Designation: E2970 – 15

Standard Practice for Specifying Color by the Natural Colour System (NCS)[1]

This standard is issued under the fixed designation E2970; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 The Natural Colour System (NCS) (see 1.7) provides a color notation system that can be used to communicate color. This practice introduces the Natural Colour System, its terminology, and conversion to and from CIE tristimulus values.

1.2 The system described in this standard includes color percepts that appear to belong to the surface of a material, provided the surface is not perceived to be fluorescent or to exhibit directional color effects.

1.3 The system does not include colors that appear to belong to translucent or luminescent objects (so-called volume colors and luminous colors), nor does it include other visual properties of the surface layer, such as gloss and texture. An NCS notation does not describe the physical or chemical properties of an object.

1.4 This practice also specifies the conditions for visual or instrumental determination of the NCS notation of a color sample, defines the relationships between psychometrically determined NCS notations and the corresponding CIE color coordinates which are to be used in this context.

1.5 For the accuracy requirements associated with NCS standards and NCS color samples, the user is referred to Swedish Standard SS 19104. The colored illustrations in this standard shall not be used as standard color samples in any way. Color illustrations that are shown on screen or in printouts may be significantly different than the original NCS color samples with the same NCS Notation due to limited color reproduction capabilities in screens and printers.

1.6 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.7 *Acknowledgement—NCS, Natural Colour System is a trademark of the NCS Colour AB Stockholm, Sweden and is protected by copyright (www.ncscolour.com). All rights reserved. Original NCS color samples are only available form NCS Colour AB or any authorized NCS distributor. Commercial use of the NCS System requires a license from NCS Colour AB.*

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]
E284 Terminology of Appearance
E308 Practice for Computing the Colors of Objects by Using the CIE System
E1164 Practice for Obtaining Spectrometric Data for Object-Color Evaluation

2.2 *Swedish Standards:*[3]
SS 19100 Colour Notation system
SS 19102:2004 NCS Colour Atlas
SS 19104 NCS colour samples — Observation and measurement conditions and tolerances

2.3 *Other Documents:*[4]
CIE 15:2004 Colorimetry

2.4 *ASTM Adjuncts:*
Spreadsheet for NCS Notations and CIE Coordinates[5]

3. Terminology

3.1 Terms and definitions in Terminology E284 are applicable to this practice.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *elementary color, n*—one of the six color percepts each of which can be described only by reference to itself.

[1] This practice is under the jurisdiction of ASTM Committee E12 on Color and Appearance and is the direct responsibility of Subcommittee E12.07 on Color Order Systems.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Swedish Standards Institute, SIS Förlag AB, SE-118 80 Stockholm, Sweden, www.sis.se.

[4] Available from U.S. National Committee of the CIE (International Commission on Illumination) or CIE Webshop http://www.techstreet.com/cie.

[5] Available from ASTM International Headquarters. Order Adjunct No. ADJE2970S-EA. Original adjunct produced in 2014.

3.2.1.1 *Discussion*—The elementary colors, which are designated with uppercase letters, are as follows: white (W), black (S), yellow (Y), red (R), blue (B), green (G). All other colors can be described in terms of their resemblance to these six. White and black are achromatic elementary colors. Yellow, red, blue and green are chromatic elementary colors.

3.2.2 *elementary attribute, n*—the degree of resemblance of a color to an elementary color.

3.2.2.1 *Discussion*—The elementary attributes, which are designated by italic lowercase letters, are: *whiteness (w), blackness (s), yellowness (y), redness (r), blueness (b), and greenness (g). Whiteness* and *blackness* are achromatic elementary attributes. *Yellowness, redness, blueness* and *greenness* are chromatic elementary attributes. All are perceptual quantities, which are expressed by a number between 0 and 100. For any arbitrary color the following apply:

(a) the color cannot simultaneously possess *yellowness* and *blueness*,

(b) the color cannot simultaneously possess *redness* and *greenness*,

(c) the sum of its elementary attributes is 100.

It follows that a color can have at most four elementary attributes in one of the following combinations:

$$w + s + c_1 + c_2 = 100 \quad (1)$$

where c_1 and c_2 are adjoining elementary chromatic colors, such as *y* and *r*, *r* and *b*, *b* and *g*, or *g* and *y*.

3.2.3 *full chromatic color, n*—a color that lacks the elementary attributes of whiteness and blackness.

3.2.3.1 *Discussion*—A full chromatic color, regardless of hue, is designated by an uppercase letter, *C*. The four chromatic elementary colors Y, R, B and G are also full chromatic colors.

3.2.4 *NCS chromaticness, n*—the degree of resemblance of a color to the full chromatic color of the same hue.

3.2.4.1 *Discussion*—NCS chromaticness is a perceptual quantity derived from the chromatic elementary attributes. The NCS chromaticness is expressed by a number between 0 and 100 for the sum of the (at most two) chromatic elementary attributes, and it is designated by an italic lowercase c. It follows that:

$$c = c_1 + c_2 \quad (2)$$

where c_1 and c_2 are adjoining elementary chromatic colors, such as *y* and *r*, *r* and *b*, *b* and *g*, or *g* and *y*.

Eq 1 and Eq 2 can then be written:

$$w + s + c = 100 \quad (3)$$

For achromatic (pure gray) colors including the elementary colors white and black, $c = 0$ and $w + s = 100$. For maximal colors, $w + s = 0$ and $c = 100$.

3.2.5 *NCS hue, n*—the relation between the (at most two) chromatic elementary attributes of a color, regardless of the whiteness and blackness of the color.

