GEODEZJA I KARTOGRAFIA
t. L, z.2 , s.99 - 118 (2001)

Joanna Puszkarska

Institute of Photogrammetry and Cartography
Warsaw University of Technology
(00-661 Warszawa, Pl. Politechniki 1)

Influence of white point colour temperature set-up on cartographic pictures appearance displayed on CRT monitor

The experiment conducted with the NOKIA Multigraph 447Xpro presented in this article shows that a change of colour temperature results in a change of general colour appearance displayed on the CRT screen. However, it does not considerable affect chromatic coordinates of RGB monitor primary stimuli. The change of a produced colour appearance which it causes can have a considerable influence on colour matching – at the stage of map designing on the screen. Discordances among given colour temperature set-up in the screen menu in relation to computed by means measurements of colour temperature are shown. Of computing and Methods of colour temperature calculating and setting are given. It has been stated which channel has a critical (decisive) influence on a colour temperature set-up.

In cartography colour plays two roles – in the first place it is an information vehicle and an important element which influences visual attractiveness and aesthetics of a map. At the stage of map graphics designing an important part is played by determination and composition of colour. The cartographer, while matching map colours, uses available to him colour gamut and relies on his eyesight. The available colour gamut depends on the work instrument. Nowadays such instruments are most often computers, which support cartographic designs. It is on the screen where the cartographer designs maps colours, evaluates visible differences between them, checks their legibility, their univocal character and easiness of their perception. The way in which a computer displays colours has a major influence at this designing stage, and so on the final maps effect.

Primary colour stimuli of the monitor CRT (cathode-ray tube) are light emissions of three kinds of phosphorous. These phosphorous are able to emit light when stimulated by a flow of electrons incident on them. They are matched in such a way that they emit light of three different ranges of wavelength, that is ranges of red, green and blue waves. That is why they can be briefly described as RGB (R-red, G-green, B-blue). Therefore, a CRT screen is a source of light. Mixture of colours on it means an additive mixture of three primary stimuli RGB. Colours possible to achieve are dependent on these stimuli. However, the way in which a computer-controlled monitor displays these primary colour stimuli is a composed process. One of the elements of this process is white point colour temperature (T_c) of the screen. To a large extent it is responsible for the colours displayed on the screen. Set up and colorimetric characterisation of this element have a great influence on a quality of displayed picture.

Colour temperature is defined as the blackbody radiator temperature, at which the blackbody emits light with given chromaticity coordinates. Relationship between the blackbody radiator and the chromaticity of the light emitted by it was determined by Planck and is commonly called the Planckian locus. The Planckian locus consists of points, placed on a chromaticity diagram, representing chromaticity of emitted light for different colour temperatures. The Planckian locus is presented in Fig.1.

The idea of colour temperature T_c appears also in a colorimetric understanding. Among others, it defines white point colour temperature and various light sources. In this way their *hue* is characterised. In references to these objects, temperature does not define their warmth but their chromaticity. It is defined as a blackbody radiant temperature, whose radiation has the same chromaticity as that of a given stimulus. For stimuli whose chromaticities lie near, but not exactly on, the Planckian locus, the colour of the stimulus is usually characterized by a blackbody temperature release emitting light having the most similar colour to the colour of the Planckian radiator whose perceived colour most closely resembles that of a given stimulus seen at the same brightness and under specified viewing conditions. The recommended method of calculating the correlated colour temperature of a stimulus is to determine on the CIE *uv* (or CIE *xy*) chromaticity diagram the temperature corresponding to the point on the Planckian locus that is nearest to the point representing the stimulus.

The *uv* diagram is obtained by plotting:

$$u = 4X/(X+15Y+3Z), \qquad \upsilon = 6Y/(X+15Y+3Z)$$

While the CIE *xy* diagram by plotting:

$$x = \frac{X}{X+Y+Z}, \qquad y = \frac{Y}{X+Y+Z},$$

where : X, Y, Z – are the tristimulus values determining the position of the point, which represents a given colour in the CIE *XYZ* space [2].

The concept of correlated colour temperature is only valid for the stimuli whose chromaticities are reasonably close to the Planckian locus; no formal limits of "closeness" have been specified by the CIE, but accepted practice is to determine correlated colour temperatures for commonly used "white" light sources and various aspects of daylight.

In Colorimetry light references are widely used. The most common are the ones based on, so called "CIE daylight locus". They are marked with the symbol *D* (daylight). This locus has been created through interpolation of points representing chromaticities measured at different times of the day on the surface of the Earth and measured in different directions. On the basis of these measured chromaticity coordinates correlated colour temperatures were determined. Light references are defined by stating their colour temperature, (for example, *D*65-daylight with the colour temperature 6500 K, *D*50-daylight with the temperature 5000 K, etc). Therefore, CIE daylight locus brings together points representing daylight chromaticities with different colour temperature.

- Daylight from the sun plus the total sky incident on a horizontal surface ranges in correlated colour temperature from about 5000 K to 7000 K regardless of cloud coverage (i.e., clear to overcast sky). These are medium colour temperatures.
- Daylight from the north sky or, equivalently, daylight from the total sky but with the sun excluded, has correlated colour temperature above 7000 K. These are high colour temperatures:

the correlated colour temperature is determined more accurately by the amount of cloud coverage. For a clear north sky, very high correlated colour temperatures of 40 000 K and higher can be reached. The sky covered with clouds has colour temperature from 5000 K to 7000K (among other things the sky completely covered excluding the sun at minimum luminance 0.2-0.5 cd/m^2 has correlated colour temperature of 6500 K).

- Daylight from the sun disk alone or daylight from the sun disk at low altitudes plus sky generally constitute spectral power distributions corresponding to correlated colour temperatures below 5000 K. These are low colour temperatures.

At present it is more common to determine colour temperature not on a basis of Planckian locus, but on the basis of CIE daylight locus. The way to determine white point correlated colour temperature of a screen and daylight locus is described more accurately further on.

CRT monitor white point colour temperature

Colour temperature T_c notion is also applied to computer-controlled CRT display systems. In this case colour temperature determines percentage participation of RTG monitor three primary stimuli in white colour. Displayed white colour, for the given percentage set-ups, will have chromatic coordinates corresponding to chromaticity of CIE daylight reference at given colour temperature (K). This temperature is defined as monitor colour temperature. Colour temperature is sometimes called "colour balance".

From the physical point of view a diminution of percentage participation in white of any of the three RGB monitor primary stimuli, will cause a diminution of the given stimuli maximum video voltage. Video voltages are analogue output signals from converter DAC (digital to analogue converter). This value appears in a linear relationship between DAC normalized digital values *d* and obtained at the converter output video voltage values υ. This relationship is a part of a model GOG (gain – offset - gamma)[1] and can be expressed by the following formula:

$$\upsilon = (\upsilon_{\max} - \upsilon_{\min})\left(\frac{d}{2^N - 1}\right) + \upsilon_{\min}$$

where:

υ – DAC converter output video voltage,

$\upsilon_{\max}$ – maximum video voltage, its value depends on a chosen percentage share in white of the given stimulus,

$\upsilon_{\min}$ – minimum video voltage,

d – digital value determining a stimulus level ranging from 0 to (2^N-1), (N – number of DAC bits).

The lower the value of the maximum video voltage, $\upsilon_{\max}$ is, the lower voltage CRT video will reach the amplifier. Subsequently, this changed value is nonlinearly projected on the luminance value of monitor irradiating phosphors. A change of maximum video voltage values causes a change in the whole appearance of a picture displayed on the screen.

Changes of colour temperature in the screen white point result in essential consequences of the observed picture quality. Chromaticity coordinates (*xy*) of RGB monitor three primary stimuli in reality are not subject to a greater change, however; their luminance (*Y*) changes in a decisive way. These changes are especially great in relation to red (R) and blue (B) stimuli.

In order to illustrate colour temperature influence on the picture appearance displayed on the monitor we will assume that colour temperature set-ups available in the monitor menu provide in fact a display of white with such a colour temperature. It will be verified hereafter. We will consider two extreme colour temperatures available in the CRT (NOKIA Multigraph 447 XPro) monitor menu set-ups, T_c = 5000 K and T_c = 10000 K. Suggested set-ups of RGB monitor primary stimuli percentage participation in white colour are as follows: for T_c = 5000 K : R = 100% , G = 50% and B = 12% ; for T_c = 10 000 K : R = 25% , G = 50% and B = 81% (see Fig. 2 and 3).

A colour temperature change from T_c = 5000 K to T_c = 10 000 K is obtained by the red stimulus participation change from 100% to 25% and by the blue stimulus participation from 12% to 81%. The green stimulus remained unchanged. This set-ups change influences a luminance value of phosphors – Fig. 4. Emission ratio value *E* represents a stimulus luminance value. The higher ratio is, the higher stimulus luminance. As you can observe, while changing colour temperature from lower to higher, maximum luminances of red phosphor (R) decrease and of blue phosphor (B) increase.

A change in the emission ratios causes tristimulus *XYZ* values changes of these stimuli. After determination of the chromatic coordinates *xy* it emerges that mainly the lightness (*Y*) values of stimuli changed. Their chromaticities (*xy*) remained unchanged within measuring and calculations error. The results are compiled in the Table1.

Table 1. Setting-up of CIE *XYZ* tristimulus values and the computed on their basis chromaticity *xy* coordinates of the three primary RGB monitor stimuli for two monitor colour temperatures. T_c = 5000 K and T_c = 1000 K

stimuli:	T_c [K]	CIE *XYZ* tristimulus values			chromatic coordinates *xy*	
		X	*Y*	*Z*	*x*	*y*
R	5 000	36.000	19.915	2.555	0.616	0.341
	10 000	22.630	12.503	1.533	0.617	0.341
G	5 000	26.475	53.956	8.620	0.297	0.606
	10 000	26.102	53.695	8.445	0.296	0.608
B	5 000	12.804	6.427	65.115	0.152	0.076
	10 000	18.691	9.158	97.257	0.149	0.073

CIE chromaticity diagram *xy* is particularly useful for demonstrative explanation of reason for the whole change of the displayed picture appearance at the moment of the monitor colour temperature T_c set-up change. As it is shown in the table, the colour temperature change does not modify in an essential way chromaticity coordinates of RGB monitor three primary stimuli. However, it changes its brightness.

According to the *centre* of *gravity law* of colours mixing on the CIE chromaticity diagram *xy* - result mixture colour lies on the line joining two mixed stimuli. If two colour stimuli are mixed: C_1 and C_2 with chromaticity coordinates (x_1, y_1) and (x_2, y_2), respectively and in the mixture m_1 luminance units of colour C_1 and m_2 luminance units of colour C_2 take part, then chromaticity result colour can be computed according to the following formula [3]:

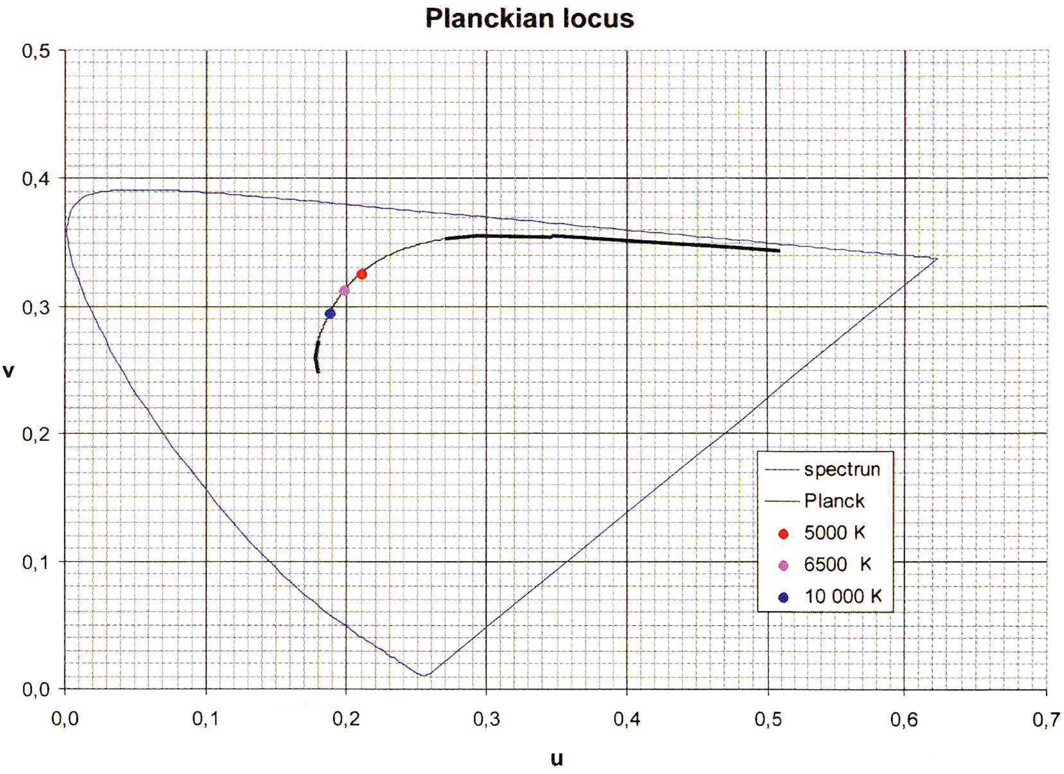


Fig. 1. Planckian locus on CIE uv chromaticity diagram

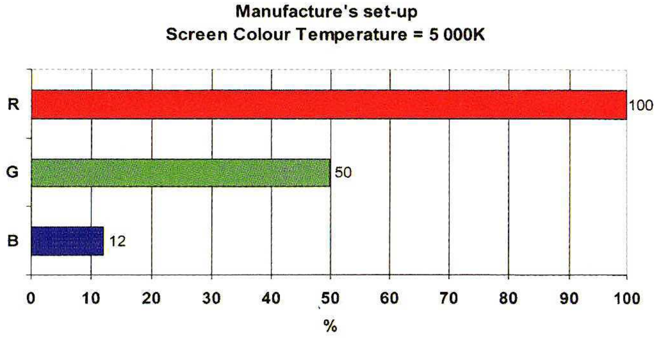


Fig. 2. Percentage participation of CRT monitor three primary stimuli for colour temperature $T_c = 5000$ K - producer's set-ups (R = 100%, G = 50%, B = 12%)

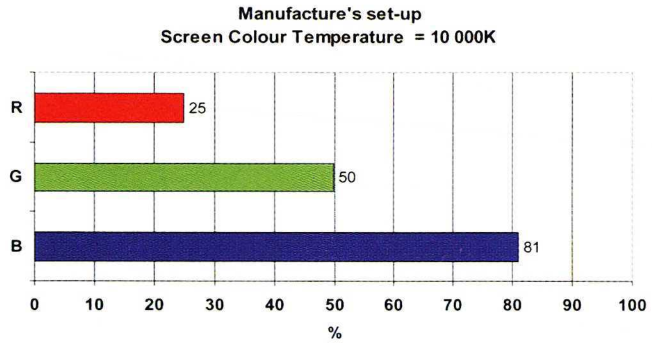


Fig. 3. Percentage share of CRT monitor three primary stimuli for colour temperature T_c = 10 000 K - producer's set-ups (R = 25%, G = 50%, B = 81%)

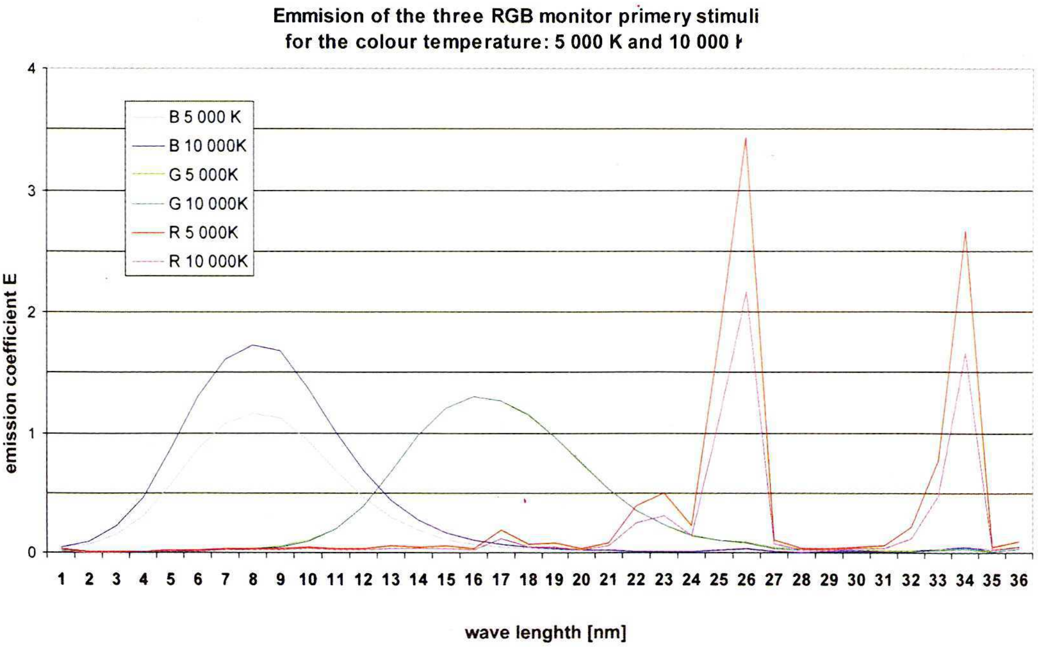


Fig. 4. Emission of the three RGB monitor primary stimuli for the colour temperatures: T_c = 5000 K and T_c = 10 000 K

$$x = \frac{\frac{m_1 x_1}{y_1} + \frac{m_2 x_2}{y_2}}{\frac{m_1}{y_1} + \frac{m_2}{y_2}} \quad \text{and} \quad y = \frac{\frac{m_1 y_1}{y_1} + \frac{m_2 y_2}{y_2}}{\frac{m_1}{y_1} + \frac{m_2}{y_2}} = \frac{m_1 + m_2}{\frac{m_1}{y_1} + \frac{m_2}{y_2}}$$

The geometrical interpretation of the two colour stimuli C_1 (x_1, y_1) and C_2 (x_2, y_2) mixture is that the point C_3 is on the line joining the points C_1 and C_2, in the ratio:

$$\frac{C_1C_3}{C_2C_3} = \frac{m_2 / y_2}{m_1 / y_1};$$

This means that C_3, result colour, is at the centre of gravity of weights m_1/y_1 and m_2/y_2 at C_1 and C_2 colour, respectively.

Since $m = kY$ where k is constant, then the above mentioned proportions will be real when suitable lightness values Y_1 and Y_2 are inserted instead of m_1 and m_2 values in the above formulae. Then the ratio of C_1C_3 to C_2C_3 segments can be expressed by the formula:

$$\frac{C_1C_3}{C_2C_3} = \frac{Y_2 / y_2}{Y_1 / y_1}$$

From the above formula results that length of the segment joining the point representing result colour and mixed stimulus colour point on the chromaticity diagram is inversely proportional to Y lightness value of this stimulus. In other words, the brighter the stimulus is, the closer to it is result mixture colour with its participation. The geometrical interpretation of the centre of gravity law is presented in Figure 24 in appendix 3.

The colour temperature change T_c of the screen white point causes brightness value of a red stimulus Y_R and a blue stimulus Y_B, and then:

- chromaticity coordinates of RGB monitor primary stimuli should not be subject to an essential change,
- chromaticity coordinates of derivative colours which are mixtures of primary stimuli will be changed, while:
  - if a high colour temperature T_c is set up (over 7000 K), then the brightness value of the primary blue stimulus Y_B increases while the brightness value of primary red stimulus Y_R decreases. It causes a change of chromaticity coordinates of all colours, which were created as a result of additive mixture of these stimuli. All points representing derivative colours in relation to a red stimulus R and blue stimulus B are moved towards the blue stimulus. An decrease in brightness value of blue stimulus causes increase in its weight, while increase in the brightness value of red stimulus causes a decrease in its weight. Thus, the centre of gravity visibly moves towards primary blue stimulus B. All colours gravitate towards blue colours.
  - if a low colour temperature is set-up T_c (5000 K and less) the process is opposite. The weight of the red primary stimulus R increases while the weight of the blue primary stimulus B-decreases (brightness value Y_R increases, and Y_B decreases). Thus, the centre of gravity is moved towards the red primary stimulus R. All colours gravitate towards red colours.

Figures 5 and 6 presented below simulate colour appearance of a picture displayed on the screen at two different set-ups of colour temperatures $T_c = 5000$ and $T_c = 10\,000$ K. Simulations of the colour gamut were executed using Photo Shop programme. In this programme using a function "colour balance" participation of red and blue colour in the colour was changed. It needs to be stressed that this change applied only to the change in the digital value of these colours participation in the picture. This intervention did not change the way of this picture display but it changed the picture itself. That is why this illustration was called a simulation.

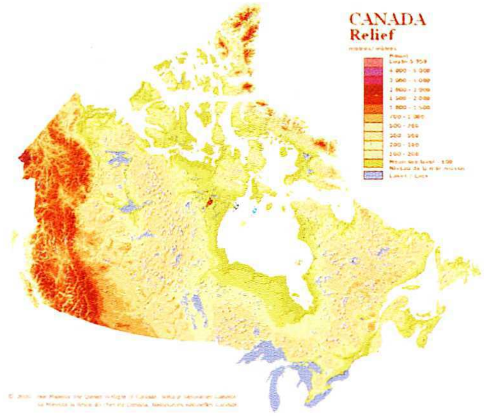
The above illustrations show how significant influence the choice of colour temperature can have on the displayed picture appearance. The consequences of this choice can be essential during the map designing on the screen. Let's assume that a cartographer's monitor has been set up at a high colour temperature (over 7000 K). It is characterized by a cold projection of colours. In this case if a cartographer wants to achieve a vivid warm red colour he will have to rely on his eyesight and choose the colour with a great participation of the red primary stimulus *R*. Only then, it will seem to him red enough. Let's assume that the cartographer's monitor has been set up at low colour temperature (below 5000 K) – characterized by a warm projection of colours. In this case, even for a small amount of the red primary stimulus *R*, the colour observed on the screen will be visibly red. In relation to the chosen colour temperature, in one case the red colour of the designed map element will be characterized by very high value of the primary red stimulus *R*, in the other case –very low. It will have a completely different digital record; consequently, it will be projected in a different way in each device processing colour, for example in a printer or on a different monitor.

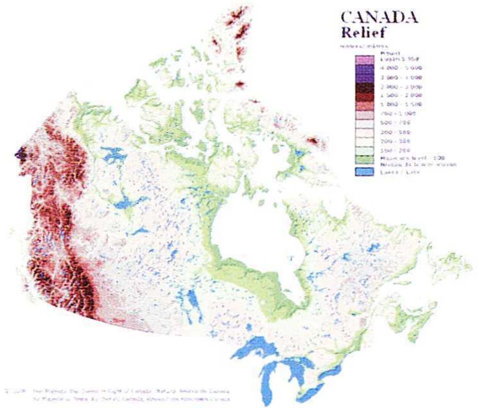
In printing and computer graphics screen colour temperature $T_c = 6500$ K is considered the best. It corresponds to a standard colour of the daylight *D*65 – daylight from the north sky with the total cloud coverage with the sun exclusion at the minimum luminance 0.2-0.5 cd/m^2. It is considered that this light ensures a very "natural colours appearance", natural because we are used to looking at colour objects in such a light.

While choosing colour temperature one can be guided by a colour gamut, which can be achieved by a particular technology of colour reproduction. For example for offset print it can be colour temperature achieved using particular triad dyes. For triad dyes - which form a cold triad –it would be advisable to choose colour temperature higher than 6500 K, which as a result gives a colder picture on the screen, more similar to the one obtained with the cold triad use. Similarly, if the picture is to be printed with warm triad, then it is good to choose the colour temperature 6500 K and a little lower, which gives as a result a picture on the screen similar in terms of colour gamut to the warm colour achieved in print by the warm triad.

CIE daylight locus

It is a locus combining chromaticity points of standard CIE *D* daylight sources of different colour temperatures. It is very similar to Planckian locus. There is a relationship between the correlated temperature T_C of illuminant *D* and the chromaticity coordinates of this illuminant (x_D and y_D) defined by the following equations [3]:





*)

Fig. 5. Low colour temperature (below 5000K)- the picture seems to be lit by warm yellow or red light.

