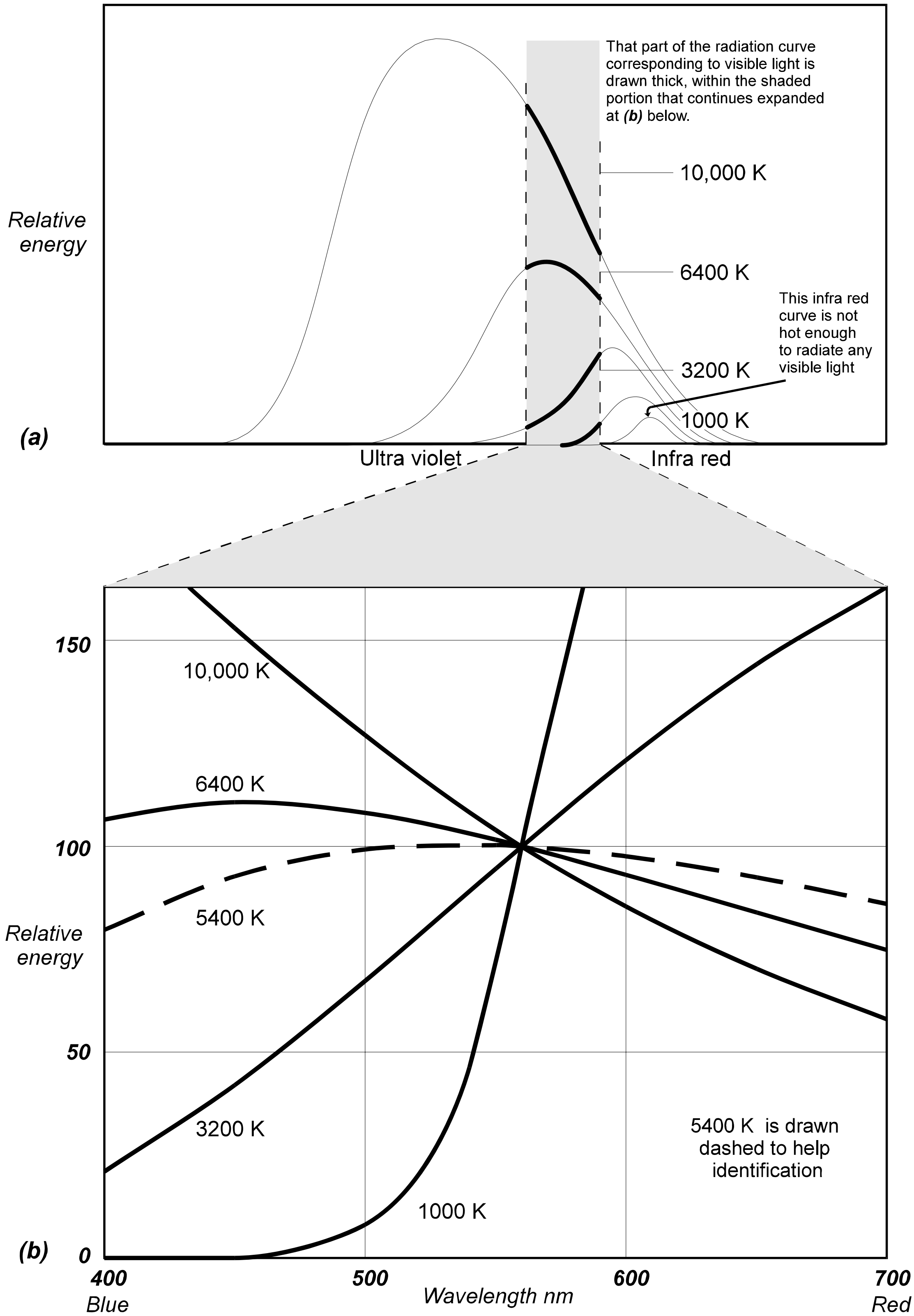
White Balance

The solution to this is to ensure that the white point of the camera is set to the same colour temperature as the prevailing illumination.

A certain white balance rule (not the only one!) is that a grey card as a scene element should look grey when reproduced. NO colour in should lead to NO colour out. With Appearance Modelling in mind this may not be exactly correct however, this type of grey balance will invariably get pretty close to looking good.

Control of white balance with film was via two types of film: Daylight and Tungsten balanced, and a camera bag full of light balancing filters, such as the 85 (orange looking) and 80 series (blue looking) Wratten filters. Today we make relative adjustment or R, G and B circuit gain as in the pre-set settings of digital cameras. It is interesting to note that mired filters of equal value but opposite sign, orange and blue , if used together will look neutral. An orange 85B (+131 mired) together with a blue 80A (–131 mired) has an equivalent density of just over two stops, a useful emergency ND (neutral density) filter if a proper ND filter is not in the camera bag.

Failing this, then the use of a number of facilities within Photoshop in post production will allow colour balance to be subjectively adjusted, as some RGB triples are adjusted to be equal. (Enter RAW files, but not with me!).



The family of curves shown **bold** at ***(a)*** represent the increasing radiation from a heated black body. Over about 1000K visible light is emitted.
At ***(b)*** the curves are superimposed with their relative emission at 560 nm made equal to 100. This allows a direct comparison of the spectral composition of light at different colour temperatures, as if we were adapted to the different brightness values represented.

Fig. 18 The Spectral Distribution of Colour Temperature

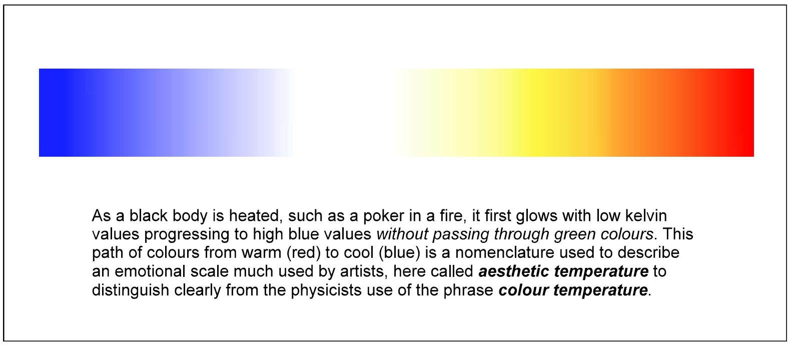


Fig. 19 The Colour Temperature Colours as seen along the Planckian Locus.

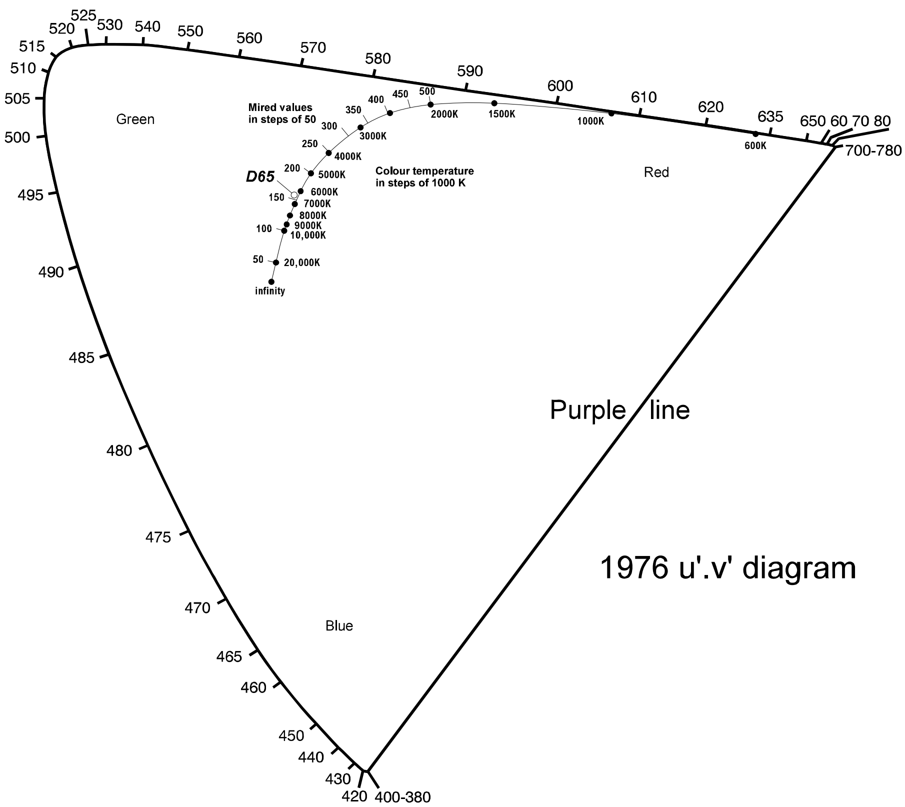


Fig. 20 The Planckian Locus plotted on the u'.v' Chromaticity Diagram

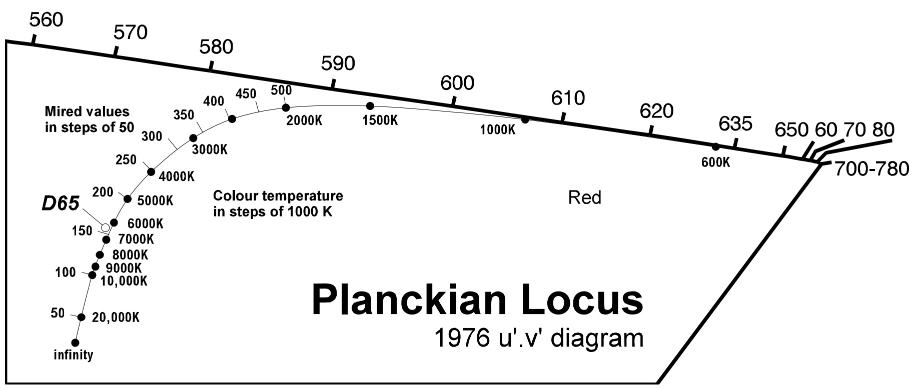


Fig. 21 Comparing Evenness of MIRED and Colour Temperature Values

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Viewing Conditions
We have seen how the eye is ready to automatically change its perception of brightness and colour, always looking for an average and comfortable result. We call this *adaptation*, and out-and-about in the world at large it serves us well. Our colour perception of an image on screen, or in print, is dependant upon the image itself – its white balance, as well as the colour of the surround of the screen or print, *&c.*. Purveyors of set up gizmos will tell you this, of course!

We may not be able to switch off the auto adaptation facility of the eye, but we can constrain it to something useful. If the environment, where we work with colour images, avoids strong colouring and adopts the same white colour as D65 colour matching fluorescent tubes then the eye will be in an *adapted* condition of colour balance ready to tell us if something is odd in any picture it sees, rather than adapt to it and let it go.

Last but NOT least, we need to calibrate the colour monitor with respect to white and black level. In detail, this means peak white brightness, peak white colour – those two elements comprise the White Point. A black level setting that allows dark shadow to just show. It follows that all reproduced greys (RGB triples) between black to white levels should be colourless, and follow an input to output contrast law (gamma) of ??n??.

Different standards apply here, between broadcast television (D65) and graphic arts design studios (D50).

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Colour Spaces
When Newton analysed white light and used the colour circle to describe his findings he gave a prominence to two of the three attributes of colour, Hue and Saturation which, seen together on a colour circle, colour triangle or chromaticity diagram we call *chromaticity.* In this way diverting attention away from the important scale of painterly tonal values or rather, he left them in limbo. The attribute of brightness had to wait until the colour solid or space appeared, so reminding us to give proper attention to all three attributes of colour in a three dimensional manner.