3.2.5.1 *Discussion*—The NCS hue is a perceptual quantity derived from the chromatic elementary attributes. The NCS hue is expressed by a number between 0 and 100 as the proportion of one chromatic elementary attribute in the sum of the (at most two) chromatic elementary attributes, that is, the NCS chromaticness. The "one" always refers to the chromatic elementary attribute which is placed last in Eq 2. In formulae (but not in NCS notations), the hue is denoted by the symbol Φ together with a suffix. The suffix consists of the italic lowercase letters for the pair of chromatic elementary attributes in question, that is, *yr*, *rb*, *bg*, or *gy*. It follows that:

$$\Phi_{yr} = 100\ r/(y + r) = 100\ r/c \quad (4)$$

$$\Phi_{rb} = 100\ b/(r + b) = 100\ b/c \quad (5)$$

$$\Phi_{bg} = 100\ g/(b + g) = 100\ g/c \quad (6)$$

$$\Phi_{gy} = 100\ y/(g + y) = 100\ y/c \quad (7)$$

Eq 4-7 can also be used in reverse to calculate the chromatic elementary properties when the NCS chromaticness and NCS hue are known.

3.2.6 *NCS nuance, n*—the composition of whiteness, blackness and chromaticness in a color, regardless of the hue.

3.2.6.1 *Discussion*—The NCS nuance is expressed by a pair of numbers which represent the blackness and chromaticness of the color. The whiteness is excluded, since it is given by Eq 3. The NCS nuance is a perceptual quantity derived from the elementary attributes. It has an unambiguous NCS notation through the first four figures in the alpha–numerical basic code.

3.2.7 *NCS saturation, n*—the relation between the chromaticness of a color and its whiteness, regardless of the hue.

3.2.7.1 *Discussion*—NCS saturation is a perceptual quantity derived from the elementary attributes. The NCS saturation is expressed by a number between 0 and 1 for the ratio of the chromaticness (*c*) of the color to the sum of its whiteness (*w*) and chromaticness (*c*). The NCS saturation is designated by an italic lowercase *m*. It follows that:

$$m = c/(w + c) \quad (8)$$

where $w + c$ is equal to 100 -*s*.

3.2.8 *NCS lightness, n*—a characteristic of a color such that it appears to have more of the elementary color black or white than another color.

3.2.8.1 *Discussion*—NCS lightness is a perceptual quantity, designated by a lowercase *v*, the value of which varies between zero (0) for the elementary color black (S) and one (1) for the elementary color white (W) . For achromatic (pure gray) colors including the elementary colors white (W) and black (S), for which $c = 0$, *v* is defined as:

$$v = (100 - s)/100 \quad (9)$$

The NCS lightness of any arbitrary color specimen is determined by comparison edge-to-edge with a reference scale of achromatic color samples ($c = 0$). The color specimen is assigned the same lightness value as that of the reference sample for which the border between specimen and reference is perceived to be least distinct.

3.2.9 *luminance factor, Y, n*—ratio of the luminance of a specimen to that of a perfect diffuser, when illuminated and viewed under specified geometric conditions.

3.2.9.1 *Discussion*—In the CIE 1931 system, this quantity is tristimulus value *Y*.

4. Summary of Practice

4.1 *Visual Method*—Observers should have normal color vision. Specimens should be viewed on an essentially nonselective gray background of approximately 56 % luminance factor with natural or artificial daylight of approximately 1000

lux. The test specimen should be compared edge-to-edge to the colors in the NCS 1950 Original Collection (for example, in SS 019102:2004 NCS Colour Atlas). The size of the specimen should be at least 40 by 50 mm with an immediate white surround of 85 % luminance factor. The specimen and color chip should be perpendicular to the observer with the illumination at an angle of approximately 45°.

4.2 *Instrumental Method*—CIE 1931 tristimulus values for standard illuminant D65 and the CIE 1931 standard colorimetric observer are obtained from spectrophotometric or colorimetric measurement. See Practices E308 and E1164. Computation of NCS notation values can be achieved by following the directions in Annex A1 and using the tables in the adjunct.[5]

5. Significance and Use

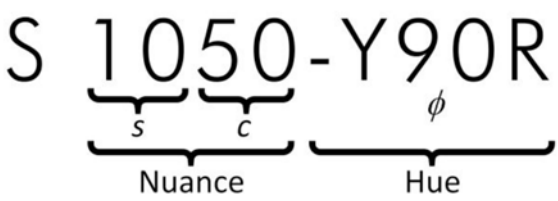
5.1 The Natural Colour System is a color notation system that builds on how a human being sees color. An NCS notation represents a specific color percept and describes the color as perceived; it is not dependent on limitations caused by pigments, light rays or nerve signals that have given rise to this perception. The NCS system is used internationally in such fields as architecture, corporate identity, cosmetics, education, fashion and textile forecasting and production, interior design and product design. The Natural Colour System describes colors exactly as they are seen. Any of the millions of colors that exist can be defined within the NCS system and given a precise notation. When the NCS system is known, it is possible to judge the attributes of a color by its NCS notation; for example, how much blackness, how much chromaticness, and what hue? This helps to communicate and check specifications and to identify colors. Some examples of the use of NCS are: (*1*) Architects and designers use the NCS color samples to select colors for all kind of products and materials; (*2*) They also use the NCS notation to analyze the colors in use in a particular area and to document their specifications; (*3*) Companies use the NCS color samples as the production standards for their products; (*4*) Paint manufacturers and other industries use the NCS notation and the NCS color samples to visualize the color of their products to customers, and (*5*) Companies use the NCS samples as high quality color standards in corporate identity programs and manuals.

6. Specifying Color with a NCS Notation

6.1 *NCS Notation*—An NCS notation consists of an alpha-numerical code, the letters and figures of which describe the appearance of the designated color.

6.1.1 *The Alpha-numerical Code*—The alpha-numerical basic code for an NCS notation has nine characters, which in turn indicate the blackness and NCS chromaticness, each with two figures (00–99), and thereafter the NCS hue by a hyphen followed by two capitals enclosing two figures (00–99). The capitals show the relevant chromatic elementary colors. See Fig. 1. In practice a variation of this basic code with different or fewer characters is often used.