Fig. 6. High colour temperature (above 7000 K) – the picture is very light, lit by cold bluish light.

---

*) Free examples of maps from Internet http://www.omnimap.com

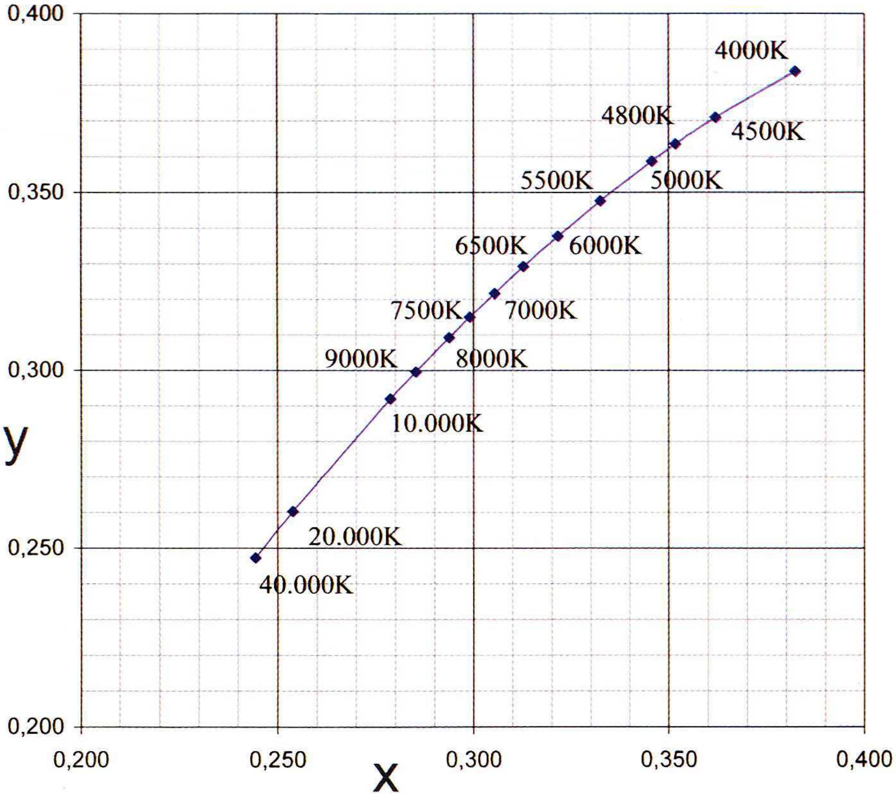


Fig. 7. CIE daylight locus on a fragmentary CIE x, y chromaticity diagram

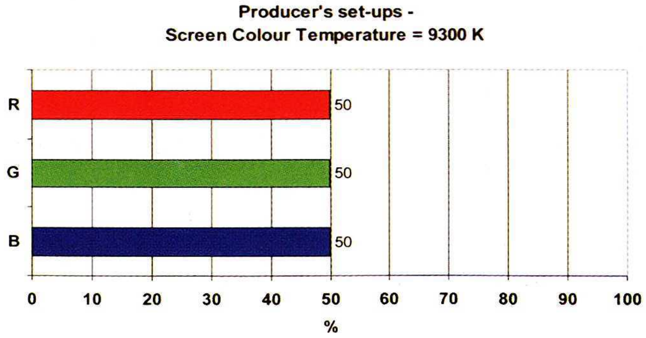


Fig. 8. Percentage participation of three primary CRT monitor stimuli for colour temperature 9300 K - producer's set-ups

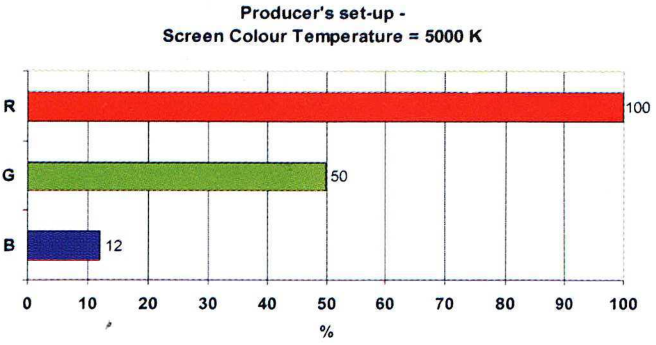


Fig. 9. Percentage participation of three primary CRT monitor stimuli for colour temperature 5000 K - producer's set-ups

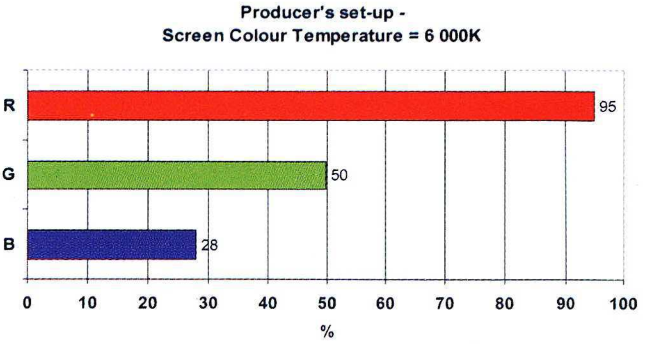


Fig. 10. Percentage participation of three primary CRT monitor stimuli for colour temperature 6000 K - producer's set-ups

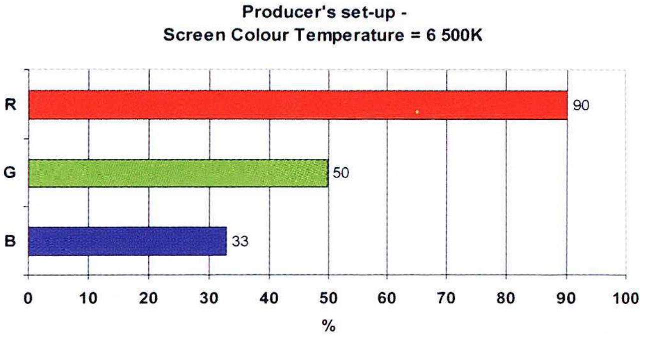


Fig. 11. Percentage participation of three primary CRT monitor stimuli for colour temperature 6500 K - producer's set-ups

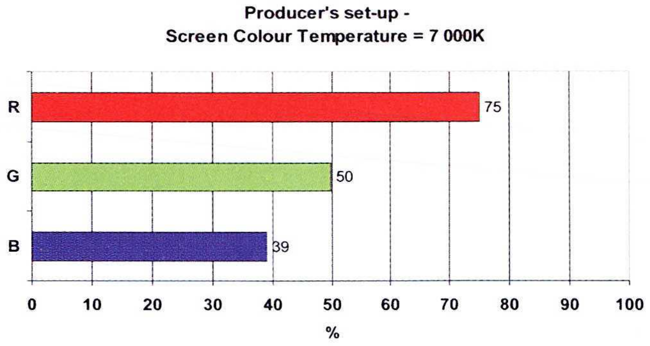


Fig. 12. Percentage participation of three primary CRT monitor stimuli for colour temperature 7000 K - producer's set-ups

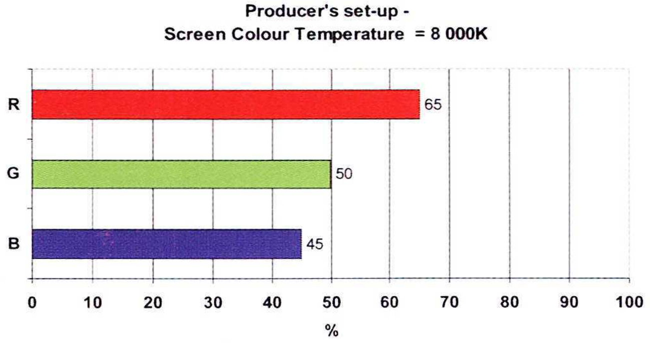


Fig. 13. Percentage participation of three primary CRT monitor stimuli for colour temperature 8000 K - producer's set-ups

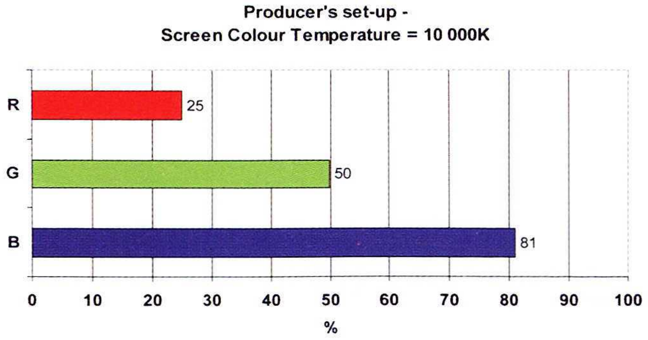


Fig. 14. Percentage participation of three primary CRT monitor stimuli for colour temperature 10 000 K - producer's set-ups

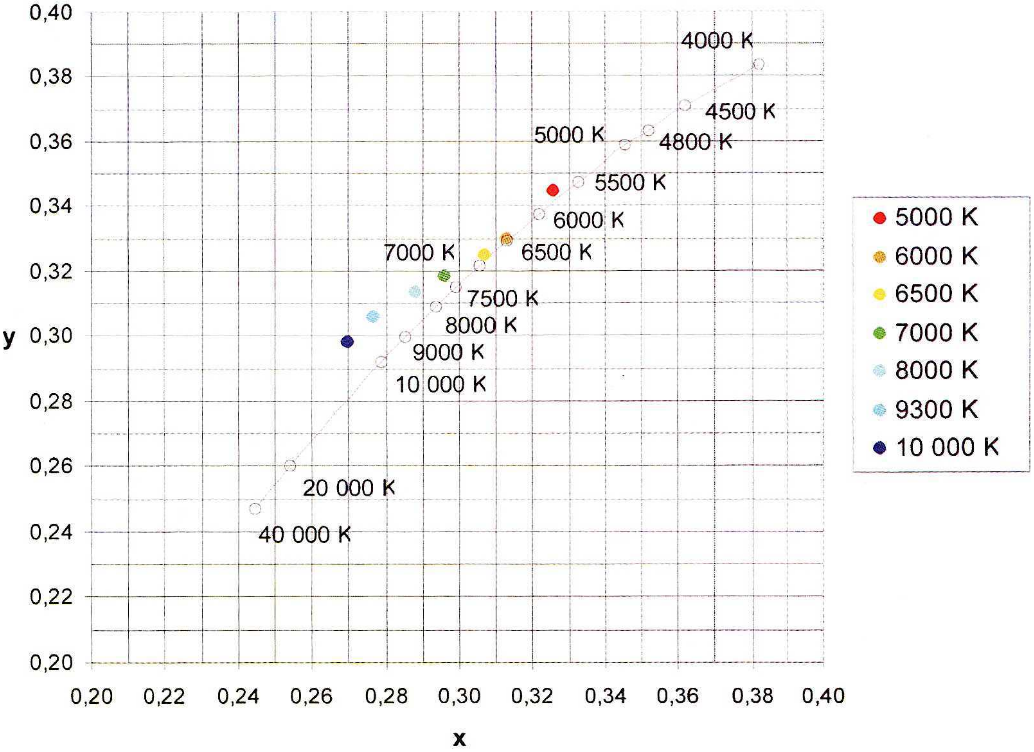


Fig. 15. The position of the determined white points in relation to the CIE daylight locus. Projecting these points along the isotemperature lines onto the CIE daylight locus colour temperatures for white can be achieved, which those points represent.