A colour space is a finite mathematical construction, visualised in geometrical form on paper whose outer limits represent saturated colours in one direction (all degrees horizontal), and vertically between the limits of black and white. Our eyes determine these colours, and they form the space that contains all practical colour spaces and colour models originated for the better understanding and explanation of colour. Regular shapes such as the sphere, pyramid and cone come to mind plus those irregular shapes created by collections of physical samples that go to make up colour atlases. The whole business of colour is about something that finally rests as a response in our eye / mind system. The phrases *colour space* and *colour solid* are synonymous. They can also be called colour models, being modelled and used to explain certain characteristics of colour. The three dimensional nature of these structures allows one to reside inside another, if the latter is big enough.

A colour range or colour gamut can be shown on a chromaticity diagram generally as an area bounded by mixture lines joining chosen chromaticities (the colour of screen phosphors or printing inks). The two areas that represent and compare the gamut of phosphors and inks are not the same; some areas are covered by one and not the other. This means that the reproduction of some colours is better served on the CRT while others are better seen in print. The presentation of this problem is often made with the 1931 *x, y* chromaticity diagram which is known to be uneven in its representation of colour differences. This evenness problem has engaged many minds and the CIE has attempted to produce a chromaticity diagram with a more uniform spacing of colour differences. The 1976 *u', v'* uniform chromaticity diagram represents the best to date and 1931 *x, y* data is here converted to 1976 *u', v'* but, the 1931 data continues strongly in available literature and some laboratory practices.

The image on the CRT and its equivalent in print are just two uses to which an image file may be put, each requiring a particular profile. See ***Fig. 22*** *Comparison of sRGB and Adobe RGB (1998).*

1. If the image is to be viewed on a CRT, by the additive colour mixtures of RGB phosphors then a profile that is compliant with CRT phosphors is required, such as sRGB.

2. If the image is to be seen in print, by the subtractive colour mixtures of CMYK printing inks, then we need a profile with a different distribution of primary colours, to (1) above, which are CMY inks compliant with (say) Adobe RGB 1998.

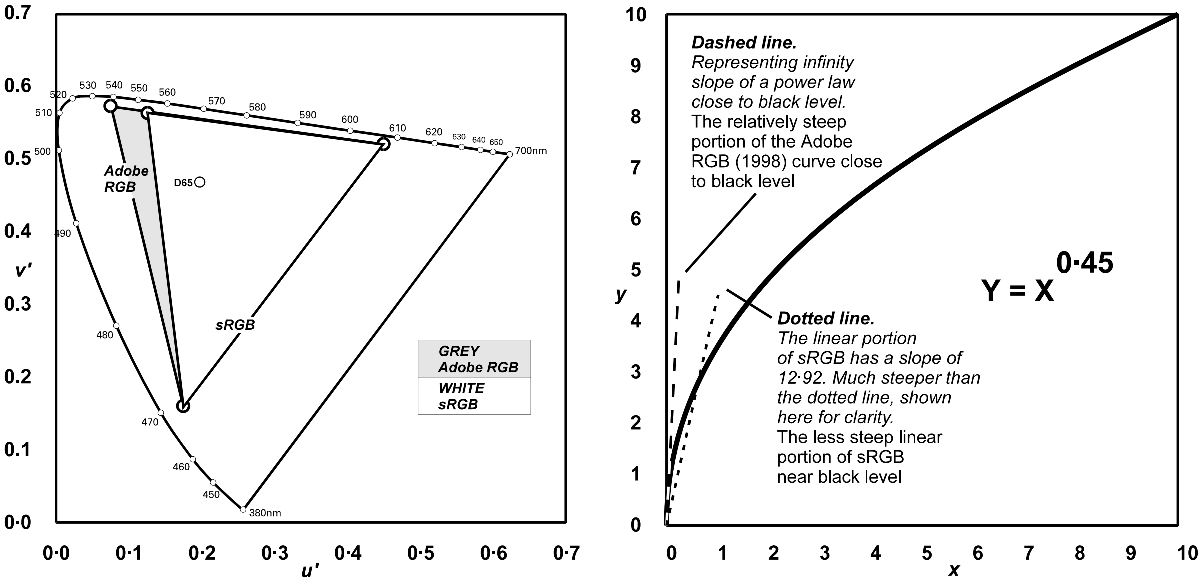

Fig. 22 Comparison of sRGB and Adobe RGB (1998)

Simple Comparison of the Adobe RGB (1998) and sRGB Colour Space

The above is included to illustrate the luminance law (that is similar for sRGB and Adobe RGB[1998]) which, if it is not implemented properly, can modify tonal reproduction, especially near black level. If this correction is reduced (naughtily) in order to improve signal to noise ratio we may see tonal compression near black level, called black crushing when severe.

The CRT as a display device was fundamental to the development of broadcast television and computing. The tonal response of a CRT is a power law of 2·2 for which television camera signals were compensated with *black stretch*. (the reciprocal of 2·2, 0·45). Flat screen technology is now driving digital imaging and supplanting the CRT. But flat screens have a linear tone response, and for the display of vast reserves of archival television recordings, the flat screen linear response is given a power law shape by effectively removing the *black stretch* inserted in signals for the CRT.

The omission, or reduction, of the adjustment to the flat screen, intended to make it look like a CRT when viewing archival material, has the effect of increasing the image brightness. This may be seen (erroneously) as a good thing – more brightness – and accepted as such. I have seen this at exhibitions and I suspect one major manufacturer of the practice in their television receivers.

These two images, one on the CRT, the other in print, are actually quite different. The CRT image is created from red, green and blue (RGB) primary colours via the principles of additive colour mixing, while the image in print is created from cyan, magenta, yellow and black (CMYK) primary colours via the principles of subtractive colour mixing where pigment absorption within the dyes in use results in simple subtractive mixing. As well as absorption a considerable amount of light is lost due to scattering which renames Simple Subtractive Mixing to *Complex* Subtractive Mixing. We talk about the range of mixed colours in each case (RGB or CMYK) as forming a range of mixtures or *a gamut of colours*. Where the colours from these two gamut's are similar (CRT and print), meaning they overlap each other on a colour diagram, we have few problems. But where the two colour gamut's do NOT overlap there is a potential colour reproduction problem, which the ICC (International Color Consortium®) was set-up to address.

As the attached ICC profile progresses through the digital workflow the image file it is attached to will be looking to be seen on a CRT, or in print. Such knowledge of the file's intent (I want to be seen in print, say) is read from the attached or embedded ICC profile by the Colour Management Module (CMM). In Photoshop this can be the Adobe Color Engine (ACE). The Profile Connection Space (PCS) within ACE does this recognition and then goes about making calculations to ensure the file is suitable for its intended use. These calculations are made with respect to four ICC rendering intents, *or compromises*, because there is not a *one fit all solution* to the problem of making the *screen image* and its equivalent *in print*, look alike, for all colours.

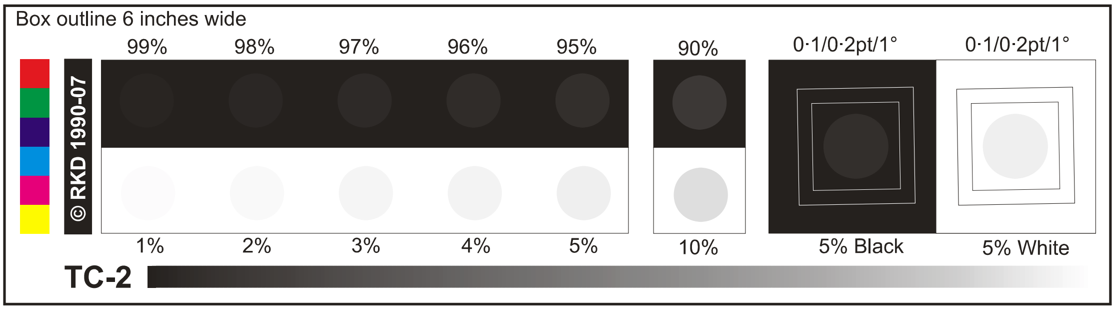

Fig. 23 Test Target TC-2

While the TC-2 grey patches read well on a laser print the fine white line rectangles may not show at all. This could probably be a function of Dot Gain. For the fine rectangles to be of 0·1 and 0·2 point thickness, the box outline should measure 6 inches wide. This is of secondary importance when looking at grey scale reproduction.

TC-2 is a synthetic chart in that its elements are not a reflection of the real world but a critically designed analogue of it. It has 5 dark grey circles on black and 5 light grey circles on white. These greys are measured in Photoshop on a scale of 8 bit code values from 0 (black) to 255 (white), the equivalent ink coverage values are marked on the TC-2 Test Target, where 100% ink equals black and zero % ink equals white. This apparent reversal of grey values occurs because the additive RGB and subtractive CMYK traditions conflict in the interpretation of what one hundred percent *means and looks like*. RGB video and computer signals range from zero at black level to 100% at white level, whereas CMYK inks range from zero ink at white level (unprinted substrate) to 100% at black level (solid ink). Photoshop wisely offers the facility to reverse the axis of their curves facility with a click of the pointer. This is really workshop knowledge and routine, but without it you may become somewhat confused and wish to withdraw with your cup of coffee, quickly.

When TC-2 was designed up we were at liberty to choose whatever grey steps might prove to be of use. We wanted a critical test of dark grey tonal separation. The TC-2 chart is marked in percent of ink coverage and the reported signal values will be 8 bit readings from the Photoshop Info Menu. It was decided to give TC-2 the finest gradation of grey steps, hence the one percent steps from black as: 99, 98, 97, 96, 95 and 90% of ink coverage. These synthetic test signal levels are virtual in the sense that they have not originated from a real imaging device. They represent a very high original brightness range: but nevertheless a useful and critical test. When the vector drawing is converted to a pixel format, as a dot.PSD file in Photoshop, it is left untagged as far as a profile is concerned. Photoshop allows us to Assign a Profile or Convert to Profile as required, later.

One of the positive things about drawing such a test chart is that the colourless nature of any grey scale *as a test is guaranteed* by ensuring that the RGB triples are originated as equal (R=G=B or iso RGB).

Uses of TC-2

The closely separated dark grey patches may be of use when assessing

1. Black Generation, and its effect.
2. Dot Gain, and its compensation, in conjunction with the fine lines.
3. Dark grey tonal separation. The luminance performance near black level of Colour Profiles.

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RGB to CMY

All colour analysis for colour film, digital cameras, scanners *and densitometer instruments* is performed according to the principles of Red, Green and Blue (RGB) colour analysis. The three RGB output signals (from imaging devices) are then available for reproduction as:

Additive colour reproduction

Images seen on screen (CRT or flat screen) use additive colour reproduction principles, utilising Red, Green and Blue phosphors. (The sRGB colour space applies).

Subtractive colour reproduction

In print, using subtractive principles, commonly known as "four colour printing", the ink colours are Cyan, Magenta, Yellow and Black (K), collectively referred to as CMYK. (The Adobe RGB [1998] colour space applies).

In order to arrive at four separate CMYK signals, to drive the four separate inking units to be found on a four colour press, (and similarly for a desktop ink jet printer) two processes are required.
(1). Colour separation must be performed whereby RGB is converted to CMY. This is a relatively simple algebraic exercise made complicated, and practical, by noting the characteristics of whatever ink sets are in use.
(2). Then Black Generation kicks in and searches for those areas of colour mixture that will look neutral, replacing them (or modifying them) with black ink (K) screened to look grey.

