Colour Standards

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Abstract

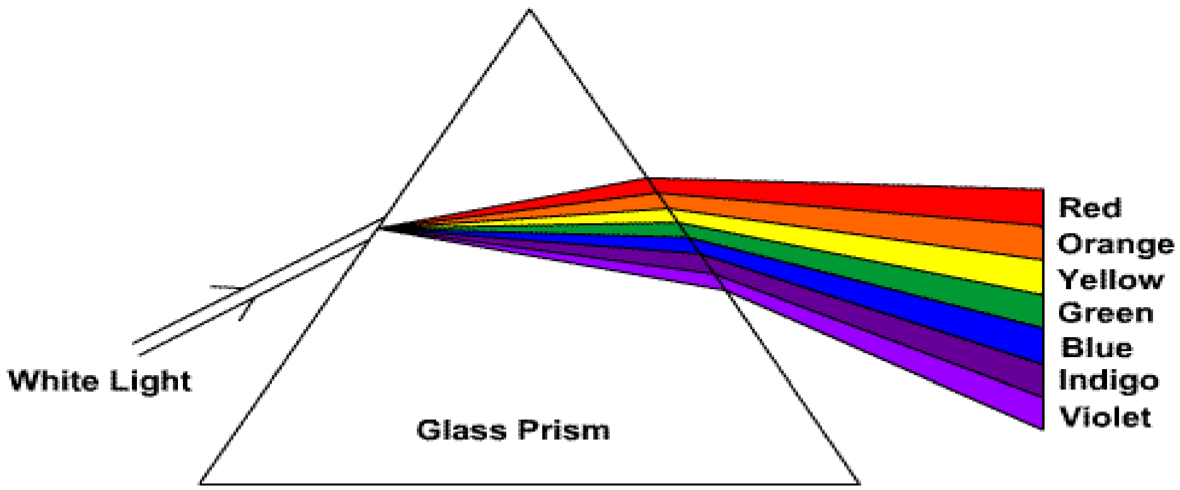
The measurement of colour is now an exact science. This is due to the simultaneous evolution of high-quality instrumentation, and high-quality standards to calibrate and control this instrumentation. This publication outlines the evolution of colour measurement from being an arbitrary and subjective measurement, to being the highly sophisticated and quantitative science that it is today. A central component of this evolution was the development and interpretation of the Tristimulus 3D Model, which is presented and explained in simple terms. However, complexity in colour measurement is due to the fact that different conventions and classifications have evolved that are applicable to different industries. The chronology of these developments, the key measurement scales and the industry segments where accurate colour measurement is an imperative is presented. Although broadly speaking, the same instrumentation can be used irrespective of the convention or scale of interest, the standards used to calibrate the instrument, control the measurement, validate the test or qualify the instrument, must be specific to a particular scale. Therefore, details of standards specific to such conventions or mandated by ASTM, Saybolt, Gardner, Hazen, and the various Pharmacopoeias are presented. Because of the familiarity of the authors with Reagecon Colour Standards, these are used as examples in this publication. In addition to specific part numbers, optimal packaging options are also presented. Ultimately, irrespective of the quality or sophistication of the instrumentation, or the technique used, achieving results that are accurate, quantitative and fit for purpose is totally dependent on the quality of the standards. Rather than being prescriptive in any way, this paper is designed to enable the analyst to understand colour measurement and to have enough information to select fit for purpose colour standards.

1.0 Background Theory

No exact definition exists for colour. The Oxford dictionary quotes colour as "the sensation produced on the eye by rays of light when resolved as by prism into different wavelengths", the Merriam Dictionary quotes "a phenomenon of light as red, brown, pink or grey or visual perception that enables one to differentiate otherwise identical objects". Therefore, colour determination by the human eye has always been subjective, meaning an analyst's interpretation of colour was always open to question.