6.1.2 A chromatic color with c <100 and with two chromatic elementary attributes is designated by the basic code. Example: 5535-R20B designates a color with a blackness of 55, a chromaticness of 35, and a hue of (80 %) red and 20 % blue.



For example in the NCS notation 1050-Y90R, 1050 describes the nuance, that is, the degree of resemblance to whiteness (40 %) and blackness which is 10 % and to the maximum chromaticness which is 50 %. The whiteness is not shown but is the remaining 40 % (100-10-50=40). The hue Y90R describes the degree of resemblance between Yellow and Red (Y and R). Y90R describes a red color with (10 %) yellowness. In the NCS notation this is written as yellow with 90 % redness. (The letter S preceding the complete NCS notation (S 1050-Y90R) denotes an NCS notation that is available as standardized physical color samples in SS 19102:2004 NCS Colour Atlas.

FIG. 1 NCS Notation

The parentheses are added here to mark that this figure is not shown in the notation.

6.1.3 A chromatic color with c <100 and with only one chromatic elementary attribute is designated by a code which lacks the last three figures of the basic code. Example: 5535-R.

6.1.4 An achromatic (pure gray) color, but not one of the elementary colors white and black is, however, designated by a code with a capital N instead of the last four figures of the basic code. The capital N means “neutral.” Two examples: 2500-N and 7000-N.

6.1.5 A full chromatic color, but not one of the elementary colors yellow, red, blue or green is, however, designated by a code with the capital C instead of the four first characters of the basic code. Example: C-R80B.

6.1.6 The six elementary colors are designated by the capitals W, S, Y, R, B and G. See Fig. 2.

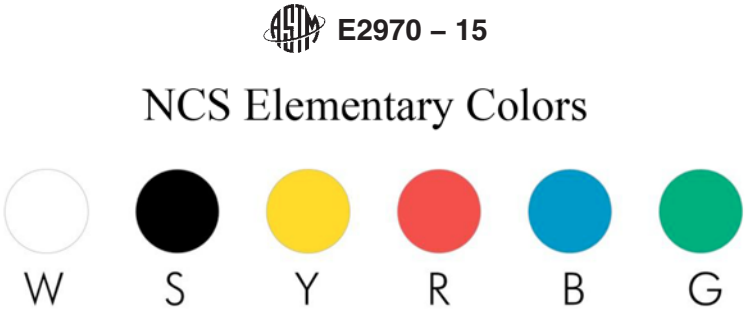
6.2 *NCS Color Triangle*—An NCS color triangle is an equilateral triangle within which each point unambiguously represents a color with a certain NCS nuance, regardless of the hue of the color. See Fig. 3.

6.2.1 The three perpendicular distances from the sides of the triangle to an arbitrary point within the triangle are designated *w, s* and *c* and the height of the triangle is set equal to 100, see Fig. 3. According to the geometry of equilateral triangles, it follows that:

$$w + s + c = 100 \quad (10)$$

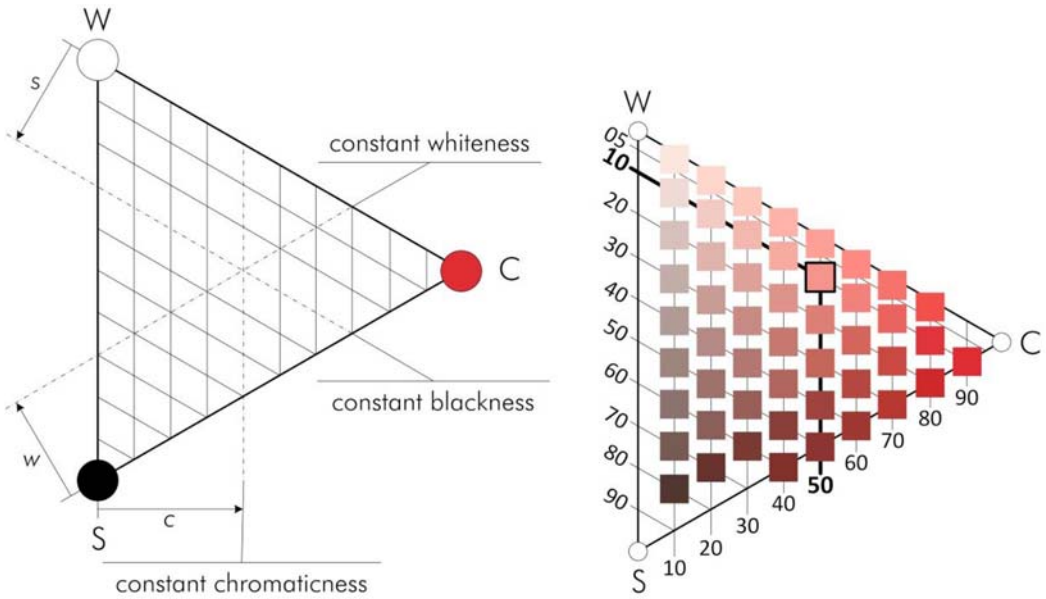
that is, the same as Eq 3.
This means that a given point in the color triangle unambiguously represents all colors with a certain composition of whiteness (w), blackness (s) and NCS chromaticness (c), that is, all colors with the same NCS nuance. To determine the location of the point and thereby the NCS nuance, it is sufficient to indicate the numerical values of *s* and *c*, since the sum of *w, s* and *c* is always 100.

6.2.2 The three corners of the NCS color triangle represent the elementary color white (W), the elementary color black (S) and the full chromatic color regardless of hue (C). Points within the NCS color triangle on lines parallel to the sides S-C, W-C and W-S represent colors having respectively the same whiteness, the same blackness and the same NCS chromaticness. In the NCS color triangle, points for colors having the same saturation lie on straight lines emanating from the black point (S).