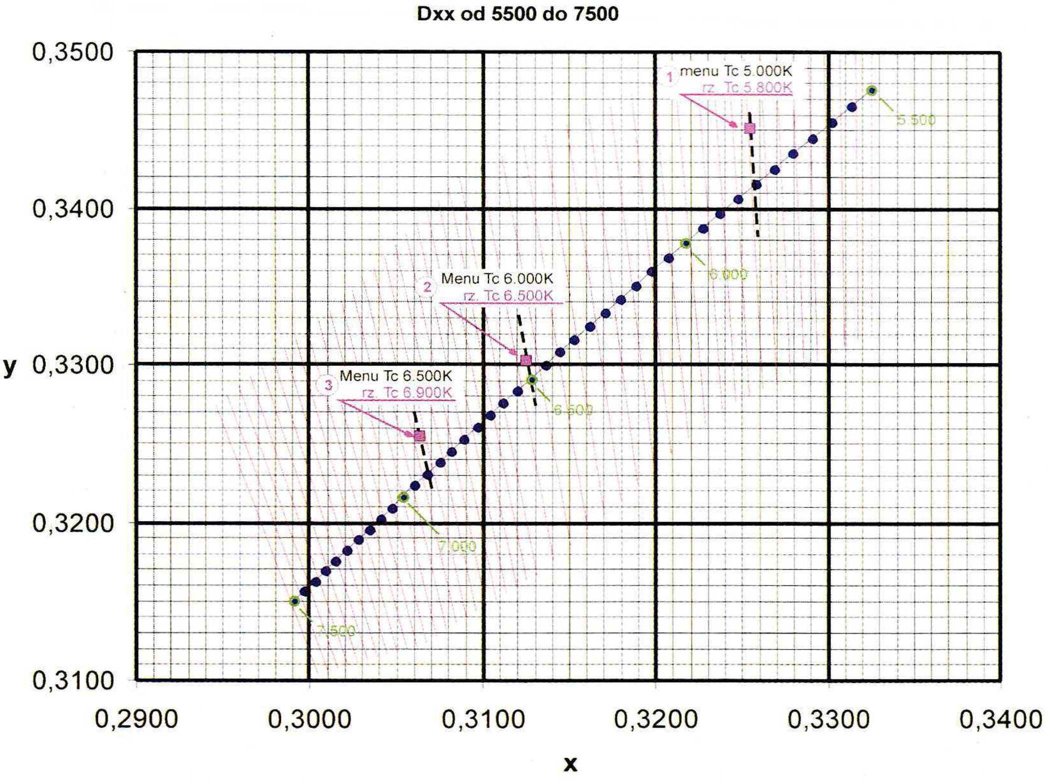


Fig. 16. Illustrates determining of colour temperatures for points: point 1 – 5000 K, point 2 – 6000 K and point 3 – 6500 K, blue points – they represent points of different colour temperatures on the CIE daylight locus points marked with the magenta squares – represent computed coordinates *x*, *y* of the displayed white colour at different colour temperature set-ups in the monitor menu respectively: point 1 –5000K, point 2 – 6000K, point 3 – 6500K) In addition to the colour temperature values from the menu there are also the interpolated from the diagram values of colour temperature obtained as a result of the measurement. They are referred to as “rz. T_C” (i.e. actual T_C) red lines – directions of isotemperature lines (calculated by Kelly in 1964) black dashed lines – the projection lines of the measured points onto the CIE daylight locus

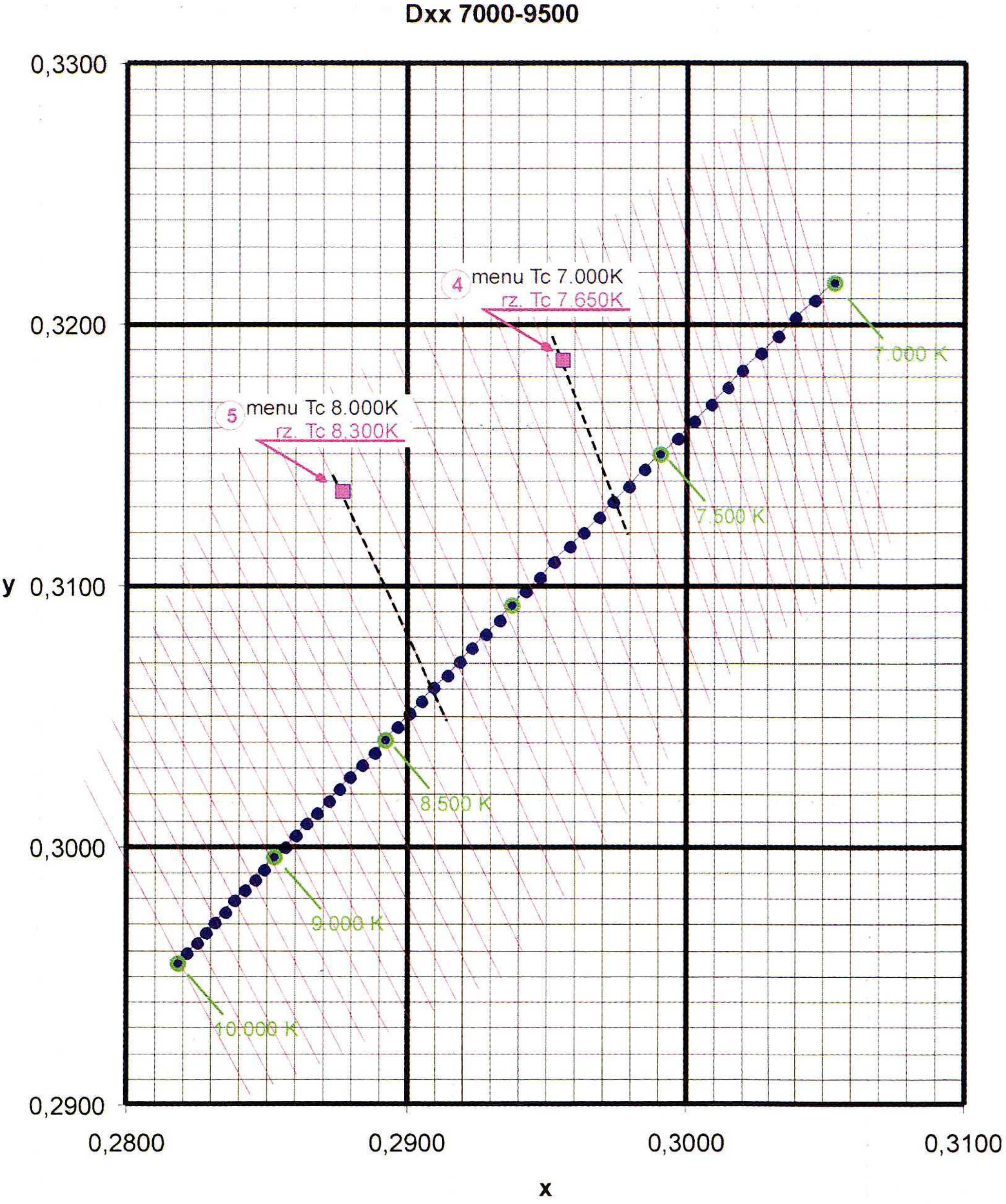


Fig. 17. See notes for Fig. 16

Dxx od 9000 do 10 100

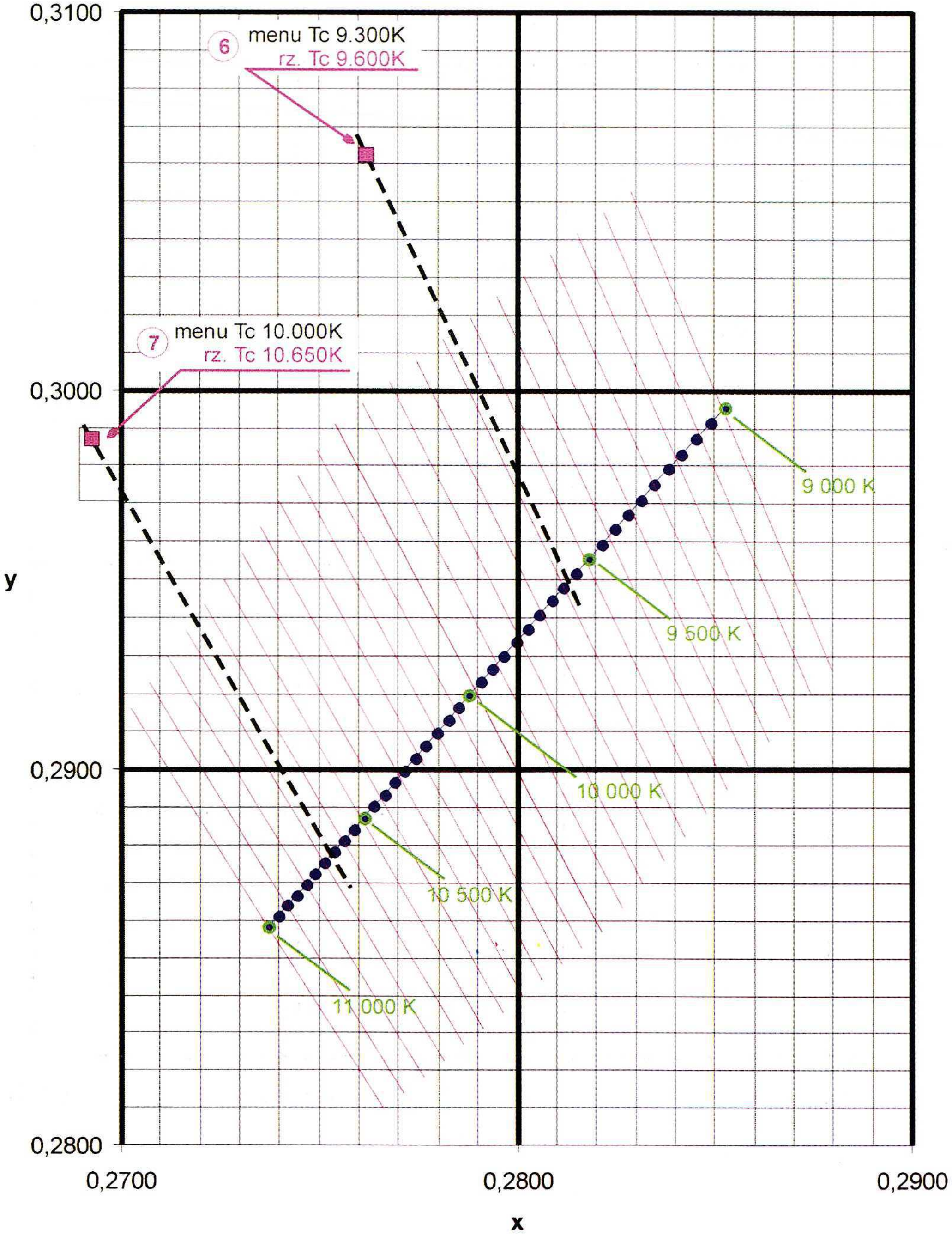


Fig. 18. See notes for Fig. 16

For from about 4000 K to 7000 K:

$$x_D = -4.6070\frac{10^9}{T_C^3} + 2.9678\frac{10^6}{T_C^2} + 0.09911\frac{10^3}{T_C} + 0.244063$$

For correlated colour temperatures from about 7000 K to 25000 K:

$$x_D = -2.0064\frac{10^9}{T_C^3} + 1.9018\frac{10^6}{T_C^2} + 0.24748\frac{10^3}{T_C} + 0.237040$$

The chromaticity coordinate y_D is computed for x_D values according to the following equation:

$$y_D = -3.000x_D^2 + 2.870x_D - 0.275$$

By inserting the temperature values [K] into the above mentioned equations we receive the set of points with chromaticity coordinates *x, y* (Table 2).

Table 2. The computed values of chromaticity coordinates *x, y* for different colour temperatures [K]

T	x_D	y_D
4000	0.3823	0.3838
4500	0.3621	0.3709
4800	0.3519	0.3634
5000	0.3457	0.3587
5500	0.3325	0.3476
6000	0.3217	0.3378
6500	0.3128	0.3292
7000	0.3054	0.3216
7500	0.2991	0.3150
8000	0.2938	0.3092
9000	0.2853	0.2996
10000	0.2788	0.2920
20000	0.2539	0.2603
40000	0.2444	0.2472

A graphic illustration of the CIE daylight locus is shown in Fig. 7. The locus is a result of joining the points of computed chromaticity coordinates for different colour temperatures ranging from 4000 K to 40000 K.

Since the chromaticity coordinates of the different considered white lights do not exactly lie on the locus, it is essential to know, at least approximately, the direction of isotemperature lines. These lines provide information about how to project points of defined coordinates *x, y* onto Planckian locus; with a slightly lesser accuracy they can be used for projecting onto CIE daylight locus (see: Fig. 16, 17, 18). They were determined in 1936 by Judd and since in 1936 a more uniform colour space was introduced (CIE LUV), they were computed again by Kelly, in 1964.

