

1. Introduction

The definition of the colour of a finished product's surface made of a gold alloy is mostly very hard, and it makes sense only if it is referred to a series of samples taken as terms of comparison. The Swiss organization "Normes Industrielles de l'Horlogerie Suisse" was the first one which established, in 1966, a series of standard compositions of gold alloyed 18 ct, named with the codes 2N, 3N, 4N and 5N. Afterwards, the French and German goldsmith's industry conformed themselves (even if with some changes) to these standards until the redaction of the European EN 28654 rules. Such rules are the adoption of the ISO 8654.

2. Short description of the EN 28654 rules

Purpose and application field

The rules examined have the aim of defining the colours in a limited number, referring to the given denomination without having to refer to a sample of the desired colour. Such rules are applicable to jewellery, to watchcases and to accessories made entirely by gold alloys, as well as to watchcases and accessories plated using a gold alloy. In the daily routine these rules are gathered better in the production of watchcases, accessories and similar, rather than in jewellery.

Definition

Colour of the gold alloy: tridimensional chromatic space represented by the chromatographic coordinates x and y and by the reflection ρ , in accordance to the CIE publication n. 15.

The colorimetric model CIE has been suggested in 1931 by the Commission Internationale d'Eclairage. Such model represents all (and only) the colours the human eye can see and is displayed in the following figure 1.



Figure 1 - CIE 1931 Chromaticity's diagram

This chromaticity's diagram is bidimensional: in the centre there is the white colour and along the perimeter's curved line there are the saturated colours of the light spectrum (anticlockwise: red, yellow, green, blue, violet). The central colours are unsaturated (white colour is the most unsaturated), and the peripheral colours are saturated. Therefore, the diagram represents the colours (along the perimeter) and the saturations (from the perimeter to the centre). Each colour is represented by a point inside the horseshoe bat area. The whole area is included in a system of x , y Cartesian coordinates, as shown in figure 2.

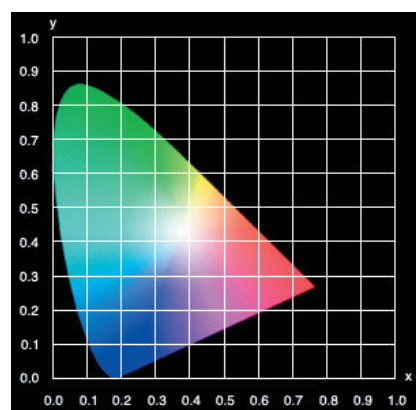


Figure 2 - x , y coordinates in the chromatic space CIE1934

Both the coordinates x and y take values from 0 to 1. Each colour corresponds to a couple of coordinates x and y , but not any couple of coordinates corresponds to a colour. We did not consider the brightness of the colours, which can be introduced by adding a third dimension to the barely seen diagram. In fact, the CIE 1931 chromaticity's diagram is just a "portion" of a more complete space, the CIE 1934 colours' space, to which the coordinates x , y and z are assigned. This space has the shape displayed in figure 3.

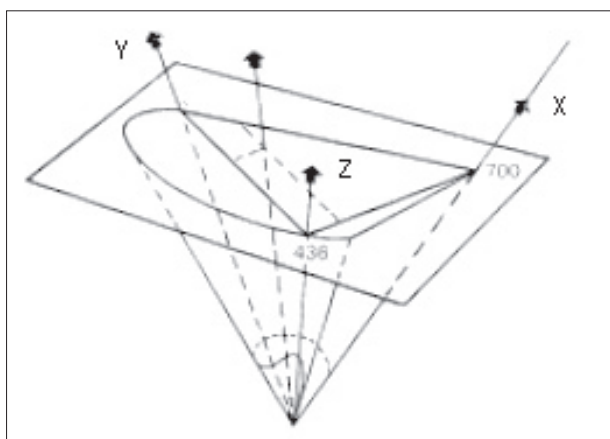


Figure 3 – The XYZ space. Its projection on a plane is a chromaticity diagram xy .