The NCS system starts with six elementary colors, which are perceived by human beings as being "pure." For example, the elementary red color is only red, not a red with a little bit of yellow or a reddish-blue. These six elementary colors correspond with the perception of color in our brain. The four chromatic elementary colors are Yellow (Y), Red (R), Blue (B) and Green (G), and the two non-chromatic elementary colors are White (W) and Black (S). All other colors can be described in terms of their degree of visual resemblance to the elementary colors. These resemblances are the elementary attributes (yellowness, redness, blueness, greenness, whiteness and blackness). NCS color notations are based on how much a given color seems to resemble two or more of these six elementary colors.

FIG. 2 NCS Elementary Colors



The NCS color triangle is a vertical section through the color space for the different hues. The base of the triangle is the gray scale from withe (W) to black (S) and the apex of the triangle is the maximum chromaticness (C) in the current hue, here Y90R. In the triangle you can find the nuance of the color, which shows the visual amount of whiteness, blackness and chromaticness.

FIG. 3 NCS Color Triangle

6.2.3 A point within the NCS Color Triangle does not define the hue of the color. If, on the other hand, a certain hue is assigned a certain NCS color triangle, a point within this triangle will unambiguously represent a certain composition of NCS nuance and NCS hue, that is, a single color.

6.3 The NCS color circle is a circle, within which each point unambiguously represents a color with a given combination of NCS chromaticness and hue, regardless of the whiteness and blackness of the color. See Fig. 4 a and b.

6.3.1 In a circle with two mutually perpendicular diameters (axes B-Y and G-R), the length of the radius is set equal to 100 and the right angles between the axes are assigned values of 100. The distance from the center to any point in the circle is denoted *c*, see Fig. 4, and the angle between the radius through the point and the nearest axis Y, R, B or G in the counter-clockwise direction is denoted Φ_{yr}, Φ_{rb}, Φ_{bg} or Φ_{gy}.

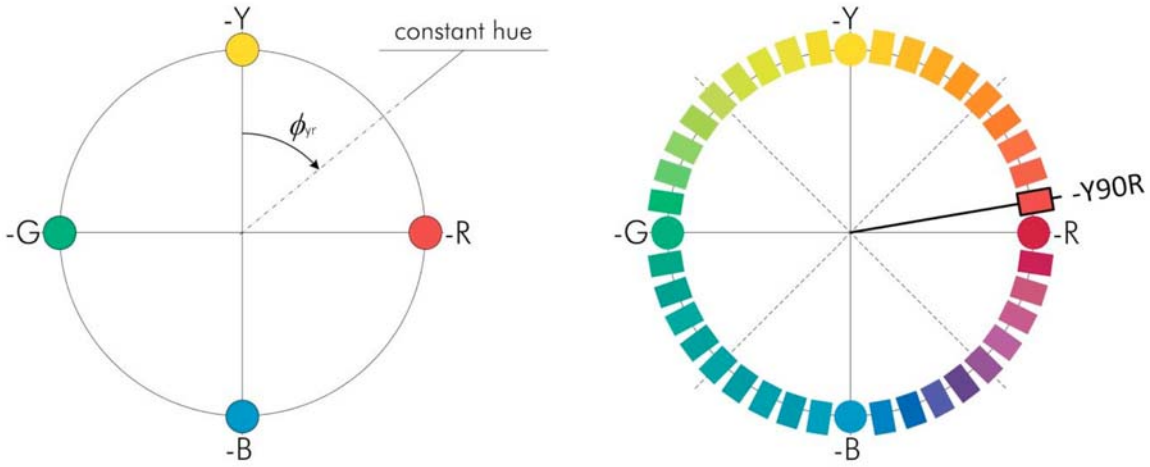
6.3.2 A given point in the NCS color circle thus represents all colors with a certain composition of chromaticness (*c*) and hue (Φ), and thus all colors with a certain composition of the chromatic elementary attributes.

6.3.3 A point on the circumference of the NCS color circle represents a full chromatic color with a certain hue. The points Y, R, B and G represent the four chromatic elementary colors.

6.3.4 The center of the NCS color circle represents the elementary colors white (W) and black (S) and all other achromatic (pure gray) colors. A point within the NCS color circle says nothing about the blackness of the color (except for the full chromatic colors that have blackness equal to 0).