Determining of screen colour temperature

Most monitors of average and high quality make it possible to interfere in colour gamut and colour temperature set-up. They are producer calibrated for the given colour temperature, e.g. for NOKIA monitor the colour temperature is 9300 K. This calibration means producer's equalization for this temperature of the participation of three RGB monitor primary stimuli in white colour as it is shown in Fig. 8. The following pictures represent nominal set-ups of stimuli percentage participation for different colour temperatures, which can be chosen from the monitor menu: 5000 K, 6000 K, 6500 K, 7000 K, 8000 K, 10000 K. (Fig. 9-14).

The colour temperature set-ups of the monitor menu presented on Fig. 8-14 contain a record of the primary RGB stimuli percentage participation in white colour. White colour is achieved through maximum digital values $d = 225$ for each channel (i.e. R = 255, G = 555, B = 255). Thus, RGB stimuli percentage participation in white colour defines the maximum video voltage possible to achieve for each of RGB channels. Selecting colour temperatures from the monitor menu means choosing the maximum video voltage for each channel. However, it is not certain whether or not they guarantee a display of white of the set colour temperature.

In order to verify this regularity, the chromaticity coordinates (x, y) of white colour displayed on the screen, for which the given colour temperature has been selected from the monitor menu, are calorimetrically measured. On the basis of the measured chromaticity coordinates it is possible to determine the actual colour temperature of the screen for the maximum video voltage selected set-up.

Determining of screen colour temperature

It consists of:

- measuring chromaticity coordinates (x, y) of the displayed white colour R = 255, G = 255, B = 255,
- plotting of the point with these coordinates onto the chromaticity diagram xy of CIE white light locus,
- projecting that point onto the locus along isotemperature lines,
- interpolation of the correlated colour temperature for this point.

Determining of the screen colour temperature was conducted for NOKIA Multigraph 447Xpro monitor. For displaying white colour standard Windows system colour set was used. A GretagMacbethTM Spectrolino colorimeter with measurement optics 45°/0°, sampling every 10 nm within the range from 380 nm to 730 nm. GretagMacbeth KeyWizard 2.1 software was also used.

1. The white colour (R = 255, G = 255, B = 255) was displayed on the screen of the stabilised and warmed up (after a few-hour work) monitor,
2. The colour temperature $T_C = 5000$ K was set in the monitor hardware menu
3. After one minute the Spectrolino colorimeter was used to measure chromaticity coordinates xyY five times; it was set as follows: Observer 2°, the reference white – the white standard for which the measuring device was producer's calibrated, filter – none, measuring mode – emission, photometric mode – computing lightness value Y performed in relation to the reference white lightness,

4. The average values of the measured chromaticity coordinates *x, y* as well as average measuring errors m_x, m_y, m_Y, were determined using the following formulae:

$$m_x = \pm\sqrt{\frac{\sum_{i=1}^{i=n}\left(\bar{x}-x_i\right)^2}{n}}\,; \qquad m_y = \pm\sqrt{\frac{\sum_{i=1}^{i=n}\left(\bar{y}-y_i\right)^2}{n}}\,; \qquad m_Y = \pm\sqrt{\frac{\sum_{i=1}^{i=n}\left(\bar{Y}-Y_i\right)^2}{n}}$$

where: x_i, y_i, Y_i represent the measured values *x, y* and *Y*, respectively;

$\bar{x}, \bar{y}, \bar{Y}$ – computed average values;

n – a number of observations (in this case $n = 5$),

5. The averaged values of the coordinates *x, y* were plotted onto the chromaticity diagram CIE daylight locus and projected along the isotemperature lines onto the locus,

6. Steps 3 - 5 were repeated for other colour temperature set-ups, consecutively: 6000 K, 6500 K, 7000 K, 8000 K, 9300 K, 10000 K.

The achieved results are presented in Table 2.

Table. 2. The average values of the measured chromaticity coordinates *x, y* and average measuring errors m_x, m_y, m_Y for different set-ups of colour temperature in the monitor menu

T_C	x	y	Y	m_x	m_y	m_Y	T_C – 'real'
5 000 K	0.3253	0.3452	74.0256	0.0001	0.0001	0.0498	5 800 K
6 000 K	0.3123	0.3306	73.9273	0.0001	0.0001	0.0295	6 500 K
6 500 K	0.3062	0.3255	73.6073	0.0000	0.0000	0.0234	6 900 K
7 000 K	0.2956	0.3188	72.3574	0.0001	0.0001	0.0364	7 650 K
8 000 K	0.2874	0.3137	71.4649	0.0000	0.0001	0.0522	8 300 K
9 300 K	0.2764	0.3062	70.1176	0.0001	0.0001	0.0203	9 600 K
10 000 K	0.2693	0.2987	70.0508	0.0000	0.0001	0.0372	10 650 K

Figure 15 shows a general position of the determined white points in relation to the CIE daylight locus.

T_C resulting from the measurements was graphically interpolated which was achieved through the projection of xy points plotted onto the diagram and representing the white for different colour temperature points onto the CIE daylight locus along the isotemperature lines (Fig, 16-18). Fig. 16 illustrates determining of colour temperatures for points: 1 – 5000 K, 2 – 6000 K, 3 – 6500 K.

Figure 17 illustrates determining of colour temperatures for the consecutive two points: point 4 – 7000 K and point 5 – 8000 K.

Figure 18 illustrates determining of colour temperatures for the consecutive two points point 6 – 9300 K and point 7 – 10000 K.

As it is indicated by the achieved results, the colour temperature displayed in the monitor menu is considerably lowered in comparison with the measured colour temperature of the displayed white colour. The settings shown in the monitor menu do not guarantee a picture display with the expected colour temperature. A much higher degree of such certainty can be achieved by setting the required screen colour temperature, e.g. temperature of 6500 K. As a result of this method appropriate RGB percentage values will be achieved. The setting of these values in the monitor menu will guarantee white colour display with the chromaticity coordinates *xy* corresponding to the given temperatures e.g. 6500 K.

Setting of the selected actual colour temperature 6500K

The process of setting colour temperature is iterative. It can be conducted in the following way:

- changing the percentage participation of the RGB monitor primary stimuli (hardware change),
- displaying white colour with the following values: R = 255, G = 255, B = 255,
- performing the chromaticity coordinates xy measurements of this colour by means of a colorimeter,
- plotting those coordinates onto the CIE daylight locus,
- projecting the plotted value along the isotemperature lines onto the locus,
- graphic interpolation of the obtained colour temperature value,
- comparing this value with the value of the one which is being aimed at i.e. 6500K
- another change in the RGB percentage participation in the monitor menu,
- repeating the whole procedure until the value of 6500 K is achieved exact to about 100 K. (Such accuracy has been determined as possible to achieve by using the applied graphic method)

Changing the percentage participation of the primary RGB stimuli in the monitor menu

At this stage a question arises how to change the RGB participation in the monitor menu. The percentage of R (white obtained for R = 100% contains the highest measured lightness value $Y = 74.0256$) is, to a great extent, responsible for the white point lightness. Therefore, assuming the value of R percentage participation in the white point as being 100% seems to be justified.

Figure 19 represents white colour emission spectrum displayed at different colour temperatures, selected from the monitor menu. This spectrum has been determined through performing colorimetric measurements (Spectorlino). The analysis of the obtained emission values shows that the green range G does not have a significant influence on the change in the colour temperature. Therefore, G participation can be maintained at the constant level G = 50% (such percentage participation level in the white of the primary stimulus G has been producer's set for all colour temperatures).

Provisionally the following percentage participation values of the primary monitor RGB stimuli in the monitor white colour were assumed: R = 100%, G = 50%, B = 10%, and subsequently only the B parameter, was changed whose percentage participation was being gradually increased.

Table 3 contains individual settings of RGB percentage participation in the white point, measured values *x*, *y* for these settings as well as the interpolated colour temperatures. As you can see, the white point colour temperature equal 6500 K was obtained for the following percentage participation settings: R = 100%, G = 50%, B = 33%. In the case of the examined NOKIA monitor such values should be set in the menu instead of values suggested for this temperature (R = 92%, G = 50%, B = 36%) so that the white point with the temperature 6500 K could be really achieved.

Table 3. Setting-up of the interpolated actual colour temperature values for the selected settings of the RGB percentage participation in the white colour

Settings:			Chromaticity coordinates			Interpolated T_C
R	G	B	x	y	Y	
100	50	11	0.3245	0.3461	73.08	5 850
100	50	12	0.3235	0.3447	73.15	5 900
100	50	17	0.3214	0.3405	73.56	6 000
100	50	25	0.3173	0.3342	73.79	6 250
100	50	29	0.3150	0.3310	74.31	6 355
100	50	33	0.3133	0.3279	74.43	6 500

Colour gamut comparison of the images displayed on the NOKIA Multigraph 447Xpro monitor at the nominal colour temperature settings: 5000 K, 10000 K

For each colour temperature T_C = 5000 K and T_C = 10000 K chromaticity coordinates and lightness CIE *xyY* values of the colour set were measured. The measurements were performed by means of a Spectrolino spectrophotometer. The set of colours consisted of the three RGB primary stimuli colours and their mixtures. On the whole, for each colour temperature 29 colours were measured. Numeric expressions values *d*(R,G,B) as well as the measurements results are set up in Table 4 of Appendix 1.

Graphic illustrations of the results of the performed measurements were made in order to conduct comparative analysis of the obtained results. To compare the chromaticities of the measured colours, the points which represent them were plotted onto the chromaticity xy diagrams. The position of a point on the diagram is marked with a colourful spot. The colour of this spot constitutes the illustration of the displayed colour, measured at the given colour temperature T_C. The illustration of the colours was made by converting *xyY* coordinates into CIE $L^*a^*b^*$. Since the expressions used for determining these coordinates require defining reference white, for all colours one reference white (*D*65, white with colour temperature T_C = 6500 K) was adopted. Referring all the colours to one reference white enables colour gamut comparison. In order to convert the *xyY* coordinates into CIE $L^*a^*b^*$, first tristimulus values were determined (•) CIE XYZ on the basis of the measured trichromatic coordinates x, y as well as the brightness Y value:

$$X = x\frac{Y}{y}, \qquad Y = Y, \qquad Z = (1 - x - y)\frac{Y}{y},$$

Subsequently $L^*a^*b^*$ coordinates were determined

$$L^* = 116\left(\frac{Y}{Y_n}\right)^{1/3} - 16; \qquad \text{for: } \frac{Y}{Y_n} > 0.008856$$

$$L^* = 903.3\left(\frac{Y}{Y_n}\right); \qquad \text{for: } \frac{Y}{Y_n} \leq 0.008856$$

$$a^* = 500\left[\left(\frac{X}{X_n}\right)^{1/3} - \left(\frac{Y}{Y_n}\right)^{1/3}\right]; \qquad b^* = 200\left[\left(\frac{Y}{Y_n}\right)^{1/3} - \left(\frac{Z}{Z_n}\right)^{1/3}\right];$$

Where X_n, Y_n, Z_n, are values X, Y, Z for white reference. $D65$ was adopted as reference white, therefore $X_n = 95.642$; $Y_n = 100.000$; $Z_n = 92.085$ [3].

If any of the fractions: $\frac{X}{X_n}$, $\frac{Y}{Y_n}$ or $\frac{Z}{Z_n}$ is lower than or equal to the value 0.008856 then the expression: $\left(\frac{X}{X_n}\right)^{1/3}$, $\left(\frac{Y}{Y_n}\right)^{1/3}$ or $\left(\frac{Z}{Z_n}\right)^{1/3}$ is substituted in the formula by: $7.787\mathrm{F} + \frac{16}{116}$, where F is $\frac{X}{X_n}$, $\frac{Y}{Y_n}$ or $\frac{Z}{Z_n}$, depending on the case [2].

For the measured set of testing colours twice occurred the case $\frac{Y}{Y_n} \leq 0.008856$ creating the need for appropriate formula substitution. In both cases this necessity occurred for the measured black colours $d(000)$.