Ink jet printers are CMYK devices and they mimic the Colour Separation, Black Generation and Dot Gain characteristics of Four Colour litho presses. Generating the black signal (K) is a quietly clever process, taken very much for granted in most places other than where it actually happens, *i.e.,* at pre-press or in a print shop, often with four colour litho printing. That the foregoing occurs in a desk top ink jet printer gets quite glossed over.

Black Generation

The actual operation, or function, of a subtractive dye or pigment in a colour mixing sense is intimately tied up with its spectral absorption. A spectral analysis reveals a tendency for economically available dyes and pigments, of the Cyan and Magenta colours to have some unwanted absorption's, which do not allow a CMY colour mix to be a good black. Colour film uses relatively expensive dyes that are spectrally good and are able to reproduce good blacks without the use of a black dye. For printing we can use an additional black ink, called (K) to distinguish it from Blue, which involves looking for visually equivalent amounts of colorant (CMY) and replacing these with black ink, screened to *look grey*. This ink was always on the press for printing text. We will not see these (K) additions as grey because they are mixed in with the CMY colour mixtures. This use of black (K) allows a certain number of mechanical advantages to follow, associated with the total amount of printed ink, its drying, printing wet-on-wet, the maintenance of colour balance on a print run, and image sharpness, *etc.* Some of these mechanical advantages may not show in a visual comparison or inspection, but they show in an accountants books.

It is possible to obtain passable results mixing CMY inks alone, without a black ink, as illustrated in *Photography* by C. E. Kenneth Mees. G Bell & Sons Ltd (1937), see Plate II, opposite page 164. A proper reproduction demonstration of the three-colour subtractive process (without black) could show surprisingly good results if the printing set-up was optimised for that to happen, using good CMY inks only. Today, four colour printing uses CMY and K and the printed result is the outcome of many adjustments including Black Generation. To illustrate the absence of K using a properly adjusted CMYK press, by omitting to print K shows a false result because the CMY *alone* is then not optimised for printing without the now missing black ink (K).

The CMY part of a CMYK mixtures does not follow the rather ideal RGB equality rule that we find associated with additive colour mixing, where R+G+B in equal visual amounts (triples) produces a grey. They are however there and if we ever take the CMYK signal apart we can expect to find odd quantities of colorant present, as indicated by associated signal levels. If we look at the CMYK set-up facility in Photoshop we will see graphs of these relationships which are far from simple. They are not linear straight lines but complex and interesting curves.

The Black Generation in Photoshop involves the following definitions. To view them in Photoshop CMYK Set-up go to **Shift + Ctrl + K > CMYK > Custom CMYK,** and see the following notes.

BPC Black Point Compensation
GCR Grey Component Replacement
UCR Under Colour Removal
UCA Under Colour Addition

Parameters Within the CMYK Colour Separation Menu of Photoshop
These parameters are listed here in order to bring to the reader's notice the operational detail Photoshop offers its CMYK colour separation.

INK OPTIONS
Drop down list of 12 types, including Custom.
Custom provides the opportunity to set ink chromaticity to Lab or Y,x,y coordinates. We can also use this in reverse and determine the chromaticity of the 12 listed ink types, including the mixtures MY (Red), CY (Green), CM (Blue) and CMY, a poor black that K is designed to correct.

DOT GAIN
Dependant upon ink chosen above.
Standard. Enter percentage
Curves. Adjust ***each*** CMYK curve shape at 13 points.
Or make them all the same.

SEPARATION OPTIONS
Separation Type. GCR. (Grey Component Replacement)
UCR (Under Colour Removal)

BLACK GENERATION
(Note the direction of the greyscale on the 'x' axis. White to the left and black to the right, a measure of printed ink, white paper meaning zero ink.)

Custom Adjust curve shape at 4 points. Enter
None
Light
Medium
Heavy
Maximum

Black ink limit. Enter
Total ink limit. Enter

UCA Amount Enter (Under Colour Addition)

Traditional Design and Print. A physical work flow

When it was found that full colour printing could be performed using three primary colours, plus a derived black (K), two phrases were coined. ***'CMYK'*** printing and ***'Four Colour Process Printing',*** CMY standing for Cyan, Magenta and Yellow. Colour analysis is carried out by first dividing the visible spectrum into three sections as Red, Green and Blue. Colour synthesis is carried out using Cyan, Magenta and Yellow colours. We can now note the complimentary nature of RGB and CMY, as the drawing and colour circle illustrate below.

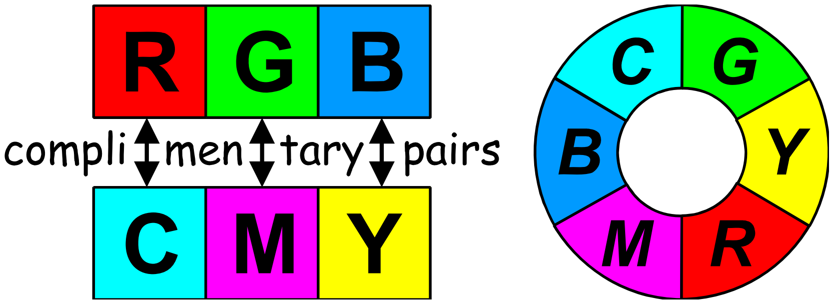

Fig. 24 Magenta and Cyan are Sometimes Referred to as Printers Red and Printers Blue.

We find quite distinct divisions of manual labour within the Design and Printing industry, that mirrored early apprenticeship schemes of training, leaving its members as experts within certain disciplines. Early Type was moulded from an alloy that included much lead, and hand-set with individual characters or with some mechanisation into individual lines of text, called slugs. Galley proofs of 18 to 24 inches long (46 to 61 cm) were printed on flimsy paper for author correction or approval, and finally printed onto a white matte coated stock for inclusion in the final page artwork. The alphabet, numbers and many other characters were kept in two large flat divided trays or cases, one above the other. The top case contained the capital letters and the lower case the remaining small characters, hence the naming of capital characters as *upper case* and the smaller characters as *lower case*.

Eventually the development of Design and Print, as promoted by newspapers and magazines, required something quicker and more flexible. Letterpress principles and practice gave way to Offset lithography and became the standard means of printing, for which the lithographic printing plate was exposed to a film record of the artwork which was itself made up of individual items placed and pasted into position with hot wax. Hence the computer phrases of cut and paste.

We fast forward to the computer Word Processor which can now be operated directly by journalists whose work (or copy) is very easily inserted into the finished page, plus typographic errors called typos, once removed by assiduous proof reading. The traditional position of type setter could still operate a page make up programme to originate text, but economics and other attractions soon saw that tradition undermined. The traditional work flow became computerised (including type setting). Artwork to film, to plate was all in place and a new device was required to colour separate and expose photographic film and paper to computer files. Enter the Image Setter plus the RIP (Raster Image Processor). The image setter uses a laser to expose the film or bromide paper, of the same size (SS) as the work to be printed on press, together with appropriate photo processing and drying.

The Modern RIP Workflow

The RIP is based upon the Adobe Postscript language and is relied upon to translate Postscript fonts, and artwork into a raster image for exposing film and then to plate making. At the same time a Server was incorporated into the idea because print houses are, after all, busy places. A server assembles all work ready to output in sequence. So today, we find a RIP with a Postscript server, dedicated to see a Page, and able to colour separate and half tone screen to the appropriate screening angles, *&c.* Finally, the most up-to-date workflow in the print industry has dispensed with the film stage and now exposes the printing plate direct in what is called a Computer to Plate system.

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The Modern DTP Set-up Using Epson and Photoshop as Examples

The simple ink jet printer on the furniture desk, printing direct from every available application, to acclaimed photo quality is clearly a marvel, producing many satisfying full colour prints, somewhat easy in an amateur sense. However, if you are following a particular tradition where colour fidelity is paramount, then accuracy of colour repro (reproduction) can be much improved by using a custom made Print Profile, a sort of calibrated feedback with respect to a particular combination of printer, paper and ink – particularly if you wish to use a specialist paper. Unfortunately such a profile may not do much for the dark tones close to black level, because the print driver which performs the Epson Colour Separation and Black Generation (K) function for CMYK, remains active when a custom Print Profile is applied. Commercially this is not considered much of a disadvantage by Epson, who offer a pretty good range of printers, printing paper, dyes and inks, all with on board profiles – but not quite to the standard of the best etching papers.

Given the approach of taking the RGB output from a number of application's direct to a CMYK printer, it is unfortunate that the advanced CMYK output available in Photoshop has not found a direct operational route to driving the CMYK printer inks, arranged to override the Colour Separation and Black Generation resident in the print driver. In actual fact, Epson do offer a solution in this form called a StylusRIP (Raster Image Processor), made for a professional design-to-press workflow containing within it the where-with-all to by-pass the resident EPSON (or other) Print Driver Black Generation. My intention was to talk about this type of workflow, for which the previous section, number 11 was prepared, *Colour Separation & Black Generation.* However, this RIP work was not completed and Section 11 remains in place out of interest and for discussion.

Creating a Print Profile – Brief examination

A custom Print Profile is intended to fine adjust colour balance. The colours (chromaticity) recorded on the Test Print, are measured and compared to what the ***Standard TIFF Test File*** should produce, and then used as feedback (within Photoshop) to adjust the output colours (chromaticity) to be correctly printed out. This feedback difference is used to generate an ICC Print Profile, which is fed back to the printer in question to modify (correct) its performance. The profile does not necessarily make a tonal change to the grey scale rendering, although I am told it can adjust values of gamma. *In actual fact the profile is in use alongside the resident Epson colour separation and black generation in the print driver,* which is where (I postulate) that we run into a problem. *When attempting to 'edit' a profile* to improve dark shadow separation as for say low key images, some dark grey steps adopted a warm hue.

The test image used for creating a Print Profile consists of many coloured rectangles, whose chromaticities are chosen to fully populate the printer colour space. They range widely in hue, saturation and lightness and are each referenced with margin letters and numbers. There are about 900 of these patches. This image is referred to as a ***Standard TIFF Test File*** to be printed out by the printer being finger-printed (making a test print). There are many different test files/images available, referenced under ICC, ISO and Profiling businesses.

This profile correction is valid only for the conditions prevalent at the time the Test Print was printed, those settings in force in order to operate the printer, in particular the settings for:

1. Paper.
2. Ink type in use.
3. Printer resolution, and other settings, *etc.*

These same settings – ***exactly*** – should be used when applying the Print Profile.