For centuries colour was determined based on Newtons classification of Primary, Secondary and Tertiary colours. The Primary colours, Red, Blue and Yellow are pure colours, which cannot be produced by mixing other colours. Mixing two primary colours in equal parts creates a Secondary colour, e.g. green (blue + yellow), orange (yellow + red). Tertiary colours are then made by mixing a primary colour and a secondary colour in equal proportion. By the end of the 19th and early 20th ***c***entury colour had become an increasingly important parameter commercially. Virtually all manufacturing sectors required standardization and consistent interpretation of colour measurements for both solid and liquid products. At that time, colour and its understanding and interpretation was defined largely by the classic colour spectrum as presented in Graphic 1.

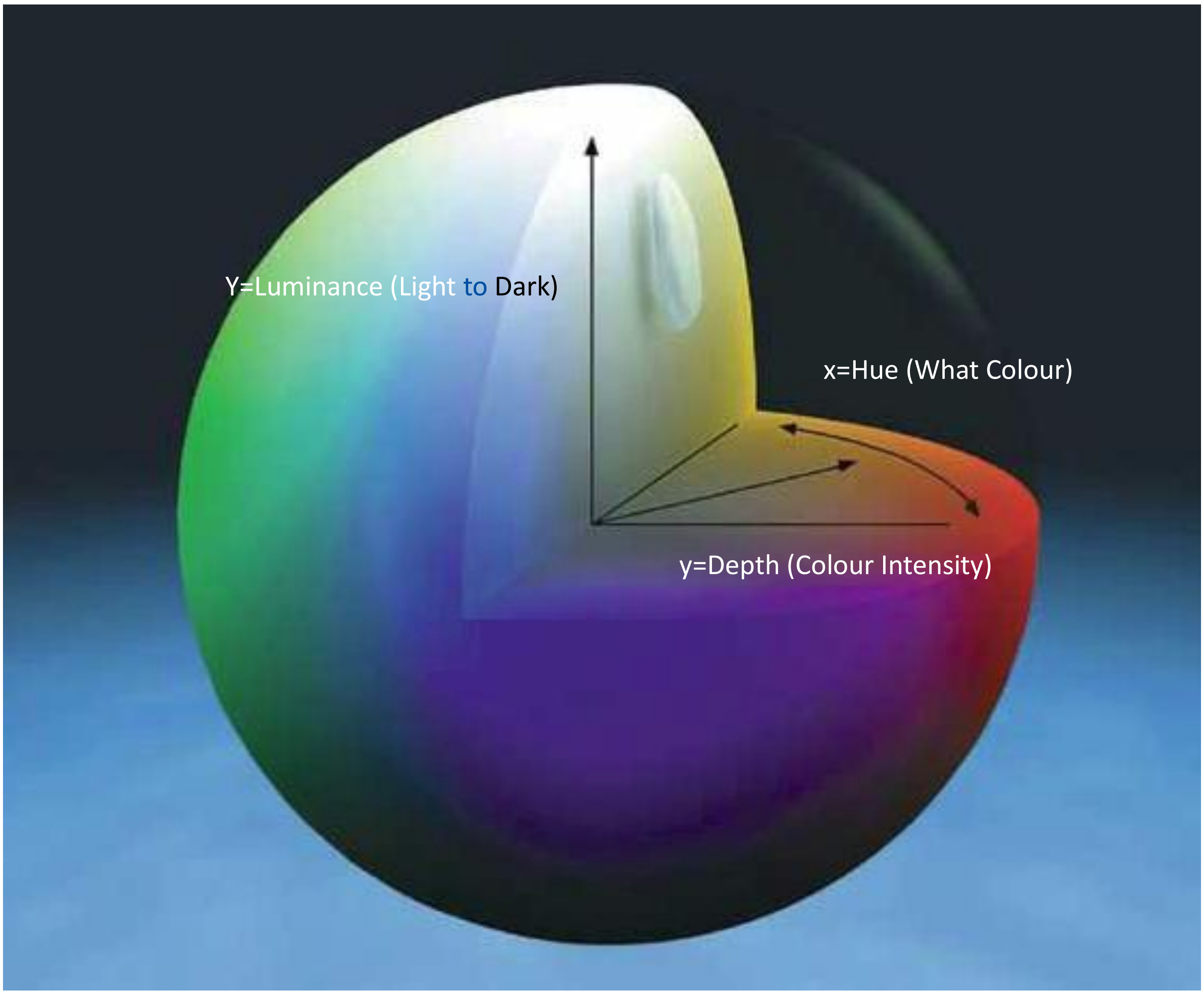
Classic Colour Spectrum



Graphic 1

The ***s***cience behind colour measurement had also advanced and colour now took account of several other factors such as depth (the "richness or intensity" of a colour to the eye), hue (the gradation of colour, e.g. we see a rainbow as a gradation of one colour to the next) and luminance (perceived brightness of a colour, light to dark). This is called the tristimulus model and is a 3-dimensional interpretation of colour, which is a much more complex interpretation than the classic colour spectrum. An elegant, but simplified explanation of this tristimulus concept is presented in Graphic 2.

Tristimulus 3D Interpretation of Colour



Graphic 2

Around this time and across different industries, a series of measurement apparatus, instruments and reporting scales evolved to allow for uniform determination of colour, this requirement for uniformity was driven by companies and industries establishing operations in new territories. Unlike other scientific parameters, no single colour measurement system has been adopted globally. Different measurement scales and hence Calibration Standards are still mandated as the scale of choice for specific industry applications today. A brief chronological summary pertaining to the evolution and thought development relating to the science to colour is presented Graphic 3.

Brief Chronology of Colour Development

1892	Alan Hazen (Platinum Cobalt)
1915	Albert Munsell Colour Atlas
1920	Lovibond Tintometer System
1920's	Gardner Visual Scale
1931	CIE Standard Colorimetric System (Tristimulus Determination)
1940's	ASTM Petroleum Scale
1958	Hunter (for HunterLab Colour Analyser)