The determined coordinates Lab can be used in the graphic programme for example CorelDraw to produce chromaticity diagrams coloured illustrations. On these diagrams the

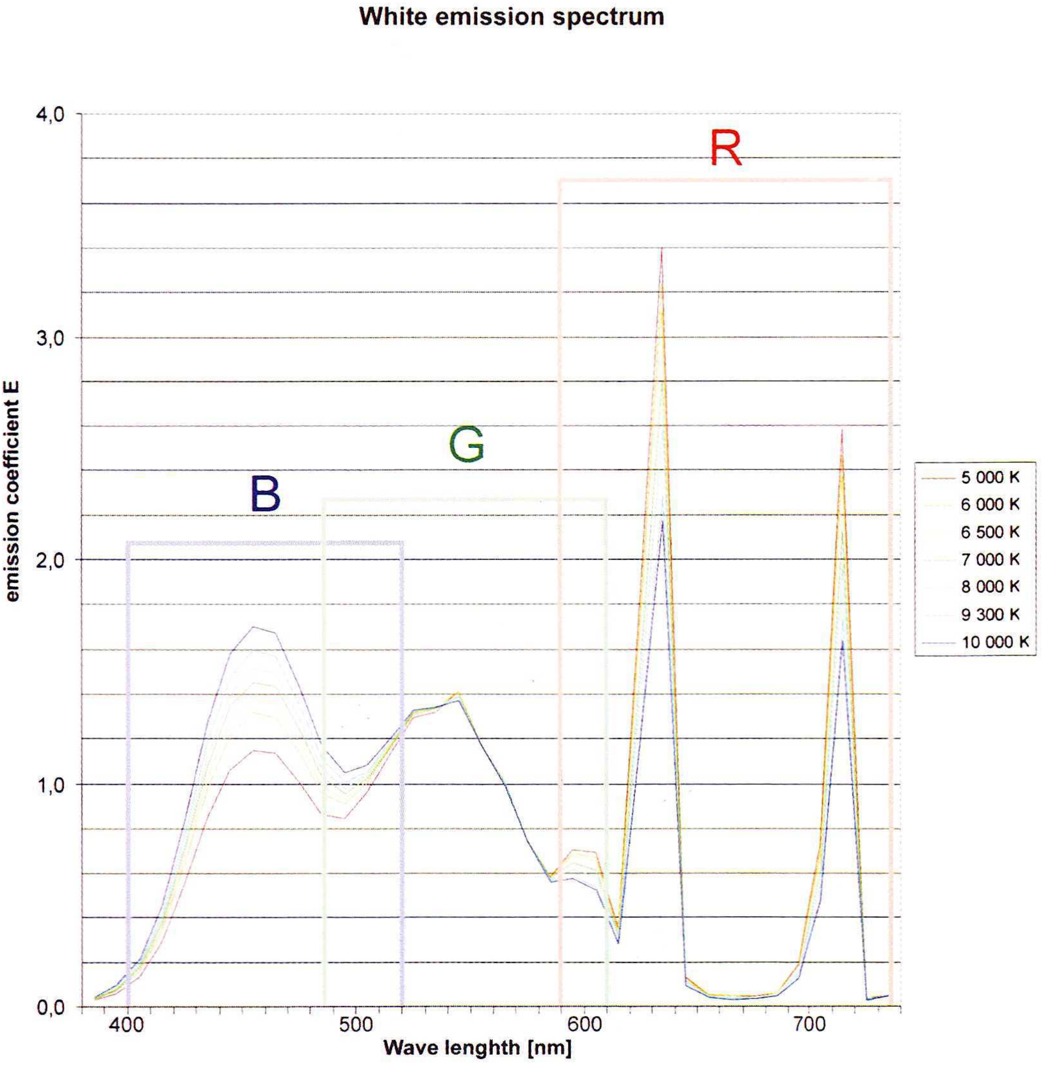
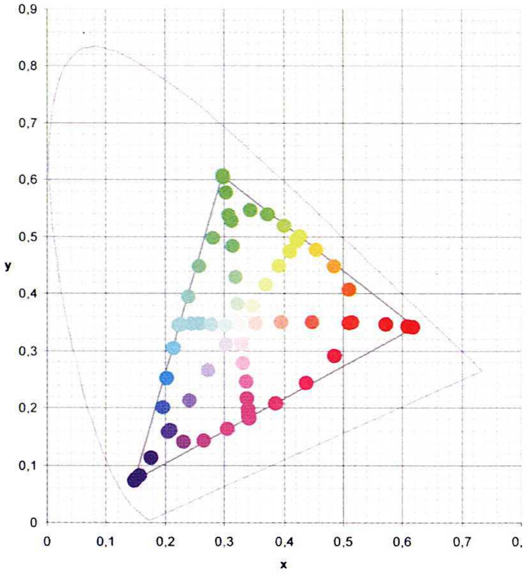


Fig. 19. White colour emission spectrum diagrams (R = 255, G = 255, B = 255) displayed at different colour temperature set-ups in the monitor menu. (the ranges have been plotted on the basis of Fig.4 representing emission coefficients of the three primary monitor RGB stimuli. The wavelength ranges have been chosen for which the given stimulus had an emission coefficient value *E*>0.25).



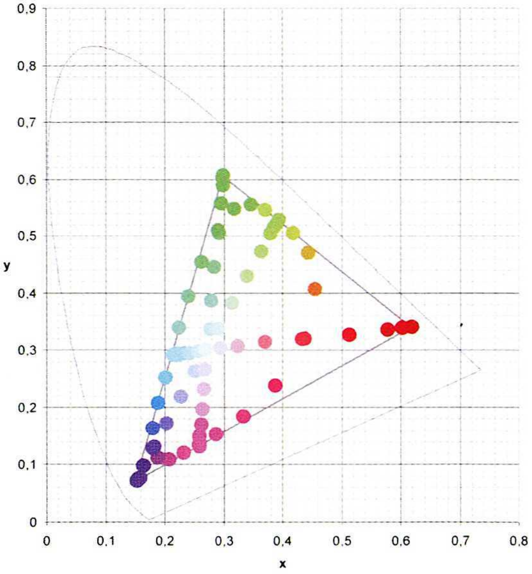


Fig. 20. Chromaticity coordinates of the points representing the measured colours displayed on the screen at colour temperature 5000 K. Spots colour marking the points position on the diagram illustrates colour gamut of the measured colours.

Fig. 21. Chromaticity coordinates of the points representing the measured colours displayed on the screen at colour temperature 10000 K. Spots colour marking the points position on the diagram illustrates colour gamut of the measured colours.

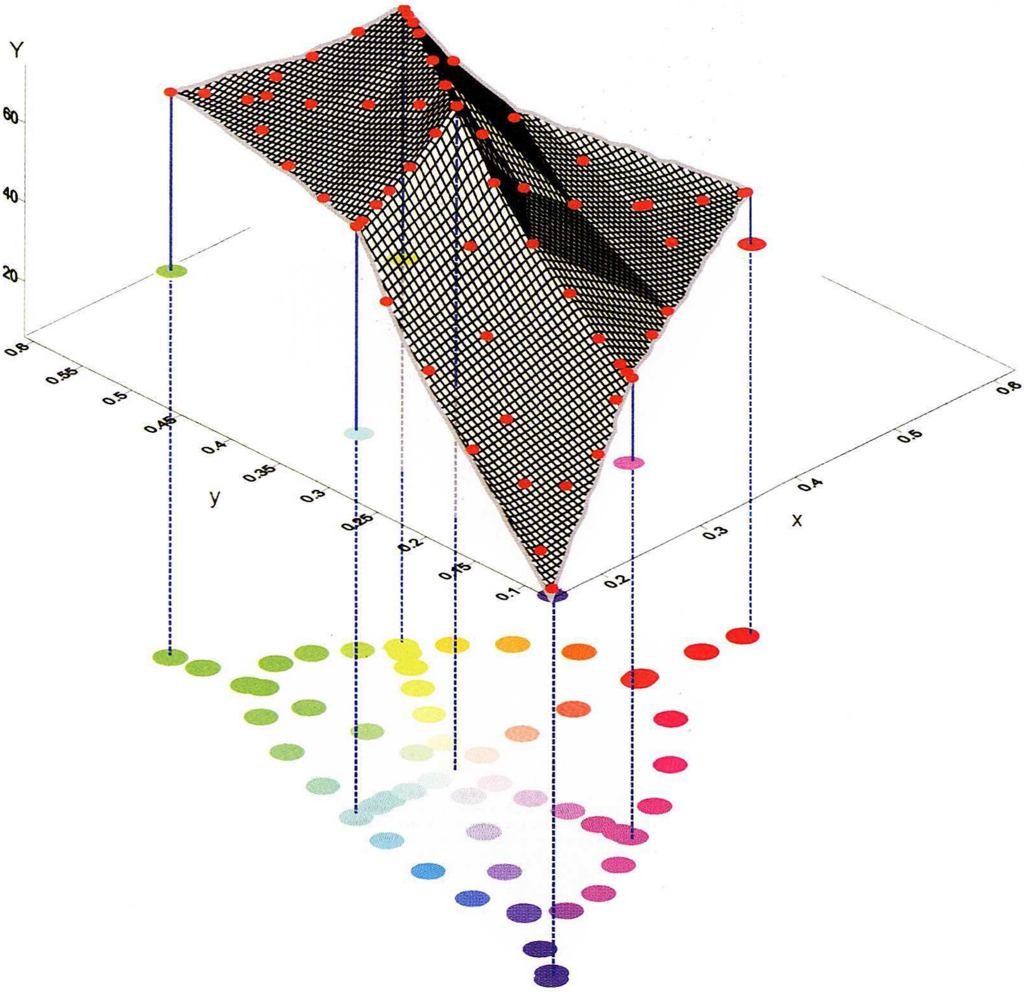


Fig. 22. Dimensional distribution of the points representing the measured colours displayed on the monitor at the white point colour temperature 5000 K

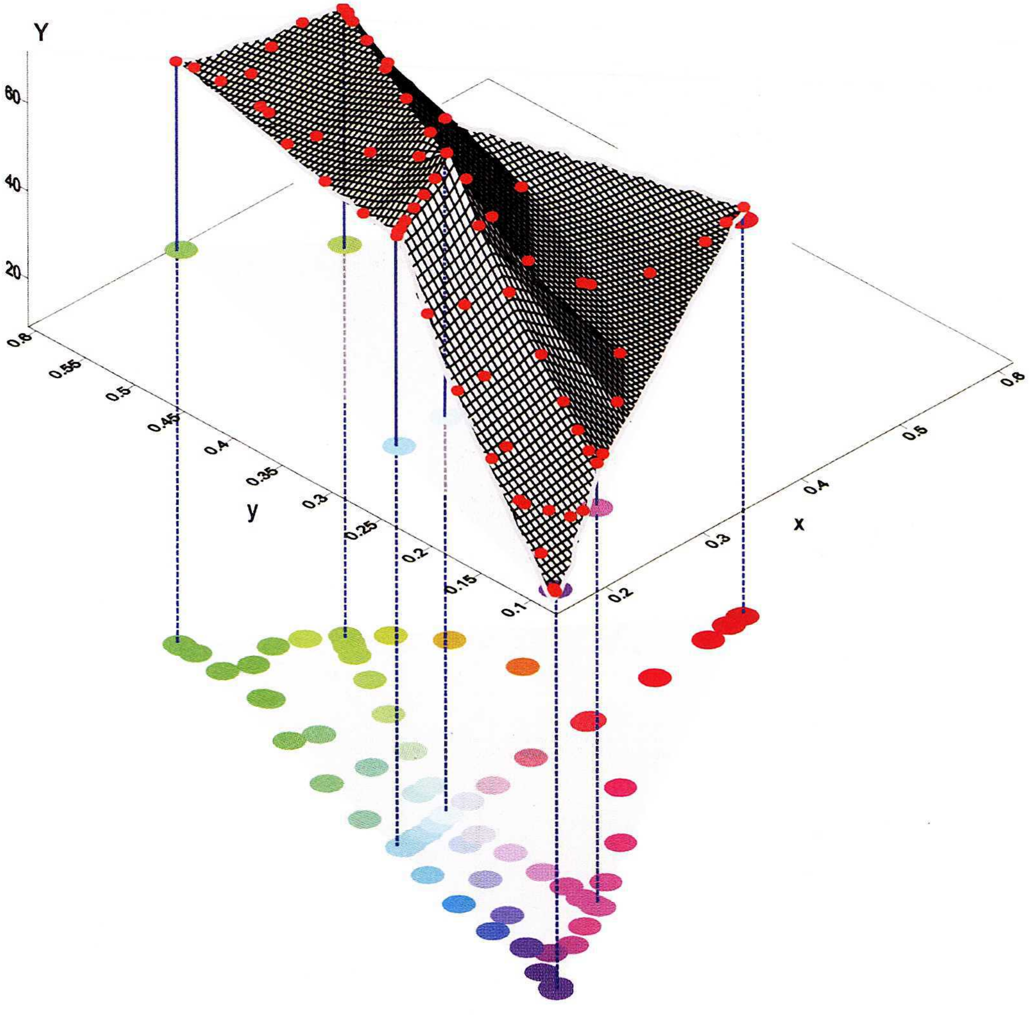


Fig. 23. Dimensional distribution of the points representing the measured colours displayed on the monitor at the white point colour temperature 10000 K

points representing the position of the measured colours were marked with colourful spots. The spots colours were determined in the programme by inserting $L^*a^*b^*$ values.