The y coordinate of the XYZ space, the way this space is built, expresses the brightness of the required colour.

Furthermore, it is possible to consider another system of coordinates: the xyY space, obtaining by adding a third dimension to the xy diagram, that is the Y coordinate.

An important property of the CIE 1931 chromaticity diagram is that, mixing additively two colours (represented on the diagram by two points) you obtain, changing the parts of the two starting colours, all the colours lying on the segment which joins the two points. In small words, the additive mixings of two colours lie on a straight segment. From this, it derives that, mixing additively three colours, represented by the three points diagram, you can obtain all the colours inside the triangle, where the three points are the apexes.

Placing the three apexes equidistant on the perimeter, it is evident that with three colours well placed you can generate, even if not entirely, most of other colours. This is the trichromatic principle.

3. Colour range and designation

The samples have to be prepared in order to make the colour of each sample's surface to be in accordance with the chromatographic coordinates of Table 1.

Table 1

Colour designation	x	Nominal y	p	x	Tolerances y	p
0N	0,3383	0,3662	0,90	0,3345	0,3644	0,90
(yellow green)				0,3404	0,3740	+0,01
				0,3456	0,3725	-0,08
				0,3386	0,3633	
1N	0,3526	0,3700	0,82	0,3486	0,3685	0,82
(pale yellow)				0,3527	0,3730	+0,01
				0,3557	0,3717	-0,08
				0,3513	0,3674	
2N	0,3590	0,3766	0,82	0,3558	0,3764	0,82
(light yellow)				0,3600	0,3810	+0,01
				0,3635	0,3795	-0,08
				0,3590	0,3750	
3N	0,3601	0,3729	0,79	0,3578	0,3724	0,79
(yellow)				0,3623	0,3767	+0,01
				0,3663	0,3748	-0,05
				0,3614	0,3707	
4N	0,3612	0,3659	0,76	0,3577	0,3660	0,76
(pink)				0,3626	0,3701	+0,01
				0,3663	0,3682	-0,05
				0,3610	0,3644	
5N	0,3591	0,3604	0,74	0,3555	0,3591	0,74
(red)				0,3621	0,3638	+0,01
				0,3660	0,3616	-0,05
				0,3589	0,3572	

It is important to notice that the rule provides for the designation of the colour by chromatographic coordinates and not by the alloy's chemical composition.

It is written in an appendix (where it is specified that it is not an integral part of the rules) and it is also reported, by way of information, a table of the approximate chemical compositions of the alloys, which should be used as colour sample of reference.

Table 2

Colour designation	Chemical composition [%]		
	Au	Ag	Cu
0N	585	300 a 340	
1N	585	240 a 265	Parte
2N	750	150 a 160	
3N	750	120 a 130	Rimanente
4N	750	85 a 95	
5N	750	45 a 55	

The rule establishes the principle for the colour's designation is defined by the chromatographic coordinates and not by the alloy's composition. This is correct because it is the colour of the surface you are actually observing.

In fact, in a finished product, the variables which determine the superficial colour are several:

- superficial finishing treatments, which can be various, both chemical (different kinds of electroplating (flash, by thickness, by colour etc.) and physical (polished, satin, sand-blasted etc.);
- metallurgic treatments made for obtaining the item (that is annealing carried out in different

conditions, to be followed or not by pickling treatments), final state annealed or work-hardened, of items from investment-casting;

In fact, at least for some alloys, the colour changes depending on the applied deformation. For example the binary Gold-Silver alloys (with a content of Gold from 58.5 to 75%) displays a white-greenish colour after annealing, while after being deformed it displays a yellow, yellow-greenish colour. On the contrary as far as the ternary alloys Gold-Silver-Copper are concerned, there is not this colour changing phenomenon after undergoing a mechanical deformation, except for some particular compositions. For example, the alloy made of 52Au-22Ag-26Cu moves from a reddish white to a yellowish white after deformation, while the alloy 58Au-32Ag-10Cu moves from a faded green to a yellowish green.