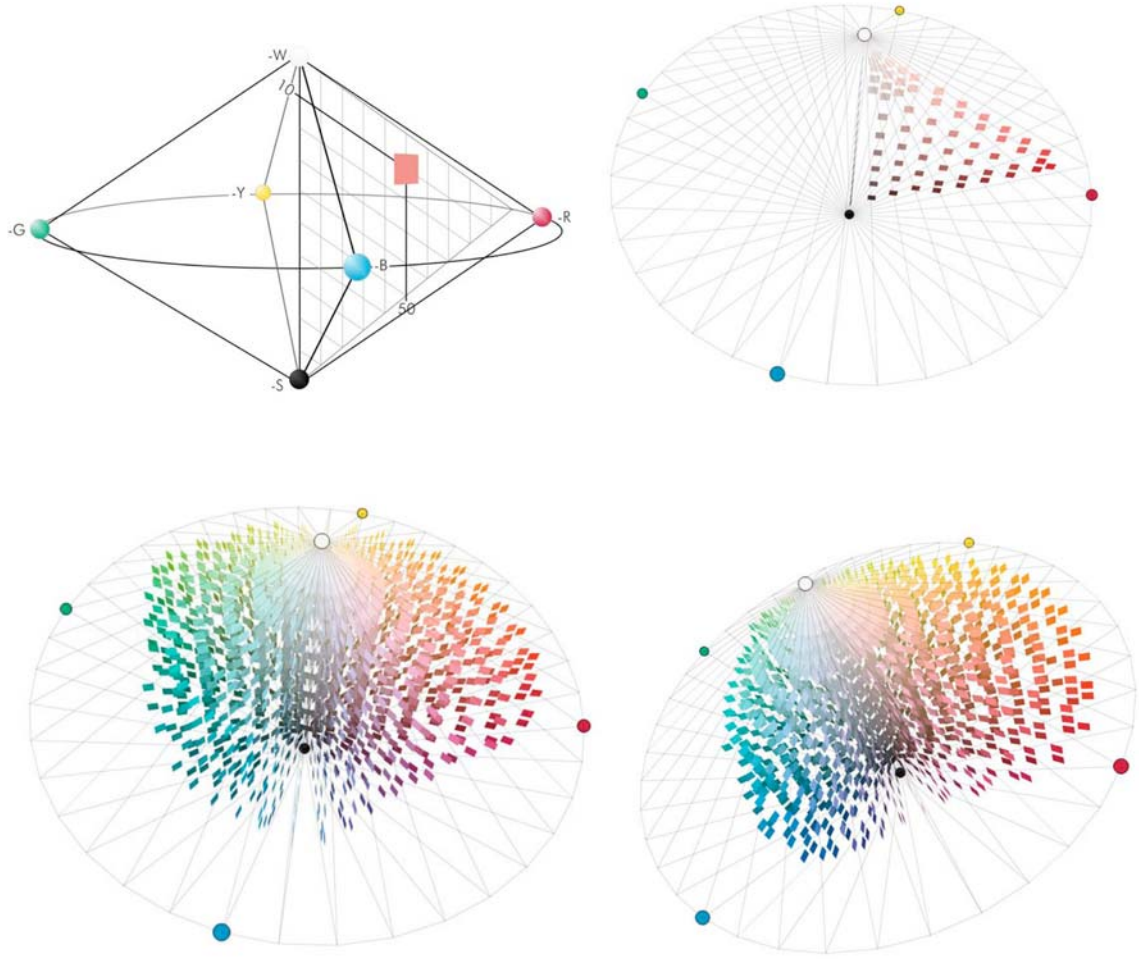
6.4 *NCS Color Space* takes the form of a circular double-cone, within which each point unambiguously represents a certain color. See Fig. 5.

6.4.1 The NCS color space is formed when the NCS color triangle rotates about the side W-S so that the corner C follows the circumference of the NCS color circle. See Fig. 4.



The NCS color circle is a horizontal section through the middle of the color space seen from above where the four chromatic elementary colors are placed like the cardinal points of a compass. Each quadrant between two elementary colors is divided into 100 equal steps. The hue of the color you find in the NCS color circle describes whether the color is a yellow or a yellowish red etc.

FIG. 4 NCS Color Circle



Views of the three-dimensional NCS color space.

FIG. 5 NCS Color Space

6.4.2 The hues of the NCS color circle are assigned the corresponding NCS color triangles in the sections through the axis W-S of the double-cone. This means that a given point within the double-cone unambiguously represents a single color with a certain NCS nuance and NCS hue, that is, a certain color.

7. Determination of NCS Notations

7.1 NCS is a universally applicable perceptual system according to which colors are arranged in accordance with their appearance and such that each color is given an alpha-numerical notation which defines its position in the NCS color space. The system has been realized and standardized (SS 19100) together with an illustrative NCS Colour Atlas (SS 19102:2004) after extensive psychometric tests with many participants (**1**, **2**, **3**).[6] With the aim of anchoring this work and facilitating continued practical use of the system without having to repeat these tests, physical measurements were made on all the color samples and a relationship between NCS color coordinates and CIE color coordinates was established. The continuing use thus requires a rigorously constructed system for both visual estimation and instrumental measurement using the established psychometric relationships to ensure the highest possible quality, stability and accuracy of the NCS color samples which are produced and used.

7.2 The NCS color coordinates of a colored surface can in principle be determined by visual observation, with or without comparison with a NCS standard. The method can be used to obtain an approximate NCS notation for the perceived color of objects in different observation situations. The method assumes a reasonable knowledge and training in the NCS notation system. The precision in the assignment of the NCS notation varies somewhat between different persons, depending on their training and experience and on external conditions.

7.3 The colored illustrations in this standard shall not be used as standard color samples in any way. Color illustrations that are shown on screen or in printouts may be significantly different compared to the original NCS color samples with the same NCS Notation due to limited color reproduction capabilities in screens and printers.

8. Determination of NCS Notations by Visual Comparison

8.1 The NCS color coordinates of a colored object are determined visually by comparison with NCS color samples, for example, in SS 19102:2004 NCS Colour Atlas. It should be noted that the NCS notation assigned to each color sample is valid only when the color sample is observed in daylight. Since the appearance of a color sample can be influenced by factors such as the illumination and the surroundings, visual assessments should be carried out as follows:

8.1.1 Color samples should have a size of at least 40 by 50 mm, and should be studied in pairs placed edge-to-edge. They should be viewed perpendicular to the surface at a distance of approximately 0.5 m by an observer with normal color vision.

8.1.2 The immediate background to the samples should be white ($Y_1 \approx 85$ %) and the rest of the surroundings light-gray ($Y_1 \approx 56$ %).

NOTE 1—The designation Y_1 is used for the luminance factor to avoid confusion with the NCS-elementary color Y.

8.1.3 The illumination should be approximately 1000 lux diffused artificial daylight at an angle of approximately 45° to the surface of the color samples. The illumination should correspond to a simulation of CIE standard illuminant D65, which is used in the determination of the color parameters for NCS color samples.

8.1.4 Under these conditions, the color object of interest is compared in pairs with a number of NCS color samples with the aim of determining which NCS color sample lies closest to the object concerned. If required, a linear interpolation between two NCS color samples can be estimated, consideration being given to the fact that such an interpolation may need to be done in three dimensions, that is, with consideration to NCS blackness, NCS chromaticness and NCS hue.