Finally, chromaticity coloured diagrams of the measured colour sets, at a given set colour temperature, were produced. These diagrams are shown in Fig. 20 and Fig. 21.

These diagrams show that the colour temperature change from $T_C = 5000$ K to $T_C = 10000$ K did not cause any grater change in the chromaticity coordinates of RGB primary monitor stimuli.

The corners of the triangles are located in almost identical points on the diagram. There is a visible change in the location of the gravity centre point representing the white colour. When colour temperature increases, it clearly moves towards the line joining the blue and green stimuli on the diagram. This change is caused by the changes in the lightness values of the RGB monitor primary colour stimuli; together with the colour temperature change. An increase in the Y_B blue stimulus brightness value results in moving of the gravity centre towards the point representing this stimulus on the diagram. A decrease in Y_R red stimulus brightness value makes the gravity centre move away from the point representing this stimulus towards the colour points of the two remaining stimuli. A change of the position of the chromaticity diagram gravity centre results in a chromaticity coordinates position change of all the points representing colours produced by additive mixing of the primary stimuli.

Similarly, by lowering colour temperature we interfere with RGB monitor primary stimuli lightness value. In this case, however, the Y_B blue stimulus lightness value decreases which makes the chromaticity diagram gravity centre move further away from the colour point of this stimulus towards the colour points of the green and red stimuli. At the same time red stimulus brightness value increases, which increases weight of this stimulus and makes the gravity centre move even closer towards it. This results in a change of the position of all mixture colour points.

A considerable density of the colour points along the line joining the green stimulus with the blue one is visible for the high colour temperature $T_C = 10000$ K. The graphic representation of the colour points distribution is completely different from the distribution characteristic of equi-energy white, for which the gravity centre of the chromaticity diagrams would lie in the geometric centre of a triangle created by joining RGB points. More similar to equi-energy distribution is a coloured points distribution obtained for the lower colour temperature $T_C = 5000$K.

The shift direction of the colour points together with the increase in the colour temperature explains the colour gamut change of the pictures presented in Fig. 5 and Fig. 6.

By visual examination a picture obtained for a low colour temperature ($T_C < 5000$ K) is characterised by high red colours intensity. Yellow colours clearly dominate. It is caused by high brightness of the red stimulus. The colours lying on the line joining on the diagram the green and red stimuli are shifted towards the red colour. The yellow colours lie on the same line, therefore the green colours turn yellow and the yellow colours shift towards the orange colours. The additive mixtures of the blue and red stimuli are also shifted towards the red stimulus. As a result the blue colour, even with a little participation of the red stimulus R tend to turn magenta or violet which is also clearly visible in Figure 5. Due to a low value of the B blue stimulus lightness also the additive mixtures of this stimulus with the green stimulus G are shifted towards the green stimulus. However, this shift is not so clear. It can manifest itself in the tendency of blue-green colours to become green-bluish colours, and those in turn green colours.

Similarly, a picture obtained for high colour temperature (T_C > 10000 K) can be visually examined. It is characterised by low lightness value of the red stimulus R and a comparatively high value of the blue stimulus B lightness. Red colours are apparently dimmed and have low intensities. They tend to turn brown or maroon. Magentas and crimsons shift towards violets. Blue colours are characterised by a very high intensity. Blue elements of the picture are noticed as the first once. Yellow-greenish colours tend to turn into green ones. This tendency is strong and causes an evident shortage of the yellow colour in the picture which is illustrated by Figure 6. Due to a high lightness value of the B blue stimulus, the additive mixtures of this stimulus with the green stimulus shifts towards the blue stimulus. This shift is not clear. It may manifest itself in the fact that the cyanic colours (blue-greenish) will tend to become bluer colours.

When the screen colour temperature changes, the whole colour gamut of the displayed picture changes as well. It takes place despite the fact that the x,y chromaticity coordinates of the RGB monitor primary stimuli do not change to a larger extent. It is influenced by the changes in the Y_R, Y_G, Y_B primary stimuli lightness values. Determining of the screen colour gamut as a triangle joining the colour points of the RGB primary stimuli on a flat chromaticity diagram is not sufficient without indicating the lightness values of these stimuli, i.e. without referring to a three-dimensional representation. Without knowing the lightness values, it is impossible to predict the colours obtained as a result of the additive mixing of the stimuli. Changes in these mixtures are very essential for the quality of the picture colours which can be seen in Fig. 5 and Fig. 6. Thus, it seems to be justified to examine picture colour gamut on the three-dimensional diagram xyY. Figure 22 contains a graphic illustration of the position in space of the xyY colour points measured for colour temperature T_C = 5000 K. Figure 23 shows a similar illustration for T_C = 10000 K.

CONCLUSION

1. A change in the monitor colour temperature T_C causes a visible change in the colour gamut of the picture displayed on it. When colour temperature decreases the produced change causes an increase in the lightness and intensity of red colours, a dominance of yellow colours, a change of blue colours into violet, a shortage of green colours. The whole picture seems to be "basking" in warm, intense sunlight. When colour temperature increases the produced change causes an increase in the intensity of blue colours, dimming and browning of red colours, and a dominance of blue-greenish colours, a shortage of a yellow colour in the picture. The whole picture seems to be lit by the cold white-bluish light of the clouded sky.

2. The cartographer designing a map colour on the screen relies on his eye-sight. The colour temperature set-up while changing the appearance of the colours displayed on the screen affects his decision on colour gamut. Mixing the same primary stimuli proportions will lead to different results for different colour temperatures. That is why colour temperature set-up should be conducted consciously and with care.

3. Colour gamut change of the picture applies to its display and not to RGB monitor colour digital record. If the same picture is displayed at two different colour temperature set-ups, its colours will look differently. The digital record of these colours will remain unchanged.

4. Percentage set-ups of the RGB monitor primary stimuli participations selected from the monitor menu for a given colour temperature, do not guarantee a display on the screen of a

picture at such a colour temperature. If it is essential that the exact set colour temperature is achieved, it might be necessary to perform colorimetric method of setting it.

5. The change in colour temperature causes little changes in the chromaticity coordinates of the RGB monitor three primary stimuli. However, it considerably changes their lightness values. This causes a change of all colours produced as a result of additive mixing of these stimuli and conforming with the centre of gravity law. The colour gamut of the picture significantly changes.

6. Determining of screen colour gamut as a triangle joining colour points of RGB primary stimuli on the flat chromaticity diagram *xy* is not sufficient without indicating the lightness values of these stimuli, i.e. without referring to a three-dimensional representation. An application of the space *xyY* seems to be a good solution.

7. If the choice of the colour temperature is not determined by such factors as, e.g. colour temperature of triad dyes which will be used for a map reproduction in print, while choosing an appropriate T_C, it is advisable to aim at achieving equi-energy white. In the case of NOKIA Multigraph 447 Xpro monitor it will be the lower out of colour temperature possible to achieve on this screen.

8. Colour temperature , besides brightness, contrast and gamma coefficient characterises the colour points distribution of the RGB stimuli mixtures in colour space *xyY*. Therefore, it is one of the parameters characterising the colours projection onto the screen.

REFERENCE

[1] Berns RS, Motta R.J., Gorzyński M.E., *CRT colorimetry. Part I. Theory and practice.* Col. Res. Appl., 18, 1993, 299-314.

[2] Hunt R.W.G., *Measuring Colour,* ed. 3, Fountain Press England 1997.

[3] Wyszecki G., Stiles W.S., *Color Science: Concepts amd Methods, Quantitative Data and Formulae,* ed.2, John Wiley & Sons, 1982.

Received June 19, 2001
Accepted August 2, 2001

Appendix 1

Table 4 The results of colorimetric measurements of the sets of colours displayed on the screen at colour temperature set-ups 5000 K and 10000 K

5000 K				
colour	stimuli *d*(R,G,B)	*x*	*y*	*Y*
B	0.0.255	0.1486	0.0734	5.8750
G	0.255.0	0.2963	0.6092	50.6428
R	255.0.0	0.6205	0.3414	18.8689
C	0.255.255	0.2238	0.3458	56.5806
M	255.0.255	0.3408	0.1823	24.6751
Y	255.255.0	0.4254	0.5030	69.7108
W	255.255.255	0.3239	0.3451	75.5850
K	0.0.0	0.3091	0.3162	0.0877
C-Y	32.255.224	0.2392	0.3951	55.3786
	64.255.192	0.2573	0.4484	54.0929
	96.255.160	0.2812	0.4981	53.8100
	128.255.128	0.3109	0.5336	54.5360
	160.255.96	0.3430	0.5474	56.7026
	192.255.64	0.3739	0.5397	59.9209
	224.255.32	0.4013	0.5202	64.3916
M-C	224.32.255	0.3063	0.1623	19.5872
	192.64.255	0.2664	0.1439	15.5283
	160.96.255	0.2313	0.1410	14.2670
	128.128.255	0.2072	0.1602	16.1597
	96.160.255	0.1979	0.2002	21.5227
	64.192.255	0.2015	0.2516	30.4273
	32.224.255	0.2127	0.3037	42.7150
M-Y	255.32.224	0.3864	0.2081	23.2931
	255.64.192	0.4381	0.2421	22.4135
	255.96.160	0.4857	0.2906	23.4679
	255.128.128	0.5129	0.3501	27.2071
	255.160.96	0.5104	0.4067	33.7070
	255.192.64	0.4854	0.4506	43.2607
	255.224.32	0.4530	0.4805	55.8310
10 000K				
colour	Stimuli *d*(R.G.B)	*x*	*y*	*Y*
B	0.0.255	0.1503	0.0740	8.9902
G	0.255.0	0.2971	0.6078	51.5032
R	255.0.0	0.6162	0.3413	12.2769
C	0.255.255	0.2099	0.2935	60.3128

M	255.0.255	0.2561	0.1340	20.9927
Y	255.255.0	0.3918	0.5301	63.7396
W	255.255.255	0.2700	0.3004	72.3177
K	0.0.0	0.3739	0.3208	0.2921
C-Y	32.255.224	0.2229	0.3393	57.7179
	64.255.192	0.2393	0.3956	55.7437
	96.255.160	0.2610	0.4556	54.4026
	128.255.128	0.2879	0.5106	54.1881
	160.255.96	0.3177	0.5471	55.0199
	192.255.64	0.3459	0.5577	56.7527
	224.255.32	0.3704	0.5466	59.7553
M-C	224.32.255	0.2301	0.1198	17.5266
	192.64.255	0.2061	0.1093	15.1302
	160.96.255	0.1883	0.1115	15.1074
	128.128.255	0.1796	0.1299	17.9198
	96.160.255	0.1801	0.1633	23.9413
	64.192.255	0.1881	0.2061	33.1518
	32.224.255	0.1995	0.2518	45.6235
M-Y	255.32.224	0.2885	0.1539	18.7104
	255.64.192	0.3327	0.1840	17.1426
	255.96.160	0.3868	0.2385	17.6903
	255.128.128	0.4361	0.3206	20.9220
	255.160.96	0.4558	0.4079	27.1596
	255.192.64	0.4438	0.4717	36.4743
	255.224.32	0.4164	0.5072	48.8448

Appendix 2

Determining the accuracy of measurements by means of Spectrolino colorimeter for colour temperature 6500 K.