- Chemical treatments of emptying out;
- Corrosion as time goes by (tarnishing phenomena, sweating etc.)

Therefore, it is not possible to define an alloy's colour by the chemical composition, except for the samples used as standards.

4. Equipment

A spectrophotometer with Ulbricht's sphere has to be used. The light source must supply a spectral arrangement similar to the one of the standardized D 65 light (day light, one of the standard light sources of the "D" series, introduced in 1963 by CIE), in accordance with CIE publication number 15. The standardization of the light sources was made to allow and define the light sources of artificial light used in trade to evaluate the colours.

In fact, an item's colour depends on three factors:

1. The light source (lighting)
2. The item itself (its reflection)
3. The item's observer (acquisition's method)

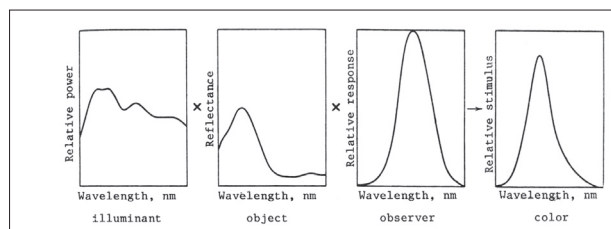


Figure 4 – Factors which determine the colour

In order to understand the importance of the light's source it may be enough to think that, in the dark, an item does not have any colour. We also know that the natural sunlight produces the rainbow's colours, but if we change the spectral arrangement (colour's intensity) of this light's source, the observed item's colour changes.

An item's colour does not depend on its shape but it is strongly depending on its surface's condition, as we've already seen.

Usually the way we perceive a colour is influenced by several factors, which can be gathered in psychological/emotional, physiological and environmental factors.

The psychological/emotional factors concern the way a person reacts, or rather it interprets a certain colour (for example it is widely known that green and blue have a relaxing effect).

The physiological factors concern the way the receptors in our eyes (cones) produce signals which, arrived to the brain, determine the sensation to the colours. Such sensors' behaviour changes from man to man; sometimes there can be malfunctioning which take to the inability to distinguish some colours.

The environmental factors are related to the light and the colours of the place in which a colour is seen.

Therefore the reason why the rules specify down to the smallest detail the kind of equipment to use is clear.

5. Conclusion

The goldsmith's industry has a wide range of gold alloys at its disposal, which allow to obtain an elevate assortment of colours of the finished product. Without taking into consideration that for different kinds of working specific alloys are used, in order to obtain a final product with the best quality possible. This is to say, that the product's colour is an important feature, but now a too elevate variety of the finished surface's colours is offered to the public, and some of these colours are slightly different one from the other.

It is important to consider, also, that it is not possible to standardize the tastes. It is sufficient to take into consideration the colour's satisfaction as function of the geographical areas.

(Examples: Red in Russia, deep/full Yellow tending to the pure colour in the Asian Countries, light brilliant Yellow in Italy; this without going deeper into details).

A common practice is requiring the same colour of a given sample. If such sample is a polished plate, it is possible to reproduce it enough by determining its composition.

For a finished item sometimes it can be not enough determining the composition, for its superficial state has a lot of influence.

It is often required the same colour for different finenesses. If you move from low finenesses (9-10ct) to a 14 ct it is possible to near a lot the required colour. Even the passage from 14 ct to 18 ct is feasible, even if the difference between the two colours is slightly more noticeable.

The most difficult colour to reproduce is the pure gold's colour (of with a very elevate fineness) for 18 ct.