1964	CIE Supplementary Standard Colorimetric System
1964	ASTM Saybolt Scale (D156)

Graphic 3

2.0 Colour Standards

Worldwide there are a small number of high-quality producers of colour standards. For illustrative purposes, in terms of the range of such standards available commercially and in order to guide the analyst on the optimal criteria for selecting the most fit for purpose standards from Reagecon are used in this publication. These are used, because they are the more familiar to the authors than the products from other producers. Some of the key colour measurement scales are described in Graphic 4, including the industry that they are targeted at, with some guide notes on each type of standard.

Key Colour Measurement Scales

Scale	Measurement
ASTM	Colour scale for Petrochem industry
Saybolt	Scale for food oils, environmental and industrial products
Gardner	Scale for yellow through to amber colour, for water and environmental analysis
Platinum Cobalt (Hazen)	Colour scale for clear liquids, waste water and brewing
Pharmacopoeia	Primary colour standards red, yellow and blue formulated and mixed to create the desired colour standard

Graphic 4

Prior to looking at each family of standards in detail, Graphic 5 demonstrates broadly the industry types, where colour standards are used.

Industry Segments where Colour Standards are used

Industry	Applications
Pharmaceutical	• Medication colour • Formulation research
Cosmetics	• Soaps and shampoos • Fragrances • Creams and lotions
Water Analysis	• Potable water • Waste water pollutant levels
Brewing	• Product presentation • Malts and caramels
Petrochemical	• Refinement process control • Petroleum oils & waxes
Industrial	• Paint & coatings • Chemicals • Dyes • Household products
Food & Beverage	• Product colour presentation • Honeys and preserves • Edible oils

Graphic 5

3.0 Types of Colour Standards

3.1 ASTM Standards

An example of where ASTM colour standards are used is the determination of colour within petroleum products. Since colour is readily observed by the user of the product, the colour may serve as an indication of the degree of refinement of the material. When the colour range of a particular product is known, a variation outside the established range may indicate possible contamination with another product. Table 1 presents the Reagecon range of ASTM Colour Standards, that include part numbers, product description, colour scale and the standard methods to which each standard applies. Pack size options are also shown.