For the colour temperature 6500 K measurements average errors xyY of eight colours by means of Spectrolino colorimeter. On the screen of the stabilised and heated up monitor, measurements of each of eight displayed colours were performed twenty times. On the basis of the obtained results measurements average errors were computed applying the following formulae:

$$m_x = \pm\sqrt{\frac{\sum_{i=1}^{i=n}\left(\bar{x} - x_i\right)^2}{n}}\,; \quad m_y = \pm\sqrt{\frac{\sum_{i=1}^{i=n}\left(\bar{y} - y_i\right)^2}{n}}\,; \quad m_Y = \pm\sqrt{\frac{\sum_{i=1}^{i=n}\left(\bar{Y} - Y_i\right)^2}{n}}\,;$$

where: x_i, y_i, Y_i are measured coordinates values respectively x, y, Y

$\overline{x}, \overline{y}, \overline{Y}$ – computed average values

n – a number of observation (in this case $n = 20$);

the following results were obtained:

	m_x	m_y	m_Y
Black (0.0.0)	± 0.0228	± 0.0199	± 0.0213
Blue (0.0.255)	± 0.0003	± 0.0003	± 0.0028
Green (0.255.0)	± 0.0002	± 0.0003	± 0.1951
Cyan (0.255.255)	± 0.0001	± 0.0003	± 0.1525
Red (255.0.0)	± 0.0003	± 0.0001	± 0.0939
Magenta (255.0.255)	± 0.0003	± 0.0001	± 0.0400
Yellow (255.255.0)	± 0.0003	± 0.0003	± 0.1820
White (255.255.255)	± 0.0002	± 0.0002	± 0.0902
Average value without black colour measurements average errors:	0.0002	0.0002	0.1081
Average value for all the measurements:	0.0031	0.0027	0.0972

Finally it was adopted that for the measurements, without the black colour, the average errors are: for chromaticity coordinates (x, y) m = ± 0.0002, while for the black colour measurement (x, y) m = ± 0.02. The measurement average error value of brightness value (for all measurements is m = ± 0.1)

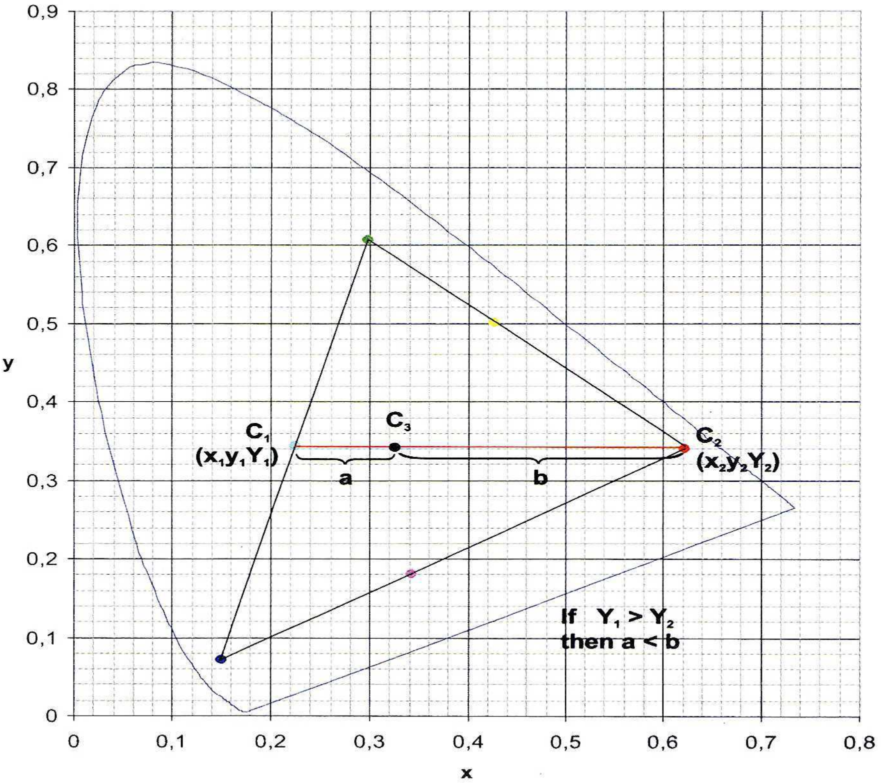


Fig. 24. Graphic illustration of the centre of gravity law.

Joanna Puszkarska

Wpływ ustawienia temperatury barwowej punktu bieli na kolorystykę obrazu kartograficznego wyświetlonego na ekranie monitora CRT

Streszczenie

W artykule przedstawiono metodę wyznaczania temperatury barwowej punktu bieli ekranu monitora na drodze pomiaru kolorymetrycznego. Za odniesienie przyjęto krzywą światła dziennego CIE. Zgodnie z opisaną metodą wyznaczono wartości temperatur barwowych dla nominalnych ustawień tego parametru na monitorze NOKIA Multigraph 447Xpro. Otrzymane na drodze pomiarów wartości różniły się od wartości nominalnych (wartości nominalne były zawyżone względem pomierzonych). Z powodu rozbieżności przeprowadzono iteracyjną metodę ustawienia żądanej temperatury barwowej. W ten sposób zostały precyzyjnie ustawione wartości temperatur barwowych $T_C = 5000$ °K oraz $T_C = 10000$ °K.

Dla obydwu temperatur barwowych pomierzone zostały wartości *xyY* zestawu barw testowych. Analizę otrzymanych rezultatów przeprowadzono na wykresach chromatyczności CIE *xy*. Punkty dodatkowo scharakteryzowano za pomocą barwy, która stanowiła ilustracje pomierzonej barwy z ekranu monitora. W celu umożliwienia porównania obydwu charakterystyk barwy te odniesiono do jednej bieli referencyjnej D_{65}. Analiza ilustracji potwierdziła wcześniejszą wzrokową ocenę barwnych obrazów wyświetlonych na ekranie monitora przy dwóch różnych ustawieniach temperatury barwowej. Rozkład punktów na wykresie umożliwił porównanie do bieli równoenergetycznej, będącej warunkiem koniecznym otrzymania możliwie szerokiej gamy kolorystycznej.

Wraz ze zmianą temperatury barwowej T_C ekranu monitora zmienia się cała kolorystyka wyświetlonego obrazu. Dzieje się tak pomimo, iż współrzędne chromatyczne *xy* podstawowych bodźców monitora RGB nie ulegają większej zmianie. Wpływają na to zmiany wartości jasności bodźców podstawowych, wywołując zmianę wszystkich barw powstałych w wyniku addytywnego mieszania tych bodźców, zgodnie z prawem środka ciężkości. Kolorystyka całego obrazu ulega wyraźnej zmianie. Przy zmniejszeniu temperatury barwowej wywołana zmiana powoduje wzrost natężenia barw czerwonych, dominacje barw żółtych, zmianę barw niebieskich na barwy fioletowe, niedobór barw zielonych. Cały obraz charakteryzuje się ciepłym oddaniem barw. Przy zwiększaniu temperatury barwowej, zmiana T_C powoduje wzrost natężenia barw niebieskich, przyciemnienie i zbrunatnienie barw czerwonych, dominacje barw niebiesko-zielonkawych, niedobór barwy żółtej w obrazie. Cały obraz charakteryzuje się zimnym odwzorowaniem barw. Powstałe obrazy są różne choć ich zapis cyfrowy pozostaje niezmieniony.

Określenie kolorystyki obrazu wyświetlanego na ekranie monitora CRT jako trójkąta łączącego punkty barwne bodźców podstawowych RGB na płaskim wykresie chromatyczności CIE *xy* nie jest wystarczające bez podania wartości jasności tych bodźców, lub wartości T_C.

Ustawienie temperatury barwowej, zmieniając wygląd wyświetlanych na ekranie barw, wpływa na podejmowane przez kartografa decyzje kolorystyczne. Dlatego ustawienie temperatury barwowej powinno być czynnością którą dokonuje on świadomie i precyzyjnie. Przy ustawianiu T_C należy kierować się dwoma kryteriami: otrzymania kolorystyki możliwie zbliżonej do kolorystyki światła równoenergetycznego lub dopasowania kolorystyki do kolorystyk osiągalnych w danej technice reprodukcji barwy, w której reprodukowana będzie mapa.

Podane w menu monitora ustawienia procentowe podstawowych bodźców RGB dla danej T_C , nie gwarantują wyświetlenie na ekranie obrazu o takiej temperaturze barwowej. Jeżeli istotne jest otrzymanie dokładnie zadanej temperatury barwowej, jest potrzebne wykonanie kolorymetrycznej metody jej ustawienia.

Temperatura barwowa, obok jasności, kontrastu i współczynnika gamma charakteryzuje rozkład punktów barwnych mieszanin bodźców RGB w przestrzeni barw *xyY*. Jest więc jednym z parametrów charakteryzujących odwzorowanie barw na ekranie monitora.

Ëанна Пушкарска

Влияние установки цветовой температуры точки белила на колорист картографического изображения, представленного на экране монитора GRT

Резюме

В статье представлен метод определения цветовой температуры точки белила экрана монитора путём колориметрических измерений. Как отнесение принятя кривая дневного света CIE. Согласно с представленным методом определены величины цветовых температур для номинальных установок того параметра на мониторе NOKIA Multigraph 447 Xpro. Полученные путём измерений величины цветовых температур для номинальных величин (номинальные величины были завышены по отношению к измеренным величинам). Из-за расхождений проведен интерационный метод установки требуемой цветовой температуры. Таким способом были прецизионно установлены величины цветовых температур T_C = 5000 K, а также T_C = 10000 K.

Для обоих цветовых температур были измерены величины xyY состава тестовых цветов. Анализ полученных результатов был проведен на графиках цветности CIE xy. Точки добавочно определены при помощи цвета, которой иллюстрирует цвет измеренный на экране монитора. С целью сравнения обоих характеристик эти цветы были приписаны к одной рефракционной белили D_{65}. Анализ иллюстраций подтверждает раньше проведённую зрительную оценку цветных изображений на экране монитора с двумя разными установками цветовой температуры. Распределение точек на графике даёт возможность сравниения с равно энергетической белили, что является необходимым условием получения возможно широкой гаммы цветов.

Вместе с изменением цветовой температуры T_C экрана монитора изменяется тоже вся колоритность представляемого изображения. Это происходит хотя координаты цветности xy основных импульсов монитора RGB не подвергают большему изменению. Здесь оказывают влияние изменения величины светлоты основных импульсов, вызывая изменение всех цветов, созданных в результате аддитивного смешения этих импульсов согласно с законом центра тяжести. С уменьшением цветовой температуры возбуждённое изменение вызывает повышение интенсивности красных окрасок, преобладание жёлтых окрасок, изменение голубых окрасок на фиолетовые окраски, недостаток зелёных окрасок. Всё изображение отличается тёплым отражением цветов. С увеличением цветовой температуры изменение T_C вызывает повышение интенсивности голубых окрасок, притемнение и принятие коричневых окрасок красными окрасками, преобладание голубого-зеленоватых окрасок, недостаток жёлтого цвета в изображении. Всё изображение характеризуется холодным воспроизведением цветов. Полученные цветы являются разными, хотя их цифровая запись остаётся неизменной.

Определение колористики изображения полученного на экране монитора CRT в виде треугольника, соединяющего цветовые пункты основных импульсов RGB на двумерном графике цветности CIE xy не является достаточным без указания величин светлосты этих импульсов или величин T_C.

Установление цветовой температуры изменяет вид представляемых на экране цветов, влияет на принимаемые картографом колористические решения. Поэтому установление цветовой температуры должно является сознательно и точно выполняемым действием. Устанавливая T_C надо придерживаться двумя критериями, а именно получения колористики по мере возможности близкой к колористике равно энергетического света или приспособления колористики к колористикам получаемым в данной технике цветопередачи, в которой будет репродуцироваться карта.

Указанные в меню монитора процентные установления основных импульсов RGB для данной T_C не гарантируют получения на экране монитора изображения с такой цветовой температурой. В случае, когда надо получить определённую цветовую температуру, необходимым является выполнение колориметрической методы её установления.

Цветовая температура, наряду с светлотой, контрастом и коэффициентом гамма, характеризует распределение цветовых точек смешивания импульсов RGB в пространстве цветов xyY . Таким способом является одним из параметров, которые характеризуют представление цветов на экрание монитора.