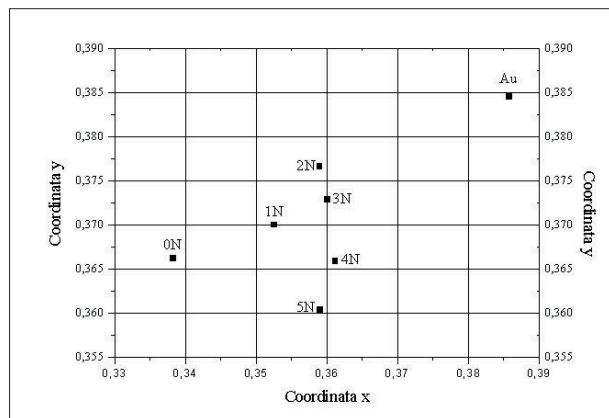


Figure 5 – Values of the CIE x and y coordinates of the reference standards

It is necessary to specify that, in nature, two metals only are endorsed with colour: Gold and Copper, and the alloy's colour is the result of the colours' adjustments on the basis of these two metals.

6. Other works about

Another colour space which, as the XYZ space, represents all the colours human eye can see, is the CIELab. CIELab is a mathematic system which uses three variables, L^* , a^* and b^* . The L^* variable represents the brightness (when L^* is 0 it represents black, when L^* is worth 100 it represents white colour). The a^* variable represents the colour's component which goes from red to green (completely red when $a^*=100$, totally green when $a^*=-100$). The b^* variable represents the part of colour which moves from yellow to blue ($b^*=100$ represents yellow colour, $b^*=-100$ blue).

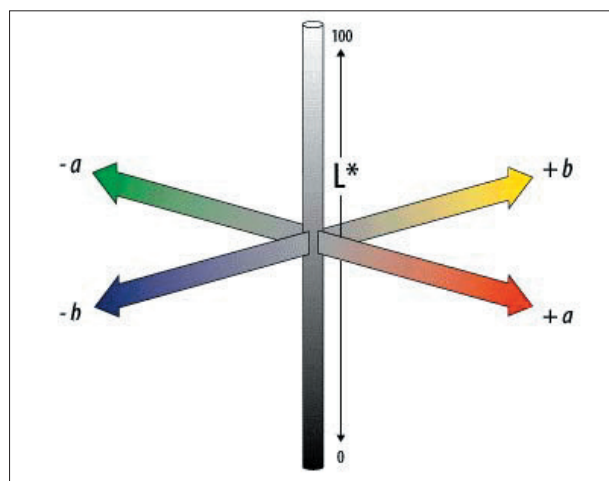


Figure 6 – The CIELab colour space

This system helps to measure the difference between two colours (it is more intuitive).

Are L_1^* , a_1^* , b_1^* the chromatographic coordinates of the first colour and L_2^* , a_2^* , b_2^* the chromatographic coordinates of the colour. The difference between these two colours can be reckoned as $DE^*=[(L_2^*-L_1^*)^2+(a_2^*-a_1^*)^2+(b_2^*-b_1^*)^2]^{1/2}$, that is as the distance between the two corresponding points.

The first colour's measuring work with the CIELab system was made by German and collaborators in 1980. In their work they determined (and designed) the curves with the constant vaults L^* , a^* and b^* of a ternary system Au-Ag-Cu. Unfortunately this work covers only a small part of the compositions used in the goldsmith's industry (even the Zinc is used a lot, together with Cu and Ag). Therefore such work was widened by Raykhtsaum, by analyzing a Au-Ag-Cu-Zn, considering only the 14 ct fineness. The author related only the effect of the chemical composition on the colour, building a diagram for the 14 ct fineness.