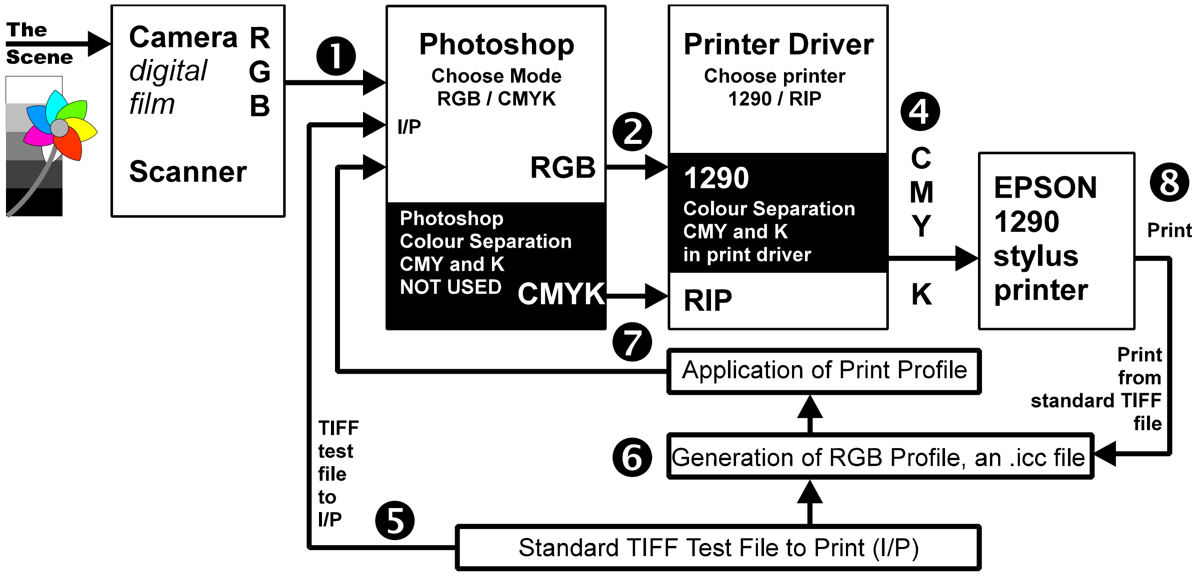

Fig. 25 Flow Diagram of Photoshop to Printer Indicating an RGB Print Profile

Profile Matters

In the above Flow Diagram, we see three horizontal boxes marked **(5), (6)** and **(7).** The box at **(5)** represents the ***Standard TIFF Test File*** to print in order to 'fingerprint' the ink jet printer, to find out how well the printer is able print certain colours. The chromaticity of the test print **(8)** is compared to the expected chromaticity at **(5).** This comparison, carried out at **(6)** produces correction figures (for all 900 patches), and forms the ICC Print Profile at **(7),** which is then sent to Photoshop. Hey Presto. Better prints!

The following is an overall look at Print Profile calculations.

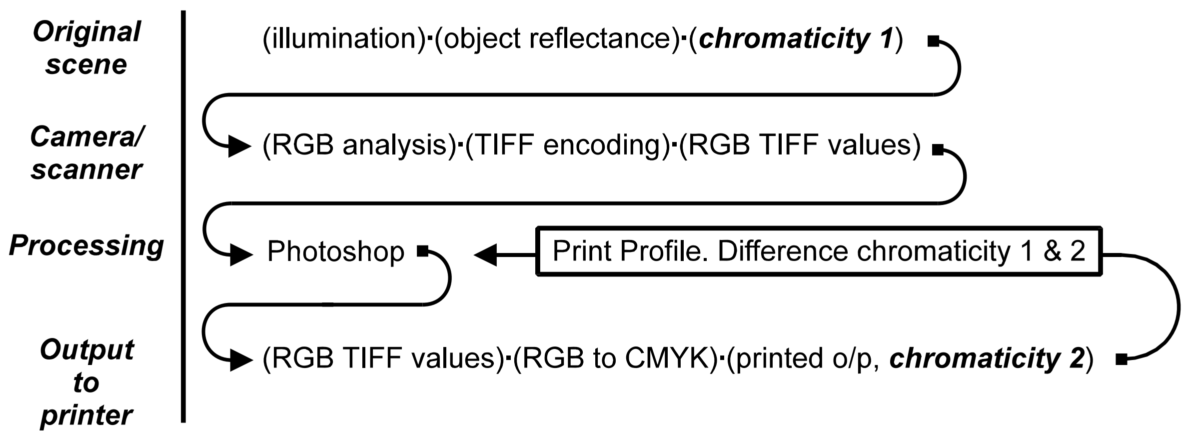

Fig. 26 The Steps Involved in Print Profile Calculations

Comparison of the original ***chromaticity 1*** with its reproduction, ***chromaticity 2,*** provides data for feedback in a Print Profile, applied within Photoshop.

A Note for Home Profilers

A chromaticity measurement relies on the geometry of the Test Print lighting being standard for a variety of paper surfaces, from gloss to matt. That Print Profiles work in practice is evidence that such diffuse *vs*. specular lighting arrangements are met, and solved, for matt and glossy papers during their chromaticity measurements. The same process aimed at fingerprinting a camera should also work, but we hear of problems that prevent this being straight forward. I suspect a cause of camera inaccuracy and inconsistency stems from *not having sufficient un-disturbed laboratory space* for the proper lighting of the test chart.

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Dot Gain

Dot Gain has been around ever since ink was mechanically applied to paper, as opposed to handwriting. Its significance was not felt until half tone screening was used to reproduce greys, leading on to full colour reproduction. Maintaining the wanted dimension of a small dot, as designed, is difficult when you consider the fluid nature of ink and the absorbent surface of paper in the case of offset litho printing, or the ink-jet printer which sprays its ink onto the paper in a controlled fashion. A poor performance in this area can affect both detail resolution, tone response and colour balance.

The illusion of a grey is obtained in printing by breaking up the image into small dots, each dot representing solid ink printed onto the substrate. This process is called Half Tone Screening. We consider black ink and white paper substrate. The different greys that comprise a grey scale are obtained by the relative area of the printed dot (black ink), to the substrate (white paper). The eye averages these black/white areas and we see greys when the dots are small enough. No dot would represent white. Minimum dot is the lightest grey that can be printed. Sold black is solid ink, and minimum dot here is the darkest grey to be printed. While dots are often round or even elliptical, there is a special case for a square dot. If the corners of a set of black squares are sized so that their corners just touch then the visually integrated grey of ink and substrate is a 50% grey.

Given the unwanted occurrence of dot gain, this impairment can be compensated by applying tone control techniques in reverse. This is particularly easy since the dot is with us to facilitate tone reproduction. If the dot grows in size due to dot gain it will print as a darker grey. Therefore we aim to compensate by printing an appropriately lighter grey. This is regular practice in 4 colour off set litho work: for which Photoshop is well equipped professionally in its colour separation department, at **File > Color Settings > CMYK set up.** Unfortunately these RGB to CMYK colour separations *originated within Photoshop* are of no use to DTP enthusiasts because the desk top ink jet printer receives its CMYK signals from the Print Driver with Epson's RGB to CMYK Colour Separation and Black Generation parameters beyond operator control. Epson claim to do all this on our behalf for their papers and inks, in the print driver.

Black Generation

In the case of regular CMYK litho work (simply referred to as 4 colour work), where each colour is printed individually from its dedicated unit comprising inking rollers, printing plate and offset blanket *etc*, any correction to C, M, Y or K is relatively easy and direct. For desk top ink-jet printers using CMYK inks, but fed with RGB signals, the matter of control is somewhat different. While the conversion from RGB to CMY is relatively straightforward, the addition of K (or black generation) is a clever compromise and calculation, and is often incorporated in the printer itself (or printer driver), after receipt of the RGB signals from the computer. Where equal RGB signals amount to a grey – and similarly for CMY equal triples that colour mix to a neutral – these can be replaced by screened black ink which is cheaper than the colour ink it replaces, and represents less ink on paper, which improves drying and wet-on-wet printing.

The Epson constants of black generation cannot be adjusted by the ink jet user. This inability to get directly at the actual ink jet CMYK printing values leaves one in the hands of the printer manufacturer, and in the practical instance of Epson Ink Jet printers at the mercy of their black generation characteristics. In 4 colour litho press work there is the opportunity to intervene in any on-press colour. (See the published work of Dan Margulis – USA). RGB work from Photoshop is called 24 bit being 3 x 8 bit to cover the three R, G and B channels. Colour separated work is known as 32 bit being 4 x 8 bit to cover the four C, M, Y and K channels. Our interest is in this colour separation within Photoshop as a direct route (workflow) to the dark colours used in the ink jet printer. We could get at the black ink and control its effect, especially as a last attempt in the face of all the corrections that may or may not have been made near to black level. Such as differences in gamma correction, the same effect but differently named in different colour spaces, and a levels layer in Photoshop.

Heavy or Over Inking

Over inking (or heavy inking) is the sort of thing that a litho press minder would watch out for, control and prevent. It is not the same as dot gain. Dot gain is fundamental to the process of printing with fluid ink on absorbent paper. Given that the generation of images from a digital camera, or from a drawing programme are satisfactory as seen on a well set-up (calibrated) CRT, then any practical ink jet compensation for dot gain and over inking falls into one of two categories:

1. A reduction in gamma, in line with the MAC figure of 1.8 instead of 2.2. Such a figure is available in the Epson print driver.

2. To lift the whole waveform (image) above black level in Photoshop at Ctrl + L by some 5 to 20 (out of 255), depending upon the effect being countered.

Users of “High Street” desktop ink jet printers do not have access to the parameters of Black Generation, as Photoshop provides for professional CMYK use. High Street users are confined to working in RGB with Black Generation for the printer CMYK being confined in some out-of-the-way corner. For most amateur photo applications this is quite satisfactory. But for a more serious photo and fine-art approach, shadow detail and rendering may require greater attention.

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At Last, a Print to Make
With a print profile in place we are in a position to make a print. This assumes that a choice of paper and ink has already been made.

Print Drying
N.B. This caution applies to using Epson materials. Other paper and ink combinations may perform differently. On attempting to make a fine print one of the first requirements is to allow the finished print some 10 to 30 minutes to establish its cured colour balance. For example, if you make two similar prints, one after the other the second print may, depending upon the image content, look quite different to the first one, to such a degree that you may thing think some changes have been made.

Image Adjustment with Layers
One of the most flexible ways of adjusting an image in Photoshop is via an Adjustment Layer. This leaves the original file intact, with no changes made to it. A number of Photoshop facilities are available in an Adjustment Layer, such as:

- Levels
- Curves
- Colour Balance
- Brightness / Contrast
- Hue / Saturation
- *&c.*

This permits a variety of adjustments that can be switched off and on at any time in the Layers Palette. They may also be returned to and their values re-set if required.

Photoshop even allows the traditional actions – from the wet darkroom – of Dodge (to selectively lighten) and Burn (to selectively darken) to be performed.

Table 1. Converting 0 → 100 to 0 → 255 (16 bit, 0 → 65,536 rounded)

0 → 100	**8-bit 0 → 255**	**16-bit**	**0 → 100**	**8-bit 0 → 255**	**16-bit**
0	0·0	**0**	**50**	127·500	**32,000**
1	2·550		51	130·050	
2	5·100		52	132·600	
3	7·650		53	135·150	
4	10·200		54	137·700	
5	12·750		55	140·250	
6	15·300		56	142·800	
7	17·850		57	145·350	
8	20·400		58	147·900	
9	22·950		59	150·450	
10	25·500	**6,500**	**60**	153·000	**39,000**
11	28·050		61	155·550	
12	30·600		62	158·100	
13	33·150		63	160·650	
14	35·700		64	163·200	
15	38·250		65	165·750	
16	40·800		66	168·300	
17	43·350		67	170·850	
18	45·900		68	173·400	
19	48·450		69	175·950	
20	51·000	**13,000**	**70**	178·500	**45,800**
21	53·550		71	181·050	
22	56·100		72	183·600	
23	58·650		73	186·150	
24	61·200		74	188·700	
25	63·750		75	191·250	
26	66·300		76	193·800	
27	68·850		77	196·350	
28	71·400		78	198·900	
29	73·950		79	201·450	
30	76·500	**19,600**	**80**	204·000	**52,000**
31	79·050		81	206·550	
32	81·600		82	209·100	
33	84·150		83	211·650	
34	86·700		84	214·200	
35	89·250		85	216·750	
36	91·800		86	219·300	
37	94·350		87	221·850	
38	96·900		88	224·400	
39	99·450		89	226·950	
40	102·000	**26,000**	**90**	229·500	**59,000**
41	104·550		91	232·050	
42	107·100		92	234·600	
43	109·650		93	237·150	
44	112·200		94	239·700	
45	114·750		95	242·250	
46	117·300		96	244·800	
47	119·850		97	247·350	
48	122·400		98	249·900	
49	124·950		99	252·450	
			100	255·000	**65,500**

Table 2. Converting 0 → 255 to 0 → 100. (8 bit).