NOTE 2—NCS color samples are produced with specified tolerance according to SS 19104. These tolerances might influence the accuracy of the visual interpolation to a small amount.

8.1.5 The visual method is not recommended for the communication of color in industrial production with high accuracy. For more accurate determinations, instrumental measurement is required.

9. Determination of NCS Notations by Instrumental Measurement

9.1 *Measurement Conditions:*

9.1.1 Measurement geometry according to CIE 15:2004 is di:8. The sample is illuminated diffusely and the reflected light is measured at an angle of 8° to the normal with the gloss component included (di:8°).

9.1.2 The instrument standard should be calibrated with traceability to the perfect reflecting diffuser.

9.1.3 The tristimulus values should be calculated from the measured spectral reflectance factors in accordance with Practice E308 and CIE 15:2004, Colorimetry using the CIE 1931 (2°) standard observer and CIE standard illuminant D65.

9.2 From these CIE tristimulus values, NCS color coordinates are interpolated between the tabled values, which define the relationship between NCS color space and CIE *xyY* color space and thereby CIELAB color space.

NOTE 3—Measurement differences between commercially available spectrophotometers and colorimeters due to construction details and the uncertainty of the absolute photometric scale influences the accuracy of the determined NCS notations.

9.2.1 The *X, Y,* and *Z* should be calculated using the CIE 1931 (2°) standard observer and the CIE standard illuminant D65.

10. Determination of NCS Lightness by Visual Observation

10.1 For achromatic colors (gray, where $c = 0$), NCS lightness v is defined as:

$$v = (100 - s)/100 \quad (11)$$

where s is the blackness.

10.1.1 The lightness of an arbitrary color object is determined by comparison edge-to-edge in the standardized observation situation in accordance with 8.1.1 with a reference scale consisting of achromatic ($c = 0$) NCS color samples, for

[6] The boldface numbers in parentheses refer to a list of references at the end of this standard.

example, in an SS 19102:2004 NCS Colour Atlas. The specimen's NCS lightness is the same lightness value as that of the reference sample for which the border between object and reference sample is perceived to be least distinct (**4, 5**).

11. Determination of NCS Lightness by Instrumental Measurement

11.1 The reflectance values determined in accordance with Section 9 should be evaluated using the CIE 1931 (2°) standard observer and CIE standard illuminant D65. For achromatic colors ($c = 0$), there is an experimentally determined psychophysical relationship between the blackness (s) and the tristimulus value (Y_I):

$$s = 100(100 + Y_{IA}).\ Y_I/(Y_{IA} + Y_I) = (100 - Y_I)/(1 + Y_I/Y_{IA}) \quad (12)$$

where Y_I is the luminance factor of the material and Y_{IA} is the average luminance factor for that part of the field of vision of the observer which determines the adaptation level. Under the conditions for visual assessment given in 8.1.1, $Y_{IA} = 56$.

11.2 Tests carried out in the viewing situation given in 4.1 have shown that color specimens with the same luminance factor are assigned the same NCS lightness value, provided that the least distinctness of border criterion is used in the assessment. From Eq 11 and Eq 12, it follows that if the luminance factor of a color specimen is known, the NCS lightness of the color can be calculated from:

$$v = 1.56Y_I\ /\ (56 + Y_I) \quad (13)$$

From Eq 13, it follows that the luminance factor can be calculated from the NCS lightness according to:

$$Y_I = 56\ v\ /\ (1.56 - v) \quad (14)$$

NOTE 4—Locus for constant NCS lightness are shown for each hue in the SS 19102:2004 NCS Colour Atlas.

12. Report

12.1 Report the following information: The NCS color of the test specimen in the form described in 6.1.1 and shown in Fig. 1, specifying whether this notation was obtained visually from the SS 91101:2004 NCS Colour Atlas or by conversion of measured colorimetric data.

13. Keywords

13.1 color; natural color system; natural colour system; NCS

ANNEX

(Mandatory Information)

A1. CIE TABLES

INTRODUCTION

The purpose of the tables (Fig. A1.1 and Fig. A1.2) associated with this standard is to convert between NCS notations and CIE coordinates. The tables are in the form of an excel file and can be downloaded from the ASTM website.[5] How to use the file is given in A1.1 and A1.2.