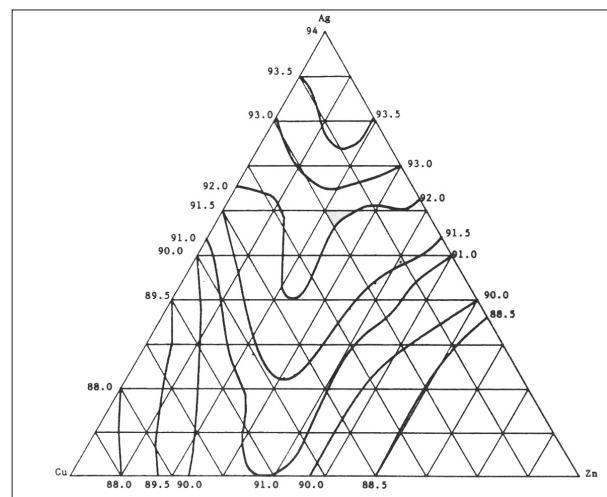


Figure 7 – Trend of the L^* coordinate with the composition of a 14 ct alloy

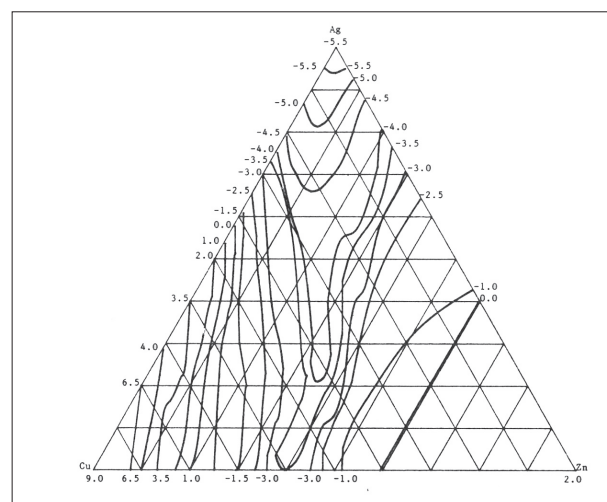


Figure 8 – Trend of the a^* coordinate with the composition of a 14 ct alloy

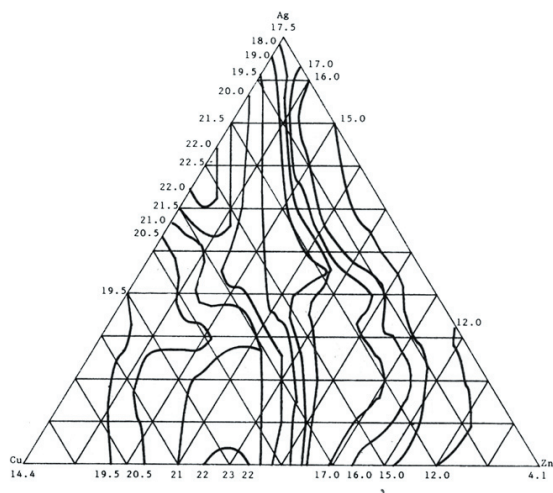


Figure 9 – Trend of the b* coordinate with the composition of a 14 ct alloy

These diagrams provide also the colour's limits (of the CIELab coordinates), obtainable with a 14 ct. To explain the use of this kind of diagrams we proceed by making an example:

We want to reproduce the colour of a ring made of 8 ct gold in a fineness of 14 ct. We calculate the CIELab coordinates of the ring with the desired colour (for example with a composition of 33% Au, 14% Ag, 53% Cu). We enter the diagrams above with the values of the coordinates and we determine that the 14 ct's composition displaying the near colour is: 58.33% Au, 6-8% Ag, remaining part Cu. We prepare three 14 ct samples with 6, 7 and 8% of Ag and we measure their coordinates, obtaining:

Alloy	L*	a*	b*	DE*
Reference	85,4	7,7	16,4	
14 k/6% Ag	85,3	8,0	16,0	0,5
14 k/7% Ag	85,3	7,8	16,0	0,3
14 k/8% Ag	85,5	7,4	16,0	0,6

The sample which is closer to the required colour is the alloy with 7% Ag.

7. Bibliography

“Colours of gold alloys – Definition, range of colours and designation”, UNI EN 28654.

“Coloured Gold Alloys”, Cristian Cretu, Elme van de Ligen, Gold Bulletin 1999.

“Color Technology for Jewellery Alloy Applications”, D.P. Agarwal, G. Raykhtsaum, The Santa Fe Symposium on Jewellery Manufacturing Technology 1988.