ASTM Colour Standards

Product No.	Description	Colour	APHA, ACS and ASTM Methods to include the following	Pack Size
ASTMA101	ASTM Colour Standard Sample A1	1	D6045,D1500	100ml
ASTMA105	ASTM Colour Standard Sample A1	1	D6045,D1500	500ml
ASTMA301	ASTM Colour Standard Sample A3	3	D6045,D1500	100ml
ASTMA305	ASTM Colour Standard Sample A4	3	D6045,D1500	500ml
ASTMA501	ASTM Colour Standard Sample A5	5	D6045,D1500	100ml
ASTMA505	ASTM Colour Standard Sample A5	5	D6045,D1500	500ml
ASTMA701	ASTM Colour Standard Sample A7	7	D6045,D1500	100ml
ASTMA705	ASTM Colour Standard Sample A7	7	D6045,D1500	500ml

Table 1

3.2 Saybolt Colour Standards

Saybolt colour reference standards are used for process control of products such as edible and industrial oils, fuels, chemicals, pharmaceuticals, paints and coatings. The full range of such standards from Reagecon, including all relevant information, is presented in Table 2.

Saybolt Colour Standards

Product No.	Description	Colour	APHA, ACS and ASTM Methods to include the following	Pack Size
SAYP301	Saybolt Colour +30	S+30	D6045	100ml
SAYP305	Saybolt Colour +30	S+30	D6045	500ml
SAYP251	Saybolt Colour +25	S+25	D6045	100ml
SAYP255	Saybolt Colour +25	S+25	D6045	500ml
SAYP191	Saybolt Colour +19	S+19	D6045	100ml
SAYP195	Saybolt Colour +19	S+19	D6045	500ml
SAYP151	Saybolt Colour +15	S+15	D6045	100ml
SAYP155	Saybolt Colour +15	S+15	D6045	500ml
SAYP121	Saybolt Colour +12	S+12	D6045	100ml
SAYP125	Saybolt Colour +12	S+12	D6045	500ml
SAYP01	Saybolt Colour +0	S0	D6045	100ml
SAYP05	Saybolt Colour +0	S0	D6045	500ml
SAYN151	Saybolt Colour -15	S-15	D6045	100ml
SAYN155	Saybolt Colour -15	S-15	D6045	500ml

Table 2

3.3 Gardner Colour Standards

These liquid colour standards range from water white through yellow to deep amber. Gardner Standards 1 through 8 are solutions of potassium chloroplatinate, are light in value, have a very slight greenish hue and are most often used in testing unheated liquids. Standards 9 through 18 are solutions of ferric chloride and cobalt chloride; they are darker and are generally used to test varnishes, oil and resins which have reached colour through heating. Specific products, at various points of the Gardner Scale are presented in Table 3. A wide range of these standards at intermediate points on the colour scale are also available.

Gardner Colour Standards

Product No.	Description	Colour	APHA, ACS and ASTM Methods to include the following	Pack Size
GARD02	Gardner Colour 2	2	D6166	500ml
GARD021	Gardner Colour 2	2	D6166	100ml
GARD04	Gardner Colour 4	4	D6166	500ml
GARD041	Gardner Colour 4	4	D6166	100ml
GARD06	Gardner Colour 6	6	D6166	500ml
GARD061	Gardner Colour 6	6	D6166	100ml
GARD08	Gardner Colour 8	8	D6166	500ml
GARD081	Gardner Colour 8	8	D6166	100ml
GARD10	Gardner Colour 10	10	D6166	500ml
GARD101	Gardner Colour 10	10	D6166	100ml
GARD12	Gardner Colour 12	12	D6166	500ml
GARD121	Gardner Colour 12	12	D6166	100ml
GARD14	Gardner Colour 14	14	D6166	500ml
GARD141	Gardner Colour 14	14	D6166	100ml
GARD16	Gardner Colour 16	16	D6166	500ml
GARD161	Gardner Colour 16	16	D6166	100ml

** Standards with intermediate Gardner values are available on request

Table 3

3.4 Platinum Cobalt Standards (Hazen)

These were first developed as a way to evaluate pollution levels in waste water. They have since expanded to being used as a common method of comparison of the intensity of yellow-tinted samples. They are specific to the colour yellow and based on dilutions of a 500ppm platinum cobalt solution. These carry ASTM Designation D1209, "Standard Test Method for Colour of Clear Liquids". The ranges of products available within this family is presented in Table 4 and intermediate values are widely available.