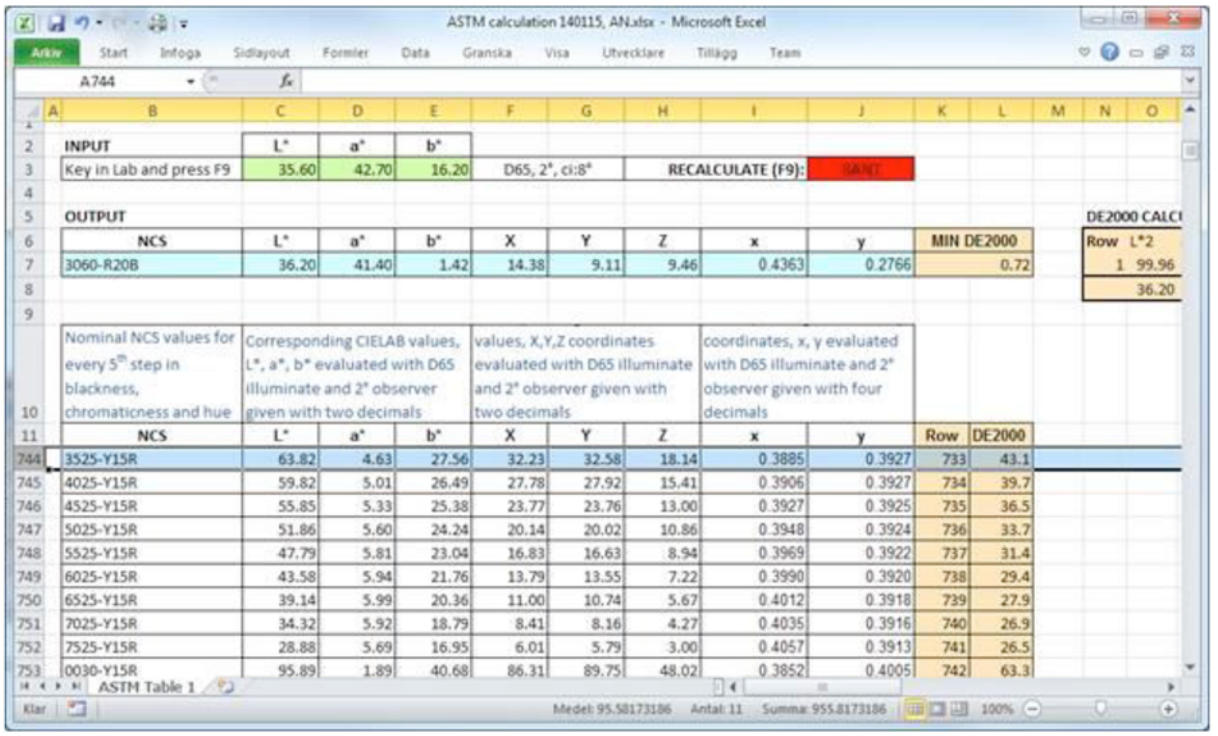
A1.1 Converting from an NCS Notation to CIE Coordinates

A1.1.1 To convert an NCS notation to CIE coordinates, just look up the closest NCS notation, for example, 3724-Y17R (round off to five steps) ⇒ 3525-Y15R (look up in table) and read the equivalent CIE coordinates (CIE *L*a*b*/XYZ/* and *xy* values). If the given NCS notation does not have an exact match, the closest notation may be selected. This may result in a maximum error of 8.15 ΔE^*_{ab}. If higher accuracy is needed, linear interpolation between the CIE coordinates of the surrounding NCS notation will reduce the error.

NOTE A1.1—The average distance in CIELAB between all points in the table is 3.0 ΔE^*_{ab}. The maximal distance is 16.3 ΔE^*_{ab}. This means that the conversion between any NCS notation by selecting the closest integer NCS notation probably is within 1.5 ΔE^*_{ab}, but in worst case around 8.15 ΔE^*_{ab}. IN CIEDE2000 the value is probably around 20 to 40 % less.

A1.2 Approximated Conversion from CIE Coordinates to NCS Notation

A1.2.1 In the table enter the CIE L^*, a^*, and b^* values (D65, 2°, di:8°) and press F9 to calculate the NCS notation. For example type L^*=35.6 a^*=42.7 b^*=16.2 into the green boxes), and then hit F9 to calculate (this can take up to a minute). When the red recalculate indicator (cell J3) goes white the resulting closest NCS is shown in the blue cells. The orange cells shows CIEDE2000 calculation and the minimum CIEDE2000 found. The CIEDE2000 value in column L of the spreadsheet indicates the color difference between the particular NCS color designation on that line and the color the user has entered in searching for the best designation going from CIE to NCS.



ASTM calculation 140115, AN.xlsx - Microsoft Excel

A744

	B	C	D	E	F	G	H	I	J	K	L
2	INPUT	L*	a*	b*							
3	Key in Lab and press F9	35.60	42.70	16.20	D65, 2°, ci:8°		RECALCULATE (F9):	SANT			
4											
5	OUTPUT										
6	NCS	L*	a*	b*	X	Y	Z	x	y	MIN DE2000	
7	3060-R20B	36.20	41.40	1.42	14.38	9.11	9.46	0.4363	0.2766	0.72	
8											
9											
10	Nominal NCS values for every 5th step in blackness, chromaticness and hue	Corresponding CIELAB values, L*, a*, b* evaluated with D65 illuminate and 2° observer given with two decimals			values, X,Y,Z coordinates evaluated with D65 illuminate and 2° observer given with two decimals			coordinates, x, y evaluated with D65 illuminate and 2° observer given with four decimals			
11	NCS	L*	a*	b*	X	Y	Z	x	y	Row	DE2000
744	3525-Y15R	63.82	4.63	27.56	32.23	32.58	18.14	0.3885	0.3927	733	43.1
745	4025-Y15R	59.82	5.01	26.49	27.78	27.92	15.41	0.3906	0.3927	734	39.7
746	4525-Y15R	55.85	5.33	25.38	23.77	23.76	13.00	0.3927	0.3925	735	36.5
747	5025-Y15R	51.86	5.60	24.24	20.14	20.02	10.86	0.3948	0.3924	736	33.7
748	5525-Y15R	47.79	5.81	23.04	16.83	16.63	8.94	0.3969	0.3922	737	31.4
749	6025-Y15R	43.58	5.94	21.76	13.79	13.55	7.22	0.3990	0.3920	738	29.4
750	6525-Y15R	39.14	5.99	20.36	11.00	10.74	5.67	0.4012	0.3918	739	27.9
751	7025-Y15R	34.32	5.92	18.79	8.41	8.16	4.27	0.4035	0.3916	740	26.9
752	7525-Y15R	28.88	5.69	16.95	6.01	5.79	3.00	0.4057	0.3913	741	26.5
753	0030-Y15R	95.89	1.89	40.68	86.31	89.75	48.02	0.3852	0.4005	742	63.3