0-255 → 0-100		**0-255 → 0-100**		**0-255 → 0-100**		**0-255 → 0-100**		**0-255 → 0-100**	
0	0	51	20·000	102	40·000	153	60·000	204	80·000
1	0·392	52	20·392	103	40·392	154	60·392	205	80·392
2	0·784	53	20·784	104	40·784	155	60·784	206	80·784
3	1·176	54	21·176	105	41·176	156	61·176	207	81·176
4	1·569	55	21·569	106	41·569	157	61·569	208	81·569
5	1·961	56	21·961	107	41·961	158	61·961	209	81·961
6	2·353	57	22·353	108	42·353	159	62·353	210	82·353
7	2·745	58	22·745	109	42·745	160	62·745	211	82·745
8	3·137	59	23·137	110	43·137	161	63·137	212	83·137
9	3·529	60	23·529	111	43·529	162	63·529	213	83·529
10	3·922	61	23·922	112	43·922	163	63·922	214	83·922
11	4·314	62	24·314	113	44·314	164	64·314	215	84·314
12	4·706	63	24·706	114	44·706	165	64·706	216	84·706
13	5·098	64	25·098	115	45·098	166	65·098	217	85·098
14	5·490	65	25·490	116	45·490	167	65·490	218	85·490
15	5·882	66	25·882	117	45·882	168	65·882	219	85·882
16	6·275	67	26·275	118	46·275	169	66·275	220	86·275
17	6·667	68	26·667	119	46·667	170	66·667	221	86·667
18	7·059	69	27·059	120	47·059	171	67·059	222	87·059
19	7·451	70	27·451	121	47·451	172	67·451	223	87·451
20	7·843	71	27·843	122	47·843	173	67·843	224	87·843
21	8·235	72	28·235	123	48·235	174	68·235	225	88·235
22	8·627	73	28·627	124	48·627	175	68·627	226	88·627
23	9·020	74	29·020	125	49·020	176	69·020	227	89·020
24	9·412	75	29·412	126	49·412	177	69·412	228	89·412
25	9·804	76	29·804	127	49·804	178	69·804	229	89·804
26	10·196	77	30·196	128	50·196	179	70·196	230	90·196
27	10·588	78	30·588	129	50·588	180	70·588	231	90·588
28	10·980	79	30·980	130	50·980	181	70·980	232	90·980
29	11·373	80	31·373	131	51·373	182	71·373	233	91·373
30	11·765	81	31·765	132	51·765	183	71·765	234	91·765
31	12·157	82	32·157	133	52·157	184	72·157	235	92·157
32	12·549	83	32·549	134	52·549	185	72·549	236	92·549
33	12·941	84	32·941	135	52·941	186	72·941	237	92·941
34	13·333	85	33·333	136	53·333	187	73·333	238	93·333
35	13·725	86	33·725	137	53·725	188	73·725	239	93·725
36	14·118	87	34·118	138	54·118	189	74·118	240	94·118
37	14·510	88	34·510	139	54·510	190	74·510	241	94·510
38	14·902	89	34·902	140	54·902	191	74·902	242	94·902
39	15·294	90	35·294	141	55·294	192	75·294	243	95·294
40	15·686	91	35·686	142	55·686	193	75·686	244	95·686
41	16·078	92	36·078	143	56·078	194	76·078	245	96·078
42	16·471	93	36·471	144	56·471	195	76·471	246	96·471
43	16·863	94	36·863	145	56·863	196	76·863	247	96·863
44	17·255	95	37·255	146	57·255	197	77·255	248	97·255
45	17·647	96	37·647	147	57·647	198	77·647	249	97·647
46	18·039	97	38·039	148	58·039	199	78·039	250	98·039
47	18·431	98	38·431	149	58·431	200	78·431	251	98·431
48	18·824	99	38·824	150	58·824	201	78·824	252	98·824
49	19·216	100	39·216	151	59·216	202	79·216	253	99·216
50	19·608	101	39·608	152	59·608	203	79·608	254	99·608
								255	100·000

DEFINITIONS

COLOUR SIGNAL NOMENCLATURE

This nomenclature, seen here in print, can also apply in speech. However, the spoken word has the benefit of instantly accommodating many diversions of reason. A full colour digital image is comprised of three individual signal channels operating on additive principles, named as Red, Green and Blue or, four individual signal channels operating on subtractive principles, named as Yellow, Cyan, Magenta and Black (K). When an 8 bit channel is referred to we have available 256 code values or signal levels (2 to the power of 8, 2^8). If 16 bit channels are referred to the number of code values or signal levels increases to approximately 65,000 (2 to the power of 16, 2^{16}). Photoshop is able to report on these 8 bit signal levels, per individual pixel or groups of 5 x 5 pixels, in its Info panel, but not for 16 bit channels.

The 256 levels (or code values) of an 8 bit channel are re-numbered as: zero for Black level, which makes White level appear at 255.

While the context of a discussion will often avoid any ambiguity the following convention might help precision. An "assumed" definition leads to clumsy clarity.

If RGB or CMYK is used it refers to the full colour image, followed by (8 bit) or (16 bit) in brackets to indicate the available precision of code values. RGB (*8 bit*) is simply read as a code value within zero to 255. If white level is referred to as being 100%, then the addition of % means that RGB (8 bit)% has a value between zero and 100.

I recommend adding the defining element in brackets rather than a superscript, as the latter can get a little too small in the rigmarole of reproduction. The use of italic further separates it from the text.

Since we are speaking about figures that are quite precise in their meaning, the word ***value*** is preferred to the phrase RGB ***points.*** The term ***points*** has gained some careless currency as the phrase "percentage points", whatever that means. We have a sign for this, it is n%.

We now have:

RGB *(8 bit)*	*Zero to 255.*
RGB *(8 bit)%*	*Zero to 100. White level being taken as 100%.*
RGB *(16 bit)*	*Zero to 65,000.*
RGB *(16 bit)%*	*Zero to 100. White level being taken as approx. 65,000.*

Taking Photoshop Curves as a starting point, for 8 bit files, we consider code values from zero to 255, reading from left to right on the input ***x*** axis, which is also from black to white. In ink terms the reverse applies. NO ink (zero) is plain substrate or paper white. 100% or solid ink is black. The term 100% sits at either end of the curve depending upon whether we are speaking about signal levels or printed ink.

SIGNAL EXCURSIONS in the printing industry, on the one hand, and television and DTP computing, on the other, are in reversed order. If we write things down stating the obvious then miss-understanding will reduce. Confusion hides within the following:

Subtractive principle. 0% looks white.	**Printed page**	**Applied ink.**	**100% looks black.**
Additive principle. 0% looks black	**Screen technology**	**Signal level.**	**100% looks white.**

GLOSSARY

Draft

q.v. *(quod vide).* See which thing; a reference, e.g. to *another part* of a book (this Glossary).

See also Glossary of terms. ICC White Paper #5. (Includes many ISO references).

'A' Range of ISO Paper Sizes. These are unique in that all their sizes have the same aspect ratio (height to width) of 1: √2. All sizes are derived from a basic sheet of 1 square metre in area, named as A0. Smaller sheets are arrived at by progressively halving the long side. The common writing paper sheet size called A4 measures 297 mm x 210 mm.

8 bit and 16 bit Image Numbers. The number of levels in an 8 bit file (its bit depth) is, for an 8 bit signal 2 to the power of 8, 2^8=256. For a 16 bit system the bit depth is 2^{16}=65,536. *q.v. Bit depth.*

Achromatic Grey is a grey without colour. In RGB signal terms it is R=G=B (iso RGB or an RGB triple), where the grey pixels in all three channels are equal in code value. [Iso is used to mean 'equal'].

Adobe Gamma Facility. A utility automatically installed with Adobe Photoshop to ensure that the computer operating system has a proper overall white balance and gamma.

Adobe Photoshop. The industry standard image editing programme, which has become indispensable with Adobe Illustrator (Vector drawing) and Adobe InDesign (Page make up), collectively named *Creative Suite*. These three programmes share common facilities and key strokes – an operational plus.

Adobe RGB (1998) colour space. The colour space promoted by Adobe for the colour management of work (image files) intended for print.

Ambient Light (or illumination). A reference to the room light that may fall upon the CRT screen and so reduce the reproduced quality of tones in the region of dark grey to black. *q.v. Brightness range.*

An RGB Flow Diagram. Complex subjects are often accompanied by a simplified diagram as an aid to understanding. In complex electronics one of the things to comprehend is the order in which processes occur – say, where does this switch sit in the overall order of things? The flow of digital camera signals in-camera, and then within say, Photoshop, requires a diagram such as ***Figure 2*****,** if we are to know and understand the relevant processes.

Analogue vs. Digital. Historically, electronics spans the early use of thermionic valves (analogue), that took a long time to warm up, to the modern and current use of solid state electronics, transistors and chips, that heralded and hastened digital techniques. Electronically, Analogue systems are characterised by the continuos nature of their signals. A Digital device samples the analogue signal into small amounts, small enough to be sub-liminal or within the definition of a JND. *q.v. Bit Depth.*

Artefacts, in the world of visual communication, are unwanted marks often due to over compensation (sharpness) or signal compression to make smaller files (JPEG).

Astigmatism. An optical defect where a regular round spot is rendered elliptical. Some interesting line gratings have been developed to detect this optical aberration.

Attractiveness of Sun-Lit Scenes is due to a number of factors. (1), The brightness of the scene is higher than for a dull day, causing the eye to adopt a more contrasty mode. (2) The cast shadows from the sun increase the contrast of the scene, adding greatly to the scenes' three dimensionality. (3), the Colour Temperature of the scene includes warm sun-light.

Bandwidth refers to the use in Telecommunications of part of the frequency spectrum. Transmitting stations and equipment circuits all occupy a range – or band – of frequencies called bandwidth. Compression techniques enable some signals to occupy less bandwidth. International agreement limits the bands allotted to transmitting stations to prevent them interfering with each other.

Bit Depth is a digital term referring to the number of digital levels available in a signal, between black and white level. For a monochrome signal, of one channel, it is the number of tonal values available which is 256 for an 8 bit file. For a colour file of three channels, R, G and B, each pixel is coloured according to the product (colour mixture) of R x G x B which equals 256 x 256 x 256 = 16·8 million levels or colours.

Black Body. Used in laboratories to set colour temperature and illumination standards. As temperature is increased radiation (light) is emitted but no light (or very little) is reflected. *q.v. Colour Temperature.*

Blue-ness and or Green-ness of the Hue Cyan is a constant problem in Hue naming. Colour theory requires that a colour be named that lies between Blue and Green – this can be shown with a spectral analysis of the colours concerned. Unfortunately the hue Cyan (between blue and green) is not as distinct to recognise as Orange is between Red and Yellow.

Brightness Adaptation of the eye is quite automatic between the extreme levels of Moonlight and Sunlight. It always seeks to make the bright parts of a scene comfortable to view. See ***Figures 14-16*** *inc.*

Brightness Range, is a term generally referred to a scene or its reproduction as the ratio of, or the range between, the brightest part to the darkest part of an image. The brightness range of a flatly lit scene will be its extreme refection coefficients. For a three dimensional scene lit with Sunlight casting shadows, the flatly lit brightness range will be increased by the introduction of shadows, and how bright they are due to the use of any fill light (lighting contrast).