Platinum-Cobalt Colour Standards (Hazen)

Product No.	Description	Colour	APHA, ACS and ASTM Methods to include the following	Pack Size
HAZ0	Platinum-Cobalt Colour 0	0	D1209	1000ml
HAZ5	Platinum-Cobalt Colour 5	5	D1209	1000ml
HAZ10	Platinum-Cobalt Colour 10	10	D1209	1000ml
HAZ25	Platinum-Cobalt Colour 25	25	D1209	1000ml
HAZ40	Platinum-Cobalt Colour 40	40	D1209	1000ml
HAZ50	Platinum-Cobalt Colour 50	50	D1209	1000ml
HAZ80	Platinum-Cobalt Colour 80	80	D1209	1000ml
HAZ100	Platinum-Cobalt Colour 100	100	D1209	1000ml
HAZ250	Platinum-Cobalt Colour 250	250	D1209	1000ml
HAZ500	Platinum-Cobalt Colour 500	500	D1209	1000ml

Table 4

3.5 Pharmacopoeia Colour Standards

Pharmacopoeia methods for colour assessment of pharmaceutical solutions are based on a visual comparison. Starting with primary colour liquid standards red, yellow and blue, formulated as per the Pharmacopoeia, dilutions and mixtures of these primary colours are made to give colour standards such as brown and green and in turn produce the working standards. Formulation vary between USP and Ph. Eur. so specific colour standards are needed when making colour determinations according to each Pharmacopoeia. The following tables show various iterations of available standards for pharmaceutical colour measurement.

Reagents as Outlined in Chapter 2 of European Pharmacopeia

Product No.	Description	Pack Size
EPPOS01	Primary Opalescent Standard	100ml

Colouration - Primary Solutions

Product No.	Description	Pack Size
EPBS01	EPBS01 Primary Blue Solution 100ml	100ml
EPRS01	EPRS01 Primary Red Solution 100ml	100ml
EPYS01	EPYS01 Primary Yellow Solution 100ml	100ml

Standard Solutions

Product No.	Description	Pack Size
EP703	Standard Solution B (Brown)	100ml
EP704	Standard Solution BY (Brown/Yellow)	100ml
EP705	Standard Solution GY (Green/Yellow)	100ml
EP706	Standard Solution Y (Yellow)	100ml
EP707	Standard Solution R (Red)	100ml

USP (631) Colour Standards

Product No.	Description	Pack Size
USPCS101	Cupric Sulfate CS	100ml
USPCS102	Ferric Chloride CS	100ml
USPCS103	Cobaltous Chloride CS	100ml

Table 5

4.0 Conclusion

The measurement of colour has evolved from being an arbitrary and subjective measurement to being a highly technical and quantitative measurement. Such a measurement has application in many industries. A significant contribution to the specific evolution of colour measurement has been the parallel development of high-quality standards related to the various colour scales and conventions set up in existence. These high-quality standards enable calibration, quality control, method validation and instrument qualification. Such metrological concepts are mandatory either from a good laboratory practice perspective, or as a mandatory obligation.

It is hoped that this paper, outlies in simple terms, the principles and applications of colour standards. It is also hoped that the ranges of standards offered are comprehensive, and enable the analyst t obtain the correct analytical result and prove the correctness of that result. The features and benefits of a good range of colour standards should include the features presented in Graphic 6.

Features and Benefits of High-Quality Colour Standards
Industrial colour standards produced in accordance with ASTM, APHA, ACS methods and conventions.
Pharmacopoeia colour standards are made according to Ph. Eur, USP or other formulations.
May be used with any colour meter.
Range covers all common colour scales.
Certificates of analysis for each batch.

Graphic 6

The producer of high-quality standards should hold ISO 17025 accreditation for calibration of laboratory balances. The resulting Balance Certificate of Calibration should be issued in accordance with the requirements of ISO/IEC 17025. The certified values of each standard should then be verified using a high-performance spectrophotometer calibrated with NIST traceable, ISO 17034 Certified Reference Standards, where possible.

5.0 Bibliography

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