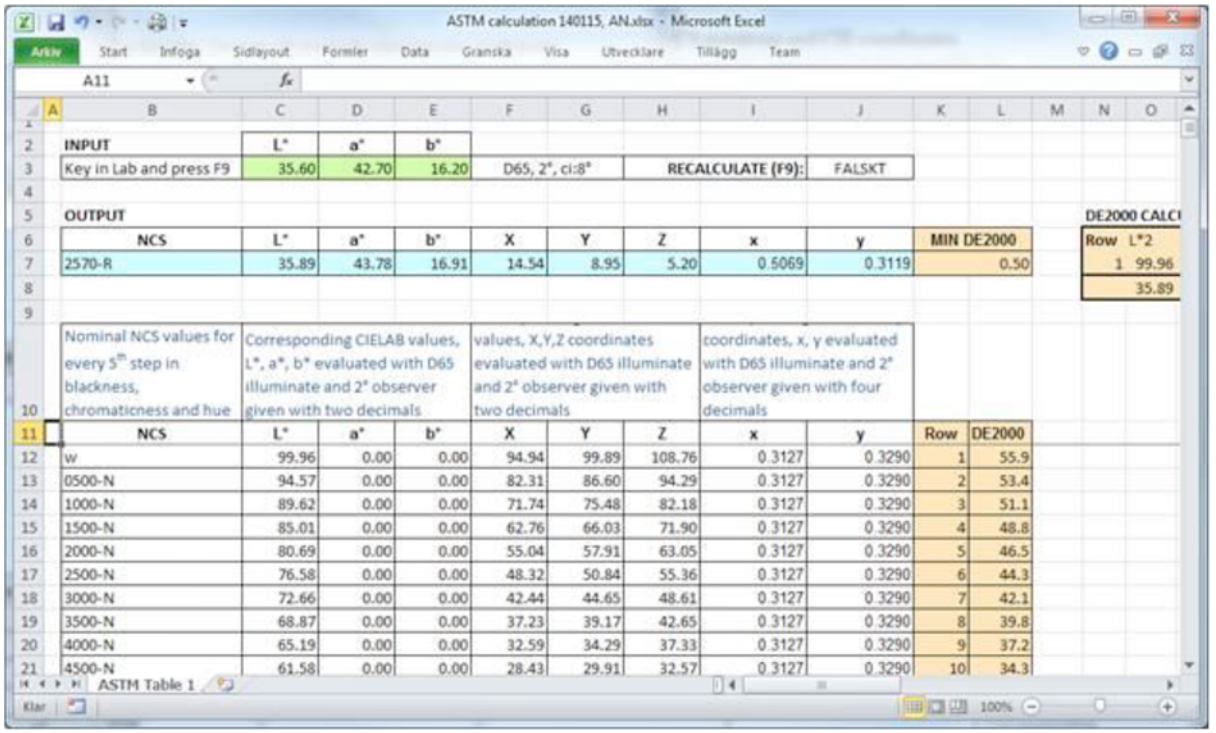
DE2000 CALC

Row	L*2
1	99.96
	36.20

ASTM Table 1

Klar | Medel: 95.58173186 Antal: 11 Summa: 955.8173186 | 100%

FIG. A1.1 Example of Looking up the CIE Values for a Specific NCS Notation



ASTM calculation 140115, AN.xlsx - Microsoft Excel

A11

	B	C	D	E	F	G	H	I	J	K	L
2	INPUT	L*	a*	b*							
3	Key in Lab and press F9	35.60	42.70	16.20	D65, 2°, ci:8°		RECALCULATE (F9):	FALSKT			
4											
5	OUTPUT										
6	NCS	L*	a*	b*	X	Y	Z	x	y	MIN DE2000	
7	2570-R	35.89	43.78	16.91	14.54	8.95	5.20	0.5069	0.3119	0.50	
8											
9											
10	Nominal NCS values for every 5th step in blackness, chromaticness and hue	Corresponding CIELAB values, L*, a*, b* evaluated with D65 illuminate and 2° observer given with two decimals			values, X,Y,Z coordinates evaluated with D65 illuminate and 2° observer given with two decimals			coordinates, x, y evaluated with D65 illuminate and 2° observer given with four decimals			
11	NCS	L*	a*	b*	X	Y	Z	x	y	Row	DE2000
12	w	99.96	0.00	0.00	94.94	99.89	108.76	0.3127	0.3290	1	55.9
13	0500-N	94.57	0.00	0.00	82.31	86.60	94.29	0.3127	0.3290	2	53.4
14	1000-N	89.62	0.00	0.00	71.74	75.48	82.18	0.3127	0.3290	3	51.1
15	1500-N	85.01	0.00	0.00	62.76	66.03	71.90	0.3127	0.3290	4	48.8
16	2000-N	80.69	0.00	0.00	55.04	57.91	63.05	0.3127	0.3290	5	46.5
17	2500-N	76.58	0.00	0.00	48.32	50.84	55.36	0.3127	0.3290	6	44.3
18	3000-N	72.66	0.00	0.00	42.44	44.65	48.61	0.3127	0.3290	7	42.1
19	3500-N	68.87	0.00	0.00	37.23	39.17	42.65	0.3127	0.3290	8	39.8
20	4000-N	65.19	0.00	0.00	32.59	34.29	37.33	0.3127	0.3290	9	37.2
21	4500-N	61.58	0.00	0.00	28.43	29.91	32.57	0.3127	0.3290	10	34.3

DE2000 CALC

Row	L*2
1	99.96
	35.89

ASTM Table 1

Klar | 100%

FIG. A1.2 Example of the Input and Output Section of the File for Calculating the NCS Color Notation Given In CIE *L*, a*,* and *b*.*

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(1) Hård, A. and Svedmyr, Å, *Färgystemet* NCS, Byggforsknigsrådet, 1995.

(2) Hård, A. Sivik, L, and Tonnquist, G., NCS: from Concept to Research and Application, *Color Res. Appl.*, 21, 180-220, (1996).

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(5) Nayatani, Y. Lightness perception of chromatic colors, *Color Res. Appl.*, 16, 16-25, (1991).