British Standards. Once a source of information at a reasonable cost. It has now become expensive to access.

Cathode Ray Tube (CRT) was the first device to offer an electronic image on display, called television. These devices became unwieldy and very heavy for large images in the order 26 inches diagonal. Flat panel screens are now available less the CRT bulk, but still quite heavy. *q.v. CRT Gamma.*

***Chromaticity Diagram*.** A form of colour circle, plotting hue and saturation, but not brightness. Generally applied to serious colorimetry, as promoted by the CIE. Strictly speaking, colour circles and triangles *&c.* are chromaticity diagrams too.

CIE 1931 x, y chromaticity diagram was published in 1931. This diagram was found to suffer from an uneven display of equal increments of colour difference.

CIE 1976 u', v' chromaticity diagram was published in 1976 with much improved evenness of display. While the 1976 diagram is to be preferred it is found that literature of today uses both diagrams.

CIE. The CIE (*Commission Internationale de l'Eclairage)* took over the functions of the earlier '*Commission Internationale Photometrie'* in 1913. The characteristics of the human eye were published in 1924.

CMYK The K in CMYK refers to the black ink, avoiding confusion with Blue if B had been used to mean Black. A dichotomy of colour naming (even wrong naming!) refers to the CMY colours Cyan and Magenta as Printers Green and Printers Red.

Colour Circles, Triangles and other shapes proliferate in the history of colour theory, as well as the formal diagrams of the CIE (see above). These shapes are often used to help visualise the three dimensional nature of colour theory. Broadly they fall into two classes. (1), A geometrical shape is chosen into which colours are placed and ordered, such as the Ostwald Colour Solid. (2) Colour samples are arranged as we see them, say in equal increments of perceived colour, as in the Munsell Atlas.

Colour Rendering Index. An artificial light source, such as a fluorescent tube, can depart from the spectral composition (colour temperature) it is compared to, to a serious degree. To inform users of these lamps a Colour Rending Index (CRI) is published to indicate how suitable they are for some critical applications, such as colour matching. A high value of CRI in the 90's is very good. Tungsten lamps rate as high as 100.

Colour Solids and Spaces are an extension of the simple two dimensional colour circle and triangle, in order to include the third dimension of colour, namely brightness.

Colour Temperature (1), taken as stated, (and, for example written as 3,000K) can miss lead because the mix of lay painterly use and that of the physicist can be quite different. The painterly use of warm / cool is derived from colour temperature in that the warm colours are said to be at the red end and the cool colours are associated with the blue end. These 'ends' belong to the Planckian Locus, that line that plots the chromaticity of a black body as it is heated in a chromaticity diagram. It is clear that when a black body is first heated up it emits infra red and red light (2000K). At the other end of the colour temperature scale the dominant colour is blue (10,000K), hence the warm / cool idea. However in between these extreme colour temperatures where either red or blue dominate, the perceived colour would be white (in the region of 5500K, all colours present). Green alone does not appear as a dominant colour.

Colour Temperature (2) is not referred to simply as Temperature. That word may be used alone in some artistic disciplines in conversation, but only carefully, because there is actually Distribution Temperature, Colour Temperature, Correlated Colour Temperature and Aesthetic Temperature.

Colour Temperature (3) is quite a complicated subject in its entirety. The word "Colour" should seldom be omitted. It is rather lazy to expect any familiarity with the subject to fill in for this word. Small changes of Colour Temperature, as given by the use of pale Mired filters, may be termed Warm or Cool as the effect passes along the Planckian Locus. Warm being towards Red and Cool being towards Blue. Hot and Cold are extreme adjectives for which colour names might better be substituted.

Colourfulness, is a word introduced to describe a visual attribute similar to saturation as: *Attribute of a visual sensation according to which an area appears to exhibit more or less of its hue*. (Hunt).

Complementary Hues are those hue pairs opposite each other on a properly designed colour circle which, when mixed together in the correct proportion, can produce an achromatic grey. Such as Red and Cyan. The subtractive primary colours Cyan, Magenta and Blue are complementary with the additive primary colours Red, Green and Blue.

Complementary Nature of Reflected and Absorbed Light. For an ink to appear a certain colour it must absorb the un-wanted colour (from white light illumination) to leave the wanted colour as reflected light. These two colours, wanted and un-wanted, are essentially a complimentary pair.

Complexion Colour. The colour of skin is one of a few critical colours that colour reproducing systems look to handle well. We prefer not to refer to flesh tone when discussing colour repro. Other critical colours are: sky, grass, snooker table and balls *&c*. Some of these colours are found on the Gretag Macbeth Colour Rendition test chart and are actual attempts to reproduce the real spectral distribution of these colours.

Critical Flicker Frequency (CFF) or Fusion Frequency. For the projection of cinema film to successfully portray movement within an otherwise steady image, the appearance of film frames must be just beyond the CFF. At 24 frames per second the movement illusion is complete but the result is a steady flicker. Each frame is therefore shown twice, raising the flicker rate to 48 per second, well beyond our CFF. Television and computer frame scanning likewise present a flickering image, but by keeping the frame scan (a TV term) or the refresh rate (a computer term) above the CFF we are able to become accustomed to a residual amount of inherent flicker based upon the UK and Europe mains frequency of 50Hz or the US mains frequency of 60Hz.

CRT Characteristic Curve. This curve shape, and that of the flat video screen, are fundamental to how the displayed image looks. The measure is of input volts V to light output L. The CRT has a power law of the form $L=V^{\gamma}$ where the indice $^{\gamma}$ is the Greek letter

Gamma, giving its name to this law. It has the value of 2·2 depending upon the setting of black level (the brightness control). Flat video screens have a linear characteristic and therefore a gamma of unity. *q.v. Gamma.*

CRT Gamma (dynamic) is the transfer characteristic measured in the presence of an amount of ambient light, given as a percentage of white level, and with the black level set (a), as for the static measure and (b), with black level increased to optimise the rendering of dark grey tones.

CRT Gamma (static) is the transfer characteristic measured with its operating condition set so that no light is emitted for a zero signal input. The CRT is not usually operated in this manner (in darkness) however this static figure is required for some calculations.

Daylight Colour Temperature and Daylight Balanced Colour Film. The colour temperature of daylight depends upon the time of day. Sunrise and Sunset are relatively warm in comparison to noon, when the Sun and a blue sky mix to a colour temperature in the region of 6500K.

Designing the Printed Page for Easy Study. A certain principle of typography is to layout and adjust text for an evenly printed page. Certain marks such as spaces, bold typeface and italic typeface *&c.* can be used for added emphasis. The *study* aspect of reading includes returning to a sentence start for a re-read. To better enable this the minimum space generally allotted after the full stop is increased to help this backwards search, or *reverse reading.* Which is returning to a previous point in the text to re-cap. This can be assisted by increasing the space between sentences to find a start point, otherwise kept small for even page appearance which does not interfere with normal forward reading.

Digital Brightness Range measured outside the camera is the same as for film and relates to the scene reflectance's as found and lit. Image brightness ranges are linked to the peaks of a display. From white paper to maximum density on a print; from display screen white (R=G=B) to black at zero signal and any ambient illumination being reflected from the screen or black ink. In between the limits of black and white level there are 256 levels (of grey) for an 8 bit system and 65,536 for a 16 bit system. *q.v. bit depth.*

Dominant Wavelength refers to that, or those, wavelengths giving a colour name to a general distribution of wavelengths.

Dot Gain An increase in printed dot size is called dot gain. Maintaining the wanted dimension of a small dot, is difficult when you consider the fluid nature of ink and the absorbent surface of paper. It is thought that the erroneous gamma of 1·8 attributed to the Mac computer is an attempt to build in dot gain correction that invariably occurs in printing.

Dynamic Exposure Range The only signal range that is dynamic in a digital camera is directly related to the exposure of the image sensor, and those sensor signals subsequently converted to digital values. The limits of this range are set by the Sensor Saturation (white level) and the darkest shadow detail (sensor noise floor, or black level).

Encoding. The process of encoding an analogue signal to a digital signal. The frequently found 8 bit encoding produces 2^8 = 256 levels, called code levels or signal levels. The degree of presision is called 'bit depth'.

Exposure Latitude is a complex subject. It is simple to say that when the exposure is correct for the main subject any latitude is then expressed in the degree to which other elements, usually of a highlight and shadow nature are accommodated without serious loss of tonal detail. It is thought the S shaped curve of film work is mimicked as an addition to the naturally linear characteristics of digital image sensors, in order to offer additional exposure latitude. *q.v. S Shaped Film Curve.*

Facsimile or Fax describes the transmission of still images initially by wire in the 19th Century and now from desk top machines. The performance of facsimile machines was investigated by engineers developing early television in order to determine the resolution requirements of television.

Flat Panel Video Displays (as opposed to the CRT) are relatively new and more convenient to use in that they occupy less space. Their introduction coincides with wide screen High Definition television and the need to be able to display wide images of 16:9 aspect ratio. These displays can offer very wide images.

Flesh Colour vs. Flesh Tone When we refer to the colour of our skin we should use the term Flesh Colour, not Flesh Tone. The word Tone refers to the tonal aspect of colour, as in the "L" part of "Lab".

Flesh Colour Test. Such a test is to reduce, or eliminate, variations of reproduction colour that would otherwise upset a picture match on this critical colour. *q.v. Picture matching.*

Four Unitary Hues, are the colours attributed to Ewald Hering (1834-1918), as red, yellow, green and blue. These four important colours, share the distinction that each one can be described without reference to the other three, or any other colour.

Four-Colour Process (CMYK). Refers to the classic use of Cyan, Magenta and Yellow subtractive colour mixing primary colours, plus black (K), for printing. The black ink is used to replace equal amounts of C, M or Y that would otherwise mix to grey. This saving is worth doing and improves wet-on-wet printing.

Fourier Analysis. The detail response of images involves high frequencies that are potentially difficult to transmit and or, beyond the bandwidth of the system in question. Tests for camera sharpness are made looking at black-and-white line gratings which strictly produce a lot of unwanted high frequencies. Fourier analysis makes a mathematical analysis of a square waveform (the B/W line grating) into the many sine waves (frequencies) that constitute the fundamental square wave. This leads on to test charts with a sinusoidal density distribution for Modulation Transmission Function (MTF) tests. In turn this enabled lens manufacturers to enhance the detail performance of lenses up to the bandwidth limit of TV systems.

Frame and Line scan are terms referring to the television & computer screen scanning raster that makes up the screen image. The scanning raster writes the screen image with many lines from left to right, repeated from top to bottom. The horizontal lines are called *line scan* while the top to bottom movement is called *frame scan.*

Fraunhofer Lines are a spectral phenomena of considerable wavelength or frequency accuracy. These lines are dark, or bright, and very narrow within the full spectrum of colours. They are referred to in colorimetry to calibrate a wavelength scale. A spectroscope is required to see them.

Gamma. The lower case Greek letter γ denoting contrast.

Gamut. The total range of mixed colours obtained from a set of system primary colours. For TV and computer screens this will be from Red, Green and Blue phosphors. For traditional four colour print this will be for the inks Cyan, Magenta and Yellow plus Black. *q.v. The Four Colour Process.*

Gaussian. Gaussian actually refers to a statistical mathematical process and a bell shaped curve. Here we refer to the filter in Adobe Photoshop called Gaussian Blur. When detail is observed the sharpest looking result will be when the edges of objects (their sides) rise steeply with a minimum of grey tones. The sharpest edge will rise from black to white with no intermediate tones, or overshoots and the like. The Gaussian Blur filter will modify this clean edge and make it look like one half of the Gaussian bell shape (S shape), depending upon the number or fraction of pixel radius entered into the Gaussian Blur box.

Gestalt [psychology]. Meaning *an organised whole that is perceived as more than the sum of its parts.* If, in transmitting an image, part of its structure is lost or altered, the original purpose or intent of the image is likely to be lost. Depending upon the communication intended from the image, such loss of structure may seriously affect its purpose. There are many *parts* or components comprising an image however, we have in mind the total loss of data due to image cropping between different aspect ratios.

***Granger Rainbow*.** A test signal or image comprised of an electronic blend of all hues from black to white.

Halftones. The printing of grey from black ink, and similarly printing tints from solid colour mixtures, requires use of the half-tone illusion because it is the nature of printing presses is to lay down solid ink. By breaking down each grey (or half-tone), into a series of dots too small to see (at reading distance) but each printed with solid ink, we are able to distinguish a grey as an average reflectance of the solid dot and its unprinted ground (paper). *q.v. Dot Gain.*

Hertzian waves. Meaning wireless waves or part of the electromagnetic spectrum, of which light is a part. *q.v. Light.*

Hi-Fidelity (1), or simply Hi-Fi began some time ago when *audio* equipment was relatively easy to build with a better specification than was ordinarily available in the High Street. In more recent years the phrase *Hi-Fidelity Video* has been heralded with DVD recordings, the introduction of wide screen television and home cinema installations.

Hi-Fidelity (2), as applied to a *sound* or *video* system means the application of two principles. (1) That within the parameters of the system all forms of detectable distortion are subliminal. (2) The parameters of the system are extended to include wider attributes than commercially available “off the shelf”, such as: a wide audio frequency range, better stereo positional resolution, more spatial detail, and greater colour gamut and contrast range.

Hi-White paper is a name given to paper with a spectral reflectance curve that rises in the blue, possibly from the inclusion of UV Optical Whiteners that fluoresce to provide a whiter than white look. Not unlike the blue bag as used in the Monday wash of yesterday.

Hue angle. A colour solid particularly useful to computer users known as HSB (Hue, Saturation, Brightness). The Hue dimension (circle) is measured on a 360 degrees scale. Red is at 0/360 and counts up anti-clockwise through the spectrum. Any pair of hues 180 degrees apart form a complimentary pair.

ICC Colour Management Profiles. The International Color Consortium® *(ICC)* was set-up in the early 1990’s. The purpose was to colour manage the translation of an image on a screen display (CRT) to its reproduction in print, with the use of Profiles that carry special information to enable the translation.

International Color Consortium (ICC). The ICC was set-up (*c.* 1990) to co-ordinate the development of colour management profiles, and publishes the official ***File Format for Color Profiles,*** *currently at* ***Version 4.1.0, (© 2003 ICC),*** which runs to some 120 pages.

Images. A general term for any reproduction is an image rather than the term picture, unless pictorial quality is being referred to.

Indigo as a colour name became enshrined in the folk history of colour when Newton added it to his newly-seen spectral colours. The capital letters of the mnemonic **R**ichard **O**f **Y**ork **G**ave **B**attle **I**n **V**ain spell out these spectral colours as; red, orange, yellow, green, blue, indigo and violet. The basic naming of colours is usually made in response to spectral colours – those of high saturation. Indigo is dark (in common with all blue hues) but not a highly saturated colour. Newton was prompted to fit these newly identified colours into a harmonic relationship with a music scale This colour naming unfortunately omits to include the colour between blue and green *i.e.* Cyan. These harmonic relationships did not last.

Information Exchange about paper sizes. Given the importance of information exchange on the Internet it is high time a common page size such as A4 was adhered to or, margins so sized that they were lost instead of data or, fit to page software was always available at the receiver.

Interlaced scanning. *q.v. Frame & Line scan.* The vertical frame scan can write all the lines in one scan called *sequential*, or half the lines (comprising one field) followed by another field but this time in between the first field, called interlaced scanning. The two fields are called odd and even fields.

Interpolation. In the digital sense, to add pixels in between others in order to increase the pixel count, and hence avoid pixelation. *In the mathematical subfield of numerical analysis, interpolation is a method of constructing new data points* [pixels] *from a discrete set of known data points* [existing pixels]. *My brackets. See http://en.wikipedia.org/wiki/Interpolation.*

ISO. International Standards Organisation.

ISO Speed and Gain. Since digital camera photo sensors are assumed to be linear devices, their speed rating is a simple matter of adjusting channel gain, noise permitting.

Just Noticeable Difference (JND). In visual matters the JND it is often noted. It is the smallest change that can be observed, before becoming sub-liminal.

Key and Fill light. The key light is usually the main light that illuminates the object, creating an appropriate shadow, depending upon where the key is placed. The fill light is intended to lift the shadows. These two lights have different geometry's, illustrated by the Sun and Sky.

Legibility of Coloured Text on a coloured ground will depend upon the relative brightness of the text and ground. Many colour pairs will be readable in colour, on screen, but quite probably NOT in print. This occurs because the screen in use is not calibrated to act as a *soft proof (q.v.)* and the actual colour pairs chosen were likely to be troublesome in the first place. It is known that blue and yellow can reliably remain as a readable colour pair, but red and green (and some other colour pairs) can be confusing.

Level. Where any grey tone sits between black level (say zero) and white level (say 100%, or 1) or, the level the Red, Green or Blue constituents of a colour, between 0 and 1. *q.v. Bit Depth.*

Light conversion filters. The daylight lighting situation, measured at midday, is about 5500K. Indoor lighting called artificial lighting is tungsten based. Historically many lighting units are made with tungsten lamps burning at about 3000K. Colour film has (and is) available colour balanced for daylight or tungsten use. There are colour filters to convert between 5500K to 3000K and vice versa, and between many other colour temperatures.

Light. Light is that small part of the electromagnetic spectrum, seen through the window of the eye. If we cannot see it, we do not call it light but infra red or ultra violet, and other names. The range of visible wavelengths is approximately 700 nm (the red end) to 400 nm (the blue end).

Lighting Contrast. Lighting contrast depends upon the key and fill light. The lit side of an object (from the key light, a hard light source) also receives light from the fill light (a soft light source). The lighting ratio between the lit to filled side is therefore key+fill to fill light, not a simple key to fill ratio.

Line and Half-Tone. These terms belong to graphic reproduction. Line or Black and White (B/W) refers to a very steep contrast characteristic. When photography was alive using film reference was made to line film, of high contrast suitable for B/W work. Half-Tone refers to a characteristic capable of rendering all the tones in an image.

Line Pairs. When resolution is measured using a line grating reference is made to line pairs. A line pair corresponds to one full sine wave (the positive and negative half cycle) and to two pixels.

Macro and Micro contrast. Macro contrast (large) would correspond to the overall level of the whole image being adjusted in Curves (Photoshop) as gain. Micro contrast (small) is concerned with limiting resolution (fine detail) and the edges of objects. Micro contrast can be increased under the name of sharpness, it can also be over increased.

Matching Fields. When two colours are brought together to see how similar they are we make a matching field. For an accurate result each field should be even and butt up against each other with no line or discontinuity between them. *See **Figure 9.***

Mesopic. The brightness response of the eye includes two regions. High brightness with full colour called *Photopic q.v.* and low brightness called *Scotopic q.v.*. Between these two regions is the Mesopic range where the *Purkinje Effect q.v.* can be observed.

Metamerism is a visual effect where two (or more) colours may be seen to match, under one illuminant, but to miss-match under another illuminant. The understanding of this phenomena requires knowledge of the spectral distribution of: the colours concerned, the illuminant and the viewers visual response.

Meting Point of Tungsten. The Tungsten lamp provides light at a colour temperature of approximately 3000K. Above this temperature the filament evaporates faster, eventually failing at the meting point of tungsten; 3410°C (3683K), at some thin weak point on the filament wire. The tungsten iodine lamp retards the tungsten evaporation allowing higher colour temperatures (closer to Tungsten's melting point) to be used.

MIRED Colour Temperature Scale. (Micro Reciprocal Degree). This scale is perceptually more even than the direct colour temperature scale. Light correction filters can be assigned a Mired rating. The blue range of filters have a negative sign and the orange range a positive sign. Opposite signs of equal value combine to be a useful in-the-bag ND (neutral density) filter.

MTF. Modulation Transfer Function. An objective measure of resolution.

Munsell Colour Terms. The Munsell atlas uses Hue, Value (brightness) and Chrome (saturation) to describe its attributes of colour.

Nipkow rotating mechanical scanning disc. Polish inventor, Paul Gottlieb **Nipkow,** 1860-1940. German patent 30105 of 6 January 1884, a significant patent in the history of television development.

Number of Colours Available. In digital terms the number of available colours is calculated as colour depth. For 8 bit RGB files this works out to be 16.8 million colours, a high figure. Electronic instructions exist for this many colours, which is beyond the 10 million it is estimated we can distinguish. [2]

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2. **Hunt**, R. W. G, opens the second edition of his *Measuring Colour* with the estimate of "10 million" colours from **Judd** & **Wyszecki** *Color in Business Science and Industry*, 3rd ed, p. 388. Wiley (1975).

OECF. Opto-Electronic Conversion Function. The phrase OECF has been coined to describe the characteristic of digital sensors that convert an optical image to an electronic RGB output. Not unlike Transfer Characteristic.

Painterly Aspects of Colour. The arts (painting *etc.*) and technology (film, printing and television) each take a different stance on the common subject of colour. These two disciplines meet over the home, and industrial computer, as digital techniques offer new ways to perform traditional tasks. A more common language is required.

Palette. Colour technology would refer to a colour palette as the range of colours obtainable from a set of primary colours. The same can be applied in painting, but it is more likely to mean the hand held board on which paints are brush or palette knife mixed prior to their use.

Photopic. The response of the eye to bright light and colour, generally attributed to the cone receptors in the retina.

Picture Matching. A term applied to images seen in sequence, as in film and television, where some visual continuity is expected between scene and shot changes. Picture matching is also required on the printed page.

Pixel. The smallest element in a visual display or image file.

PLUGE. Picture Line Up Generating Equipment (BBC-date). An electronic test signal to help adjust the black level of picture monitors. This was important to Picture Matching philosophy that held that the picture monitor should have its black level set as objectively as possible, and image adjustments by lighting and vision control to exposure *(etc)* are then judged looking at such a monitor set-up.

Primary, Secondary and Tertiary. The idea is that primary colours sitting at the apex's of a triangle, within a colour circle (colour diagram), are given particular colour names for paint (called pigment or subtractive mixing). These *primary* (first) colours can be mixed and so produce *secondary* (second) colours. A further mixing of these secondary colours will produce *tertiary* (third) mixtures. Continued mixing of these tertiary colours produces quite darker mixtures as eventually black is approached, which is the nature of subtractive mixing. A similar hierarchy exists for mixing another triangle of additive primary colours, but this time their tertiary state is light and desaturated as white is approached.

Printer point. A typographic measure of length. There are 72 points to 1 inch. Photoshop uses either 72/inch – called postscript or 72·27/inch – called traditional.

Printers Red and Blue. Printers red and Printers blue refer to the subtractive ink colours Magenta and Cyan. They have the spectral qualities of Magenta and Cyan, not Red and Blue.

Properties of Subtractive and Additive Primary Colours. Cyan, Magenta and Yellow are each complimentary to Red, Green and Blue as: Cyan/Red, Magenta/Green and Yellow/Blue.

Point Spread Function. (PSF). All really sharp edges and dots are blurred to some degree, even if we cannot see any blur and think they are sharp. The analysis of PSF is an objective account of why we see soft edges *&c*.

Purkinje Effect. As the eye changes from being adapted to bright light with full colour, called Photopic Vision, to low light without colour, called Scotopic Vision, there is a changeover region called Mesopic vision. At this time a change in red and blue brightness may be seen. A red and blue seen to be of similar brightness under Photopic conditions will change under Mesopic conditions, where the red darkens and the blue lightens.

Quality Tolerance and the Story Line. We cannot expect a high standard of Image Quality to be maintained *all* the time. As a story develops to engage our interest our tolerance of poor Image Quality increases (we accept poorer quality).

R=G=B. This most simple equation, sometimes called an *RGB triple*, means an achromatic grey, which can be tested for in signal terms. Photoshop Info Panel reports these signal values per pixel or 5 x 5 group of pixels

Rainbow. The prismatic separation of Sunlight into its spectral components. For a rainbow to be seen the Sun needs to be behind you and a rain cloud in front of you. The effect is most dramatic if seen against dark storm clouds, although of low resolution and low saturation.

Rayleigh scattering – Blue sky. A clear sky is blue in colour due to the preferential scattering of blue light. Lord Rayleigh (1842-1919) established that the scattering of electromagnetic radiation is affected by spherical particles of radius less than about one-tenth the wavelength of the incident radiation (sunlight). Incident sunlight is scattered by air molecules such that the scattering of blue light is 5 times greater (or more) than that of red light in the incident beam, hence the blue sky.

Rec. 709 Gamma Correction. The gamma curve promoted in Recommendation ITU-R BT.709-5, the International Telecommunication Union (ITU), *Parameter Values for the HDTV Standards for Production and International Programme Exchange*, (date 2002). This gamma curve is supposed to be built into digital camera processing.

Refresh rate. The vertical raster scan, which can be slow enough to be seen to flicker, is sometimes called the refresh rate in computer terms. In Television terms it is called the frame rate. Television has historically used interlaced scanning with a US / UK frame rate of 25 / 30 frames per second. Modern technology is now likely to provide a refresh rate (or frame rate) in the order of 50 / 60 Hz and sometimes much higher.

Relationship between CMY and RGB Colours. The two sets of primary colours RGB and CMY are complimentary to each other. This forms a good test of how well a colour circle is designed. These two sets of colours should be directly opposite each other.

Rendering Intents. There are four of these as: *Perceptual, Relative Colorimetric (Media), Absolute Colorimetric (ICC), and Saturation.* They come about because the translation from screen to print can not be exact, but instead a very good compromise. *q.v. ICC Colour Management.*

Repro. Meaning Reproduction.

Resolution, spatial. Resolution is an objective measure of what we see as sharp, its acuteness. These measures are divided into three headings as Detection Acuity – being able to see a telephone wire at 1 km distance. Resolution Acuity – being able to recognise line pairs with an angular separation of 1 minute of arc. Recognition Acuity – as tested by an opticians eye chart or a car number plate some distance down the road.

Resolution, temporal. Refers to the resolution of moving objects. Movement may be blurred, jumpy, worrying to view or simply not steady. A special sort of blur can be attributed to a slow pan that is just a little too fast.

RIP. Raster Image Processor. The RIP is based upon the Adobe Postscript language and is relied upon to translate Postscript fonts, and artwork into a raster image for exposing film and then to plate making. Recent development now omit the film stage and allow direct exposure of the printing plate.

S shaped Film Curve. Transfer characteristic or D log E curve. Traditional Film images require the use of two processes, known as negative positive working. The D Log E curve of any emulsion compresses its output density as zero density (representing black or no exposure) is approached. The same type of compression occurs at the print stage which now represents the printing paper white. The two stages of the neg / pos process both incur tonal compression, hence the S shaped overall tonal shape.

Scanning Raster. Building up the image with a spot raster left to right across the image line by line, and down the image, returning to the top and repeating the scanning process. Not unlike reading the lines of text in a book. This process involves time and certain precautions are required to maintain good temporal (movement) resolution, especially with wide screens at home. *Raster: rectangular pattern of parallel scanning lines forming or corresponding to the display on a cathode-ray tube – a Greek word said to resemble the furrows of a ploughed field.*

Scotopic. The response of the eye to very dim light where no colour is seen, generally attributed to the rod receptors in the retina.

Selenium cell. Such a cell is sensitive to light, producing a small current when illuminated. Used in light and exposure meters. Its discovery prompted early inventive thinking about Facsimile and the idea of Television.

Sharp. An image that has the subjective appearance of much detail. *q.v. Resolution.*

Sharpness Wedge. A sharpness wedge is constructed of tapering line pairs that enable manual focus to be more easily found. By looking along the wedge we may identify where sharpness falls off, or where a pattern occurs indicating interference with a scanning pattern, pixel structure or the dot structure of halftone repro.

Signal to Noise Ratio. A measure in electronics of the wanted signal to the unwanted signal, called noise. Such noise places a limit on the ISO sensitivity rating of digital camera sensors.

Soft Proof. An image seen on screen as opposed to a hard copy in print.

Spectral Distribution. The amount of each wavelength contributing to a colour. The most fundamental description of a colour.

Spectroscope. The spectroscope is an instrument for analysing light and revealing the contributing wavelengths (colours) that constitute a given colour. Today they are complicated instruments that produce data in computer form. The instrument used by Wright (and others) to analyse the eye of the subject being tested, presented all the colours of the spectrum in their most saturated form – quite beautiful to see.

sRGB Colour Space. The colour space intended to match screen displays, therefore best used for images to be seen on the Internet *&c*.

Standard Illuminants. The electric tungsten filament lamp became the standard for illumination as the candle and oil lamp fell into disuse. However, the oil lamp prompted the design and manufacture of Wratten filters for light conversion (Mired filters) from one colour to another, especially for the motion picture (film) industry. A form of artificial daylight standard was wanted and was initially provided with a two-part liquid colour filter, for scientific colorimetry, converting tungsten to daylight. The film industry used tungsten lighting (at 3400K) and on occasion required daylight (at 5500K). The filter wanted in the above example is the blue looking Wratten 80B filter of minus 112 mireds. Fluorescent and gas discharge lighting now provide a range correlated colour temperatures, but not always of a good colour rendering index.

***Stochastic screening*.** A modern half tone process using random marks rather than regular dots. By dictionary definition, the word stochastic is; *determined by a random distribution of probabilities.* Demonstration prints and some high class advertising are impressive, in particular Agfa Cristalraster™ Technology. It is very beautiful indeed, not unlike the old Collotype process that used a grain structure derived from reticulated gelatine.

Television, the word. Constantin M. Perskyi first used the word *television* in 1900. See **Wilson,** J. C. *Television Engineering*. Sir Isaac Pitman & Sons Ltd (1937). I quote verbatim from page one:
" … The British Patent Office, until 1908, employed the term "telescopy" and Ribbe [3] *in 1904 employed the term "teleautography" in a very similar sense. In 1900, however, a Continental worker* [Perskyi] *seems to have been the first to coalesce the sections of the present term from the Greek and Latin roots, and so formed the word "tele-vision."* [4] *Apparently without knowledge of the previous existence of this word.*

Test Chart Illumination. One of the criticisms levelled at the use of test charts is that the results are not reliable, they are variable in result. The mechanics

3. **Ribbe,** Paul : Brit. Pat. No. 29428/04.
4. **Perskyi,** M : Annexes, Congres Internationale d'Electricite, 18th-25th August, 1900, pp. 54-6.

of illumination, reflection from the chart, and collection of the reflected light can vary to some degree depending upon the specular / diffuse geometry of the lighting set-up. For test results to be consistent at one site a fixed lighting geometry is required (using one test chart). For test results to be comparable between different sites (using different test charts) then the comparative specular / diffuse nature of the test charts requires some degree of similarity.

Testing Cameras. Once-upon-a-time the testing of a new camera might mean sending the camera body to the camera body expert, the lens to the lens expert and the film to the film expert, each well qualified in there own field. The digital camera revolution has upset that independence of approach by building in the sensor that now replaces film and often including a fixed zoom lens. The testing of digital cameras now exposes the tester to digital techniques and the science of colorimetry. This can conveniently be ignored by noting that the camera works, by and large as the manufacturer wanted, producing "shoot outs" between models that create their own high or low standards of lowest common image denominator for comparison and rating against each other. Any serious testing should have the camera set-up as if the results were going to be published, or presented as an exhibition entry. All that should be presented beside any automatic output that is not up to a usable standard.

The Shape of a Colour Space. There are broadly three types of space occupied by colour spaces. There is the regular geometric space such as a cone or pyramid, into which colours are set. Then there is the shape derived from practical colour samples, such as the Munsell Color Atlas. Finally there is the colour space occupied by the eye, derived from the CIE 1931 work. [5]

The Weber Fechner Fraction explains why we, as viewers, are more sensitive to small changes in the value of dark grey tones than among the highlights. The fraction is $\Delta B/B$, where ΔB (delta B) is the small fraction of B (brightness) that we are able to detect. This fraction is in the order of 0·01. We are therefore more sensitive to small changes at or near to black level than at white level.

Three Attributes of Colour. Hue, Brightness and Saturation lead to the use of colour solids to represent them. There is, of course, a problem in representing these three dimensions on paper. Traditionally the colour circle has omitted to show the brightness attribute.

Tone. The word tone is used in discussions relating to the brightness attribute of colour. It is not particularly useful to refer to flesh tones when colour or hue is meant.

Transfer Characteristic. The transfer of data through a device, from input to output, is not always linear. The CRT is a case in point where the characteristic is a power law. The light output is the input voltage raised to the power of Gamma (γ) where gamma is close to 2·2. *q.v. OETF.*

5. **Wyszecki & Stiles.** *Colour Science*. J. Wiley (1967). See Figure 3.22, p. 342.

Use of Warm / Cool as a Colour Adjective. The use of warm / cool is quite subjective but non-the-less interesting. It relates to the notion of Colour Temperature which has a red / blue bias. When small colour differences are being looked at, in the red / blue direction it is easier to report that something is a little warmer, or cooler without being specific about the actual attributes of colour. The warm / cool nomenclature cannot help a green description, other than by painterly habit. *q.v. Colour Temperature.*

Value. A term generally used to describe a numerical quantity. In the Munsell Color Atlas the word Value is used instead of Brightness, as Hue, Value and Chroma (in that order H, V, C for Munsell). An 8 bit digital pixel will have a value between zero and 256, or converted to between zero and 100.

Vector and Pixel files. Two types of file are available for drawing images. The Vector file, or object, uses mathematical points to define where lines start, finish and how they curve in between (as in Adobe Illustrator and CorelDraw). The Pixel file being composed of pixels pre-determines the start, finish and path of lines to the nearest available pixel (as in Adobe Photoshop and all digital cameras). The resolution of Vector files are not themselves limited: the devices they are sent to limits their displayed resolution. Pixel files are inherently resolution limited: they depend upon their pixel count in pixels per unit length.

Visual acuity is the capacity to distinctly see fine details that have a very small angular separation.

Workflow. Refers to the order in which processes are conducted. For the wet silver processes the idea of development, stop and fixing bath was endemic to nearly every job. It fitted into other more rigorous procedures. If you undertook archival processing then the workflow might be many more baths. We never referred to workflow then, but we could always see the dishes *etc.* that were involved. Today the idea of workflow for digital images has caught on because the processes are numerous, clever and new, computers are not always that user friendly, and most of the work is invisible in the form of a file or layer – somewhere. We can be reminded of a workflow in the simple block diagram representation of a process.